NEW BOUNDARIES BETWEEN AGING, COGNITION, AND EMOTIONS

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NEW BOUNDARIES BETWEEN AGING, COGNITION, AND EMOTIONS

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EDITORIAL
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Editorial: New Boundaries Between Aging, Cognition, and Emotions

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Keywords: aging, emotions, cognition, lifespan, positivity effect

Editorial on the Research Topic

New Boundaries Between Aging, Cognition, and Emotions

Numerous studies have reported age-related differences for emotional information (Carstensen et al., 2003; Di Domenico et al., 2016; Mammarella et al., 2017). For example, when, compared to younger adults, older adults reveal a relative preference in attention and memory for positive over negative information (Charles and Carstensen, 2010; Fairfield et al., 2015; Palumbo et al., 2015, 2018; Palumbo et al.). One explanation places emphasis on an emotion processing preference in older adults that reflects their socioemotional self-relevant goals (Custers and Aarts, 2005). Based on evidence from behavioral and neuroscientific research, researchers have realized that it is necessary to propose a new conceptual framework to describe the relationship between cognition and emotion.

Given the growing body of research focused on the interaction between emotions and cognition, the purpose of this research topic is to provide a picture of the state of the art of the interaction between aging, cognition and emotions.

The 12 articles composing this unique Frontiers Research Topic bring together experimental and theoretical research, linking state-of-the-art knowledge about the role of emotions on cognition in the lifespan. Gerino et al. investigate the way in which psychological factors—such as loneliness, resilience, and mental states, in terms of depression and anxiety symptoms—affect the perceived Quality of Life among elderly individuals.

Choi et al. provide converging evidence that social relatedness plays a significant role in physical health, particularly in the older population. Mestre et al. explore the relationship between both, emotional regulation abilities and strategies, and resilience in a sample of adolescents from suburbs high-schools. The study also examines how using different emotional regulation strategies may help the development of resilience levels at this stage.

Di Crosta and La Malva discuss the experience of passage of time in young and elderly adults. In a review of Liebherr et al. the authors present summarize neuropsychological and neurophysiological findings of age-related differences in decision making under ambiguous and objective risk. In this context, the relevance of learning, but also of cognitive and emotional contributors—responsible for age-related differences in decision making—are additionally pointed out. Walther et al. suggested that, steroid hormones and age-related alterations in secretion patterns have been shown to play a crucial role in age-related changes in emotional experience. García-Bajos et al. examined the age-based positivity effect of recall for future positive and negative autobiographical events in young and older adults. Kappes et al. present findings that are consistent with the idea that age-related changes in the processing of emotional information support older adults' general emotional well-being. Deng et al. present the development of a new standardized emotional film database for Asian culture using eight kinds of emotion: fear, disgust, anger, sadness, neutrality, surprise, amusement and pleasure.

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Palumbo et al. based on previous research that has shown effects of facial appearance on trait impressions and group stereotypes, investigate the contribution of resemblance to emotion expressions and attractiveness to younger adults' (YA) and older adults' (OA) age and gender stereotypes on the dimensions of warmth and competence. Liao et al. use event-related potentials (ERPs) to investigate the effects of age on neural temporal dynamics of processing task-relevant facial expressions and their relationship to cognitive functions. Finally, Hu et al. provided the first evidence of the Thin-slice Wisdom Paradigm's reliability, its immunity to social desirability, and its validity for assessing candidates' wisdom within a short timeframe.

Altogether, the contributions of this research topic, highlight the crucial role that emotions play on cognition highlighting their importance in the lifespan.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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ORIGINAL RESEARCH
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Social Relatedness and Physical Health Are More Strongly Related in Older Than Younger Adults: Findings from the Korean Adult Longitudinal Study

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Previous research indicates that social relatedness is beneficial to physical health; however, findings on the relative strength of the relationship between these variables have been inconsistent. The present study employed cross-sectional survey (Study 1) and a daily diary survey (Study 2) to examine the link between social relatedness and physical health by age. Using a representative sample of Korean adults ($N = 371$) aged from 20 to 69, Study 1 examines the link between social relatedness (loneliness, perceived social support) and physical health (physical symptoms, chronic health conditions) using age as a moderator. The results show that participants' age moderates the association between social relatedness and physical health. Study 2 ($N = 384$) further corroborated the findings from Study 1 by showing that when controlling for the physical symptoms experienced prior to the daily diary reports, the level of loneliness experienced over a 13-day period exacerbates the age differences in the physical symptoms. The present study thus provides converging evidence that social relatedness plays a significant role in physical health, particularly in the older population.

Keywords: loneliness, perceived social support, physical symptoms, age factors, chronic health conditions

INTRODUCTION

It has been well established that social resources constitute one of the major protective factors for both physical and mental health (Holt-Lunstad et al., 2010; Uchino et al., 2012). Social resources in terms of one's subjective evaluation of the availability of or access to social relationships, are conceptualized in a variety of ways. Loneliness, or the perception that one lacks social resources, is a pervasive experience in most modern societies (Victor and Yang, 2012; Victor and Sullivan, 2015). Loneliness is a fundamentally a distressing feeling that stems, in part, from a lack of fulfillment of one's need or desire to connect with others (Cacioppo et al., 2002). Compared to depression or anxiety, loneliness is a type of negative emotional experience that involves the social interdependence of individuals; thus, it is called a socially engaging (vs. disengaging) emotion (Kitayama et al., 2006; Uchida and Kitayama, 2009). The so-called socially engaging emotions are associated with people's happiness, particularly so in an interdependent cultural context such as in East Asian cultural context (Kitayama et al., 2006).

The counterpart of loneliness, perceived social support is the perception that one is cared for and that support from others is available (Caplan, 1974; Dunkel-Schetter and Bennett, 1990; Cohen, 1992, 2004). Though these two indices reflect the objective reality of social connectedness, as indicated by the number of close others or social contacts, they also refer to the subjective perception of social relatedness, which is primarily emotional in nature (Dunkel-Schetter and Bennett, 1990; Bolger and Amarel, 2007). Given the detrimental effects of negative emotional experiences on one's mental and physical state (Assari and Lankarani, 2016; Palumbo et al., 2017), it is no surprise that feelings of loneliness are associated with poor health.

Much empirical evidence, obtained from both longitudinal and cross-sectional studies, has shown that social relatedness has advantageous effects on physiological processes, ultimately positively affecting chronic diseases and longevity (see Holt-Lunstad et al., 2010 for a review; Hawkley et al., 2010). Previous research documents that loneliness predicts not only lower levels of psychological well-being (Cacioppo et al., 2010), but also lower self-rated health (Nummela et al., 2011), less physical activity (Hawkley et al., 2009), and worse physical functioning (Luo et al., 2012). While loneliness is the psychological measure of the lack of social relatedness, perceived social support—a natural counterpart of loneliness—is a measure of the positive presence of social relatedness. As such, perceived social support is found to be associated with better biological outcomes (Uchino et al., 1996; see reviews by Holt-Lunstad et al., 2010). A substantial amount of evidence links perceived social support with physical health status, including mortality rates (Brummett et al., 2001; Holt-Lunstad et al., 2010), immune functions (Baron et al., 1990; Kiecolt-Glaser et al., 2010), chronic health conditions such as cardiovascular disease (Barth et al., 2010), as well as self-reported health status (Alpass and Neville, 2003).

Despite the accumulating research on the effect of social relatedness on physical health, however, it is unclear whether the degree of the relationship between social relatedness and physical health is the same for individuals of different ages. Since chronic conditions and health problems are naturally more common in late adulthood, much of the research on the relationship between social relatedness and health has been biased toward older adults (Brooks et al., 2014; Yang et al., 2016) and there is limited evidence regarding the potentially varying degrees of associations between loneliness or perceived social support and physical health according to age (Umberson et al., 2010; Brooks et al., 2014). To address this limitation, the present research included participants of a broad age range (20–69) and examined whether and how the strength of the association between social relatedness and physical health varies with age.

Social Relatedness and Health across Age Groups

There are reasons to expect that the link between social relatedness and physical health may vary by age; specifically, the association between social relatedness and physical health may be stronger for older adults than for younger adults. First, according to socioemotional selective theory, individuals begin to perceive that they have less time left as they age, which leads them to be more aware of their social relationships, especially close, intimate relationships (Carstensen, 1992; Carstensen et al., 1999). Although the number and size of social ties decrease as people grow older (Tornstam, 1997), intimate social relationships are maintained and may even be more salient to the well-being of older (vs. younger) adults (Matt and Dean, 1993; Umberson et al., 2006; Elliot et al., 2017). By the time individuals reach older adulthood, their relationships have accumulated certain benefits that are possible in close relationships that have lasted a long time (Chopik, 2017). Second, it has long been suggested that social relatedness has a buffering effect on well-being in stressful situations (Cobb, 1976; Gore, 1981). Given that getting old is inevitably associated with a range of life stressors, including deterioration in physical health (Kanis et al., 2000; Walther et al., 2017); challenges in financial circumstances (Kahn and Pearlin, 2006; Wilkinson, 2016), and stressors in social relations such as the death of a spouse or friend (Steptoe et al., 2013), social resources have a particularly significant role in adaptive functioning in later life stages.

Recently, researchers have started to pay attention to the lifespan approach to examine the associations between social relatedness and physical functioning in different life stages and for extended periods of the life course (Brooks et al., 2014; Yang et al., 2016; Chopik, 2017). However, the relative predictive power of social relatedness on physical health by different age groups is still largely understudied (Chopik, 2017). Moreover, the existing empirical evidence regarding the moderating effect of social relatedness on health is not straightforward. Some studies indicate that the protective power of perceived social support is stronger for older adults than for younger adults (Seeman et al., 2002; Yang et al., 2016). For instance, in a recent analysis that examined four representative samples of adults in the United States, Yang et al. (2016) found that the effect of social relationships on physiological functioning was particularly strong among those in adolescence and in late adulthood. In contrast, in another study utilizing one of the same data sets from Yang et al. (2016), Brooks et al. (2014) found the opposite pattern. In fact, the average support from family, friends, and spouses predicted higher levels of physiological dysregulation for older adults but lower levels for younger adults. Similarly, the empirical findings are inconsistent regarding the effect of loneliness in regulating age-related differences in health outcomes, with some studies supporting the role of loneliness in amplifying the age difference of physical health (Hawkley et al., 2006), while others show opposite or null findings (Hawkley et al., 2010; Whisman, 2010; Victor and Yang, 2012).

Present Study

Given the lack of evidence and inconsistency in the literature, the present research sets out to supplement findings in this area of research by conducting a cross-sectional study and a daily diary study. In Study 1, we utilized a cross-sectional design to examine how individuals' general feelings about social connectedness are associated with their physical health, with a particular focus on the possible moderating effect of age. In Study 2, we used a data set obtained from a daily diary study and tested whether

daily experiences of loneliness could predict physical symptoms experienced during the study period after controlling for the initial physical symptoms. A daily diary study has additional advantages over traditional survey studies using retrospective assessments, in that it significantly reduces the time lapse between the experiences and the recall of those experiences (Reis and Gable, 2000; Bolger et al., 2003). Therefore, diary data can provide summary accounts of experiences with relatively fewer memory biases from retrospection over a long period. Thus, the findings from Study 1 and Study 2 can be expected to complement each other and to provide a comprehensive understanding of the relationship between social relatedness and health while considering age as an important boundary condition.

STUDY 1

The aim of Study 1 was to examine whether the perception of social relatedness predicts physical health and whether age emerges as a moderator in this prediction. We focused on loneliness and perceived social support as capturing the absence and presence of social relatedness, respectively. Naturally, people who feel socially isolated and left out would be less likely to feel cared for and supported by their friends and family (Segrin and Passalacqua, 2010; Sarason, 2013). We expected that both the level of loneliness and perceived social support would be associated with physical health and that both associations would be qualified by age. Specifically, we expected that loneliness and perceived social support would be associated with physical health more strongly for older adults.

Method

Participants and Procedure

Participants were drawn from the Korean Adult Longitudinal Study, which was designed to be in parallel with the Midlife in the United States (MIDUS) and Midlife in Japan (MIDJA) projects. The purpose of the Korean Adult Longitudinal Study was to investigate social, psychological, and physiological development in adulthood and to reveal which of these developmental changes are associated with mental and physical well-being.

The sampling goal was 500 Seoul residents equally distributed across age groups (by decade from 20 to 60s), genders, and geographical areas in Seoul (Northeast, Southeast, Northwest, and Southwest). Participants were recruited via a research firm in Seoul, Korea. The participants were selected using random-digit dialing (RDD) of cell phone numbers with the age, gender, and residential information described above. Through the selection procedure, 519 Koreans (264 males, 255 females) aged 20–69 participated. The company oversampled initially with 732 adults as potential participants with the expectation of getting a response rate of ∼70%. The participants answered a self-administered questionnaire distributed by the research company and were paid 10,000 Korean won (KRW) for the participation. The response rate was 72.4%, resulting in 530 participants who returned the questionnaire. An additional 11 participants were excluded from the final data due to low-quality responses. Of the remaining 519 participants, 148 individuals who also participated in the daily diary study (Study 2) were excluded from Study 1. Thus, the final sample for Study 1 was totaled 371 participants who participated exclusively in the Korean Adult Longitudinal Study. The mean age of the sample was 43.22 ($SD = 14.61$). The study was carried out in accordance with the recommendations of the Institutional Review Board at Seoul National University. All subjects gave written informed consent form approved by the Institutional Review Board at Seoul National University.

Measures

Social Relatedness

Loneliness

The Revised UCLA Loneliness Scale (Hughes et al., 2004) was used to assess the level of social isolation participants feel. Participants responded to the 3-items on a four-point scale ranging from 1 = *never* to 4 = *often* (e.g., "I feel left out") ($\alpha = 0.82$). The mean score was used for the analysis.

Perceived social support

Perceived social support was measured with the 12-item scale developed by Zimet et al. (1988). The participants were asked to rate on a 7-point scale (1 = not at all true, 7 = very true) the degree to which they believe they are getting support from three different sources, family, friends, and significant others (e.g., "There is a special person who is around when I am in need.") ($\alpha = 0.92$). The mean score was used for the analysis.

Physical Health

Physical symptoms

Nine physical symptoms commonly used in MIDUS II, MIDUS III, and MIDJA were selected and the participants were to report how often they experienced each of the given symptoms in the past 30 days (1 = not at all, 2 = once a month, 3 = 2–3 times a month, 4 = once a week, 5 = 2–3 times a week, 6 = almost everyday). The symptoms were "headaches," "backaches," "sweating a lot," "irritability," "hot flushes or flashes," "aches or stiffness in joints," "trouble getting to sleep or staying asleep," "leaking urine," "pain or aches in extremities (arms/hands/legs/feet)" ($\alpha = 0.81$). The responses were averaged across the nine items.

Chronic health conditions

The participants indicated whether they had either diagnosed or been treated in the past 12 months for each of 30 chronic health conditions commonly used in MIDUS II, MIDUS III, and MIDJA. The condition list included a broad range of conditions from "asthma, bronchitis or emphysema" and "tuberculosis" to "chronic sleeping problems" and "swallowing problems." A total number of chronic health conditions were calculated and used for the analysis (See Appendix for the full list).

Covariates

Socio-demographic variables

Gender and Income Level were Used as Covariates. The income level was measured with eleven categories: (1) <1 million KRW, (2) 1–2 million KRW, (3) 2–3 million KRW, (4) 3–4 million KRW, (5) 4–5 million KRW, (6) 5–6 million KRW, (7) 6–7 million KRW, (8) 7–8 million KRW, (9) 8–9 million KRW, (10) 9–10 million KRW, and (11) >10 million KRW.

Health related behaviors

Health-related covariates included smoking status (0 = have no smoking experience, 1 = have a smoking experience) and amount of exercise (the average time spent on exercise on a daily basis measured in minutes).

Results and Discussion

Table 1 shows descriptive statistics and correlations among measures. As predicted, indicators of social relatedness and health indicators were significantly correlated. Particularly, loneliness had positive correlations with physical symptoms and with the chronic health conditions. Consistent with loneliness, perceived social support had a significant negative correlation with physical symptoms and a marginal trend with chronic conditions.

We used hierarchical multiple regression to examine the association between social relatedness and physical health, and whether it is differentially associated depending on age. Following the recommendation of Aiken and West (1991), all continuous variables were centered. In Step 1, demographic variables of gender and household income level as well as health related habits such as average daily exercise time and current smoking status were included in order to control for their potential effects on physical symptoms. In Step 2, we included the main variables of interest, namely, the age of the participants and social relatedness (loneliness and perceived social support). The interaction term between social relatedness and age (loneliness x age and perceived social support × age, respectively) was entered in Step 3.

Physical symptoms and loneliness

At the first step, the model predicting the physical symptoms by demographic variables and health related habits significantly accounted for the variance ($R^2 = 0.03$, $p = 0.034$). Gender ($\beta = 0.14$, $p = 0.041$) and household income ($\beta = -0.13$, $p = 0.016$) were significantly predictive of physical symptoms. Compared with male participants, female participants reported greater physical symptoms. The participants of higher household income reported less physical symptoms. At the second step, introducing participants' loneliness and age led to a significant increase in the variance ($\Delta R^2 = 0.19$, $p < 0.001$). Both predictors, loneliness ($\beta = 0.44$, $p < 0.001$) and age ($\beta = 0.11$, $p < 0.017$) were significantly associated with greater physical symptoms, indicating that the participants who experienced greater loneliness suffered from higher levels of physical symptoms than those who experienced lower levels of loneliness and that older participants reported higher levels of physical symptoms than their younger counterparts. At the third step, the interaction between loneliness and age explained additional variance ($\Delta R^2 = 0.02$, $p < 0.005$). There was a significant age by perceived social support interaction effect ($\beta = 0.14$, $p < 0.005$). To test the moderation effect, further simple slope analyses were performed (Aiken and West, 1991). There was a significant positive association between loneliness and physical symptoms for the older adults (at 1 *SD* above the mean age), $\beta = 0.60$, $t = 8.59$, $p < 0.001$. There was also a significant, but relatively smaller, positive association between loneliness, and physical symptoms for the younger adults (at 1 *SD* below the mean age), $\beta = 0.30$, $t = 4.49$, $p < 0.001$. See **Table 2** and **Figure 1**. These findings suggested that loneliness was more detrimental to physical health among older people than among younger people.

Chronic health conditions and loneliness

The results replicated using the total number of chronic health conditions in the past 12 months as another measurement of physical health. The model predicting the chronic health conditions by demographic variables and health related habits significantly accounted for the variance in Step 1 ($R^2 = 0.05$, $p = 0.001$). Household income ($\beta = -0.14$, $p = 0.007$), physical exercise ($\beta = -0.11$, $p = 0.036$), and smoking habit ($\beta = 0.18$, $p = 0.009$) were significantly associated with chronic health conditions. Participant who had higher household income, more physical exercise, and were non-smokers reported fewer chronic health conditions than those who had lower household income, less physical exercise, and were smokers. In Step 2, adding participants' loneliness and age accounted for extra variance ($\Delta R^2 = 0.11$, $p < 0.001$). Both loneliness ($\beta = 0.28$, $p < 0.001$) and age ($\beta = 0.20$, $p < 0.001$) had significant relationship with chronic health conditions. Participants who experienced less loneliness and were younger had fewer chronic health conditions. In Step 3, the two-way interaction between loneliness and age added significant increase in the variance ($\Delta R^2 = 0.02$, $p = 0.004$). A significant moderation effect of age on the relation between loneliness and chronic health conditions was found ($\beta = 0.14$, $p = 0.004$). Further simple slope tests revealed that the slope relating loneliness to chronic health conditions was significant for those older people, $\beta = 0.44$, $t = 6.01$, $p < 0.001$, while the slope was significant, but relatively lower, for those younger people, $\beta = 0.15$, $t = 2.12$, $p = 0.035$. As in the physical symptoms, the negative effect of loneliness on chronic health conditions became stronger with age.

Physical symptoms and perceived social support

As in the previous analyses for loneliness as an indicator of lack of social relatedness, the significant moderation effect of age was warranted using perceived social support ($\beta = -0.13$, $p = 0.015$). By conducting a series of simple slope analyses, the significant association between perceived social support and physical symptoms for the older participants was found, $\beta = -0.22$, $t = -2.87$, $p < 0.005$. In contrast, the relationship between social support and physical symptoms for the younger adults was not significant, $\beta = 0.03$, $t = 0.44$, *ns*. As the absence of social relatedness (i.e., loneliness) had greater effect on physical symptoms among older participants than among younger participants, the effect of perceived social support on physical symptoms was also stronger among older participants than among their younger counterparts.

Chronic conditions and perceived social support

As shown in **Table 2**, a consistent moderation effect of age was found using perceived social support, ($\beta = -0.15$, $p < 0.005$). Further simple slope analyses yielded the result consistent with the previous findings; there was a significant negative relationship between perceived social support and chronic health conditions

TABLE 1 | Descriptive statistics and correlations among measures in Study 1.

Measure	*M* (or %)	*SD*	1	2	3	4	5	6	7	8
1. Gender	Male 52.3%	–	–							
2. Income	5.93	2.27	0.02	–						
3. Exercise	59.64	52.60	−0.09†	0.10†	–					
4. Smoking	Yes 38.5%	–	−0.65	−0.01	0.14**	–				
5. Perceived social support	5.32	0.78	0.01	0.16**	0.01	−0.11*	–			
6. Loneliness	1.69	0.64	−0.13*	−0.16**	−0.07	−0.20***	−0.44***	–		
7. Age	43.22	14.61	−0.04	−0.11*	0.15**	0.14**	−0.13*	−0.03	–	
8. Physical symptoms	1.79	0.77	0.07	−0.13*	−0.04	0.01	−0.12*	0.43***	0.10†	–
9. Chronic health conditions	0.75	1.53	−0.001	−0.15*	−0.11*	0.10†	−0.10†	0.30***	0.19***	0.58***

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 2 | Summary of hierarchical regression analysis for variable predicting physical symptoms and chronic health conditions in Study 1.

Variables	Outcome									
	Physical symptoms					Chronic health conditions				
	B	*SE B*	95% CI	β	ΔR^2	*B*	*SE B*	95% CI	β	ΔR^2
Step 1					0.03*					0.05**
Gender	0.21	0.10	[0.01, 0.42]	0.14*		0.32	0.20	[−0.08, 0.72]	0.11	
Income	−0.04	0.02	[−0.08, −0.01]	−0.13*		−0.09	0.04	[−0.16, −0.03]	−0.14**	
Exercise	0.000	0.001	[−0.002, 0.001]	−0.03		−0.003	0.002	[−0.01, 0.000]	−0.11*	
Smoking	0.16	0.11	[−0.05, 0.37]	0.10		0.55	0.21	[0.14, 0.97]	0.18**	
Step 2					0.19***					0.11***
Gender	0.20	0.09	[0.02, 0.39]	0.13*		0.27	0.19	[−0.11, 0.65]	0.09	
Income	−0.02	0.02	[−0.05, 0.02]	−0.05		−0.05	0.03	[−0.11, 0.02]	−0.07	
Exercise	0.000	0.001	[−0.001, 0.001]	−0.01		−0.003	0.001	[−0.01, 0.000]	−0.11*	
Smoking	−0.01	0.10	[−0.21, 0.18]	−0.01		0.27	0.20	[−0.14, 0.67]	0.09	
Loneliness	0.54	0.06	[0.42, 0.65]	0.44***		0.68	0.12	[0.45, 0.92]	0.28***	
Age	0.01	0.003	[0.001, 0.01]	0.11*		0.02	0.01	[0.01, 0.03]	0.20***	
Step 3					0.02**					0.02**
Gender	0.23	0.09	[0.05, 0.41]	0.15*		0.32	0.19	[−0.06, 0.70]	0.11†	
Income	−0.02	0.02	[−0.05, 0.02]	−0.04		−0.05	0.03	[−0.11, 0.02]	−0.07	
Exercise	0.000	0.001	[−0.001, 0.002]	0.02		−0.003	0.001	[−0.01, 0.000]	−0.09†	
Smoking	−0.01	0.10	[−0.20, 0.19]	−0.01		0.27	0.20	[−0.13, 0.67]	0.09	
Loneliness	0.54	0.06	[0.43, 0.66]	0.45***		0.70	0.12	[0.47, 0.93]	0.29***	
Age	0.01	0.003	[0.001, 0.01]	0.11*		0.02	0.01	[0.01, 0.03]	0.20***	
Loneliness × Age	0.01	0.004	[0.01, 0.02]	0.14**		0.02	0.01	[0.01, 0.04]	0.14**	

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

for the older adults, $\beta = -0.21$, $t = -2.77$, $p = 0.006$, but not for the younger adults, $\beta = 0.09$, $t = 1.31$, *ns*. The results of the regression analyses are summarized in **Table 3**.

Study 1 provided the evidence that the perception of social relatedness had positive association with physical health and this association was stronger for older adults. That is, higher levels of loneliness were associated with greater physical symptoms and this pattern was stronger for the older than for the younger. As for the perceived social support, the associations with physical symptoms were significant for the older only and not the younger. These results indicated that the lack/presence of social relatedness was more detrimental to/beneficial for the older adults compared to younger adults in health conditions. The consistent findings regarding the chronic health conditions confirmed that the moderating role of age was also present in the chronic health conditions as well as in the physical symptoms, which covered a relatively short-term period of time (i.e., in the past 1 month). In line with previous research, greater social support was related to positive effect on adaptation and recovery (Finlayson, 1976;

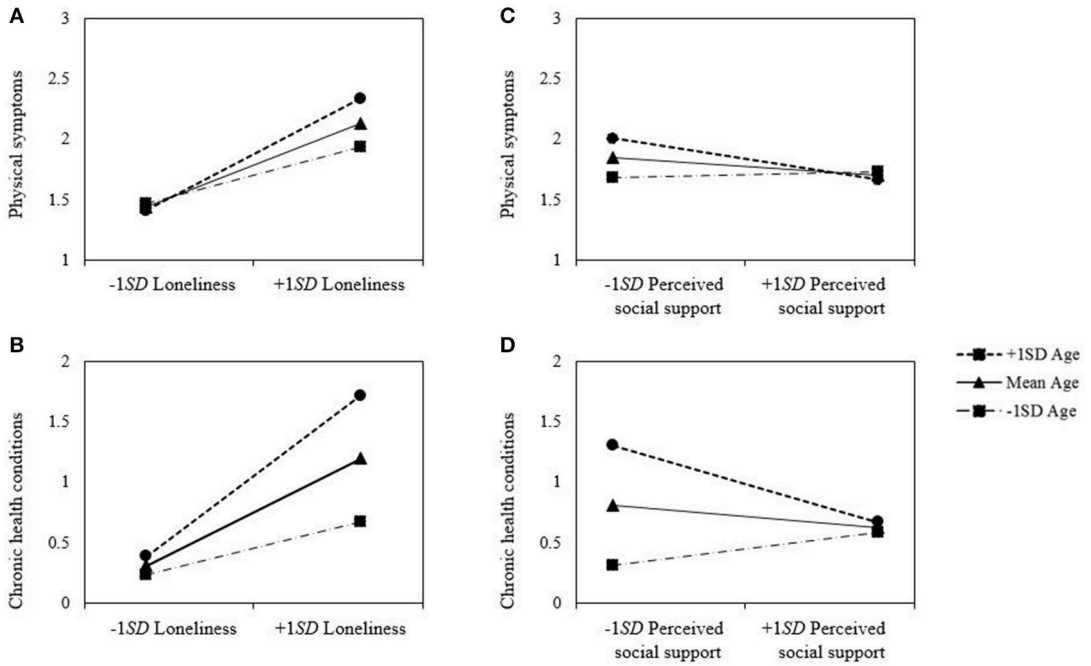

FIGURE 1 | Moderation effect of age on the relation between **(A)** loneliness and physical symptoms, **(B)** loneliness and chronic health conditions, **(C)** perceived social support and physical symptoms, **(D)** perceived social support and health conditions in Study 1.

TABLE 3 | Summary of hierarchical regression analysis for variable predicting physical symptoms and chronic health conditions in Study 1.

Variables	Outcome									
	Physical symptoms					Chronic health conditions				
	B	*SE B*	95% CI	β	ΔR^2	*B*	*SE B*	95% CI	β	ΔR^2
Step 1					0.03*					0.05**
Gender	0.21	0.10	[0.01, 0.42]	0.14*		0.32	0.20	[−0.08, 0.72]	0.11	
Income	−0.04	0.02	[−0.08, −0.01]	−0.13*		−0.09	0.04	[−0.16, −0.03]	−0.14**	
Exercise	0.000	0.001	[−0.002, 0.001]	−0.03		−0.003	0.002	[−0.01, 0.000]	−0.11*	
Smoking	0.16	0.11	[−0.05, 0.37]	0.10		0.55	0.21	[0.14, 0.97]	0.18**	
Step 2					0.01†					0.03**
Gender	0.19	0.10	[−0.02, 0.39]	0.12†		0.26	0.20	[−0.14, 0.66]	0.08	
Income	−0.04	0.02	[−0.07, 0.000]	−0.10†		−0.07	0.04	[−0.14, −0.01]	−0.11*	
Exercise	−0.001	0.001	[−0.002, 0.001]	−0.04		−0.004	0.001	[−0.01, −0.001]	−0.13*	
Smoking	0.12	0.11	[−0.10, 0.33]	0.07		0.43	0.21	[0.02, 0.84]	0.14*	
Perceived social support	−0.08	0.05	[−0.18, 0.02]	−0.08		−0.09	0.10	[−0.29, 0.11]	−0.05	
Age	0.004	0.003	[−0.001, 0.01]	0.08		0.02	0.01	[0.01, 0.03]	0.18**	
Step 3					0.02*					0.02**
Gender	0.21	0.10	[0.01, 0.41]	0.14*		0.31	0.20	[−0.09, 0.70]	0.10	
Income	−0.04	0.02	[−0.07, 0.000]	−0.10†		−0.07	0.03	[−0.14, −0.01]	−0.11*	
Exercise	0.000	0.001	[−0.002, 0.001]	−0.03		−0.004	0.001	[−0.01, −0.001]	−0.12*	
Smoking	0.12	0.11	[−0.09, 0.33]	0.07		0.44	0.21	[0.03, 0.85]	0.14*	
Perceived social support	−0.10	0.05	[−0.20, 0.01]	−0.10†		−0.12	0.10	[−0.31, 0.08]	−0.06	
Age	0.004	0.003	[−0.001, 0.01]	0.08		0.02	0.01	[0.01, 0.03]	0.18**	
Perceived social support × Age	−0.01	0.003	[−0.02, −0.002]	−0.13*		−0.02	0.01	[−0.03, −0.01]	−0.15**	

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Bromet and Moos, 1977; Wallston et al., 1983) and to fewer medical problems among elderly people (Hawkley et al., 2010).

Although the results of Study 1 provided initial evidence that the predictive power of social relatedness for physical health varies across age, given the cross-sectional design of the study, it is hard to rule out the possibility that the physical symptom might be an antecedent, rather than a consequence, of social relatedness. In order to address this limitation, we conducted a daily diary study and tested whether the experiences of the absence of social relatedness (i.e., loneliness) during a relatively short period (i.e., 13 days) could predict the physical symptoms experienced during that period, even after controlling for initial physical symptoms.

STUDY 2

Study 2 was conducted to extend Study 1 in two ways. First, Study 2 attempted to replicate the results of Study 1 with daily measures of loneliness. We assessed the loneliness that participants experienced in the course a day via the daily diary method. Even though the method did not provide a perfect online measure of loneliness, it is closer to the participants' actual lived experience of loneliness in their daily lives and is less susceptible to emotional and cognitive biases compared to the retrospective measures of social relatedness used in Study 1 (Schwarz and Clore, 1983; Schkade and Kahneman, 1997; Schwarz and Strack, 1999; Robinson and Clore, 2002). Next, we examined whether the participants' daily experiences of loneliness over a relatively short period of time (i.e., 13 days) could predict the changes in physical health for the same period. To this end, the physical symptoms that participants experienced were measured before and after the 13-day daily diary study period. In other words, we tested whether loneliness was significantly associated with post-test physical symptoms after controlling for pre-test physical symptoms and whether its association was qualified by age.

Method

Participants

A total of 407 individuals took part in a study called the Everyday Experience of Koreans, which included several surveys for multiple research projects, in return for monetary compensation of 50,000 Korean won. We used the daily diary part of the Everyday Experience of Koreans for Study 2. The participants were recruited through a research firm's panel on the basis of a stratified population sampling procedure in Seoul, Korea. Nineteen individuals were excluded because their answers were untrustworthy (e.g., they gave the same answers to all of the daily diary measures). Four were removed because their responses on the dependent variable (i.e., mean scores for physical symptoms over the course of 2 weeks) were more than 3 *SD* above the mean. Hence, 384 participants (50.8% females) were included in our analyses. Ages ranged from 31 to 69 ($M = 50.04$; $SD = 10.92$), with approximately equal numbers of participants from four age groups: 30s ($N = 90$), 40s ($N = 96$), 50s ($N = 99$), and 60s ($N = 99$). The study was carried out in accordance with the recommendations of the Institutional Review Board at Seoul National University. All subjects gave written informed consent using a form approved by the Institutional Review Board at Seoul National University.

Procedure

On the first day of the study, participants completed several online questionnaires, including surveys of demographic information (e.g., gender, age, marital status, level of education) and physical symptoms. From the second day of the study, participants filled out a daily diary for 13 subsequent days. Participants responded to daily diary measures via their own smartphones upon receiving a text message with a hyperlink that directed them to an online survey at 10:00 p.m. The participants were able to complete a daily diary measure at any time between 10:00 p.m. and 6:59 a.m. the next day. This step was taken in order to ensure adequate response rates (at the cost of some degree of memory bias) by allowing the participants to report loneliness of the previous day the next morning. The average number of daily diary responses per participants was 11.35 ($SD = 1.76$). A day after the daily diary study ended, participants were asked to complete a variety of questionnaires, including items about physical symptoms.

Measures

Pre/Post-test physical symptoms

On the first day of the study, participants were asked to report whether they suffered from each of the nine somatic symptoms (yes/no) that were used in Study 1. The number of symptoms was used as an indicator of baseline physical health. A day after the daily diary study ended, the participants reported how much they had experienced the given symptoms in the past 2 weeks, on a 6-point Likert scale (1 = not at all, 2 = once in two weeks, 3 = 2–3 times in 2 weeks, 4 = 4–5 times in 2 weeks, 5 = once every 2 days, 6 = almost everyday). The participants were presented with the same nine somatic symptoms measured at baseline, with the additional category "other." The post physical health scores were obtained by averaging the participants' ratings of all symptoms.

Daily loneliness

At each daily diary assessment, participants were asked to indicate the level of loneliness they felt on that day ("how lonely did you feel in the past 24 h?") on a scale ranging from 0 ("not at all lonely") to 10("very lonely"). We calculated the scores of overall loneliness for each participant by averaging the levels of loneliness across the 13 days.

Results and Discussion

We examined whether the daily experience of loneliness over the course of 13 days had a detrimental effect on the participants' physical health and whether such a negative effect might be qualified by age—that is, whether the negative effect of loneliness on physical health might be more evident in older participants than in younger participants. To this end, we conducted multiple regression analysis in which post-test physical symptoms that participants reported the day after the daily diary study ended were treated as outcomes and the overall loneliness, age, and

their interaction as predictors, after controlling for the pre-test physical symptoms participants reported the day before the daily diary study began. It is common to use multilevel linear modeling for the analyses of daily diary data, since the data have a hierarchical structure: the daily level (level 1) and the person level (level 2). In our study, however, multilevel linear modeling was not appropriate, since the outcome (i.e., post-physical symptom) is measured at level 2 (i.e., the person level), not level 1 (i.e., the daily level). Furthermore, whereas the new statistical methods such as the latent variable two-step approach (Croon and van Veldhoven, 2007) and the Full Information Maximum Likelihood latent variable technique (Lüdtke et al., 2008) were introduced for multilevel data with group-level outcomes, a recent simulation study showed that OLS analysis of the group mean not only provides low bias in estimations and good statistical power compared to the new techniques but also is free of convergence problems (Kromrey and Foster-Johnson, 2015). Hence, we aggregated loneliness scores measured at the daily level so that the loneliness and person-level variables can be included in a single level of analysis.

The correlation analyses showed that overall loneliness was positively related to post-test physical symptoms. Gender and age were not correlated with post-test physical symptom. Means, standard deviations, and intercorrelations for variables are shown in **Table 4**. Subsequently, we conducted three-step hierarchical regression. Covariates such as gender and pre-test physical symptom were entered in the first step. Overall loneliness and age were entered in the second step, and interaction between the loneliness and age were entered in the third step. All variables in the interaction terms were mean-centered.

As presented in **Table 5**, the results revealed that pre-test physical symptoms ($\beta = 0.512$, $p < 0.001$) in the first step ($R^2 = 0.27$, $p < 0.001$) were significantly associated with post-test physical symptoms, but gender was not ($\beta = 0.070$, $p = 0.111$). As expected, there was a strong association between pre- and post-test physical symptoms. Both overall loneliness ($\beta = 0.268$, $p < 0.001$) and age ($\beta = 0.113$, $p = 0.008$) in the second step ($\Delta R^2 = 0.072$, $p < 0.001$) positively predicted post-test physical symptoms, indicating that participants who experienced more loneliness during the daily-diary study experienced more physical symptoms than did those who experienced less loneliness, after controlling for baseline physical symptoms and that older participants suffered from more physical symptom than did younger participants.

TABLE 4 | Descriptive statistics and correlations among measures in Study 2.

Measure	*M*	*SD*	1	2	3	4	5
1. Gender	0.51	0.50	–				
2. Pre-test physical symptom	1.40	1.05	0.08	–			
3. Age	50.04	10.92	0.003	−0.14***	–		
4. Loneliness	4.47	1.86	−0.12***	0.20***	−0.16***	–	
5. Post-test physical symptom	2.13	0.82	0.11	0.52***	0.003	0.33***	–

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

More importantly, the main effect of loneliness on the post-test physical symptoms was significantly qualified by age ($\beta = 0.094$, $p = 0.025$) in the third step ($\Delta R^2 = 0.009$, $p = 0.025$). We decomposed the interaction by examining how loneliness influenced physical symptoms in older (−1 *SD*) and younger (+1 *SD*) adults. Simple slope analysis showed that the association between loneliness and post-test physical symptoms was stronger among older adults, $\beta = 0.368$, $t = 5.95$, $p < 0.001$, compared to among younger adults, $\beta = 0.171$, $t = 2.82$, $p = 0.005$, suggesting that the detrimental effect of loneliness becomes stronger with age. The findings of Study 2 indicated that the daily experiences of loneliness over a 13-day period were negatively associated with physical health and that this negative association was more evident for older participants.

GENERAL DISCUSSION

The present research provided consistent findings across Study 1 and Study 2, indicating that social relatedness (i.e., higher levels of loneliness and lower levels of perceived social support) is detrimental to physical health and that this effect is stronger for older adults compared to younger adults. In Study 1, using loneliness and perceived social support as two indices of social relatedness, we showed that subjective feelings of social connectedness were associated with physical health for older adults to a greater degree than for younger adults. Specifically, higher loneliness was associated with worse physical symptoms and chronic conditions, and this pattern was stronger for older adults than for younger adults. Regarding perceived social support, the associations with physical symptoms and chronic symptoms were significant for older adults but not

TABLE 5 | Summary of hierarchical regression analysis for variable predicting post physical symptom in Study 2.

Variables	Post-physical symptom				
	B	*SE B*	95% CI	β	ΔR^2
Step 1					0.27***
Gender	0.11	0.07	[0.02, 0.26]	0.07	
Pre-physical symptom	0.40	0.03	[0.33, 0.47]	0.51***	
Step 2					0.07***
Gender	0.17	0.07	[0.04, 0.31]	0.11*	
Pre-physical symptom	0.37	0.03	[0.30, 0.43]	0.47***	
Loneliness	0.12	0.02	[0.08, 0.16]	0.27***	
Age	0.01	0.003	[0.002, 0.02]	0.11**	
Step 3					0.01*
Gender	0.19	0.11	[0.05, 0.32]	0.11**	
Pre-physical symptom	0.37	0.03	[0.30, 0.43]	0.47***	
Loneliness	0.12	0.02	[0.08, 0.16]	0.27***	
Age	0.01	0.003	[0.002, 0.02]	0.12**	
Loneliness × Age	0.004	0.002	[0.001, 0.007]	0.09*	

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

for younger adults. Interestingly, although it did not reach statistical significance, the association between perceived social support and chronic conditions was positive for younger adults. It would be interesting to explore this pattern further in future research. There is empirical evidence of an adverse relationship between one's well-being and social support (Williams et al., 2017), whereby individuals are excessively dependent on and preoccupied with relationships such that the balance between autonomy and interdependency is disrupted (Blatt, 2008). Study 2 further showed that when controlling for the initial symptoms, the loneliness experienced over the 13 days amplified the age difference in physical symptoms afterwards. Together, these findings provide support for the importance of considering age differences in examining the benefits that social relatedness can bring to health.

It is worth noting that this study is one of the first to examine the relationship between the social relatedness and physical health of Korean adults, especially those of a wide age range. Not only were previous studies on the link between social relatedness and physical health across different age ranges conducted mostly in Western countries, but also those that were conducted among Koreans focused primarily on elderly populations (Kim et al., 2005; Wong et al., 2007; Shin et al., 2008). By including participants of a wide age range, the present study was able to identify the conditions under which the perception of social connection was particularly influential to one's health.

Our attempt not only allows us to expand this research to a new cultural context (i.e., Korea) but also provides a unique contribution to the literature examining the role of cultural context in understanding health processes. In recent years, researchers have begun to consider cultural background as an important moderators in explaining the seemingly inconsistent associations between social relationships and well-being (Kim et al., 2008; Uchida et al., 2008; Park et al., 2013; Campos and Kim, 2017; Ishii et al., 2017). Given the strong interdependent and collectivistic cultural norms in Korea (Triandis, 1993; Oyserman et al., 2002), a sense of belongingness and supportive social relationships may be particularly critical for one's well-being in this cultural context (Kitayama et al., 2006; Uchida and Kitayama, 2009). Also, the fact that older (vs. younger) adults' health is more influenced by the perception of social connectedness may indicate that the interdependent cultural values are more pertinent to older than to younger adults in the Korean context. It would be a worthwhile task for future research to explore whether cultural values have any role in amplifying the impact of the perception of social connectedness.

There are several limitations of the present study that are worthy of consideration. First, our measure of health relied on self-reports, which are more closely associated with subjective evaluations of one's health status than objectively measured biomarkers. Although the evaluation of chronic health conditions was objective in the sense that these conditions were either diagnosed or treated by health professionals, such measures are nonetheless less accurate than biomarker measurements. Future work should also employ objective measures of health indicators. Second, we compared the relative strength of the association between social relatedness and physical health across different age range. Hence, it is hard to determine whether the observed difference in the effect of social relatedness on health across age is due to aging effects, cohort effects, or a combination of the two. Longitudinal studies using several methods, such as self-report measures, daily diary measures and experience sampling measures, are needed in order to illuminate this issue. In addition, although we used the daily diary method for Study 2, we did not conduct a within-person analysis of the relationship between loneliness and physical well-being, which would have shed further light on the potential fluctuations of the relationship between these two factors over the two-week period.

Healthy aging is one of the major tasks that individuals face in a time when life expectancy will soon exceed 90 years for the first time in human history (Kontis et al., 2017). In fact, the rate of the increase in the national life expectancy does not seem to be slowing down (Oeppen and Vaupel, 2002). South Korea, in particular, along with some Western countries, is one of the top performers in the rise in life expectancy. Nearly 60% of the South Korean girls born in 2030 will be likely to have a life expectancy of 90 years (Kontis et al., 2017). As individuals spend more years in later life, maintaining healthy physical status has never been more critical in determining one's quality of life, and loneliness is indeed a troubling challenge of getting old for most lay people (Pew Research Center, 2009). According to the findings of the present research, the consequences of loneliness among the older population are not unreasonable. Studies conducted in the West document that up to 40% of people aged 60 or older experience loneliness (Dickens et al., 2011). In the process of rapid societal change in recent years in Korea, there has been as much as a fourteen-fold increase in the divorce rate among the elderly compared to 20 years ago (Statistics Korea, 2014). Considering that spousal support is a major source of social support (Dehle et al., 2001), social isolation among older individuals has thus become an important social problem now more than ever (Jung, 2017). The findings of the present research call policymakers' attention to the need for intervention programs providing social support in a group format targeting the older population such as group discussions, group physical activities, and network-building programs at various sites including nurseries, clinics, and hospitals (See Dickens et al., 2011 for a review).

AUTHOR CONTRIBUTIONS

EC is the first author on this paper–she led study design and implementation, analyses, and manuscript preparation; YK, and ML assisted with study design, implementation, and manuscript preparation; JC is the corresponding author on this paper–he led study design, implementation, analyses, and manuscript preparation; IC is the senior author on this paper, he oversaw study design, implementation, and analyses.

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APPENDIX

Full list of items used for chronic health conditions in Study 1
In the past 12 months, have you experienced or been treated for any of the following?
a. Asthma, bronchitis, or emphysema
b. Tuberculosis
c. Other lung problems
d. Arthritis, rheumatism, or other bone or joint diseases
e. Sciatica, lumbago, or recurring backache
f. Persistent skin trouble (e.g., eczema)
g. Thyroid disease
h. Hay fever
i. Recurring stomach trouble, indigestion, or diarrhea
j. Urinary or bladder problems
k. Being constipated all or most of the time
l. Gall bladder trouble
m. Persistent foot trouble (e.g., bunions, ingrown toenails)
n. Trouble with varicose veins requiring medical treatment
o. AIDS or HIV infection
p. Lupus or other autoimmune disorders
q. Persistent trouble with your gums or mouth
r. Persistent trouble with your teeth
s. High blood pressure or hypertension
t. Anxiety, depression, or some other emotional disorder
u. Alcohol or drug problems
v. Migraine headaches
w. Chronic sleeping problems
x. Diabetes or high blood sugar
y. Multiple sclerosis, epilepsy, or other neurological disorders
z. Stroke
aa. Ulcer
bb. Hernia or rupture
cc. Piles or hemorrhoids
dd. Swallowing Problem

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REVIEW
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Decision Making under Ambiguity and Objective Risk in Higher Age – A Review on Cognitive and Emotional Contributions

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The ability of decision making plays a highly relevant role in our survival, but is adversely affected during the process of aging. The present review aims to provide a better understanding of age-related differences in decision making and the role of cognitive and emotional factors in this context. We reviewed the literature about age-effects on decision-making performance, focusing on decision making under ambiguous and objective risk. In decisions under ambiguous risks, as measured by the Iowa Gambling Task, decisions are based on the experiences with consequences. In this case, many articles have attributed age-related impairments in decision making to changes in emotional and somatic reward- and punishment processing. In decisions under objective risks, as measured for example by the Game of Dice Task, decisions can be based on explicit information about risks and consequences. In this case, age-related changes have been attributed mainly to a cognitive decline, particularly impaired executive functions. However, recent findings challenge these conclusions. The present review summarizes neuropsychological and neurophysiological findings of age-related differences in decision making under ambiguous and objective risk. In this context, the relevance of learning, but also of cognitive and emotional contributors – responsible for age-related differences in decision making – are additionally pointed out.

Keywords: aging, decision making, cognition, emotion, learning

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INTRODUCTION

Research on decision making over the life span shows fascinating, surprising and not seldom controversial results. Studies suggest that with increasing age people can display stability, improvements as well as downgrades when making decisions (Mata et al., 2011; Wiesiolek et al., 2014). On the one hand, older people have a large collection of experiences at their disposal, and seem to develop an emotional balance to make foresighted choices. On the other hand, some older people show a decline of cognitive functions. Other older persons demonstrate forgetfulness, inflexibility, slowness, and are overstrained when confronted with decisions. Many decision situations imply a risk that a bad choice is followed by suboptimal or very negative consequences. A psychological understanding of older adults' decision-making competence and mechanisms

contributing to risk-taking preferences are not only interesting from a basic-research perspective, but also from an applied perspective. Here, the increasing age of our world population – especially in the most industrialized countries – plays a highly relevant role. The literature provides some theoretical models, which describe neuropsychological mechanisms underlying decision making in general (Bechara et al., 1997; Brand et al., 2006; Schiebener and Brand, 2015a). However, there has been little attempts to bring together the diverse empirical findings and existing theoretical models to explain different changes in decision making of higher age.

The review aims at reviewing theoretical models on decision making as well as literature that investigated circumstances under which older aged individuals' decision making undergoes changes and which mediators and moderators help to understand the underlying mechanisms. In contrast to previous theoretical works in the field of decision making, we focus especially on age related differences and implement both theoretical as well as empirical findings in a model at the end of the manuscript at hand.

TWO TYPES OF DECISION SITUATIONS AND TWO EXEMPLARY DECISION TASKS

In the present context, we address decision making under risk conditions, i.e., decision situations in which two or more options are available, the outcome of the decision is uncertain and there is a risk that suboptimal consequences follow, which cannot be completely anticipated (Kahneman and Tversky, 1979). For the review, we adopt the common distinction between decision making under ambiguous risk conditions and decision making under objective risk conditions (e.g., Krain et al., 2006; Schiebener and Brand, 2015a).

In decisions under ambiguous risk conditions there is no explicit information provided regarding the probabilities and extents of positive and negative consequences connected to the decision options (Brand et al., 2006). In other words, there are options available but individuals have no information they may use for reasoning which options are better and which are worse. Thus, they have to make choices and learn from feedback which options should better be preferred and which avoided. The task most frequently used to assess decisions under ambiguous risks is the Iowa Gambling Task (IGT; Bechara et al., 1994). The task has been used in uncounted numbers of studies addressing basic decision-making processes (e.g., Li et al., 2010), potential decision-making impairments in patients with neurological diseases and psychiatric disorders (e.g., Sevy et al., 2007), as well as studies on decision making and aging (e.g., Wiesiolek et al., 2014). In the IGT, participants are faced with four decks of cards lying face down. They have to choose between the four decks. After each choice, fictitious money is won but sometimes an additional loss follows. Participants have the aim to win as much money as possible and to lose as little of it as possible. During the course of the task participants can learn that the two left decks (A and B) lead to high gains but occasional very high losses. Overall, these two decks are disadvantageous. The two right decks (C and D) lead to low gains and occasional low losses. Overall, they are advantageous. The heights and occurrences of gains and losses vary in a way making it impossible to calculate probabilities. Most psychologically healthy individuals begin to prefer the advantageous options in the IGT on average around the 40th of the 100 IGT trials (Bechara et al., 1994; van den Bos et al., 2006). More details on the IGT can be found elsewhere (Buelow and Suhr, 2009).

In decisions under objective risk, there is explicit information about the rules for positive and negative consequences and the probabilities of their occurrence. The probabilities need not necessarily to be given but may also be calculable by considering the rules. In this type of decision situation individuals can make calculations to assess, which options are more favorable than others. In case the situation remains stable over several decision trials, individuals may even make long-term plans, develop strategies and apply them continuously. Two executive functions play a major role in generating a proper choice: (i) the ability to predict future outcomes of goal-directed actions; and (ii) the ability to cancel them when they are unlikely to accomplish valuable results (Mirabella, 2014). In fact, to make an optimal decision, the brain should confidently estimate the consequence of each choice. A very frequently used task to assess decision making under objective risk is the Game of Dice Task (GDT; Brand et al., 2005). Participants have to guess 18 times, which number will occur on top of a single virtual die. If they guess correctly, they win fictitious money, otherwise they lose the same amount of money. Participants can choose between 14 options involving four types of guesses: Betting on a single number or a combination of two, three, or four numbers. When they bet on more than one number they win, if one of the numbers in the combination is thrown. The possible gains and losses of the riskier options are higher (one number: €1,000, two numbers: €500, three numbers: €200, four numbers: €100). The winning probabilities are not presented but can be calculated (1/6, 2/6, 3/6, 4/6). Participants can calculate from the beginning that betting on less numbers is very risky and will probably lead to many high losses, while betting on more numbers is less risky and will probably lead to more frequent low gains and only low losses.

There are several other tasks assessing decisions under ambiguous risks [e.g., the Balloon Analog Risk Task (BART; Lejuez et al., 2002] or objective risks (e.g., the Cups Task, the Probability Associated Gambling Task, the Cambridge Gambling Task, and the Columbia Card Task; Figner and Voelki, 2004). In the present context, we mainly concentrate on the IGT and the GDT, respectively. Both tasks have been used in numerous previous studies to assess age-differences in decision making. Furthermore, the two tasks are not only used for addressing main effects of age, but also of cognitive and emotional factors. For example, Bruine de Bruin et al. (2012) reported a mediation of age and performance on decision tasks by fluid cognitive ability. Next to the IGT and GDT, other tasks will be mentioned if studies using them point to contrary results.

MODELS OF DECISION MAKING AND THE ROLE OF AGE

Many models of decision making follow a dual-process approach (e.g., Epstein et al., 1996; Kahneman, 2003; Evans and Curtis-Holmes, 2005). In these models two systems are differentiated. One system is emotional, intuitive, impulsive as well as associative and works effortless, automatized and quickly. This system had the upper hand, when a decision was fast and thoughtless. It is – for example – called the impulsive system, intuitive-experiential system, or system one. The other system is rational, rule-guided, cognitively controlled and works effortful and slow. This system had the upper hand, when a decision was thought through, considering pros and cons, risks and chances and so on. In recent literature, dual-process models have been criticized for the strict separation of the systems, for potential theoretically wrong conclusions and are considered unsatisfactory by some authors (Evans and Stanovich, 2013, for review). From a neurobiological perspective there is strong evidence that the brain indeed has particular areas processing emotional impulses and particular areas processing cognitive reflections (Bechara, 2005). However, this evidence would also not support a strict separation of the systems but rather an interaction between them (Schiebener and Brand, 2015a).

There is a neurobiological oriented model on decision making suggested by Bechara (2005) implying an impulsive and a reflective system, which interact during the decision-making process. The impulsive system mainly involves the amygdala, ventral striatum and orbitofrontal cortex and is emotional and short-termly oriented. It elicits immediate emotional reactions (e.g., reward anticipation or fear) to the environment (e.g., presented decision options). The reflective system mainly involves the dorsolateral prefrontal cortex, anterior cingulate cortex and posterior parietal lobe and is long-term oriented. It processes knowledge and memories about possible consequences, situational rules and can control and strategize behavior.

The somatic marker hypothesis (e.g., Bechara and Damasio, 2005) harmonizes with this model. In summary, it says that making advantageous decisions can be learned emotionally from rewarding and punishing feedback from previous decisions. For example, when choosing a particular decision option is followed by a positive or negative consequence the impulsive system reacts with reward-processing, including the elicitation of bodily activation changes (e.g., increasing heart rate, visceral activations, slight muscle contractions, slight sweat segregation). The brain interprets these bodily reactions as being emotional. When being later on confronted with, the decision option may already be somatically marked. In this case, the reactions can be re-elicited, which can bias individuals' cognitions and behaviors and guide individual toward the option again (in case it has been rewarding) or warn from choosing the option once more. These processes are anticipatory and can remain below an awareness threshold (Hicks et al., 2010). Somatic markers are regarded an important motivational aspect in decision making, providing individuals with affective information and the necessary emotional lift or warning in order to be able to make up their minds and be guided toward advantageous decision options. In contrast to the somatic marker hypothesis, Camille et al. (2004) and Coricelli et al. (2005, 2007) introduced a contrary perspective. The authors assume a top-down modulation of emotions as result of counterfactual thinking after a decision has been made (Camille et al., 2004; Coricelli et al., 2005, 2007). Furthermore, they reported reactivation of activity in the orbitofrontal cortex and amygdala occurring during the phase of choice, when the brain is anticipating possible future consequences of decisions. Based on these findings, Coricelli et al. (2007) suggested that the activation pattern reflects learning is based on cumulative emotional experience.

A more recent model (Schiebener and Brand, 2015a) follows the idea of two interacting systems and also implies age as a potentially modulating variable of decision-making processes. The model suggests that during decision making the impulsive and the reflective system are active but in most cases one of them is triggered as the leading processing mode. If this is the impulsive system, individuals go by immediate feelings (intuitions, impulses, urge for reward, fear of punishment), constituting a liking/disliking of options. If the reflective system guides the decision-making process, individuals use cognitive control (extract information, deliberate on options, plan, strategize and monitor behavior). In the case the decision is made under objective risk, this may also guide processing on ratios (e.g., calculating probabilities). In the impulsive system, feedback about consequences can trigger immediate reward and punishment reactions and can lead to the development of somatic markers. In the reflective system feedback can be used to check and monitor the success of a current decision-making strategy and revise the strategy (Brand et al., 2009). Whether a decision is made more impulsively or more reflectively is connected to the relative power of the two systems in a certain individual and situation and can lead to different decisions. For example, if the impulsive system has the upper hand decisions more probably become spontaneous and riskier. If the reflective system has the upper hand, decisions can become thought through, planned and guided by ratio considerations (Schiebener and Brand, 2015b). Which of the two processing systems becomes the leading one in a situation can be affected by several attributes of the individual and environmental aspects of the situation itself. For example, impulsive individuals and people in stress situations seem to be prone to be guided by the impulsive system, while persons with better executive functions or after induction of bad mood seem to be more frequently guided by the reflective system (Kahneman and Tversky, 1979; Epstein et al., 1996; Vohs, 2006; Schiebener and Brand, 2015a,b). Age is one of the factors named in the model that can affect impulsive and reflective processing in decision making, because aging has been shown to influence decision-making performance by affecting several executive functions and therefore our general ability of reasoning, processes controlled by reflective system. Given that we believe that alterations in cognitive abilities and emotional processing are the basis of age-related changes in decision making, we first

consider the literature on the development of these aspects and then review the findings on age-related changes in decision-making performance.

ALTERATIONS IN COGNITIVE AND EMOTIONAL DOMAINS IN HIGHER AGE

The process of aging is accompanied by neuropsychological changes in cognitive and emotional domains. Corresponding with structural and functional brain changes – especially in the frontal lobe and the hippocampus (Fiell and Walhovd, 2010) – these changes typically affect executive functions such as inhibition, cognitive flexibility, planning, working memory, susceptibility to inference and strategy choice (Reuter-Lorenz and Sylvester, 2005; Uekermann et al., 2006; Allain et al., 2007; Ashendorf and McCaffrey, 2008; Elderkin-Thompson et al., 2008; Hodzik and Lemaire, 2011). In this context, Del Missier et al. (2012) discussed the ability to apply decision rules, and successful engagement in cognitive reflection as related to the monitoring and inhibition dimension of executive functions. In general, monitoring is described as key component for surviving in a constantly changing environment. This system is formed by a network of areas that determines the best strategy based on the available data, learned behaviors and the outcomes of previous actions. Depending on the task being performed, monitoring can engage different networks (Mirabella and Lebedev, 2017). Inhibition, as further executive function, must be seen as highly relevant in the context of impulse control in decision making. The relevance is witnessed by the wide range of neurological and psychiatric disorders characterized by poor control of urges such as Parkinson's disease (e.g., Mirabella et al., 2012, 2017), eating disorders (Bartholdy et al., 2017), ADHD (Lipszyc and Schachar, 2010), gambling disorders (Marchetti et al., 2016; Nigro et al., 2018), OCD and depression (Christodoulou et al., 2006). Additionally, an age-related decline in the function of inhibition is reported in numerous previous studies (e.g., Sebastian et al., 2013; Bloemendaal et al., 2016; Coxon et al., 2016; Hsieh and Lin, 2017). Along with the function of monitoring and inhibition, Del Missier et al. (2012) discussed the executive function of shifting as important ability to provide consistent judgments in risk and is also adversely affected during the process of aging (e.g., Cepeda et al., 2001).

In the context of memory, many functions such as short-term memory, semantic memory and procedural memory remain relatively intact until old age (find summary in Glisky, 2007). A major difference between reduced vs. impaired functions is often seen in the amount to which they require active, quick and flexible cognitive processing that involves manipulation of information (see e.g., Salthouse, 1996; Salthouse et al., 2003). Thus, many older adults remain successful in the accomplishment of well-known everyday tasks and follow clearly instructed or familiar tasks (requiring semantic- and procedural memory) but are highly demanded when they need to combine new information, make plans or weigh up controversial pros- and cons (requiring quick information processing, cognitive flexibility, planning and/or working memory; see Glisky, 2007).

Emotional processing in older age has been reported to be biased in different ways compared to younger adults. Several authors have observed a positivity effect for processing of emotional information (Reed et al., 2014): for example, older adults are better at remembering positive information (Carstensen and Turk-Charles, 1994) and react less to negative stimuli (Knight et al., 2007), which indicates an insulation against negative information in higher age (Mather, 2012). This is accompanied by a reduction in amygdala activity during presentation of negative stimuli (Mather et al., 2004). Furthermore, older adults show an increase in prefrontal activity during presentation of emotional stimuli (Gunning-Dixon et al., 2003; Mather, 2012). Similar findings are reported in studies with more complex emotional stimuli such as pictures, words and faces. In comparison with patients with bipolar disorder, Altamura et al. (2016) identified that older adults recognized happy expressions faster and rated emotional faces more intensely. Further evidence comes from Mammarella et al. (2016b), who showed a higher sensitivity in older adults to positive stimuli by presenting a series of affective words or pictures. Within a second study of the research group (Mammarella et al., 2016a) the authors reported evidence for a potential involvement of different genetic polymorphisms in driving the positivity effect of older adults.

Event-related potential correlates of feedback processing have been observed to be less pronounced in older adults (Kardos et al., 2016). Comparable to the findings of the positivity effect, older adults adapt their behavior more to positive feedback and less to negative feedback (which tended to be the other way round in younger adults) (Di Rosa et al., 2015). In addition, activity in the ventral striatum positively correlated with age during rewarding feedback compared to neutral feedback (Vink et al., 2015). Rademacher et al. (2014) reported reduced activity in the nucleus accumbens of older adults when presenting monetary reward cues, while younger individuals showed increased activity (Rademacher et al., 2014). Samanez-Larkin et al. (2007) showed normal activity in striatal areas and the insular during gain anticipation in older age. In contrast, there was a relative reduction of activity during loss anticipation (see also Samanez-Larkin and Knutson, 2015). In reward anticipation, Vink et al. (2015) reported no general decline in activity during anticipation of consequences. Furthermore, Nielsen et al. (2008) reported increased negative arousal in younger adults when anticipating losses and positive arousal when anticipating gains, whereas older adults showed more positive arousal when anticipating gains but no increased negative arousal during the anticipation of losses.

In summary, studies focusing age-effects on emotion-processing, show consistent evidence that processing of negative information, negative feedback and loss/punishment are calmed in older adults. Positive information, positive feedback and gain/reward expectation were comparable to older adults or were intensified. Thus, there seems to be a negativity neglect combined with a tendency toward a positivity bias in several aspects potentially involved in decision making.

AGE-RELATED CHANGES IN DECISION-MAKING PERFORMANCE

Mata et al. (2011), reviewed 29 studies, which considered older and younger individuals in tasks assessing decisions under ambiguous and objective risk. They observed that the pattern of age-related differences in decision making depend on the type of decision situation as well as the tasks used. Although, both the Balloon Analog Risk Task (BART) (participants had to choose between pumping up a balloon to earn more points if it doesn't explode and collecting the earned money and getting a new balloon) and the IGT represent tasks for quantifying decision making under ambiguous risk, contrary findings between the two paradigm were reported (Mata et al., 2011, for review). In the IGT, older adults showed riskier and less advantageous behavior but when measured with the BART, older adults were more risk averse. Here, age-related effects were attributed to older-adults' difficulties in learning from consequences. In decision making under objective risk, older adults behaved comparably to younger adults (e.g., in tasks offering a choice between a safe consequence and a gamble). However, when the decision task (such as the Cambridge Gambling Task) couples the low risk with low losses in the advantageous options and high risk with high possible losses in the disadvantageous options, older adults behaved less advantageously than younger adults (i.e., they had a higher preference for the high-gain–high-risk options). This conflict between high reward and risk may be particularly challenging for older adults (Mata et al., 2011) and is also inherent in the GDT.

In the following, we take a more detailed look at aging research. Here, we are focus on the IGT and GDT, which are considered among the most important decision-making tasks for decisions under ambiguous (IGT) and objective risk (GDT), respectively (Gleichgerrcht et al., 2010) (see **Table 1** for further details).

Carvalho et al. (2012) provided new insight into the effects of learning in the context of age-related differences in decision-making under ambiguous risk. Although, they did not found overall differences between younger and older adults, they revealed significant differences between their learning curves. Considering single block-performance, older adults had a significantly better performance (only) in the first block compared to the younger ones. This is because the first block is the most implicit one and processing is guided by emotions, while the second is the most ambiguous block because there is no sufficient time to evaluate contingencies of gains and losses. No age-related differences neither in single block nor in overall IGT-performance were reported by Kovalchik et al. (2005) and Schneider and Parente (2006). In a further study, the authors pointed out the role of reversal learning in IGT-performance by using a modified version of the IGT, which involved a contingency reversal midway through the task (Kovalchik and Allman, 2006). Here, participants had to learn from recurrent changes of the decks from advantageous to disadvantageous. Thereby, reversal learning, the ability to adjust responses when the reinforcement value of stimuli change, is assumed to be distinct from the somatic marker process (Bechara et al., 2000) and affected by a decline of the ventromedial frontal cortex (Fellows and Farah, 2003). Fellows and Farah (2004) confirmed the assumption by indicating impairments in the IGT in both patients with ventromedial and patients with dorsolateral prefrontal lesions, but deficits of reversal learning were only shown in patients with ventromedial prefrontal abnormalities. The process of learning was further pointed out by Wood et al. (2005). Missing age-related differences in the IGT, the authors reported the usage of different strategies in younger and older adults. With an equal weight to gains and losses, they argue that older adults' choices are highly dependent on learning parameter from recently experienced outcomes, rather than producing the maximum expected payoff. Bauer et al. (2013) used two versions of the IGT, in one version an immediate reward was always delivered regardless of deck choice while in the other version an immediate punishment was always delivered followed on occasion by a delayed reward. Age-related differences were only indicated in the first version. It is suggested that decision making in the elderly is disproportionally influenced by prospects of receiving reward, irrespective of the presence or degree of punishment. This is in turn in accordance with the socioemotional selectivity theory, which claims a fundamental role of time and therefore a change of social goals with a decrease of remaining time (Carstensen et al., 1999). Furthermore, Weller et al. (2011) reported a decrease in risk propensity with increasing age. This behavior is explained by the fact that older adults aim to achieve potential gains, rather than increased risk to avoid losses. Using the Cambridge Gambling Task, Deakin et al. (2004) reported, next to an age-associated reduction in risk-taking, longer deliberation times, poorer decision making, but no changes in delay aversion. Furthermore, the authors pointed out the relation between intelligence and the time need for the decision as well as the amount of modulation of risk-taking. While Denburg et al. (2005) indicated age-related differences in the total score of IGT-performance, they found no evidence in general cognitive functions such as attention, memory, visual perception or language, responsible for these differences. Only a weak relationship between used measures of cognition and IGT performance was reported by Beitz et al. (2014), although an interaction of modeling parameters suggested that cognitive changes are causal for age-related differences. Furthermore, Schiebener and Brand (2017) pointed out the role of cognitive abilities as mediator of age-related differences in both IGT and GDT performance. Thereby, age-related effects in the GDT were indicated only in the last 60 trials. Age-related differences in IGT were additionally associated with a decline in immediate but not delayed retrieve of memorized content (Fein et al., 2007). Again, Zamarian et al. (2008) reported an age-related decrease of IGT performance, whereas no differences were found in the Probability Associated Gambling task (PAG). In contrast to the IGT, decisions in the PAG task are based on estimable probabilities and alternatives, associated reward as well as punishments are explicitly given. Here, participants had to choose between a fixed amount of money or gamble in the lottery with the probability to win or lose a higher

TABLE 1 | Considered neuropsychological studies of age-related differences in decision making.

Studies	Participants		Task	Age-related differences	Explanations of the authors
	Younger	Older			
Bauer et al., 2013	*N*: 265, age: 23–88		IGT	Yes	Age-related increase in hypersensitivity to reward, whereby decisions of older adults are disproportionately influenced by prospects of receiving reward, irrespective of the presence or degree of punishment.
Beitz et al., 2014	*N*: 1,583, age: 5–89		IGT	Yes	Critical developments in decision processes during the adolescent years and decline in a cognitive process.
Brand and Schiebener, 2013	*N*: 538, age: 18–80		GDT	Yes	Relevance of executive functioning.
Carvalho et al., 2012	*N*: 40, age: 25.5 ± 4.7	*N*: 40, age: 67.4 ± 5.0	IGT	No	Significant differences in learning curve of the two age-groups.
Deakin et al., 2004	*N*: 177, age: 17–73		CGT	Yes	Age-related decreases in the risk tolerance factor, but unrelated to the delay aversion; neither factor was significantly related to verbal IQ.
Denburg et al., 2005	*N*: 40, age: 26–55	*N*: 40, age: 56–85	IGT	Yes	Disproportionate aging of the ventromedial prefrontal cortex.
Denburg et al., 2007	*N*: 40, age: 41.0	*N*: 40, age: 70.4	IGT	Yes	Poor decision makers display defective autonomic responses (or somatic markers).
Fein et al., 2007	*N*: 112, age: 37.8 ± 10.8	*N*: 52, age: 73.7 ± 7.4	IGT	Yes	Performance was associated with auditory working memory and psychomotor function in young adults, and immediate memory in older adults.
Kovalchik et al., 2005	*N*: 51, age: 18–36	*N*: 50, age: 70–95	IGT	No	Elderly individuals demonstrate highly accurate meta-knowledge evaluations. Older individuals have more accurate beliefs about their knowledge and its limitations.
Kovalchik and Allman, 2006	*N*: 65, age: 21.9 ± 3.9	*N*: 26, age: 80.5 ± 6.9	IGT	Yes	Equivalent monetary rewards might have less value to older adults than young adults, resulting in divergent preference behavior. Socioemotional selectivity theory which argues that an insensitivity to emotionally negative stimuli results from normative aging. Role of life experiences.
Lamar and Resnick, 2004	*N*: 23, age: 28.4 ± 5.9	*N*: 20, age: 69.1 ± 5.0	IGT	No	Sensitivity of the orbitofrontal cortex to age-related effects.
MacPherson et al., 2002	*N*: 30, age: 28.8 ± 6.0 *N*: 30, age: 50.3 ± 5.7	*N*: 30, age: 69.9 ± 5.5	IGT	No	Age-related differences depend on executive functions. Specific dorsolateral prefrontal theory of cognitive changes with age, rather than a global decline in frontal-lobe function.
Schiebener and Brand, 2017	*N*: 210, age: 18–86		IGT	Yes (last 60 trials)	Reductions in cognitive functions in older age.
Schneider and Parente, 2006	*N*: 42, age: 24 ± 4.4	*N*: 40, age: 68 ± 5.0	IGT	No	Lack of maintenance of the learning process.
Weller et al., 2011	*N*: 734, age: 5–85		Cups task	Yes	Evidence concerning the role of frontal lobe in decision making.
Wood et al., 2005	*N*: 88, age: 22.1 ± 4.5	*N*: 67, age: 77.3 ± 4.6	IGT	No	Different age-groups used different strategies. Strength of the younger group: learning and memory. Strength of the older group: accurate representation of wins and losses (valence).
Zamarian et al., 2008	*N*: 33, age: 36.1 ± 13.7	*N*: 52, age: 69.3 ± 7.0	IGT/PAG	Yes (IGT)/No (PAG)	Contribution of executive functions. Old people can make advantageous decisions when complete information about the decision situation is available.

amount. Choosing the fixed sum means a gain or loss of €20, whereas choosing the lottery the participant will win €100 when a red cube is drawn, and lose €100 when a blue cube is drawn. Furthermore, participants were asked to perform tasks of executive functions such as phonological verbal fluency, categorical verbal fluency, verbal short-term memory, verbal working memory, divided attention, cognitive flexibility and mental complex calculation. Correlational analyses indicated a contribution of executive functions to both types of decisions. Similar findings are reported in the Game of Dice Task. For example, Brand and Schiebener (2013) indicated that people with good executive functions performed well in the GDT, whereas people with bad executive functions performed worse. Furthermore, the authors reported a mild correlation between age and decision making, moderated by subcomponents of executive functions (categorization, learning from feedback) and logical thinking (process of clearly moving from one related thought to another).

Another aspect discussed by Denburg et al. (2007) refers to autonomic responses. While a sizeable subset of older participants performed more disadvantageous in the IGT, the same poor decision-makers also displayed defective autonomic responses or somatic marker. Furthermore, the authors suggested a link between ventromedial prefrontal dysfunctions and decreased decision making. In contrast, MacPherson et al. (2002) postulated a greater sensitivity of orbitofrontal than ventromedial prefrontal cortex to the effects of aging. Using three cognitive tasks (WCST, Self-Ordered Pointed Task, Delayed-Response Task) assigned to dorsolateral prefrontal dysfunction and three (IGT, Faux Pas Task, Emotion Identification Task) to ventromedial prefrontal dysfunction, the authors reported age-related differences in dorsolateral but not in ventromedial prefrontal measures. Similar, Lamar and Resnick (2004) also assigned different measures either to the orbitofrontal (IGT, Delayed Match and non-match to sample task) or the dorsolateral prefrontal cortex (Self-ordered pointing task, Letter fluency, WAIT-R Digit Span Backward, Month Backward from the Boston Revision of the Wechsler Memory Scale). Here, the authors found no age-related differences in IGT performance, but proposed a sensitivity of measures of orbitofrontal cortex functioning to age effects.

In order to get a better understanding of age-related differences in neurophysiological findings, we end up the present section by reviewing imaging studies focusing older adults' decision making (see **Table 2** for a summary). In this context, Samanez-Larkin et al. (2007) reported an age-related reduction of striatal activity in loss anticipation, but intact activity in gain anticipation. A relationship between increased variability in the nucleus accumbens and increased aging was reported in a further study by Samanez-Larkin et al. (2010), facing participants with financial decisions. Consistent with their behavioral results, which showed age-related impairments

TABLE 2 | Considered neurophysiological studies of age-related differences in decision making.

Studies	Participants		Task	Age-related differences	Underlying brain mechanisms
	Younger	Older			
Chowdhury et al., 2013	*N*: 22, age: 25.18 ± 3.85	*N*: 32, age: 70.0 ± 3.2	Two-armed bandit choice task	Yes	Age-related increase in dopamine level as well as activity in the striatum.
Eppinger et al., 2013	*N*: 13, age: 28.8 ± 3.3	*N*: 13, age: 70.0 ± 4.6	Two-choice decisions	Yes	Reduced ventromedial prefrontal activity during reward learning in the elderly.
Halfmann et al., 2014	*N*: 31, age: 59–88		IGT	Yes	Age-related increase in prefrontal cortex.
Halfmann et al., 2016	*N*: 80, age: 21	*N*: 29, age: 75.8 ± 6.8	IGT	Yes	Age-related increase in striatum activity.
Hosseini et al., 2010	*N*: 16, age: 20	*N*: 24, age: 69	Two-choice decisions	Yes	Age-related decrease in activity in the right inferior parietal lobule.
Lee et al., 2008	*N*: 12, age: 29.9 ± 6.2	*N*: 9, age: 65.2 ± 4.2	Risky-gains task	Yes	Age-related increase in contralateral prefrontal activity, particularly at the orbitofrontal cortex as well as the right insula.
Rogalsky et al., 2012	*N*: 15, age: 58–95		IGT	Yes	Age-related increase in right ventromedial prefrontal cortex activity.
Samanez-Larkin et al., 2007	*N*: 12, age: 19–27	*N*: 12, age: 65–81	MID	Yes	Age-related reduction of striatal and insular activity in loss anticipation.
Samanez-Larkin et al., 2010	*N*: 54, age: 21–85		Dynamic financial investment task	Yes	Age-related increase in variability in nucleus accumbens activity.
Samanez-Larkin et al., 2011	*N*: 12, age: 19–26	*N*: 13, age: 63–85	Intertemporal decision making task	Yes	Relevance of mesolimbic dopamine system as well as striatal regions during the process of aging.

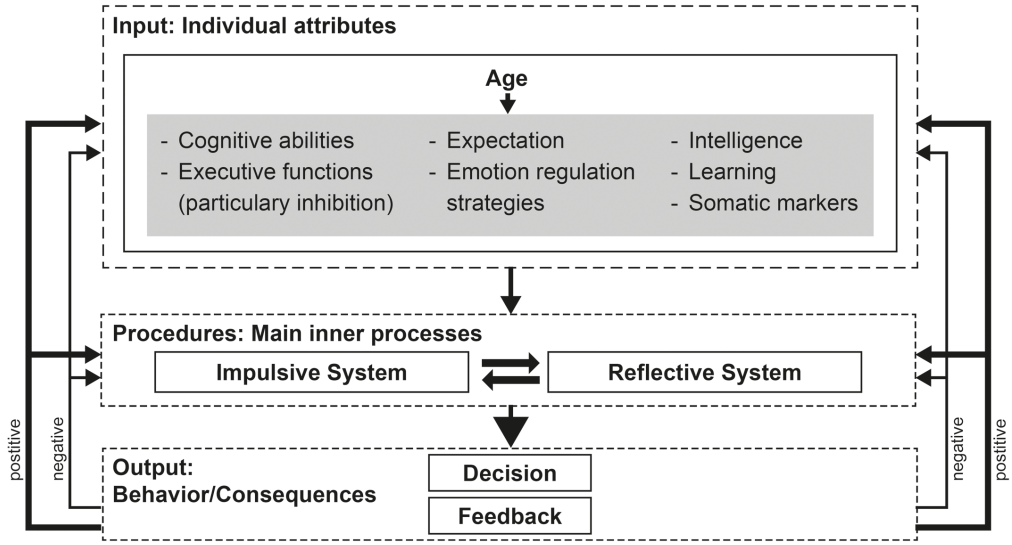

FIGURE 1 | Modified version of the decision-making model of Schiebener and Brand (2015a). The illustrations give an overview of aspects, relevant in older adults' decision making. Individual attributes (with the gray background) should not be seen as disjoint constructs, but rather as overlapping and interacting functions.

in learning from reward, Eppinger et al. (2013) demonstrated reduced ventromedial prefrontal activity during reward learning in the elderly. In the IGT, Rogalsky et al. (2012) reported an age-related increase in right ventromedial prefrontal cortex activity. Along with the ventromedial prefrontal cortex, Halfmann et al. (2016) reported a greater activity in the striatum during IGT performance in older adults. Thereby, the increased activity in prefrontal cortex was already reported in a previous study of the authors (Halfmann et al., 2014), where older adults showed more advantageous behavior in the IGT. Applying a two-choice prediction paradigm while participants were scanned with functional magnetic resonance imaging, Hosseini et al. (2010) reported a network of brain regions activated in healthy older adults similar to their younger counterparts. In contrast to others, the authors reported no increase in brain activity, but an age-related decrease in activity in the right inferior parietal lobule. Performing a risky-gains task older adults in the study by Lee et al. (2008) showed increased contralateral prefrontal activity, particularly in the orbitofrontal cortex as well as increased activity in the right insula in the older adults compared to the younger ones. The influence of the dopaminergic and serotoninergic brain system needs to be considered additionally. While Mohr et al. (2010) assumed a relationship based on the findings of decision making and neurotransmitter as well as aging and neurotransmitter, direct evidence comes from Chowdhury et al. (2013) (see also Shohamy and Wimmer, 2013). The authors used L-Dopa – the standard medication for Parkinson's disease – to increase dopamine levels in the brain, in healthy older participants. Results demonstrated that increasing dopamine levels in the brain of the elderly increased task-based learning rate and task performance as well as activity in the striatum. Furthermore, Samanez-Larkin et al. (2011) reported that older adults with weaker correlations between activity in regions associated with the mesolimbic dopamine system and expected value, make less optimal decisions.

In summary, evidence from both behavioral and neurophysiological studies highlighted the effects of the process of aging on humans' decision-making.

BRINGING TOGETHER THE THEORETICAL MODELS AND EMPIRICAL FINDINGS

The present review was conducted in order to provide a better understanding of decision making under ambiguity and objective risk in the elderly. On the one hand, we confirm the findings of the key role of learning (Mata et al., 2011; Samanez-Larkin and Knutson, 2012). On the other hand, we suggest a lot more variables – adversely affected during the process of aging – responsible for characterizing older adults' decision making.

In order to get a better understanding of the variables – responsible in this context – we modified the model proposed by Schiebener and Brand (2015a) (see **Figure 1**).

In the original model Schiebener and Brand (2015a) pointed out three aspects named 'individual attributes,' 'information about the decision situation,' and 'situational induced states and external influences' as input factors, affecting the process of decision-making. Due to the fact that the present modified model focus exclusively on age-related differences, we disregarded the external factors 'information about the decision situation' and 'situational induced states and external influences,' which are not influenced by the process of aging. Furthermore, we disregarded the individual attributes 'need for arousal,' 'state impulsivity,' and 'self-control,' which have not been reported to be influenced in elderlies' decision making. In this context, it should be noted that these factors are related to the function of inhibition,

summarized under the term of executive functions. We added the variables of learning, intelligence and expectation, which are described to be influenced during the process of aging. In sum, there are numerous individual attributes affected during the process of aging. Some of them act as mediator/moderator and affect the process of decision making. These attributes comprising cognitive abilities (such as visual perception, and language), somatic marker, expectation (e.g., the ability to predict future outcomes), emotion regulation, intelligence, learning and executive functions.

The considered studies reported highly inconsistent effect-sizes of considered variables. Within the model we integrated all aspects without any weight or priority, as well as hierarchical structure. We argue that the inconsistency is based on numerous factors. First, the mean age of sample size differs strongly between the single studies from 69.1 years (Lamar and Resnick, 2004) to 82 years (Kovalchik et al., 2005) (see also **Tables 1**, **2**). Second, the use of the paradigm might also influence the effect size. While most IGT studies focused the total score, some reported age-related differences in a single-block consideration. Carvalho et al. (2012) for example found no overall differences between younger and older adults in IGT performance but found a significantly better performance in the first block of the elderly. Furthermore, Beitz et al. (2014) indicated a correlation of Wisconsin Card Sorting Test, *n*-back task and matrices subtests performance with IGT decks C + D but not with B + D. Third, effects of task characteristics additionally influence age-related differences in decision making. This became obvious in the study conducted by Bauer et al. (2013) who reported age-related differences in the condition of the IGT, which requires choosing lower immediate reward but not in the condition, which requires choosing higher immediate punishment.

Within the second step of the model named 'procedures: main inner processes,' we suppose an age-related influence of both, the impulsive and the reflective system. While the original model describes the impulsive system as consisted of emotional reactions, conditioning as well as somatic activity, the reflective system is described to be associated with executive functions and working memory. The considered studies indicated age-related impairments in components of both systems. Furthermore, neurophysiological findings demonstrated reduced activity in the striatum as well as the orbitofrontal cortex – mainly involved in impulsive decisions – of older adults as well as age-related differences in dorsolateral prefrontal cortex and the parietal lobe, which are – inter alia – associated with reflective decisions. Considering unfamiliar situations in which people had to analyze, balance, plan etc., executive functions especially working memory capacity might be highly relevant. Therefore, it could be assumed that handling these situations are affected during the process of aging. In contrast, we suppose that experiences from the past such as strategies of risk-avoidance are used as compensational strategies. This is in accordance with the findings that long-term memory, procedural memory, etc. are relatively unaffected in the elderly. Furthermore, it could be assumed that successful processing might also depend on the amount of crystalline or fluid intelligence used in the respective situation (see also Li et al., 2013).

In the last step of the decision-model by Schiebener and Brand (2015a) named 'Output: Behavior/Consequences,' we further differentiate between positive and negative feedback. While the original model didn't consider a subdivision of feedback, this aspect might be highly relevant in older adults' decision making. As already stated in the previous subchapter, older adults tend to hide negative feedback/information, whereas positive feedback/information is intensified. This is underpinned by the fact that feedback processing about reward and punishment as well as anticipating reward and punishment in decision making are major emotional components (e.g., Bechara et al., 1994, 1997; Damasio, 1994; Figner et al., 2009; Figner and Murphy, 2011; Panno et al., 2013; Schiebener and Brand, 2015a) and adversely affected during the process of aging.

CONCLUSION

The present review demonstrates the importance of considering decision making in older adults. Until now there is a limited number of studies focusing the effects of different cognitive and emotional mediator or moderator. Furthermore, existing studies in this context are highly inconsistent, which lead to difficulties in comparing the results. There is also a lack of longitudinal studies. Nevertheless, the review at hand provided an overview of possible variables affecting older adults' decision making as well as a possible assignment in this context. We pointed out the relevance of learning, but further addressed cognitive and emotional contributors, responsible for age-related differences in decision making. Based on these findings, future studies should systematically focus on possible mediators and moderators affecting decision making in the elderly.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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frontiers in Psychology

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Loneliness, Resilience, Mental Health, and Quality of Life in Old Age: A Structural Equation Model

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Objectives: In the scientific literature on aging, a recent core issue has been the role of individuals' internal and external resources, which are considered intrinsically connected, in contributing synergistically to physical and psychological quality of life (QoL). The current study investigates the way in which psychological factors—such as, loneliness, resilience, and mental states, in terms of depression and anxiety symptoms—affect the perceived QoL among elderly individuals.

Method: Data from 290 elderly Italian participants were used to study the mediation effects of both mental health and resilience to elucidate the relationship between loneliness and psychophysical QoL.

Results: The best model we obtained supports the mediation effect of both resilience and mental health between loneliness and mental and physical QoL. These results highlight that loneliness influences mental and physical QoL via two pathways, with the impact of loneliness mediated by mental health and resilience dimensions.

Conclusions: The findings suggest the importance of the support that elderly people receive from social relationships. In terms of clinical interventions, the reduction of loneliness could be an important factor in primary prevention or the recovery process. A way to reduce levels of mental distress could be represented by the increasing of resilience and self-efficacy and reduction of loneliness dissatisfaction. A high degree of resiliency contributes to increasing perceived life quality at the physical and psychological levels, and at the same time, reducing anxiety and depressive symptoms.

Keywords: old age, loneliness, resilience, mental health, quality of life

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INTRODUCTION

In old age, people experience profound changes and face important challenges, including modifications in their roles, retirement, and the death of loved ones (friends and family members). These experiences can increase their levels of stress and lead to a decrease in the resources that individuals feel they have in dealing with their daily lives (Sachs-Ericsson et al., 2014).

In demographic studies, it has been estimated that by 2050, the elderly population in Europe will reach 28%, which emphasizes that the highest proportion of elderly people is currently concentrated on the European continent (Börsch-Supan et al., 2005). This percentage will rise to 34% in Italy by 2025 (United Nations, 2002), while in the last Eurostat report (Eurostat, 2015a), as of 1 January 2014, there were almost 94 million people aged 65 and over in the European Union. The report

showed that 16.1% of these people were aged 65–84 years, while 2.4% were 85 years and over. In this scenario, the health condition of the elderly is a core issue; however, although there is a shared recognition of the importance of this aspect at the medical, public, and social levels, unfortunately, it is often a neglected area of scientific study and intervention (National Board of Health and Welfare, Sweden, 2008; Djukanovic et al., 2015; Eurostat, 2015b). As the issues of health, and above all, illness or disability in old age, are a matter of increasing public concern, a perspective on healthy aging is crucial when it comes to identifying, designing, and implementing appropriate strategies to meet the growing needs of the population (Djukanovic et al., 2015).

Considering the projections on the European population aging—especially in Italy—it can be assumed that this issue will become increasingly central in national policies. Lately, as noted by Stephens et al. (2015), the focus of social policies has been changing, shifting from care or symptom reduction to the promotion of well-being according to the biopsychosocial paradigm. The Health Psychology perspective, in opposition to a deficit model, is useful for critically analyzing the effects of strategies to promote healthy aging and reflect on the factors that could improve their efficacy to develop more inclusive models of intervention. Old age is stereotypically considered a period of progressive decline, and consequently, a heavier and heavier healthcare burden for society. This bias in social narratives on aging is traditionally widespread (Jeste et al., 2013; Settersten and Godlewski, 2016), although it has been refuted by experts. For these reasons, and starting from a holistic perspective, there is a growing need for empirical studies that enable the assessment of psychological functioning and overall health in the Third Age (Fry and Debats, 2010; Jeste et al., 2013). Specifically, analyzing the scientific literature, it appears that little is known about the resources that contribute to resilience and well-being in the elderly, as the research has focused more on the weaknesses or dysfunctions in elderly people than on their strengths (Fry and Debats, 2010).

According to the World Health Organization (2002, 2015), quality of life (QoL) can be defined as a subjective perception of the self-positioning in life that combines a person's psychological and PHY—cultural position, value system, expectations, aims and states, independence, and personal beliefs—with the capacity to create relationships. From another viewpoint, the perspective assumed in the theoretical framework of health-related QoL is based on a complex set of relationships that involves biopsychosocial factors related to well-being (Bowling, 2001; Ekwall et al., 2005; Gerino et al., 2015). In line with this, QoL is defined as a multidimensional concept with both objective and subjective factors that refer to general satisfaction with life or its components (Lawton, 1991; Bowling et al., 2002; Arkar et al., 2004). In the context of geriatric psychology and older people's awareness, it is increasingly clear that individuals' internal and external resources are intrinsically connected, and both these aspects contribute synergistically to physical and their psychological well-being (Ryff and Singer, 2000; Fernández-Ballesteros, 2003, 2008; Fry and Debats, 2010).

Loneliness, Mental Health, and Quality of Life

For the analysis of psychological factors that expose the elderly to the risk of malaise, it has been evidenced that depressive symptoms affect the QoL of the elderly population (Beekman et al., 1999; Blane et al., 2008). Concerning adult life, according to Blazer (2003), among the causes of emotional distress, the presence of depressive symptoms is the most frequent, as this condition significantly contributes to decreasing the QoL of the older segment of the population. For example, depressive symptoms have been proven to be associated with functional impairment, chronic diseases, and mortality (Schoevers et al., 2000; Nilsson et al., 2011; Djukanovic et al., 2015). Moreover, researchers have identified close associations between the presence of depressive symptoms and loneliness (Barg et al., 2006; Cacioppo et al., 2006, 2010; Hawkley et al., 2009; Hawkley and Cacioppo, 2010). As indicated by Peplau and Perlman (1982), loneliness can be defined as a set of negative emotional states arising when a subject feels a discrepancy, in an unfavorable direction, between the desired and actual social relationships. Studies have shown that loneliness can be a significant predictor of increases in depressive symptomatology at least 1 year later (Cacioppo et al., 2010).

Although many older people maintain a satisfactory condition of life, risks related to loneliness and psychological distress grow with age (Fry and Debats, 2002). As stated by Fry and Debats (2002), in fact, some elderly people with self-expectancies or internalized beliefs about their aging can experience severe anxiety connected with feelings of loneliness. Clinicians and institutions that are dealing with the elderly have shown a growing concern about its consequences, including profound depressive feelings. Cacioppo et al. (2006) observed that loneliness is associated with strong negative feelings, and other researchers have shown that it impairs self-regulation (Baumeister et al., 2005) or that "[l]onely adults have poor emotion regulation and are less likely to use positive feelings to alleviate their negative mood" (Wong et al., 2016, p. 2487). Loneliness, anxiety, and depressive symptoms may contribute synergistically to a significant decrease in levels of well-being (Liu and Guo, 2007). In addition, Sachs-Ericsson et al. (2014) studied the consequences of rape in an elderly sample, and found a connection between loneliness, depression, anxiety, and psychological functioning. Considering that multiple studies have pointed out that depression and loneliness are strongly associated and that they have detrimental effects on well-being in the Third Age (Tiikkainen and Heikkinen, 2005; Cacioppo et al., 2006; Golden et al., 2009; Theeke, 2010, 2012; Prieto-Flores et al., 2011; LeRoy et al., 2017), it is important to further investigate the prognosis for older persons suffering from depression (Bjørkløf et al., 2013).

Loneliness, Resilience, and QoL

In the general population, people with a low sense of self-efficacy are subject to an increased risk of physical and mental health issues (Marshall, 1991; Krause, 1994; Smith-Osborne and Felderhoff, 2016). In the elderly, loneliness dissatisfaction can

significantly contribute to reduce self-evaluations of perceived self-efficacy (i.e., Fry and Debats, 2002). In Bandura's (1977) definition, self-efficacy can be conceptualized as the perception that a person has his/her own ability to enact effective and functional responses to environmental demands. Specifically, this construct refers to people's individual differences in their aptitudes and dispositions when they evaluate themselves as able or unable to cope with situational demands in different contexts and situations (Jerusalem and Schwarzer, 1992). It can be considered a global personality trait, specifically, and permanently connected to the self-perception of mastery (Bandura, 1977, 1982, 1986, 1997, 2000; Luszczynska et al., 2005), and because of its core role in individuals' evaluation of their skills, it is closely linked with the dimension of subjective well-being (Gabriel and Bowling, 2004).

The level of generalized self-esteem is a factor that is interrelated with the dimension of well-being in its physical, emotional, and psychological components (Smith et al., 2000; Bandura, 2004; Fry and Debats, 2010). Longitudinal studies support the view that resilience traits, like self-efficacy, are protective in the later life stage (Smith-Osborne and Felderhoff, 2016) and that these beliefs are linked to stress resistance in the face of minor distress (i.e., anxiety and loneliness; e.g., Fry, 2001; Fry and Debats, 2006, 2010). As pointed out by the American Psychological Association (2004) and Bonanno (2004), resilience is configured as a common response to losses and conditions of severe stress during the lifecycle. Concerning people's ability to deal with adverse conditions in the lifespan, the attention to the construct of resilience progressively increases in relation to QoL in older people (Fry and Keyes, 2010; MacLeod et al., 2016). Gattuso (2003), Braudy Harris (2008), and recently, other authors (Wiles et al., 2012; Stephens et al., 2015), have suggested that the construct of resilience is useful for understanding health in older people. The American Psychological Association (2011) defines resilience as a successful adaptation process in response to threatening, stressful, or traumatic adverse experiences, or the ability to bounce back from difficult life conditions. It is a flourishing state despite adversity (Hildon et al., 2010), where, in the case of the elderly, "adversity" may be considered in terms of an increased frequency of life conditions that entail personal loss, inequalities, disabilities, and the general PHY challenges of aging (Stephens et al., 2015).

Wild et al. (2013) stated that resilience is a key component in successful aging. Several authors have specified that the different generations do not differ in their ability to be resilient (Carstensen et al., 2003; Laditka et al., 2009; Vahia et al., 2012), but MacLeod et al. (2016) stated that resilience may support longevity. Furthermore, according to these authors, high resilience in later life has been associated with positive health outcomes. According to the international scientific literature, it is possible to identify the following outcomes: reduced vulnerability to depressive symptomatology and mortality risks (Sharpley and Yardley, 1999; Carstensen et al., 2003; de Jager et al., 2003; Fredrickson et al., 2003; Inui, 2003; Wallace, 2003; Charney, 2004; DeSalvo et al., 2006; Montross et al., 2006; Reichstadt et al., 2007; Laditka et al., 2009; Lamond et al., 2009); better self-perceptions of aging successfully (Montross et al., 2006); and increased levels of QoL, mental health, and well-being, with improved lifestyle behaviors (Inui, 2003; Montross et al., 2006; Reichstadt et al., 2007; Vahia et al., 2012). According to Connor and Zhang (2006), resilience is a key target of anxiety and depression treatment. Studying the role of the ability to savor positive life experiences in terms of older people's life satisfaction, Smith and Hollinger-Smith (2015) confirmed that people with lower levels of resilience tend to report higher depression. Finally, resilience seems to be a protective factor for depression symptoms in the case of the spousal careers of people with dementia (O'Rourke et al., 2010; O'Dwyer et al., 2013).

To our knowledge, and according to Bowling et al. (2002), the way in which psychological factors—including loneliness, resilience, and individuals' mental states, in terms of depression and anxiety—affect the perceived QoL is still largely unexplored. As described above, authors have studied the psychological variables that can be predictive of QoL, but how variables mediate and influence perceived QoL requires further elucidation.

AIMS

The purpose of the study was to explore a multidimensional model including the relationships among loneliness, resilience, mental health, and mental and physical QoL among elderly individuals. In line with authors who found relationships between loneliness and mental and physical QoL (Tiikkainen and Heikkinen, 2005; Cacioppo et al., 2006; Golden et al., 2009; Theeke, 2010; Prieto-Flores et al., 2011) and those who found relationships among loneliness, resilience, and mental health (Fry and Debats, 2002; Fry and Keyes, 2010; Wild et al., 2013; Sachs-Ericsson et al., 2014), our hypothesis was that higher loneliness levels would be associated with low levels of mental health and resilience, and loneliness, resilience, and mental health would be associated with mental and physical QoL. It was also expected that both resilience and mental health would mediate the negative association between loneliness and mental/physical QoL.

MATERIALS AND METHODS

Participants

The sample comprised 290 older adults from Italy (70% females and 30% males), aged 65–90 years (M_{Age} = 74.7 years, SD = 6.9 years); the participants were split into two groups—those in the age range of 65–74 years old (66% females and 34% males) comprised the young old group (M_{Age} = 69 years, SD = 2.9 years), while those older than 74 years (73% females and 27% males) comprised the old group (M_{Age} = 81 years, SD = 4.3 years). Participants volunteered for the study. They were all Italian native speakers, and they were active in the cultural and social activities of the neighborhood. None of the participants were undergoing medical/neurological or psychiatric treatment at the time of assessment. Their education levels were as follows: 58% of the participants had an elementary school education, 31% had a high school diploma, and 11% had completed a university degree. Fifty-one percent of participants were married or in a civil partnership and lived independently with their spouses; 49% of the participants were single, widowed, separated, or divorced and

lived alone (40.2%), with their children (6.4%), with brothers or sisters (1.4%), or with other people (e.g., carers; 1%).

Measures

The UCLA Loneliness Scale (Version 3)

The UCLA Loneliness Scale (Version 3) (Russell, 1996; 10 positively worded items [PI] = non-loneliness and 10 negatively worded items [NI] = loneliness) is used to assess participants' level of loneliness, defined by an incongruity between actual and desired social interaction. On this scale, participants are asked to report how often (from 1 = never to 4 = often) they feel the way illustrated for each item. Positive items are reverse coded to generate a global measure in which higher scores denote greater loneliness. For the present study, the authors adapted the scale into Italian using the back-translation technique to guarantee the semantic correspondence of the Italian and English versions. Based on the current participants, the Cronbach's alpha coefficient was 0.87 for global loneliness, 0.83 for the loneliness subscale (NI), and 0.84 for the non-loneliness subscale (PI).

The Geriatric Anxiety Inventory—Short Form

The Geriatric Anxiety Inventory—Short Form (GAI-SF; Byrne and Pachana, 2011) consists of five items, and it is used as a screening tool for individualizing anxiety in older adults. Questions require yes/no answers. It was developed as a briefer version of the full 20-item GAI, and its validity and internal consistency have been demonstrated (Cronbach's alpha 0.81). For the present investigation, the authors adapted the GAI-SF into Italian using the back-translation technique to guarantee the semantic correspondence of the Italian and English versions. Based on the current participants, the Cronbach's alpha coefficient was 0.78.

The Geriatric Depression Scale

The Geriatric Depression Scale—Short Form (GDS-SF; Hoyl et al., 1999; Italian version, Rinaldi et al., 2003) consists of five items, and it is used as a screening tool for individualizing depression in older adults. It comprises items about how the person has felt over the past week. The questions require yes/no answers. It was developed to be a version of the 15-item GDS, and its overall performance has been demonstrated to be comparable to that of the 15-item scale. Moreover, the 5-item GDS is a better screening tool than the 15-item version is (Hoyl et al., 1999). Based on the current participants, the internal consistency coefficient was 0.70.

The Generalized Self-efficacy Scale

The Generalized Self-efficacy (GSE) Scale (Jerusalem and Schwarzer, 1986; Italian version, Sibilia et al., 1995) consists of 10 items, and it is designed to measure a sense of perceived self-efficacy with the objective of predicting coping with everyday adversity, as well as adjustment after experiencing different types of stressful life events. The participant responds to the instrument using a 4-point Likert scale (from 1 = not at all true to 4 = exactly true). A high score signifies a high perception of self-efficacy. The GSE has been administered widely and has been found to have satisfactory internal consistency reliability. Based on the current participants, the internal consistency coefficient was 0.87.

The Resilience Scale

The Resilience Scale (RS; Wagnild and Young, 1993; Italian version Peveri, 2010) consists of 10 items rated on a 7-point Likert scale (from 1 = disagree to 7 = agree), and it is a measure of the ability to bear stressful life events and make meaning from challenges. The concurrent validity and internal consistency reliability of the RS scale have been shown to be adequate (Wagnild, 2009). Based on the current participants, the internal consistency coefficient was 0.91.

The World Health Organization Quality of Life Questionnaire

The World Health Organization QoL (WHOQOL-BREF; World Health Organization, 1993; Italian version, De Girolamo et al., 2000) Questionnaire evaluates QoL in four areas, as follows: psychological health (PSY), physical health (PHY), environment (E), and social relationships (SR). It includes 24 self-report items, and the participant responds to the instrument via a 5-point Likert scale (from 1 = not at all to 5 = completely). It is a shorter version of the original tool, and it may be better adapted for use in big clinical trials or studies. Higher scores show a higher perceived QoL. The WHOQOL-BREF is appropriate for use with older adults (Lucas-Carrasco, 2012). For this study, the subscales assessing QoL across the physical and PSY domains were used. Based on the current participants, the internal consistency coefficient was 0.85 for the PHY subscale and 0.78 for the PSY subscale.

Procedure

All participants were contacted individually at their place of living and signed the written informed consent. Participants who agreed to participate, understood the instructions, and met the selection criteria autonomously completed a questionnaire on demographic data, the UCLA, GAI-SF, GDS-SF, GSE, RS, and WHOQOL–BREF self-reports. The questionnaires were offered in a counterbalanced order on two forms, and no order effect was found. The confidentiality of participants' answers was guaranteed. The time needed to fill in the questionnaires was approximately 60 min.

Data Analyses

Descriptive statistics were computed on the evaluated psychological variables, reporting means, standard deviations, kurtosis, and skewness. The association between continuous variables was tested by means of Pearson correlations. A two-step process was adopted to test the hypothesized model, as follows: (1) a confirmatory factor analysis was implemented to create a measurement model with an adequate fit to the data; and (2) the structural equation model (SEM) established after this phase was verified in the second step (Anderson and Gerbing, 1988). The hypothesized model comprised four latent factors (loneliness, mental health, resilience, and mental and physical QoL) and eight observed variables. Specifically, it comprised one hypothetical latent independent factor, two latent mediator

factors (mental health and resilience), and one latent dependent factor (mental and physical QoL). The loneliness latent factor was measured using the two subscales of UCLA (PI and NI). The mental health latent factor was measured using two sources, the GAI-SF and GDS-SF, while the resilience latent variable was measured by the GSE and RS. As mentioned above, the concept of resilience is a multifaceted construct, and together, these scales may provide a more complete assessment of resilience than each measure alone would. Finally, the mental and physical QoL latent factor was measured using two subscales of the WHOQOL–BREF (PHY and PSY).

For evaluating the model fit, a set of fit indices were used based on recommended criteria, including the following: a comparative fit index (CFI) and Tucker–Lewis index (TLI) $\geq$0.90, which showed an acceptable fit of the model (Bentler, 1990; Schumacker and Lomax, 1996; Kline, 2005; Brown, 2006); the root mean square error of approximation (RMSEA), where values $\leq$0.05 can be regarded as an appropriate fit and values between 0.05 and 0.08 as an acceptable fit (Browne and Cudeck, 1993; Hu and Bentler, 1999; Brown, 2006); and the standardized root mean square residual (SRMR) of <0.1 (Bentler, 1990).

To compare the models, the Akaike information criterion (AIC; Akaike, 1987) of smaller values representing a better fit of the hypothesized model (Byrne, 2001) and expected cross-validation index (Browne and Cudeck, 1993) of the smallest values exhibiting the greatest potential for replication (Byrne, 2001) were also considered to establish the best model. Finally, to establish whether the hypothesized model performed equivalently across age, multi-group analyses were run.

RESULTS

Descriptive Analysis

Descriptive statistics of eight observed variables were tested to check for the normality of distribution. For each of the observed variables, the kurtosis and skewness values were between 1 and −1; therefore, this sample can be defined as having a normal distribution. The descriptive statistics of the eight observed variables are shown in **Table 1**. Correlations were computed to study the relationships of all eight measured continuous variables. The coefficients of correlation are shown in **Table 2**. The results revealed that loneliness is significantly and positively correlated with anxiety and depression and negatively associated with resilience, self-efficacy, and psychological and PHY.

TABLE 1 | Means, standard deviations, skews, and kurtosis for eight observed variables.

Variable	M	*SD*	Skewness	Kurtosis
PI	28.4	4.4	−0.7	1
NI	24.6	6	0.3	0.1
GAI-SF	1.7	1.7	0.6	−0.9
GDS-SF	1.2	1.2	1	0.8
RS	54.9	9	−0.9	1
GSE	27.7	4.1	−0.4	0.5
PSY	80.7	13.1	−0.5	0.8
PHY	101.7	18	−0.6	0.6

PI, positively worded items of UCLA Loneliness Scale-3; NI, negatively worded items negatively worded items; GAI-SF, Geriatric Anxiety Inventory—short form; GDS-SF, Geriatric Depression Scale; RS, Resilience Scale; GSE, Generalized Self-Efficacy Scale; PSY, psychological health subscale of WHOQOL-BREF-World Health Organization Quality of Life Questionnaire; PHY, physical health subscale of WHOQOL-BREF- World Health Organization Quality of Life Questionnaire.

Mediation Model

First Phase: Measurement Model

The confirmatory factor analysis measured four latent factors (loneliness, mental health, resilience, and mental and physical QoL) and eight observed variables (**Figure 1**). All latent factors were found to associate with one another. The model was assessed using the method of maximum likelihood. A test of the measurement model showed a very acceptable fit to the data, $\chi^2 = 27.80$, $df = 14$ $p = 0.05$, CFI = 0.99, TLI = 0.98, RMSEA = 0.05 [90% confidence interval (CI): 0.01–0.08], SRMR = 0.03. In addition, all the factor loadings were significant, $p < 0.001$, which supports the convergent validity of the indicators (Anderson and Gerbing, 1988). These results indicate that all the latent factors were well exemplified by their observed variables. In addition, the four latent factors were significantly connected, $p < 0.001$. Thus, this model was used to examine the hypothetical structural model.

Second Phase: The Structural Equation Model

The SEM was verified using the method of maximum likelihood. To obtain the best model, five alternative models were calculated (**Table 3**). First, a partially mediated model (Model A) with two mediators and a direct path from loneliness to mental and physical QoL showed an appropriate fit, $\chi^2 = 29.85$, $df = 15$ $p = 0.01$, CFI = 0.98, TLI = 0.97, RMSEA = 0.06 (90% CI: 0.03–0.08), SRMR = 0.04. However, it is important to note that there was no significant direct effect of loneliness mental and physical QoL in this model, $b = 0.11$ $p > 0.05$. Thus, a fully mediated model (Model B) was verified with this path constrained to zero, which showed a good fit to the data, $\chi^2 = 29.97$, $df = 16$ $p = 0.02$, CFI = 0.98, TLI = 0.97, RMSEA = 0.05 (90% CI:0.02–0.08), SRMR = 0.03.

Comparing the chi-square differences, no significant difference between Model A and Model B, $\Delta\chi^2 = 0.12$, $df = 1$, $p > 0.05$, showing that the Model B exhibited a better fit for the data. Next, a path from mental health to resilience was added to the fully mediated model (Model C), and the results showed an extremely satisfactory fit to the data, $\chi^2 = 23.84$, $df = 15$ $p = 0.07$, CFI = 0.99, TLI = 0.98, RMSEA = 0.05 (90% CI: 0.0–0.08), SRMR = 0.03. Comparing Model B to Model C, $\Delta\chi^2 = 6.13$, $df = 1$, $p = 0.01$, it was shown that the added path contributed significantly to the model. The path coefficient from mental health to resilience was significant, $b = -0.51$, $p < 0.01$; however, the path from loneliness to resilience became non-significant, $b = -0.28$, $p > 0.05$. Thus, this path was eliminated, and the model was retested (Model D). The results also showed an extremely appropriate fit to the data, $\chi^2 = 26.66$, $df = 16$ $p = 0.05$, CFI = 0.99, TLI = 0.98, RMSEA = 0.05 (90% CI: 0.01–0.08), SRMR = 0.03. However, the chi-square difference between Model C and Model D was not significant, $\Delta\chi^2 = 2.82$, $df = 1$, $p > 0.05$, suggesting that Model D was better.

TABLE 2 | Pearson correlations for the eight observed variables.

	1	2	3	4	5	6	7	8
1.PI	1							
2.NI	0.403**	1						
3.GAI-SF	0.288**	0.268**	1					
4.GDS-SF	0.368**	0.330**	0.447**	1				
5.RS	−0.394**	−0.422**	−0.388**	−0.498**	1			
6.GSE	−0.160**	−0.238**	−0.335**	−0.314**	0.629**	1		
7.PSY	−0.431**	−0.410**	−0.531**	−0.559**	0.676**	0.529**	1	
8.PHY	−0.289**	−0.302**	−0.387**	−0.439**	0.509**	0.410**	0.638**	1

***p<0.01.*

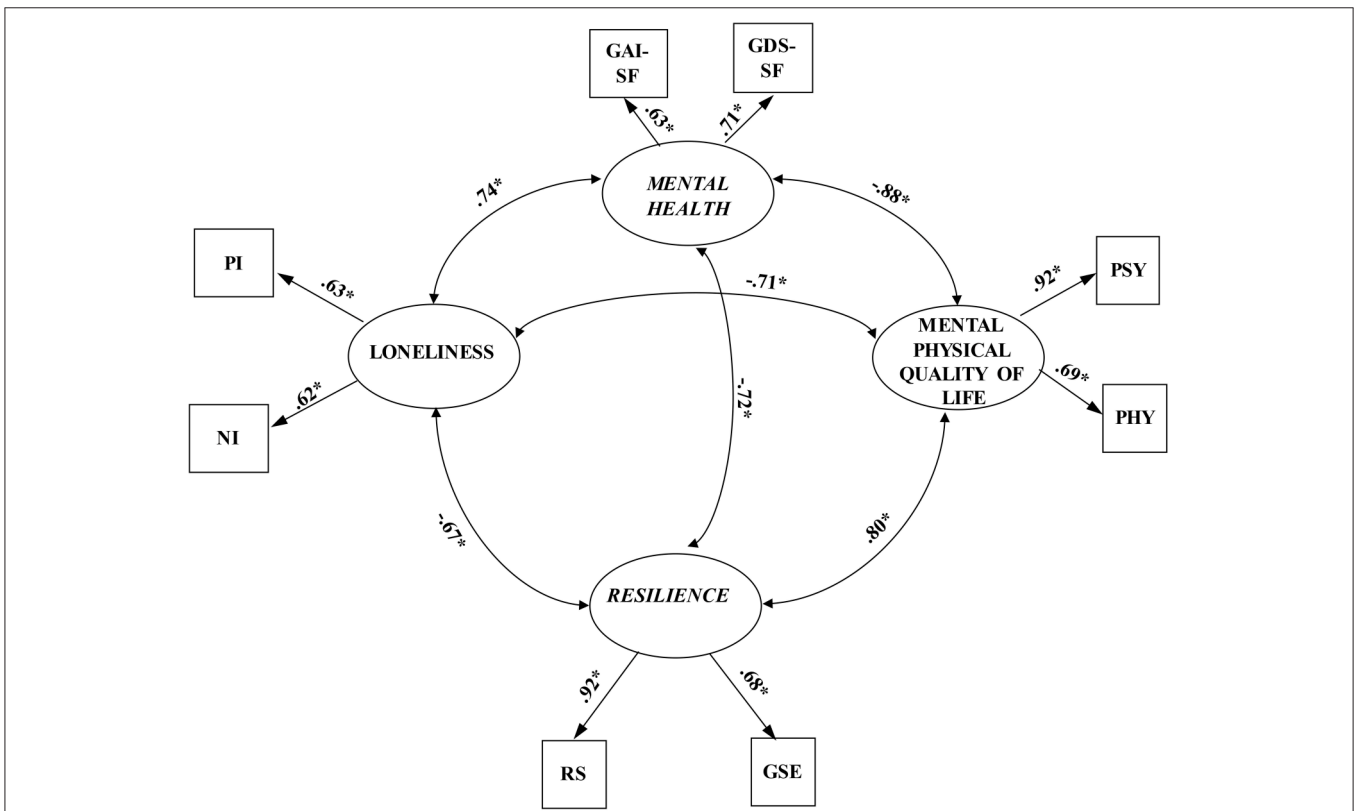

FIGURE 1 | The measurement model ($N = 290$). Factor loadings are standardized. PI, positively worded items of UCLA *Loneliness Scale-3*; NI, negatively worded items negatively worded items; GAI-SF, Geriatric *Anxiety Inventory—short form*; GDS-SF, *Geriatric Depression Scale;* RS, *Resilience Scale;* GSE, *Generalized Self-Efficacy Scale;* PSY, psychological health subscale of *WHOQOL-BREF- World Health Organization Quality of Life Questionnaire;* PHY, *physical* health subscale of *WHOQOL-BREF- World Health Organization Quality of Life Questionnaire.* $^*p < 0.001$.

Finally, Model E was verified by adding a path from resilience to mental health to Model B, which showed a good fit to the data, $\chi^2 = 23.84$, $df = 15$ $p = 0.07$, CFI = 0.99, TLI = 0.98, RMSEA = 0.05 (90% CI: 0.0–0.08), SRMR = 0.03. The standardized path coefficients from resilience to mental health, $b = -0.40$, $p < 0.01$, from loneliness to mental health, $b = 0.49$, $p < 0.001$, and from loneliness to resilience, $b = -0.66$, $p < 0.001$, were significant.

The chi-square difference between Model D and Model E was not significant, $\Delta\chi^2 = 2.82$, $df = 1$, $p > 0.05$, implying that Model E was a better model. Furthermore, the slightly smaller AIC value (see **Table 3**) implied that Model E was better than Model D. Therefore, Model E was designated as the best model (**Figure 2**). In Model E, mental health and resilience fully mediated the link between loneliness and mental and physical QoL. The partial mediation effect of mental health in the link between resilience and mental and physical QoL was significant. Moreover, resilience partially mediated the link between loneliness and mental health ($z = -2.98$, $p < 0.001$).

TABLE 3 | Fit indices among the competing models.

	Model A	Model B	Model C	Model D	Model E*
χ^2	29.85	29.97	23.84	26.66	23.84
df	15	16	15	16	15
CFI	0.98	0.98	0.99	0.99	0.99
TLI	0.97	0.97	0.98	0.98	0.98
RMSEA	0.06	0.05	0.05	0.05	0.05
CI for RMSEA	0.03–0.08	0.02–0.08	0.00–0.08	0.01–0.08	0.00–0.08
SRMR	0.04	03	03	03	03
AIC	71.85	71.85	65.84	66.66	65.84
ECVI	0.25	0.25	0.23	0.23	0.23
CI for ECVI	0.21–0.32	0.21–0.32	0.20–0.29	0.20–0.29	0.20–0.29

*N = 290. *Represents the best model.*
CFI comparative fit index, TLI Tucker Lewis Index, RMSEA root-mean-square error of approximation, SRMR standardized root-mean square residual, AIC Akaike information criterion, ECVI expected cross validation index, CI confidence interval.

Especially, the path of loneliness → resilience → mental health → mental, and physical QoL was significant. This path indicated that elderly people with high loneliness levels are not able to face the adversity, trauma, and stress, which may lower their mental health, and in turn, lead to low mental and physical QoL.

Finally, the multigroup analysis was tested to investigate whether the path coefficients were moderated by age. The age differences (young old group and old group) were tested by comparing the first model, which allows the structural paths to vary across ages, with the second model, which constrains the structural paths across ages to be equal. All the factor loadings, structure co-variances, and error variances were constrained to be equal.

The non-significant chi-square differences between the two models, $\Delta\chi^2 = 8.43$, $df = 6$, $p > 0.05$, as well as the slightly smaller AIC value, suggested that the structural paths of the final model did not differ by age, offering initial support for its robustness.

DISCUSSION

The current study was planned to test the mediation effects of both resilience and mental health for the relationship between loneliness and mental and physical QoL with a sample of elderly Italian people, given the lack of national and international literature concerning a multidimensional model of QoL, loneliness, resilience, and mental health. The best model from the current study supports the mediation effect of both resilience and mental health between loneliness and mental and physical QoL.

These results strongly suggest that loneliness influences mental and physical QoL via two pathways, with the impact of loneliness mediated by mental health and the impact of loneliness mediated by resilience. In other words, elderly people with high levels of loneliness are at an increased risk of experiencing low levels of mental health and low capacity to withstand stressors, resulting in low mental and physical QoL. The QoL seems to be the outcome of different psychological processes interrelated in a complex way, and not a direct effect of the perceived loneliness level.

Another relevant finding of the study regards the path of loneliness → resilience → mental health → mental and physical QoL, which was shown to be significant. This path could underline that elderly people with high loneliness levels are not able to face adversity, trauma, or stress; persons in this condition may evidence a lower resilience level, which may threaten their mental health. In turn, this condition could lead to a lower mental and physical QoL. That is, mental health is a mediator between resilience and mental and physical QoL, while resilience partially mediates the relationship between loneliness and mental health.

In line with the literature (Fry and Debats, 2010), the results of our study seem to indicate that people with greater levels of self-efficacy and resilience can mobilize emotional and psychological resources to face the stressful elements of their lives, and therefore, to express and feel more QoL satisfaction. According to the socio-cognitive model of health proposed by Bandura (1977, 1986, 1988), the concept of self-efficacy is included in a perspective that considers people as having an active role in producing and giving meaning to their experiences. These agency beliefs would affect the way in which the elderly face typical limitations and loss at their stage of life. In fact, according Lawton et al. (1999), maintaining a sense of agency can help a person to preserve a positive attitude toward life, moderating the emotional effect of loneliness and distress and supporting a greater life satisfaction.

In terms of clinical interventions, the model highlights how important the support that elderly people receive from social relationships could be. The reduction of loneliness dissatisfaction may be an important factor in primary prevention or the recovery process. Elderly people's active participation in social activities in their communities could be increased via specific initiatives aimed at the elderly population. The opportunity to reduce the level of mental distress has been evidenced in the model with increasing resilience and self-efficacy and reduced loneliness dissatisfaction. This reduction will strengthen the capacity to face adversity, different losses, and stressful situations (resilience). In addition, as evidenced by the literature, a high degree of resiliency contributes to increased perceived life quality at the physical and psychological levels, and at the same time, reduces anxiety and depressive symptoms. The fact that loneliness could be reduced (Findlay, 2003; Cattan et al., 2005; Fokkema and Van Tilburg, 2007; Dickens et al., 2011; Forsman et al., 2011; Masi et al., 2011; Hagan et al., 2014), self-efficacy beliefs modified (Bandura, 1993), and resilience strengthened (Hartling, 2008) makes these factors primary for early intervention in support of QoL among the elderly (Fry and Debats, 2002). Ultimately, the results could also have economic implications in term of reducing healthcare costs (Bramley et al., 2002) and resulting in fewer contacts between elderly people and general practitioners and hospitals.

Limits and Future Perspectives

Critically analyzing the outcomes of the present study, it could be interesting to consider the results in the context of the study's limitations. First, self-report tools were used, and they

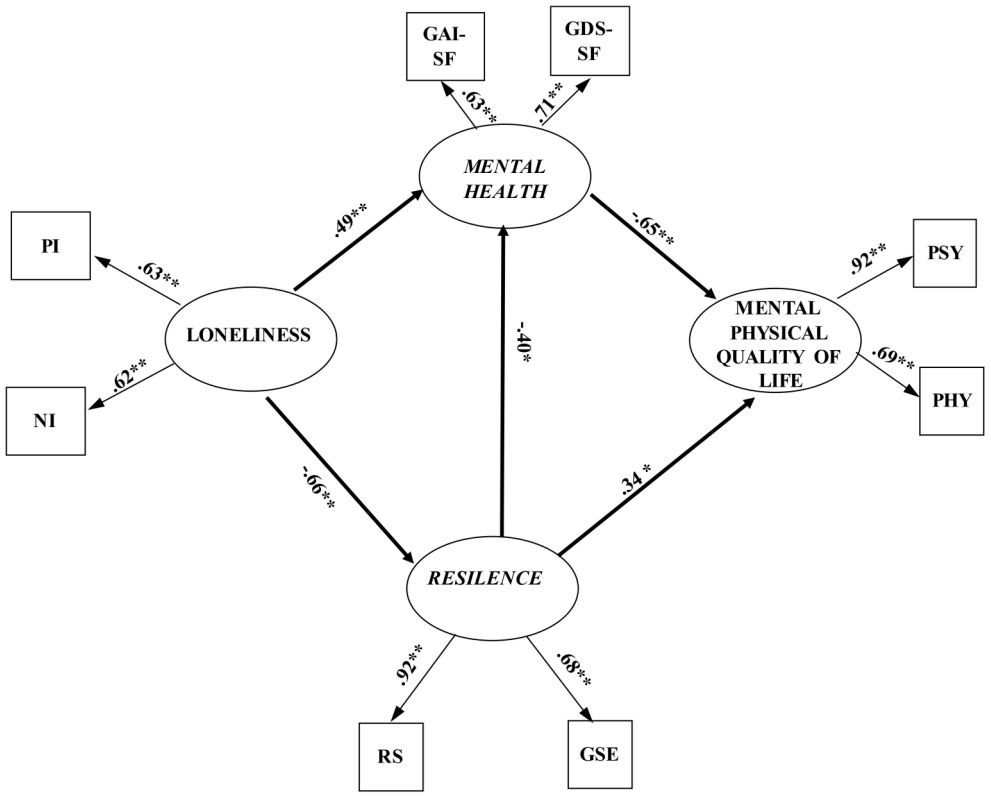

FIGURE 2 | The finalized structural model ($N = 290$). PI, positively worded items of UCLA *Loneliness Scale-3*; NI, negatively worded items negatively worded items; GAI-SF, Geriatric *Anxiety Inventory—short form*; GDS-SF, *Geriatric Depression Scale;* RS, *Resilience Scale;* GSE, *Generalized Self-Efficacy Scale;* PSY, psychological health subscale of *WHOQOL-BREF–World Health Organization Quality of Life Questionnaire;* PHY, *physical* health subscale of *WHOQOL-BREF-World Health Organization Quality of Life Questionnaire.* $^{*}p < 0.01$ $^{**}p < 0.001$.

are not exempt from limitations, such as, inaccurate reporting and social desirability bias. Second, the participation in the study was voluntary; consequently, the sample composition may not represent the characteristics of the general Italian population. Third, the did not considered the variables of being in a couple (Ha, 2016), having siblings (Cicirelli, 2013), or being in a twin relationship (Brustia et al., 2013; Prino et al., 2016).

Future studies should examine and consider the relationship between mental health—in terms of anxiety, depression, resilience, and QoL—from a longitudinal perspective. For example, research could compare people's conditions at different stages in the Third Age or monitor longitudinal changes in the relationships between these factors in the lifecycle. Moreover, they could analyze people resilience and self-efficacy before and after completing a specific intervention program. It would also be interesting to further analyze the absence of the relationship between loneliness and QoL and to carry out the following: (1) pre–post evaluation of a specific training program on increasing resilience and reducing loneliness in a group of elderly people to see if their QoL increases (Lloyd et al., 2017); (2) consider the variable of being in a couple or whether the person a caregiver everyday life; and (3) consider older people who have experienced specific Third Age losses and study the evolution of the mediation model presented here.

ETHICS STATEMENT

This research project has been approved by Scientific Commission of "Fondazione Giovanni Goria" and everything has been done in accordance with the ethical standard of Associazione Italiana di Psicologia and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed sheet on the questionnaire was given and discussed with all individual participants included in the study and no identifying details (name, surname, dates of birth, identity numbers, and other information) of the participants that were studied has been gathered and collected. After the discussion on the information sheet and to have answered to the their questions about the issues on the administration/questionnaire, each participant gave oral consent before filling. Researchers don't have any opportunity to identify any specific participant.

AUTHOR CONTRIBUTIONS

EG prepared the study design, organized the sample recruitment, collected data, and contributed to the writing of the manuscript's introduction, discussion, and references sections. LR contributed to the study design and writing of the manuscript's introduction,

discussion, and references sections. CS prepared the data set, performed statistical analysis, prepared the tables, and contributed to the writing of the methods and results sections. PB prepared the study design and supervised the research team.

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Emotion Regulation Ability and Resilience in a Sample of Adolescents from a Suburban Area

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Earlier research has identified a remarkable number of related factors to resilience during adolescence. Historically, theoretical treatments of resilience have been focused almost exclusively on psychosocial levels of analysis to derive explanatory models. However, there is insufficient understanding of the role of emotion regulation explaining competent functioning despite the experience of adversity (resilience), especially during adolescence. This study explores the relationship between both, emotional regulation abilities and strategies, and resilience in a sample of adolescents from suburbs high-schools (Jerez de la Frontera, Spain). The study also examines how using different emotional regulation strategies may help the development of resilience levels at this stage. Participants of the study were 164 adolescents ranging from 13 to 16 years old ($M = 13.98$; $SD = 0.66$). Emotion regulation was measured using the Cognitive Emotional Regulation Questionnaire (CERQ, Garnefski et al., 2001), and sections D and H of Mayer-Salovey-Caruso Emotional Intelligence Test, a performance test (Emotion Regulation Ability sections, MSCEIT, Spanish version, Mayer et al., 2003). Resilience was evaluated with ERE (Educative Resilience Scale for children and adolescents, Saavedra and Castro, 2009). Verbal Intelligence (Yuste, 1997) and personality traits (Cattell and Cattell, 1986) were assessed as two independent variables. Results supported the idea that emotion regulation ability (MSCEIT, D and H sections, Extremera et al., 2006) is a significant predictor of adolescents' resilience. Moreover, cognitive regulation strategies, such as positive reappraisal, predicted perceived resilience among students. Sociability (A factor of HSPQ, sociability) also correlated with resilience levels. Hence, these results are promising, implying that emotion regulation ability may act as a helpful tool preventing adolescents from irrational risky behaviors, commonly assumed at this developmental stage.

Keywords: emotion regulation ability (ERA), cognitive regulation strategies, resilience, adolescence, adaptation

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INTRODUCTION

Many changes and vulnerabilities affect adolescents at this life stage. Moving from primary school to high-school, unfavorable socioeconomic conditions, and personal attributes may favor risky behaviors that often lead to school failures. Risk factors understood as individual, school, peer, family, and community influences might increase the probability that a child will experience,

maintain, or exacerbate, both social and mental problems (Shumow et al., 1999; Jenson and Fraser, 2005). According to Kurian (2012), low socioeconomic condition influenced teenagers' psychological growth and development. The fact that some adolescents get over these risk factors and triumph in the academic and social context depends on their resilience development (Wang et al., 1995; Waxman et al., 2003).

Resilience: Is a Fixed or Ongoing Term?

Defining resilience has been controversial, and still, there is not enough consensus regarding a unified description of the construct (see Afifi and MacMillan, 2011; Lee et al., 2013). According to Lee et al. (2013), resilience definitions can be grouped into two different perspectives: resilience as a *trait* vs. resilience as a *developmental process*.

The first group of definitions —resilience as a trait- stated that resilience is the ability to "bounce back." This approach is in line with the physical sciences, which postulated that resilience is a property that allows materials to assume their original shape after being bent or stretched (Dyer and McGuinness, 1996; Southwick and Charney, 2012). Particularly within this view, Block and colleagues introduced the concept of *ego-resilience* as "the dynamic capacity to modify his or her model level of ego-control, in either direction, as a function of the demand characteristics of the environmental context" (Block and Kremen, 1996, p. 48). However, these definitions implied that resilience is fixed and stable, and thus unable to explain the adaptation between individuals and the environment (Lee et al., 2012). Moreover, the concept of ego-resilience did not infer the presence of adverse situations (Luthar et al., 2000).

Conversely, the second group of authors stated that resilience is a dynamic process by which individuals successfully adapt within the context of significant adversity (Luthar et al., 2000; Connor and Davidson, 2003; Masten and Obradović, 2006; Lee et al., 2013). Within this view, resilience is changeable over time and influenced by protective factors (Dyer and McGuinness, 1996; Connor and Davidson, 2003; Lee et al., 2013). According to Dyer and McGuinness (1996), protective factors are abilities and skills (competencies) needed to build resilience. The authors identified three types of competencies: individual, interpersonal, and familiar. Thus, resilience is characterized as a developmental process in which the environment is crucial determining personal resilience (Brownlee et al., 2013). Accordingly, a group of APA's experts defined resilience as a "process of adapting well in the face of adversity, trauma, tragedy, threats or even significant sources of threat" (American Psychological Association, 2017). We agree with this second view of resilience as a dynamic process stating that in fact, resilience can be viewed as the successful adaptation and development to stressful situations (Masten, 2001; Tugade and Fredrickson, 2004).

Resilience and Emotional-Cognitive Abilities

Reviewing the literature, we have found studies that show the importance of *cognitive and emotional abilities* predicting resilience. For example, Artuch-Garde et al. (2017) exposed in their cross-sectional research that the ability to self-regulate behavior is associated with high levels of resilience in high-school students. Likewise, positive emotions appeared to aid resilient people to deal with daily strain (Tugade and Fredrickson, 2004; Ong et al., 2006). Gloria et al. (2013) developed a cross-sectional study demonstrating that positive affectivity strongly predicts resilience among public school teachers. In particular, this research has revealed that positive affectivity increases one's cognitive resilience levels, allowing individuals to effectively deal with adversity and stress (Gloria et al., 2013). In later ages, emotional-cognitive abilities might have an important role promoting also both personal and social functioning. For example, implementing an emotional-based intervention in a sample of Alzheimer's patients increases motivational process to reduce apathy among patients that were randomly assigned to the brief emotional intervention (see Di Domenico et al., 2016).

According to the emotion regulation (ER) meta-analysis conducted by Naragon-Gainey et al. one of the ER's theoretical models is the Ability-Based ER model—besides Strategy-Based ER Model and Temporal Process ER Models (Naragon-Gainey et al., 2017). The Ability-Based ER model "are primarily organized around dispositional abilities believed to facilitate healthy emotion regulation" (Naragon-Gainey et al., 2017 p. 386). To assess these dispositional abilities to solve risky emotional situations, i.e., emotional intelligence as ability, we believe that is more appropriate the use performance measures rather than self-report instruments (see MacCann et al., 2014; Mayer et al., 2016; Mestre et al., 2016). However, after a literature review concerning ERA and resilience, authors do not consider performance measures in the research of the role of ERA in perceived resilience among adolescents.

Resilience has also been associated with *coping strategies* (Beasley et al., 2003; Campbell-Sills et al., 2006; Min et al., 2013; Lee et al., 2017). Lazarus and Folkman (1984) have classically defined cognitive coping strategies as "constantly changing cognitive and behavioral efforts to manage specific external and internal demands that are appraised as taxing or exceeding the resources of a person" (p. 141). According to this definition, coping strategies present two main functions: problem-solving focus coping strategies, or acting on the stressor; and emotion-focus coping strategies, or managing emotions provoked by the stressor (Garnefski et al., 2001). Some authors have supported this assumption stating that problem-solving strategies lead to a better adaptation to adversity while emotion-focus strategies drive to a worst adjustment (Beasley et al., 2003; Campbell-Sills et al., 2006). However, recently, Lee et al. (2017) found out that emotion-focus coping strategy was also determinant enhancing a resilient outcome. In particular, these authors carried out a cross-sectional study and demonstrated that resilient adolescents engage in both strategies simultaneously, emotion-focus and problem-solving focus. Nevertheless, Garnefski et al. (2001) established a new division of coping strategies, behavioral and cognitive, arguing that cognitive coping precede behavioral coping strategies. In other words, whether this process is conscious or unconscious, when a potentially adverse situation

arrives, individuals first think and then act. Thus, teaching people how to react in the face of adversity, focusing in their cognitions, may favor a resilient response (Garnefski et al., 2001). Moreover, they also pointed out the simplistic classification made by Monat and Lazarus (1991), stressing people engage in many more coping strategies than emotion or problem-solving focus. Notably, they proposed a set of nine coping strategies: self-blame, acceptance, focus on thought/rumination, positive refocusing, refocus on planning, positive reappraisal, putting into perspective, catastrophizing, and blaming others (Garnefski et al., 2001). Following this statement, Min et al. (2013) examined the relationship between cognitive coping strategies and resilience among depressive and/or anxiety disorder patients. This cross-sectional study suggested that engaging in adaptive strategies, such as positive reappraisal and refocus on planning, were the two most significant predictors of resilience among adult population. However, many of the research conducted so far, concerning coping strategies and resilience, have been concentrated on adulthood, and little is known about the role played by these cognitive strategies during adolescence.

Because stressful events have by nature an emotional component, people's ability to *manage emotions* may be another critical factor determining resilience (Caston and Mauss, 2011). Indeed, school life is full of emotional stimuli (even stress), which affect students' motivations and academic achievement (Pekrun et al., 2002; Lopes et al., 2012). Emotion research has demonstrated the importance of emotion regulation in adaptation, cognition, well-being, attention, and social interaction (f. i., Peña-Sarrionandia et al., 2015; Mayer et al., 2016). In fact, emotional dysregulation can undermine decision-making processes, increase anxiety, and produce a lack of social competence (Loewenstein and Lerner, 2003; Wills et al., 2016; Hartman et al., 2017). Emotion regulation has been defined as "all the extrinsic and intrinsic processes responsible for monitoring, evaluating and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals" (Thompson, 1994, pp. 27–28). In this study, we focused on adolescents' ability to manage own and others' emotions to adapt in the face of adversity successfully. Thus, we conceptualized emotion regulation ability (ERA) following Mayer and Salovey's emotional intelligence theory (Mayer and Salovey, 1997; Mayer et al., 2016). According to Mayer and colleagues, emotional intelligence is defined as the ability to problem-solving with and about emotions (Salovey and Mayer, 1990; Mayer and Salovey, 1997; Mayer et al., 2003). The concept comprises four interrelated abilities involved in the intake of emotional information: perceiving emotions, using emotions to facilitate thought, understanding emotions, and regulating own and other's emotions (Lopes et al., 2005, 2012). As we mentioned above, only the fourth branch of emotional intelligence, management of emotions, was considered for this research. Hence, ERA constitutes the ability to differentiate, label, and display both, own and others' emotions as well as using appropriate strategies to modify own and other's feelings. In this regard, ERA plays a key role favoring adolescents mental health and school adaptation (Brackett and Salovey, 2006; Mestre and Guil, 2006; Rivers et al., 2012; Sánchez-Álvarez et al., 2015; Fernandez-Berrocal and Extremera, 2016).

Resilience, Personality Traits, and IQ

Other non-emotional psychological factors have also been considered regarding resilience research. For example, personal characteristics, such as self-concept and intelligence, appeared as the most significant predictors of resilience during adolescence (Garza et al., 2014). Other studies have demonstrated that other personality factors such as extraversion significantly predicted resilience (Campbell-Sills et al., 2006; Hsieh et al., 2016; de las Olas Palma-García and Hombrados-Mendieta, 2017). Following the Five-factor model of personality, Friborg et al. (2005), in a sample of 482 applicants for a military college, found that resilience factors were positively correlated with a well adjusted personality profile, which included "personal strength," "social competence," "structured style," "family cohesion," and "social resources." However, resilience was unrelated to cognitive abilities. Based on the view of resilience as a dynamic process, Campbell-Sills et al. (2006) pointed out that resilience was negatively associated with neuroticism, and positively related to extraversion and conscientiousness.

Concerning the relationship between resilience and personality among adolescents, we have found discrepancies in the literature. For example, some studies used personality instruments that are not specifically designed for adolescents, while others show correlations among very different personality factors. Moreover, the resilience approach (fixed vs. ongoing) may also influence the outcome variance founded.

Regarding IQ and resilience, conceptually, some degree of connection between both variables is expected. According to the idea that adaptability is an indicator of efficient functioning of underlying intellective components, Block and Kremen (1996) investigated the expected relationship between ego-resilience and IQ. The authors, based on a trait resilience view, found out a relationship between resilience and IQ, only significant for the female sample ($R = 0.10$ females, $R = 0.31$ males), measured in individuals at the age of 18. Anyhow, they called for further studies to understand the role of IQ on resilience. According to the view of resilience as a developmental factor, we believe that IQ measures should be more focused on crystallized IQ (Gc)—f. i., verbal intelligence- than on fluid IQ (Gf). In this sense, Gc is more related to external experiences than Gf and has stronger connections to emotional-cognitive abilities as emotional intelligence (Mestre et al., 2016). Friborg et al. (2005) developed a study with 411 applicants for military college. Participants had to complete a resilience, personality, and IQ questionnaire. Confirmatory factor analyses confirmed the fit of the five-factor model, however, authors found anunrelated relationship between cognitive abilities and resilience. Nonetheless, this study was applied to young adults instead of adolescents. Contrary to their expectations, IQ had an "insignificant and negligible" relationship with resilience (Friborg et al., 2005, p. 38). Even though the efforts made up to date, it is still unclear the role of IQ on resilience perception.

Resilience at Adolescence Stage: The Role of Emotional-Cognitive Abilities

Although literature has been interested in the role of resilience during adolescence (Compas et al., 1995; Hunter and Chandler, 1999; Anthony et al., 2009; Skrove et al., 2013; Newsome and Sullivan, 2014), little is known about the role played by emotional-cognitive abilities in the development of resilience. Because resilience allows individuals to cope with adversity, this concept may be relevant to adolescents dealing with school adaptation. Due to the lack of studies concerning the cognitive and emotional processes underlying resilience at this life stage, the overall objective of this research was to explore the relationship between both ERA and cognitive-emotional strategies, and perceived resilience among adolescents. Particularly, including other predictors as personality and verbal intelligence, we proposed that adolescents high on ERA would present higher levels of perceived resilience. Moreover, we expected that appraisal cognitive-emotional regulation strategies would also lead to higher levels of resilience. The study highlighted the importance of building resilience, based on the development of cognitive and emotional abilities, in adolescents under a risk context.

METHOD

Participants and Procedure

The sample comprised 164 Spanish adolescents from eighth grade of middle school and ninth high school (second and third of compulsory schooling in Spain). Participants were selected by quota sampling from a suburban area of schools in Jerez de la Frontera, Spain. Participants average age was 13.98 (range = 13–16, $SD = 0.66$). Adolescents were nearly equally divided by gender (53.9% male). Participants had to complete a questionnaire with all the scales presented at the same time during class time. Participation was anonymous and volunteer, and data collection was accomplished by following the ethical guidelines applicable to people under the age of 18. Before completing the questionnaire, participants also presented a parental authorization. This study was approved by the school Parents' Association and the school administrators. Due to missing data, one participant had to be excluded from the sample.

Instruments

Resilience

Escala de Resiliencia para Escolares (ERE, Resilience Scale for Schoolchildren, Saavedra and Castro, 2009). These Chilean authors developed this instrument to understand how resilience can be a key personal factor to face extreme experiential situations—Chile is considered a leading global example of resilience (Vergara, 2014). Authors pointed out that resilience is a learned trait, and therefore changeable (Varas and Saavedra, 2011). This point of view led Varas and Saavedra (2011) to consider the interactive sources of resilience by following Grotberg's perspective (see Grotberg, 1996, 2003). According to Grotberg (2003), there are three resilience sources: (1) perceived support a person believes he/she has; (2) personal psychological strengths and internal conditions; and (3) problem-solving abilities and skills.

The original scale, designed for adults, was comprised of 60 items regarding 12 resilience factors named identity, autonomy, satisfaction, pragmatism, links, networks, models, goals, affectivity, self-efficacy, learning, and asking for others' assistance (see Saavedra and Castro, 2009). However, Saavedra and Castro (2009) developed a shorten 27-items instrument regarding three resilience factors grouped into *identity-self efficacy* (referring to perceived personal and internal strengths of the children/adolescents); *networks-models* (perceived support from others); and *learning-asking for others' assistance* (perceived ability to solve own and others' problems). Finally, a total score for resilience is also given. Responses were given on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's alpha for each of the subscales were 0.55, 0.85, and 0.81 respectively. Reliability for total ERE score was 0.87. Due to the high correlations found between the three subscales of ERE (above 0.75), only total resilience score was used in this study.

Emotion Regulation Ability

Sections D and H of the Mayer-Salovey- Caruso Emotional Intelligence Test, Spanish version adapted to the Spanish context by Extremera et al. (2006) (MSCEIT-S). MSCEIT measures four skill groups of EI: (a) perceiving emotion accurately, (b) using emotion to facilitate thought, (c) understanding emotion, and (d) managing emotion (Grunes et al., 2013). This is a performance test, based on the conceptualization of emotional intelligence as ability, involving problem-solving with and about emotions. For the purpose of this study, only sections regarding management of emotions (sections D and H) were administered to participants. ERA is assessed asking adolescents to evaluate the effectiveness of several actions making an individual feel in a certain way. The questions described different situations (e.g., Debbie just came back from vacation. She was feeling peaceful and content. How well would each action preserve her mood?). Several actions are presented afterwards, (e.g., she started to make a list of things at home that she needed to do) and respondents had to identify the most adaptive ways to regulate own and others' feelings. Responses were given on a Likert scale ranging from 1 (*very ineffective*) to 5 (*very effective*). This section includes six situations with three alternatives to be evaluated out of 18 items.

This test has been chosen due to two main reasons. First, it is based on the emotional intelligence ability model developed by Salovey and Mayer (Lopes et al., 2012). Second, previous studies found limitations regarding self-report measures of emotional intelligence ability such as insufficient reliability and connections with personality factors even in Spanish samples (Extremera et al., 2006). Even though MSCEIT was designed for individuals aged 17 and above, this instrument is used in this study due to the high reliability of the test assessing emotional regulation abilities with high-school adolescents (see Mestre et al., 2006; Lopes et al., 2012). Split-half reliability (corrected using Spearman-Brown formula) for sections D and H of MSCEIT was 0.83.

Cognitive Emotion Regulation Strategies

Cognitive Emotion Regulation Questionnaire Spanish version (CERQ-S, Domínguez-Sánchez et al., 2013). The original version was created and validated by Garnefski et al. (2001). CERQ-S is a 36-item questionnaire measuring cognitive emotional regulation strategies used in response to stressful life events. The test consists of nine subscales, with four items per subscale. Responses were given on a 5-point Likert scale ranging from 1 (*almost never*) to 5 (*almost always*). Example items were "I want to understand why I feel the way I do about what I have experienced" and, "I think that I can become a stronger person as a result of what has happened." The subscales are the following: self-blame, other-blame, acceptance, planning, positive refocusing, rumination or focus on thought, positive reappraisal, putting into perspective, and catastrophizing. Cronbach's alpha for this scale was 0.84. Subscales had reliabilities ranging from 0.53 to 0.74.

Control Variables: Personality Traits and Verbal Intelligence

High School Personality Questionnaire Spanish version (HPSQ-S, Cattell and Cattell, 1986). HSPQ comprised 140 items regarding personality traits of adolescents and their relation with school and social activities. The items are distributed in 14 factors, in which 13 of the 14 factors, measure personality traits and the remaining mental ability or general intelligence. The questionnaire measures primary personality constructs. Factorial research has differentiated the 14 scales, and each of the factors represents different dimensions of personality (Aluja and Blanch, 2004). In this research, we used factors for personality traits: sociability, intelligence, ego-strength, excitability, dominance, enthusiasm, conformity, boldness, sensitivity, withdrawal, apprehension, self-sufficiency, self-discipline, and tension. Participants had to answer several questions with three different choices. Example items were "Do you find it easy to go and introduce yourself to an important person? Yes, maybe, no," and "what kind of movies do you like best? Musicals, I'm not sure, war." Cronbach's alpha for the 14 dimensions were ranged from 0.64 to 0.81.

We used a standardized, multi-level test of general intelligence, entitled "Inteligencia General Factorial" (IGF3-R; Yuste, 1997). The test was initially developed in Spanish and has been validated for the Spanish student population. It is a cognitive performance instrument, which measures verbal reasoning, verbal understanding, spatial aptitude, and numerical and abstract reasoning. We used the intermediate version, comprised of 24 items, recommended for high school samples. For the sake of parsimony, we only reported verbal intelligence score in the 13–16-year-old age group. Split-half reliability (corrected by the Spearman-Brown formula) for verbal intelligence IGF3-R subscale was 0.83.

RESULTS

Before presenting the results of the two primary objectives of the research, descriptive statistics and correlations among all variables involved, are presented in **Tables 1**, **2**. **Table 1** also shown correlations between predictors and criterion variable.

Predictor variables should be selected taking into consideration previous research or pilot studies that may have guided the introduction of these predictors. Due to the lack of studies including ERA and resilience, the inclusion of these variables must be guided purely by mathematical criteria. In our study we have used a backward method, following Field's suggestion: "If you do decide to use a stepwise method then the backward method is preferable to the forward method. This is because of suppressor effects, which occur when a predictor has a significant effect but only when another variable is held constant. Forward selection is more likely than backward elimination to exclude predictors involved in suppressor effects. As such, the forward method runs a higher risk of making a Type II error (i.e., missing a predictor that does in fact predict the outcome)" (Field, 2013, p. 213).

First, **Table 2** (correlations) was studied, and then regression analyses were performed, in order to find the variables that better predicted Total Resilience (dependent variable). Finally, was found that these variables were ERA (MSCEIT), Positive reappraisal (CERQ), and Sociability (HSPQ).

In addition to the analysis of the complete sample, a cross-validation study was performed, in order to avoid, as far as possible, the "over-fitting" effect of the model (including too many variables) or "under-fitting" (leaving out predictors that actually matter), when performing a stepwise regression. Descriptive statistics for total sample and both halves and are presented in **Table 3**. Although sample size may be problematic, such a study is strongly recommended in exploratory models (Field, 2013). Taking into consideration the 80% of the sample, the model shows a good adjustment, representing 31.0% of variance explained of the dependent variable (**Table 4**).

Regarding the control of multicollinearity, measures of variance inflation factors (VIF) are provided in **Table 4**. VIF measures are below the recommended values of tolerance. Therefore, no problems of multicollinearity are observed. Moreover, all tolerance values are well above 0.2 (Bowerman and O'Connell, 1990), and the correlations matrix does not present any value high enough to confront the results.

After controlling for multicollinearity stepwise multiple regression analysis was performed (**Table 5**).

DISCUSSION

This research aimed to assess the role of emotional-cognitive abilities on resilience perception of adolescents from a suburban area. Literature up to date has been focused on the relationship between resilience and psychosocial factors (Hunter and Chandler, 1999; Jenson and Fraser, 2005; Ungar et al., 2005, 2014; Tusaie et al., 2007). However, little is known about the relationship between emotional and cognitive skills and resilience among young people.

Regarding the resilience scale employed, we decided to use a truthful instrument for Spanish samples instead of other measures developed under different cultural meanings (f. i., Von Soest et al., 2010). ERE (Saavedra and Castro, 2009) was validated among cross-cultural Spanish-speaking adolescent

TABLE 1 | Instruments descriptive statistics and correlations with total resilience.

Instruments	Scales	*M*	*SD*	Min–Max	Resilience
	Identity-self efficacy	34.56	4.16	23–45	0.76***
	Networks-models	38.18	5.56	17–45	0.89***
ERE	Learning-generativity	38.55	4.81	24–45	0.87***
	Total resilience	111.29	12.26	75–133	–
MSCEIT	Emotion regulation ability (sections D and H)	88.01	13.45	59.87–130.88	0.39**
	Self-blame	11.43	3.11	6–20	0.23**
	Acceptance	13.42	2.84	6–20	0.31**
	Focus on thought/rumination	13.77	3.09	4–20	0.36**
CERQ	Positive refocusing	13.44	4.10	4–20	0.27**
	Refocus on planning	14.62	3.48	4–20	0.36**
	Positive refocussing	14.38	3.11	4–20	0.36**
	Putting into perspective	13.46	3.18	6–20	0.14
	Catastrophizing	10.94	3.19	4–19	0.06
	Blaming others	9.97	2.83	4–18	−0.06
	Sociability	5.19	1.82	1–10	0.23**
	Intelligence	3.54	1.88	1–9	0.08
	Ego-strength	5.53	1.86	1–10	0.20*
	Excitability	5.15	1.76	1–9	−0.10
	Dominance	6.04	1.95	1–10	−0.21**
	Enthusiasm	5.04	1.75	1–9	−0.08
HPSQ-S	Conscientiousness	4.66	1.78	1–9	0.22**
	Venturesome	6.03	1.63	1–9	0.21**
	Sensitivity	5.62	1.71	2–10	0.09
	Individualism	7.38	1.78	1–10	0.05
	Apprehension	4.63	1.91	1–10	−0.07
	Self-sufficiency	6.06	1.71	1–10	0.01
	Will power	5.39	1.79	1–10	0.20**
	Tension	4.90	1.64	1–10	−0.08
IGF3-R	Verbal Intelligence	43.06	15.16	12.50–83.33	0.12

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

ERE, Escala de Resiliencia Escolar; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; CERQ, Cognitive-Emotion Regulation Strategies; HSPQ-S, High School Personality Questionnaire Spanish Version; IGF3-R, Inteligencia General Factorial.

samples. In our study, we found similar descriptive measures ($M = 111.29$, $SD = 12.26$, $N = 164$), than those obtained by Saavedra and Castro (2009) ($M = 116.2$, $SD = 11$, $N = 300$) and Hewitt et al. (2014) ($M = 110.24$, $SD = 21.31$, $N = 289$) with Chilean and Colombian adolescents respectively. However, in the study developed by González-Arratia López Fuentes et al. (2008, 2012), with Mexican participants, total ERE scores were higher than in those cited before ($M = 131.9$, $SD = 12.4$, $N = 300$). Despite cultural and idiosyncratic differences, our Spanish sample obtained similar descriptive results. Although all samples were collected from suburban and risky areas, these studies have shown that adolescents tend to perceive themselves as moderate-strong resilient.

Risk factors and vulnerabilities are predisposing elements that may influence individual's healthy behavior, especially under unfavorable environments (Vanderbilt-Adriance and Shaw, 2008; Grant and Kinman, 2012). Adolescents need to face these adversities to successfully adapt to the environment. Hence, what factors influence the development of resilience?

On the one hand, the environment provides its own protective factors represented in figures, resources, or appropriate contexts for a healthy individual development. In this line of reasoning, Beddoe et al. (2013) suggested to include social work education for preparing resilient practitioners. On the other hand, several studies have pointed out how individual differences can explain the use of individual strategies to successfully overcome adversity. For instance, Nota et al. (2004) found out that some aspects of personality, translated into different degrees of vulnerability, can facilitate the emergence of modulators in the resilient process.

Our sample shared similar environmental influences; henceforth, psychological factors should explain the differences in perceived resilience among adolescents. Our results revealed

TABLE 2 | Correlations between all variables of the study ($N = 164$).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1 Total Resilience	*																													
2 Identity-self efficacy	**0.76****	*																												
3 Networks	**0.89****	**0.50****	*																											
4 Learning-generativity	**0.87****	**0.49****	**68****	*																										
5 Age	0.14	0.03	0.15	0.16	*																									
6 Gender (0: males; 1: females)	0.10	−0.01	0.11	0.14	−0.02	*																								
7 ERA (MSCEIT)	**0.39****	**0.29****	**0.34****	**0.35****	0.08	**0.28****	*																							
8 IV (IGF)	0.12	0.12	0.09	0.11	−0.05	0.08	**0.18****	*																						
9 Self-blame (CERQ)	**0.23****	0.11	**0.22****	**0.23****	**0.23****	−0.07	**0.21****	−0.11	*																					
10 Acceptance (CERQ)	**0.31****	**0.17***	**0.29****	**0.30****	0.15	0.04	0.11	0.08	**0.42****	*																				
11 Focus on thought (CERQ)	**0.36****	**0.16***	**0.37****	**0.35****	**0.16***	0.14	**0.30****	0.03	**0.40****	**0.49****	*																			
12 Positive refocusing (CERQ)	**0.27****	**0.20****	**0.27****	**0.20****	**0.17****	−0.06	0.00	−0.01	**0.17***	**0.36****	**0.21****	*																		
13 Refocus on planning (CERQ)	**0.36****	**0.27****	**0.34****	**0.28****	**0.16***	−0.05	**0.26****	0.09	**0.20***	**0.25****	**0.38****	**0.37****	*																	
14 Positive reappraisal (CERQ)	**0.36****	**0.24****	**0.36****	**0.31****	**0.22****	−0.07	0.17*	−0.02	**0.34****	**0.33****	**0.40****	**0.37****	**0.60****	*																
15 Perspective (CERQ)	0.14	0.06	**0.16***	0.12	0.12	0.07	0.11	0.05	**0.29****	**0.21****	**0.24****	**0.27****	**0.25****	**0.41****	*															
16 Catastroohizing (CERQ)	0.06	−0.01	0.04	0.10	0.08	0.09	−0.04	−0.14	**0.28****	**0.23****	**0.20***	−0.08	0.04	0.06	**0.25****	*														
17 Blaming others (CERQ)	−0.06	0.04	−0.11	−0.05	−0.04	**−0.27****	**−0.19***	**−0.22****	0.12	0.06	0.07	0.12	0.13	0.04	0.07	**0.40****	*													
18 Sociability (HSPQ) [A]	**0.23****	**0.26****	0.14	0.20**	−0.02	−0.09	0.01	0.14	−0.05	0.13	0.02	0.04	0.16*	0.05	−0.08	−0.04	−0.05	*												
19 Intelligence (HSPQ) [B]	0.08	0.09	0.03	0.09	**−0.19***	−0.02	0.12	**0.38****	0.00	0.04	0.09	−0.07	0.12	0.02	−0.03	0.06	−0.10	0.06	*											
20 Ego-strength (HSPQ) [C]	**0.20****	**0.31****	**0.16***	0.05	−0.09	−0.09	0.06	−0.02	−0.13	0.03	−0.04	**0.25****	0.14	**0.16***	−0.03	**−0.21****	−0.01	0.08	−0.02	*										
21 Excitability (HSPQ) [D]	−0.10	−0.11	−0.12	−0.03	0.03	0.01	−0.11	0.10	0.08	−0.12	−0.02	−0.15	−0.06	0.00	0.02	0.11	0.09	0.04	−0.01	−0.33**	*									
22 Dominance (HSPQ) [E]	**0.21****	−0.00	**−0.27****	**−0.23****	**−0.18****	−0.09	−0.13	0.06	**−0.26****	0.00	**−0.26****	−0.04	−0.08	−0.14	−0.10	−0.07	0.04	−0.06	0.02	0.11	−0.05	*								
23 Enthusiasm (HSPQ) [F]	−0.08	0.00	−0.09	−0.10	0.09	0.05	−0.05	0.06	0.03	0.03	−0.10	−0.08	−0.01	−0.07	−0.14	0.13	−0.02	0.04	−0.02	0.09	0.06	0.21**	*							
24 Consciousness (HSPQ) [G]	**0.22****	**0.29****	**−0.19***	0.09	−0.06	−0.05	0.11	0.09	0.04	−0.13	0.05	0.15	0.13	0.08	0.04	−0.07	−0.07	0.11	**0.19***	**0.35****	−0.11	−0.14	**−0.22****	*						
25 Venturesome (HSPQ) [H]	**0.21****	**0.24****	0.14	**0.16***	−0.05	**0.19***	0.11	**0.18***	−0.14	0.09	0.06	0.01	0.13	0.05	−0.00	−0.00	0.09	**0.27****	0.13	**0.24****	−0.22	0.02	0.02	0.14	*					
26 Sensivity (HSPQ) [I]	0.09	0.05	0.07	0.11	0.01	0.03	0.11	0.02	**0.17***	0.05	0.08	−0.06	0.12	0.12	0.09	0.14	−0.09	0.04	0.14	−0.11	0.07	**−0.28****	−0.09	0.05	−0.07	*				
27 Individualism (HSPQ) [J]	0.04	−0.01	0.09	0.02	**0.16****	**0.38****	**0.18***	−0.02	0.06	−0.01	0.13	0.01	0.02	0.07	0.14	0.06	−0.15	**−0.16***	−0.04	**−0.16***	0.08	**−0.16***	0.01	0.07	−0.11	0.07	*			
28 Apprehension (HSPQ) [O]	−0.07	**−0.21****	0.03	−0.03	0.07	**0.24****	0.09	−0.01	0.12	0.02	0.10	−0.17	−0.18*	−0.09	0.08	0.10	−0.09	**−0.19***	−0.09	**−0.31****	0.11	**−0.29****	−0.07	−0.03	−0.15	0.01	**0.16***	*		
29 Self-sufficiency (HSPQ) [Q2]	0.01	−0.05	0.07	−0.01	−0.00	0.05	0.09	−0.08	0.03	−0.05	0.00	0.00	−0.08	−0.03	0.05	−0.04	−0.07	**−0.34****	−0.06	−0.06	−0.05	−0.06	**−0.23****	0.04	**−0.28****	0.03	0.14	0.13	*	
30 Willpower (HSPQ) [Q3]	**0.20****	**0.19***	**0.21****	−0.01	−0.00	0.04	0.11	03	−0.13	−0.09	−0.00	0.14	0.13	0.12	0.14	−0.14	−0.08	0.13	0.04	**0.33****	**−0.33****	**−0.19***	**−0.30****	**0.41****	**−0.23****	0.07	0.01	−0.14	0.05	*
31 Tension (HSPQ) [Q4]	−0.08	−0.14	0.11	0.09	0.09	−0.04	−0.02	−0.13	0.10	−0.02	0.02	**−0.23****	−0.03	−0.14	−0.03	**0.25****	0.10	−0.03	−0.03	**−0.39****	**0.26****	0.05	−0.07	−0.09	**−0.16***	0.13	0.13	**0.16***	−0.09	**−0.30****

In bold significative correlations.

$^*p < 0.05$; $^{**}p < 0.01$. MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; CERQ, Cognitive-Emotion Regulation Strategies; HSPQ-S, High School Personality Questionnaire Spanish Version; IGF3-R, Inteligencia General Factorial.

TABLE 3 | Descriptives for each sample analysis (total, 80%, and 20%) for the cross-validation study.

Sample	Total ($N = 164$)	Random 80% ($n = 129$)	Random 20% ($n = 32$)
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Total Resilience (ERE)	111.29 (12.26)	111.35 (12.45)	111.18 (11.73)
ERA (MSCEIT)	88.01 (13.45)	88.24 (13.35)	85.87 (11.70)
Positive Reappraisal (CERQ)	14.38 (3.11)	14.33 (3.12)	13.77 (3.70)
Sociability (A factor, HSPQ)	5.19 (1.82)	5.33 (1.83)	5.09 (1.95)

ERE, Escala de Resiliencia Escolar (School Resilience Scale); MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; CERQ, Cognitive-Emotion Regulation Questionnaire; HSPQ-S, High School Personality Questionnaire.

TABLE 4 | Coefficients of backward regressions, 95% Interval of confidence, zero-order correlations, and variance inflation factors of the cross-validation (total, 80%, and 20% of the sample).

		Values presented for Total (In parenthesis values for 80%) [In brackets values for 20%]			
		(Constant)	Emotion regulation ability MSCEIT	Positive reappraisal CERQ	Sociability [A] HSPQ
Unstandardized coefficients	B	60.25 (61.74) [64.09]	0.31 (0.28) [0.27]	1.16 (1.32) [1.54]	1.41 (1.10) [0.48]
	Std. Error	6.51 (7.23) [12.43]	0.06 (0.07) [0.13]	0.27 (0.30) [0.41]	0.45 (0.49) [0.77]
Standardized coefficients	Beta		0.34 (0.30) [0.27]	0.29 (0.33) [0.48]	0.21 (0.16) [0.08]
	t	9.25 (8.54) [5.15]	4.96 (4.05) [2.11]	4.34 (4.43) [3.80]	3.12 (2.22) [0.63]
	Sig.	0.000 (0.000) [0.000]	0.000 (0.000) [0.041]	0.000 (0.000) [0.000]	0.002 (0.028) [0.535]
95.0% Confidence Interval for B	Lower Bound	43.9 (47.44) [38.96]	0.18 (0.14) [0.01]	0.63 (0.73) [0.72]	0.52 (0.12) [−1.08]
	Upper Bound	73.12 (76.03) [89.21]	0.43 (0.42) [0.53]	1.69 (1.91) [2.37]	2.30 (2.08) [2.04]
Correlations	Zero-order		0.39 (0.36) [0.32]	0.36 (0.41) [0.51]	0.23 (0.18) [0.12]
Multicollinearity	Tolerance		0.97 (0.96) [0.99]	0.97 (0.95) [0.99]	0.99 (0.99) [0.99]
Statistics	VIF		1.03 (1.04) [1.01]	1.03 (1.05) [1.01]	1.00 (1.01) [1.00]

Total resilience (DV). VIF, Variance Inflation Factors.

moderate to high levels of total resilience among teenagers, which means that sample adolescents perceive themselves able to overcome this risky environment and to adapt in the face of adversity (Lee et al., 2013). These results are in line with previous research, which stated that children under low socioeconomic environments develop high levels of resilience helping them to successfully adapt to stress (Wang and Gordon, 1994).

Mean ERA score ($M = 88.01$, $SD = 13.45$) yielded low levels of managing emotion for normative samples. Note that MSCEIT scores computed by test publishers are standardized ($M = 100$, $SD = 15$) (Mayer et al., 2003; Roberts et al., 2006; Karim and Weisz, 2010). ERA subscale of MSCEIT (Spanish version by Extremera et al., 2006), was validated in a sample of 946 Spanish individuals obtaining lower mean ERA scores than in the original study ($M = 96.31$, $SD = 11.54$). Due to cultural biases (Extremera et al., 2006; Karim and Weisz, 2010) and sample average age, mean ERA score was as expected and similar to other studies using Spanish adolescents (Mestre et al., 2006; Lopes et al., 2012). These results imply that at this life stage, adolescents have not completely developed ERA (Zeidner et al., 2003). Probably because this is the most complicated ability to acquire within the Mayer and Salovey's emotional intelligence model (Mayer and Salovey, 1997; Zeidner et al., 2003; Dulewicz and Higgs, 2004; Gratz and Roemer, 2004; Urry and Gross, 2010; Côté et al., 2011).

Due to the multicollineality values obtained in **Table 4**, no suppressor effect is found in the data. Moreover, comparing beta coefficients between both portions (80 and 20%), they are statistically alike. Matching determination coefficients, they are very similar, 0.27 and 0.34; also analogous to the $R^2 = 0.28$ using the whole sample. We can conclude that, despite very limited sample size (affecting mostly 20% half) the model can be cross-validated.

To verify the predictive capability of the model, a stepwise multiple regression analysis was performed. Only variables, which significantly correlated with resilience, were included. According to the coefficient of determination of model 1 ($R^2 = 0.15$, $p < 0.01$), ERA explained 15% of the variance of perceived resilience among adolescents. ERA involves the capacity to modulate feelings to promote personal understanding and growth (Mayer and Salovey, 1997). Therefore, adolescents with higher ERA scores exhibited higher perceived resilience levels. These results involve that adolescents with high scores on ERA, may show better outcomes in mental health, displaying higher levels of well-being and lower depression symptoms (Fernandez-Berrocal and Extremera, 2016), may have better job opportunities (Lopes, 2016), and may also reach better standards for school adaptation (Rivers et al., 2012). Other studies using MSCEIT measures (especially sections D and H, managing emotions) have also found associations between ERA and resilience. For instance, Schneider et al. (2013) found that

TABLE 5 | Multiple stepwise regression analysis of predictors of self-reported resilience.

Variable	Self-report resilience			
	Model 1 *B*	Model 2		Model 3
		B	*B*	95% CI
Constant	80.06**	67.01**	60.25**	[47.39, 73.12]
ERA (MSCEIT)	0.39**	0.34**	0.34**	[0.19, 0.43]
Positive reappraisal (CERQ)		0.31**	0.30**	[0.63, 1.70]
Sociability (HSPQ-S)			0.21**	[0.52, 2.30]
R^2	0.15	0.24	0.29	
F	28.93**	25.71**	21.36**	
ΔR^2		0.91	0.04	
ΔF		19.23	9.83	

*N = 164. *p < 0.05; **p < 0.01. CI, confidence interval; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; CERQ, Cognitive-Emotion Regulation Strategies; HSPQ-S, High School Personality Questionnaire Spanish Version.*

emotional intelligence facilitates stress resilience. Frajo-Apor et al. (2016) examined emotional intelligence and resilience concerning the mental health of first-year college students finding positive correlations between both variables. Caston and Mauss (2011) also found that ERA is a protective factor that promotes a resilient response when facing stressful stimuli. Even though none of these studies used adolescents as participants, our study revealed similar findings. As ERA can be taught (Barchard et al., 2016; Nathanson et al., 2016) it is essential to keep in mind that fostering adolescents' ability to regulate own and other's emotions can improve their real-life management of emotions (Peña-Sarrionandia et al., 2015). In this sense, by promoting the ability to manage emotions, adolescents will perceive themselves able to adapt in the face of adversity. These results are in line with Montgomery et al. (2008), who found a relationship between both variables resilience, and ERA, in young adults with Asperger's disorder. Even though, our sample is not officially diagnosed with any mental illness, we consider that the environment is crucial for a child's development. For that reason, adolescents growing under a risk context (i.e., low socioeconomic environment) can face emotional and psychological difficulties that, in turn, can undermine their mental health (Ng et al., 2012). As mention in the introduction section, literature is mainly focused on the relationship between emotional intelligence and resilience, in mental illness patients (Frajo-Apor et al., 2016; Artuch-Garde et al., 2017), but little is known about the role played by these two variables in healthy youths. In this sense, our article contributes to prior research increasing previous knowledge in a non-psychopathological sample.

Regarding *coping*, mean CERQ dimensions results (see **Table 1**) are similar to those obtained by Domínguez-Sánchez et al. (2013) in their Spanish validation of the instrument. Correlation analysis between all variables included in the study revealed significant positive correlations between resilience and ERA, self-blame, acceptance, focus on thought/rumination, positive refocusing, refocus on planning, positive reappraisal, sociability, ego-strength, conscientiousness, venturesome, and willpower. Moreover, correlation analysis also showed a significant negative correlation between resilience and dominance.

After including the emotional-cognitive strategy, *positive reappraisal*, our model increases its predictivity in 9%. According to these results, promoting adolescents' ability to positively reinterpret stressful situations can also enhance their resilience perception. Positive reappraisal is a coping strategy typically related to resilience (Bonanno and Mancini, 2008). Min et al. (2013) found that this strategy is associated with resilience, in individuals diagnosed with anxiety and/or depression. Furthermore, research has shown that other cognitive coping strategies are related to resilience levels. For instance, positive coping strategies, such problem-focused coping, infusing positive meaning to ordinary life events, and once again positive reappraisal are associated with the occurrence and maintenance of positive affect (Folkman and Moskowitz, 2000), ultimately predicting increases in psychological well-being and health (Affleck and Tennen, 1996). Coping has also been associated with negative emotions (anxiety, anger), aggression (Ng et al., 2012), and secure attachment (Li, 2008).

As mention before, people use positive emotions to recover from stressful situations (Fredrickson et al., 2000; Tugade and Fredrickson, 2004). Indeed, earlier theoretical writings have indicated that resilient individuals are characterized by high positive emotionality (Block and Kremen, 1996). In order to enhance positive emotions, resilient individuals use positive reappraisal to extract positive meaning from adverse circumstances (Garnefski et al., 2001; Tugade and Fredrickson, 2004; Ong et al., 2006; Caston and Mauss, 2011; Ng et al., 2012; Min et al., 2013; Kalisch et al., 2015; Fernandez-Berrocal and Extremera, 2016; Hughes and Evans, 2016; Mestre et al., 2016). Therefore, this individual factor appears to be a key element developing resilience in different environments. According to the above mention, teaching mindfulness can be an exciting way to promote this vital coping strategy (Garland et al., 2009). Moreover, and considering resilience is largely associated with well-being (Craciun, 2013), fostering both, ERA and positive cognitive-regulation strategies in intervention programs can also help adolescents to develop resilient outcomes. It is important to note that adaption to stressful stimuli at this life stage is crucial (Ong et al., 2006; Kinman and Grant, 2011), and can determine adolescent adjustment in their forthcoming future (Feragen et al., 2009).

To a lesser extent, *sociability* (A factor of HSPQ) also contributes to a better resilience perception among adolescents ($\Delta R^2 = 0.04$). Including all predictive variables, sociability, ERA, and positive reappraisal, our model shows that these abilities are good predictors of efficient social functioning (Eisenberg et al., 2004). As shown in **Table 2**, the relationship between ERA, cognitive-emotional regulation strategies, and sociability explained 29% of the variance of perceived resilience among adolescents. In line with our findings, Hopp et al. (2011) found that people who exhibit a resilient outcome after a stressor are less vulnerable to be affected by negative outcomes. Hence, these

results also support our view of resilience, in the sense that adverse situations and environmental interactions are necessarily for developing a resilient response.

The resilience scale used in this study (ERE), has been applied and validated in countries with similar characteristics to the Spanish culture. However, we obtained high correlations between ERE subscales showing dependency between its different elements. Furthermore, we could not determine whether ERA was related or not to other factors of resilience such as generativity, or personal strengths. Although we only considered one ERE factor (total resilience score), our study is congruent with the meta-analysis carried out by Lee et al. (2013). In their study, the authors pointed out that correlations between risk factors and resilience were less significant than correlations between protective factors and resilience. Positive affectivity, self-efficacy, and self-esteem appeared as the most important protective factors promoting resilience.

In our study, verbal intelligence, most of the personality traits, gender, and age were not significantly related to resilience. Hence, our research stresses the importance of ERA explaining perceived resilience among adolescents. As Wang et al. (1995) pointed out, protective factors depend on the context. ERA, coping, and sociability may be related to adolescent resilience, but not necessarily in all contexts.

Our research presents a few limitations. The first of all is related to the resilience concept. Whether resilience is a personality trait or a set of developmental process, there is not a strong theoretical background that determines how a researcher should evaluate this topic. To overcome this difficulty, it will be necessary to conduct longitudinal and qualitative studies to deeply understand how the environment and people's development evoke resilient responses. A second limitation refers to ERE subscales. Although we have similar average resilience scores as other countries have (Chile and Colombia), ERE subscales did not show independency. Hence, this measure did not allow to assess the relationships between predictive variables and ERE's resilience subscales. Another limitation is the sample size. Some of the predictive variables would result significant predictors of resilience by increasing the sample. Moreover a larger sample size would also provide more reliable estimates to the effects. Finally, the reliability of some subscales of CERQ is questionable. This instrument might be used following the recommendations of Domínguez-Sánchez et al. (2013), who found two-second order factors (synergistic and antagonistic strategies).

IMPLICATIONS

Traditional research, including MSCEIT measures, has found differences regarding gender, where women have usually obtained higher scores than men (Extremera et al., 2006; Mestre et al., 2006). One of the advantages of this sample was its heterogeneity because we did not find gender differences. One of the reasons may be the use of high-school adolescents (without educational filters) as participants, instead of undergraduate students. During Spanish compulsory schooling, both emotional, and cognitive competencies can be taught and, hence, these protective factors can result in resilient behaviors.

Under educational resilience umbrella (see Randolph et al., 2004), adolescents develop protective factors to prevent stressful situations and adverse environments. One of these protective factors is ERA. Our findings support the increasing implementation of training programs in social-emotional-learning activities, focused on increasing ERA (Keller and Otto, 2009; Rivers et al., 2012; Nathanson et al., 2016). In this line of reasoning, teaching ERA during compulsory schooling can foster healthy skills to help adolescents facing adverse circumstances in their forthcoming future.

ETHICS STATEMENT

To protect confidentiality of participants, this research was conducted following the APA Ethics Code Standard 3.08. Besides, the study was approved by the Ethical Board of the Universidad de Cádiz and the high-school participants had to present a signed consent of their parents or legal tutors (to be included in the study).

AUTHOR CONTRIBUTIONS

JM, JN-L, and RG-M led the research and the whole process of writing the paper. JN-L conducted the research under JM and RG supervision, who designed the research and contributed in a previous pilot study. RG and AZ made substantial contributions about data analysis and interpretation of the findings. JM and RG-M wrote the paper under final supervision of both RG and AZ.

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A New Standardized Emotional Film Database for Asian Culture

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Researchers interested in emotions have endeavored to elicit emotional responses in the laboratory and have determined that films were one of the most effective ways to elicit emotions. The present study presented the development of a new standardized emotional film database for Asian culture. There were eight kinds of emotion: fear, disgust, anger, sadness, neutrality, surprise, amusement, and pleasure. Each kind included eight film clips, and a total of 64 emotional films were viewed by 110 participants. We analyzed both the subjective experience (valence, arousal, motivation, and dominance) and physiological response (heart rate and respiration rate) to the presentation of each film. The results of the subjective ratings indicated that our set of 64 films successfully elicited the target emotions. Heart rate declined while watching high-arousal films compared to neutral ones. Films that expressed amusement elicited the lowest respiration rate, whereas fear elicited the highest. The amount and category of emotional films in this database were considerable. This database may help researchers choose applicable emotional films for study according to their own purposes and help in studies of cultural differences in emotion.

Keywords: emotion elicitation, emotional film database, subjective experience, physiological responses, Asian culture

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INTRODUCTION

Emotion has always been a popular research topic, and a large range of procedures have been used to elicit emotions in the laboratory, such as pictures (e.g., Lang et al., 1999), words (e.g., Bradley and Lang, 1999), music (e.g., Sutherland et al., 1982), facial expressions (e.g., Ekman et al., 1983), imagination (e.g., Lang, 1979), films (e.g., Gross and Levenson, 1995), social interactions (e.g., Ax, 1953) and hypnosis (e.g., Bower et al., 1983). Compared to these methods the use of emotional films offers several important advantages. First, unlike slides or still photographs, films involve dynamic auditory, and visual stimuli that are complex and highly capable of capturing attention (Rottenberg et al., 2007). Second, film has a relatively high degree of ecological validity (Gross and Levenson, 1995). Third, films present more realistic emotional context whereby emotions develop over time, and allows researchers to study the time course of an emotion (Kring and Gordon, 1998). Furthermore, meta-analyses of emotion induction show that film seems to be one of the most effective ways to elicit emotions (Gerrards-Hesse et al., 1994; Westermann et al., 1996). Films can easily elicit the three main components of emotional responses: the subjective experience, behavior (including facial expression) and physiological responses (Scott, 1930; Sternbach, 1962; Averill, 1969; McHugo et al., 1982; Rottenberg et al., 2007).

Despite these advantages few film databases to elicit emotional reactions have been created. The first study using emotional films to elicit emotional reactions was done by Lazarus and his colleagues (Lazarus et al., 1962). The most commonly used standardized film set was created by Gross and Levenson (1995), which was an extension of the work of Philippot (1993) who used French dubbed film clips. Over a 5 year period they developed a set of films that reliably elicit eight different emotional states: amusement, anger, contentment, disgust, fear, neutrality, sadness, and surprise. Seventy-eight films were assessed by 494 English-speaking subjects. More recently, Schaefer et al. (2010) created another film database. They assessed 70 film clips specially developed to elicit seven types of emotion: fear, anger, sadness, disgust, amusement, tenderness, and neutrality. Development of both of these film databases relied on college students as participants, so the age range is narrow. Jenkins and Andrewes (2012) developed a new standardized film database with a wider age range of participants (18–88 years). It included 60 film clips designed to elicit six target emotions: amusement, anger, disgust, fear, happiness, and sadness, as well as a neutral state.

A more comprehensive measure of emotional response would include measures of the psychophysiological responses which are primary component of the emotion response (Scott, 1930; Sternbach, 1962; Averill, 1969; McHugo et al., 1982; Rottenberg et al., 2007). Hence, Carvalho et al. (2012) extended the previous studies by a new emotional film database that assessed both subjective experiences and physiological responses, such as skin conductance response (SCR) and heart rate (HR). They chose 52 film clips from six different categories: erotic, fear, social positive content, social negative content, scenery, and object manipulation. However, these film clips did not have sound. In a recent review Kreibig (2010) concluded many challenges remain for research on autonomic nervous system functioning using measures such as HR, respiration, and skin conductance and emotion. She noted that the heterogeneous findings could result from different paradigms to induce emotion e.g., for happiness HR is reported to increase or be unchanged with personalized recall, but also to decrease or be unchanged after viewing film clips. Furthermore, the importance of precise terminology was stressed. For example, amusement and happiness are both positive emotions but reflect different emotional responses.

One purpose of the present study is to develop a new standardized emotional movie database with audio to collect both subjective and physiological responses. It extends previous research by using Asian actors and the use of Asian participants. All the existing film databases were created by Western researchers, and have been widely used by researchers in both Western and Eastern research contexts. Some aspects of emotion are universal. Many previous studies have shown that emotional stimulus created by Western researchers can also elicit the target emotions in Asian participants (e.g., Sato et al., 2007; Zhang et al., 2013). However, the cultural differences in emotion can't be ignored. One major influence culture can have on emotion is the meaning attributed to various events. People from different cultures may appraise the same event in very different ways, depending on their own culture's system of meaning (Scherer and Brosch, 2009). Emotional responses are often influenced by culture and social environment (Kring and Gordon, 1998). For example, in the social environment where you are invited to "help yourself" at the refrigerator while being a guest in someone's home, an American might feel pleasant (an invitation to eat and you can choose whatever to eat), but a Chinese might feel unpleasant (the host will not take care of you and you can't eat anything because it's rude to take food from the refrigerator by yourself).

There is evidence from laboratory studies that shows people from different cultures have different emotional responses to the same emotional stimuli. e.g., the subjective experience for some pictures in the International Affective Pictures System (Lang et al., 1999) differs between Chinese and Western participants (Liu et al., 2009); some of the films in the database created by Gross and Levenson (1995), widely used in Western countries, do not elicit the target emotions in Asian participants (Jin, 2009). Thus, films from Western culture may elicit different types of emotions or emotional intensity in participants from Eastern cultures. The main purpose of this study was to develop an Asian emotional film database so for research on the targeted emotions in an Asian context (such as with Chinese, Japanese, Korean participants). In addition, it will allow researchers to compare emotional stimuli and emotional responses between those from Western and Eastern cultures.

MATERIALS AND METHODS

Participants and Ethics

A total of 110 undergraduates and graduates (31 males, 79 females) participated in film-viewing sessions. The participants were 17–27 years old (mean age = 21.16, SD = 2.10), and all were Chinese. All had normal (or corrected) vision and auditory functions. The experimental procedures were approved by the Institutional Review Board of the State Key Laboratory of Cognitive Neurosciences and Learning of Beijing Normal University. All the participants gave written informed consent before participating.

Materials

First, over a period of 6 months 8 psychology students collected samples of films with emotional content from commercial films and video clips from the Internet. Following Gross and Levenson (1995), the emotions contained in the films were sadness, anger, fear, disgust, pleasure, surprise, amusement and neutrality. From this larger pool short film clips were created by editing key sections using Format Factory software. The way we collected all the film clips were just as Gross and Levenson (1995) and Jenkins and Andrewes (2012) did. Second, 64 were selected for further evaluation based on the criteria: (1) the main actors in the films were of Asian appearance; (2) there were no visible watermarks, logos or mosaics; (3) were not cartoons (4) the thematic content was understandable without additional explanation; (5) the film elicited only one target emotion and not non-target emotions; (6) the level of arousal of emotion had to be appropriate high; and (7) the length of the film clips had to be relatively short. (The results of the target emotion and arousal rated by the psychology students in our lab were shown in the Supplementary Materials,

Table S5.) There were eight films for each kind of emotions. It is worth mentioning that we distinguished amusement from pleasure strictly. The amusement films were funny to people, whereas the pleasure films showed beautiful love, best dreams, etc. We also distinguished fear from disgust strictly. There were no bloody scenes or violent fights in the disgust films. Films in this set averaged 163 s ($SD = 80$) in length (range = 58–590 s), and all had sound tracks. The details of each emotional film are shown in **Table 1** (For the sources of each film please see Table S6 in Supplementary Material).

Procedure

The participants performed the task in a room under similar lighting conditions one by one and were seated at a 90°-angle arc facing the screen. The films were displayed using a 14-inch computer screen. Prior to viewing the films, the participants signed a consent form and answered several demographic questions. The experimenter stated that the purpose of the study was to learn more about emotions. Participants were told that the films would be shown on a computer screen and they should watch the film carefully but could look away or shut their eyes if they found the films too distressing or could stop the experiment if they felt uncomfortable at any time.

We collected data on both the subjective experience (described below) and physiological responses. Heart Rate (HR) and Respiration Rate (RR) are currently two of the most common autonomic nervous system markers of emotional processing (see Kreibig, 2010, for a review; Mauss and Robinson, 2009 for a review). The HR and RR data were collected on a BIOPAC MP150 system with AcqKnowledge 4.0 (BIOPAC Systems Inc.). HR was assessed using a 3 lead ECG, with a lead II configuration. RR was measured by applying a rubber band around the chest. Data were analyzed offline using AcqKnowledge 4.0 software (BIOPAC Systems Inc.).

Before watching the films, participants were asked to rest for 2 min as a baseline. Prior to each film, participants were shown a blank screen for 30 s and instructed to "clear your mind of all thoughts, feelings, and memories". While watching, participants were asked try to move as little as possible to ensure the quality of the HR and RR data. After each film, participants were asked to complete a 28-item self-report inventory which participants rated Valence, Arousal, Dominance, Motivation, Familiarity, Likability, Amusement, Anger, Confusion, Disparagement, Pleasure, Disgust, Embarrassment, Fear, Happiness, Interest, Pain, Extrication, Sadness, Surprise, Tenseness, Shame, Guilt, Repentance, Compunctious, Alertness, and Concentration. The last item was to ask the participants choose one word from the 21 items (except the valence, arousal, motivation, dominance, familiarity and likability) which best described the type of emotion of this film. This rating procedure, adapted from Ekman et al. (1980), was similar to that used by Gross and Levenson (1995). It was a 9-point Likert scale. For the familiarity and likability items the anchor points of 1 and 9 correspond with "not at all" and "very much," respectively.

Participants rated valence, arousal, motivation and dominance using the paper version of the Self-Assessment Manikin (Hodes et al., 1985). For Valence the anchor points were 1 for "very unhappy" and 9 for "very happy;" for Arousal 1 for "very calm" and 9 for "very aroused;" For Motivation 1 for "high desire to withdrawal" and 9 for "high desire to approach;" and for Dominance the rating was 1 for "feeling totally dominated" and 9 for "feeling strong control power." For the other items, 1 indicated "did not feel even the slightest bit of the emotion" and 9 indicated "feel a lot of the emotion" (see (Lang et al., 1999) for a detailed explanation). There was a 30 s delay to clear the mind before the next film was presented.

Each participant viewed 16 films (2 films per kind) and each film was viewed by 28 participants. The trial order was designed so that (1) no two films targeting the same emotion were shown in a row, (2) no more than three films of a particular valence (negative or positive) were shown consecutively and (3) each film had the same chance to be shown in every order for different participants.

Data Analysis

The mean score and SD for each kind of emotion were calculated. Six separate within-subject repeated measures of ANOVA with eight levels (sadness, anger, amusement, surprise, fear, disgust, pleasure, neutrality) were performed for the valence, arousal, motivation, dominance, heart rate and respiration rate data. All the *post-hoc* multiple pairwise comparisons were performed using Bonferroni's correction. The level of statistical significance was set at $p < 0.05$. Data analyses were performed using IBM PASW Statistics 18.0 (IBM).

RESULTS

Self-Report Ratings

Table 1 presents a general description of the film clips, with the associated self-report ratings of valence, arousal, motivation, and dominance. The results of other 24 items are shown in the Supplementary Materials, Table S6. All 64 films are included. We asked the participants use one word to describe the type of emotion of each film. We counted the number of times each word was used as a descriptor as the hit rate. The total hit rate was 99%, which showed that almost all the participants gave the target word. This result demonstrated the effectiveness of the classification and that the films elicited the target emotions. **Table 2** presents a general description of per category. **Figure 1** shows the distribution of the ratings of valence and arousal. **Figure 2** shows the rank of each category on valance, arousal and motivation.

Valence Effects

A one-way repeated measure ANOVA revealed significant differences between the valence ratings [$F_{(7, 756)} = 296.648$, $p < 0.001$, $\eta^2 = 0.733$] of the films clips. *Post-hoc* Bonferroni pairwise comparisons indicated that there were no significant differences between the film clips with negative emotions (anger, fear, and disgust) but they were significantly different from the other kinds. All the valence ratings of the positive films were significantly higher than those of neutral films, and those of neutral films were significantly higher than those of the negative films. Further, the other kinds differed significantly

TABLE 1 | Self-report ratings and psychophysiological responses for the EMDB, *mean* (*SD*).

Emotional kind	No.	Length (s)	Clip description	Valence mean (*SD*)	Arousal mean (*SD*)	Motivation mean (*SD*)	Dominance mean (*SD*)	HR mean (*SD*)	RR mean (*SD*)
Sadness	1	198	Separation of mother and son	2.519 (1.762)	5.000 (2.304)	3.778 (2.154)	4.259 (2.141)	74.333 (7.211)	14.901 (2.228)
	2	590	Brother sends younger brother and sister to others	2.833 (1.724)	5.167 (2.291)	5.367 (1.752)	4.633 (2.371)	74.793 (11.912)	
	6	154	Son knows dad die	2.500 (1.711)	5.357 (2.164)	3.786 (2.166)	4.250 (2.154)	70.082 (13.061)	15.668 (2.307)
	11	232	Aged man find himself incontinent	3.192 (1.877)	4.846 (2.292)	4.346 (2.399)	4.654 (2.038)	72.778 (10.006)	15.529 (2.970)
	12	179	Father dies in front of son	2.357 (1.545)	5.679 (2.038)	3.929 (2.523)	4.357 (2.094)	71.326 (8.988)	15.633 (2.279)
	13	179	Disabled children and unfortunate couple	3.500 (2.045)	5.333 (2.434)	5.370 (2.705)	4.296 (1.977)	72.893 (9.923)	14.967 (2.011)
	15	239	Father sends son to American	3.538 (2.044)	3.769 (2.372)	4.885 (2.215)	5.192 (2.498)	72.261 (7.965)	15.287 (1.519)
	16	234	Return objects and apologize before leaving	2.429 (1.834)	5.286 (2.665)	4.107 (2.409)	3.857 (1.938)	74.207 (11.910)	14.971 (2.167)
Anger	3	125	Don't show sympathy for disaster victims	1.393 (1.066)	5.679 (2.842)	2.143 (2.155)	5.071 (2.260)	70.803 (7.638)	15.303 (2.250)
	5	184	Hit innocent people	2.577 (1.701)	3.462 (1.985)	3.577 (1.677)	5.154 (2.327)	71.969 (8.545)	15.434 (2.308)
	6	181	Japanese bully Chinese people	2.214 (1.969)	6.071 (2.538)	4.714 (2.747)	4.714 (2.275)	74.120 (10.075)	14.918 (1.931)
	9	261	Brothers grab property after mother die	2.533 (1.613)	5.100 (2.090)	3.700 (2.575)	4.200 (2.091)	74.074 (11.188)	
	10	113	Children don't care about dead father but property	1.556 (0.974)	5.143 (2.534)	2.607 (2.283)	4.286 (2.158)	68.846 (11.782)	15.699 (2.242)
	11	146	Boss don't pay workers money	2.923 (2.058)	5.000 (2.320)	3.889 (2.190)	3.778 (2.044)	72.108 (9.406)	15.501 (2.170)
	22	180	Frame good people for money	2.346 (1.384)	4.154 (2.618)	3.538 (2.404)	5.115 (2.142)	74.014 (10.114)	16.035 (2.161)
	23	168	Passers don't save the injured girl	1.148 (0.362)	5.852 (2.741)	3.630 (2.604)	3.889 (2.391)	71.709 (8.196)	15.195 (1.987)
Amusement	5	165	Foolish robber in ancient China	6.556 (1.476)	5.963 (2.295)	5.407 (2.024)	5.519 (1.847)	71.523 (9.762)	14.564 (1.782)
	8	241	Funny competition between two teachers	5.333 (2.090)	5.600 (2.238)	4.600 (2.127)	5.033 (1.938)	72.645 (11.121)	
	9	177	Funny news	6.538 (2.353)	6.577 (1.963)	6.423 (2.403)	5.385 (2.099)	75.766 (8.441)	13.530 (2.957)
	10	196	Beautiful women seduce soldiers	5.769 (1.751)	5.615 (2.174)	5.654 (1.999)	5.731 (1.638)	72.273 (10.281)	14.889 (2.676)
	12	240	Chinese crosstalk	6.115 (2.046)	4.423 (2.101)	5.308 (2.205)	6.154 (1.515)	73.355 (8.880)	13.606 (2.077)
	13	97	Foolish robber on the train	6.964 (1.710)	6.393 (2.166)	5.926 (2.448)	5.964 (1.835)	69.618 (13.132)	14.886 (2.641)
	14	164	A rich man and a poor man sleep together	6.250 (1.956)	6.179 (2.019)	4.750 (2.784)	4.893 (2.393)	71.014 (8.177)	14.905 (1.610)
	16	225	Three officers in brothel	6.893 (1.750)	6.250 (2.102)	6.000 (2.386)	5.750 (1.936)	74.116 (13.844)	13.889 (2.406)
Surprise	1	143	An incredible fast service	5.577 (2.023)	4.231 (2.026)	5.615 (1.961)	5.385 (2.210)	73.393 (8.381)	15.219 (3.141)
	3	120	Magic	6.846 (1.759)	6.143 (2.460)	6.750 (2.319)	5.000 (2.143)	72.607 (11.373)	13.948 (2.301)
	4	99	Dominoes	7.148 (1.834)	6.556 (2.225)	7.148 (2.196)	5.741 (2.011)	72.230 (8.605)	14.597 (2.357)
	6	86	Put new steamships into ocean	5.179 (2.45)	4.25 (2.382)	4.643 (2.738)	5.321 (1.906)	73.388 (8.847)	15.476 (2.044)
	7	84	Magic in spring festival night	6.429 (1.574)	5.393 (2.25)	6.679 (1.867)	5.607 (2.347)	67.871 (11.229)	15.292 (2.758)
	12	115	Almost had a car accident but not	3.577 (2.283)	5.115 (2.613)	3.269 (2.359)	5.231 (2.338)	72.250 (10.150)	16.416 (2.434)
	13	200	Almost had a car accident but not	3.300 (2.184)	5.133 (2.300)	3.500 (2.418)	4.633 (2.526)	73.024 (11.555)	
	14	112	Peel eggs with glass cup	6.963 (1.344)	6.444 (1.625)	6.704 (1.836)	5.222 (2.136)	70.315 (7.154)	15.070 (2.139)

(Continued)

TABLE 1 | Continued

Emotional kind	No.	Length (s)	Clip description	Valence mean (*SD*)	Arousal mean (*SD*)	Motivation mean (*SD*)	Dominance mean (*SD*)	HR mean (*SD*)	RR mean (*SD*)
Fear	1	150	Ghost in the bathroom	1.889 (1.625)	6.963 (2.084)	2.556 (2.207)	3.481 (2.392)	71.861 (6.609)	15.402 (1.712)
	2	151	Meet the dead self with the ghosts	2.038 (1.685)	5.115 (2.984)	1.885 (1.532)	3.500 (2.470)	71.753 (9.903)	16.120 (2.608)
	3	83	Ghost comes out from the television	1.857 (1.433)	6.571 (2.441)	2.111 (2.359)	3.929 (2.854)	70.988 (9.224)	15.425 (2.112)
	5	156	Meet the ghost in house	2.269 (1.687)	4.462 (2.626)	2.654 (2.171)	5.038 (2.144)	71.632 (7.242)	14.357 (2.470)
	9	90	Hanged people pulled by ghost	1.370 (0.967)	5.704 (2.998)	1.556 (1.396)	3.074 (3.074)	70.907 (9.457)	15.001 (1.746)
	10	167	Ghost hides in the wig	1.800 (1.270)	6.700 (2.037)	2.690 (2.206)	4.067 (4.067)	74.797 (12.775)	
	11	80	A girl in a dark house	1.778 (1.281)	6.214 (2.470)	2.321 (2.229)	3.464 (3.464)	69.845 (13.871)	15.972 (1.763)
	12	153	Ghost under the bed	2.143 (2.121)	6.857 (2.337)	2.786 (2.558)	3.536 (3.536)	74.294 (13.841)	14.786 (2.172)
Disgust	3	68	Rack acne	2.074 (1.730)	4.704 (2.998)	2.037 (1.911)	3.000 (1.754)	74.686 (11.272)	14.404 (2.031)
	4	165	Food vomited from the stomach	1.192 (0.801)	4.500 (3.444)	1.346 (1.346)	4.231 (2.643)	74.358 (8.523)	14.873 (2.211)
	6	123	Put crawling maggots on face	1.769 (1.531)	5.308 (2.881)	1.846 (1.690)	3.846 (2.378)	72.403 (9.087)	15.822 (2.597)
	7	60	Dirty food material	1.536 (1.688)	5.643 (2.297)	2.536 (2.603)	4.750 (2.319)	72.703 (9.155)	14.609 (2.742)
	9	87	A man vomits	2.923 (2.331)	5.615 (2.368)	1.500 (1.105)	4.346 (2.513)	72.872 (5.628)	14.963 (1.927)
	11	169	Dirty and smelly foot	3.267 (3.267)	5.600 (1.886)	3.800 (2.747)	5.000 (2.101)	72.094 (9.410)	
	17	58	Cockroach is crushed	1.964 (1.575)	5.750 (2.413)	2.593 (2.422)	4.036 (2.269)	69.322 (13.360)	15.028 (2.277)
	18	71	Pustule on body	1.143 (0.448)	6.000 (3.151)	1.500 (1.753)	2.929 (2.308)	75.948 (12.723)	13.691 (2.410)
Pleasure	1	219	Children play on grass	7.615 (1.169)	5.731 (2.219)	7.192 (1.789)	5.385 (2.137)	72.837 (10.191)	13.896 (1.684)
	2	259	Lovers chat happily	7.000 (1.912)	5.200 (2.041)	6.333 (2.279)	5.333 (2.023)	73.926 (10.982)	
	5	100	Lovers chat about sex	7.444 (1.476)	5.444 (2.118)	5.889 (2.577)	5.148 (1.586)	73.124 (9.959)	14.802 (1.583)
	11	129	A man gives gifts to a woman and says love to her	7.769 (1.107)	5.462 (2.319)	6.846 (1.515)	6.346 (1.623)	72.100 (9.280)	15.571 (2.756)
	13	125	Lovers talk about the rainbow	6.704 (2.035)	4.889 (2.293)	6.222 (1.928)	5.556 (5.556)	73.047 (6.587)	15.172 (1.860)
	14	209	Happy time of father and son	8.607 (0.497)	6.929 (1.631)	8.357 (0.678)	6.321 (1.867)	74.324 (10.101)	14.266 (2.893)
	15	79	Happy time in high school	8.000 (1.333)	6.929 (1.654)	7.643 (1.420)	5.964 (2.027)	70.325 (11.392)	15.004 (2.604)
	16	97	The aged people go hiking	7.429 (1.773)	6.179 (2.262)	7.321 (2.278)	5.000 (1.981)	72.149 (8.337)	15.320 (2.804)
Neutrality	1	181	City in heavy snow	4.074 (1.615)	2.444 (2.444)	4.148 (1.975)	5.185 (1.570)	75.042 (8.028)	15.326 (2.020)
	2	244	City in snow	4.120 (1.666)	2.385 (1.602)	3.885 (1.862)	5.577 (2.248)	74.241 (10.958)	14.565 (2.008)
	3	347	Talk about the relationship between weather and red leaves	4.250 (1.818)	1.929 (1.274)	3.821 (2.144)	4.679 (2.480)	74.949 (12.05)	14.535 (1.864)
	4	110	Talk about the recovery from drought	3.714 (1.740)	2.321 (1.657)	3.714 (1.652)	5.536 (1.895)	75.901 (9.548)	15.010 (2.592)
	6	153	A man teaches how to drive	3.867 (1.995)	3.200 (2.265)	4.733 (2.318)	5.067 (2.504)	73.819 (8.216)	14.754 (1.192)
	14	150	Drive on the mountain road	4.037 (1/786)	2.963 (1.652)	3.741 (1.655)	4.444 (2.242)	74.594 (7.715)	15.493 (1.830)
	17	180	A man teaches calligraphy	5.929 (1.884)	4.214 (4.214)	5.821 (2.109)	5.357 (1.948)	71.100 (10.992)	15.493 (2.274)
	18	180	Weather forecast	4.692 (2.187)	2.538 (1.655)	4.654 (1.938)	5.923 (2.038)	75.913 (11.148)	

TABLE 2 | Self-report ratings and psychophysiological responses per category, *mean* (*SD*).

Film category	Valence mean (*SD*)	Arousal mean (*SD*)	Motivation mean (*SD*)	Dominance mean (*SD*)	HR mean (*SD*)	RR mean (*SD*)
Sadness	2.859 (0.488)	5.055 (0.576)	4.446 (0.673)	4.437 (0.394)	74.100 (11.452)	15.202 (2.064)
Anger	2.086 (0.640)	5.058 (0.880)	3.475 (0.786)	4.526 (0.561)	73.580 (10.683)	15.377 (1.830)
Amusement	6.302 (0.556)	5.875 (0.682)	5.508 (0.624)	5.554 (0.437)	72.954 (10.413)	14.388 (2.041)
Surprise	5.627 (1.514)	5.408 (0.912)	5.538 (1.551)	5.268 (0.345)	73.221 (12.763)	15.041 (2.163)
Fear	1.893 (0.273)	6.073 (0.904)	2.320 (0.437)	3.761 (0.599)	73.067 (11.889)	15.378 (1.839)
Disgust	1.984 (0.767)	5.390 (0.525)	2.145 (0.816)	4.017 (0.747)	74.588 (13.613)	14.717 (1.948)
Pleasure	7.571 (0.587)	5.845 (0.766)	6.976 (0.819)	5.632 (0.519)	74.216 (11.677)	14.921 (2.116)
Neutrality	4.335 (0.705)	2.749 (0.709)	4.315 (0.728)	5.221 (0.487)	75.538 (11.914)	14.931 (1.772)

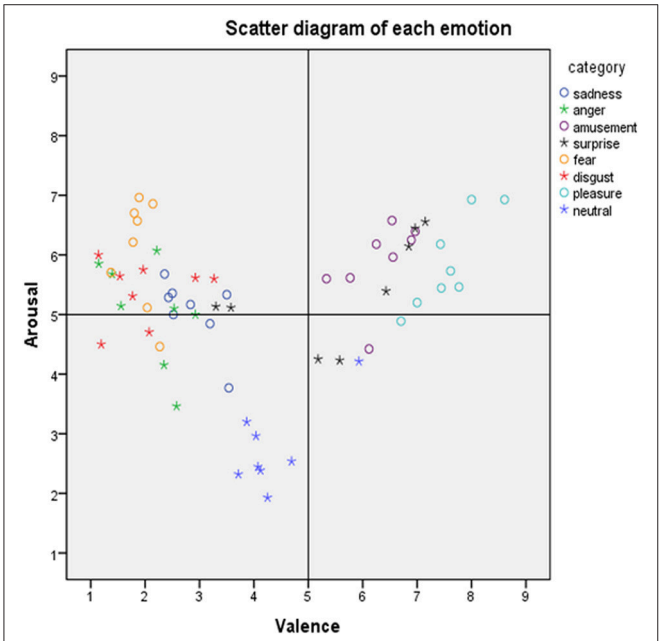

FIGURE 1 | The distribution of the film clips in the affective space (mean values for valence on the horizontal axis and arousal on the vertical axis).

from each other. The valence ratings were as follows: anger, fear, disgust < sadness ($p < 0.001$) < neutrality ($p < 0.001$) < surprise ($p < 0.001$) < amusement ($p < 0.001$) < pleasure ($p < 0.001$). In addition, pleasure was rated more positively than amusement.

Arousal Effects

A one-way repeated measure ANOVA revealed significant differences among the arousal ratings [$F_{(7, 756)} = 50.482$, $p < 0.001$, $\eta^2 = 0.319$] for the different film clips. *Post-hoc* Bonferroni pairwise comparisons indicated that arousal for neutral film clips was significantly lower than that of any other categories (all $p < 0.05$). Films depicting sadness and anger were rated as less arousing than pleasure, amusement and fear (all $p < 0.05$). Furthermore, disgust was rated as less arousing than fear ($p < 0.01$). There were no significant differences between the other comparisons.

Motivation Effects

A one-way repeated measure ANOVA revealed significant differences among motivation ratings [$F_{(7, 756)} = 100.050$, $p < 0.001$, $\eta^2 = 0.481$]. *Post-hoc* Bonferroni pairwise comparisons indicated that the motivation of these eight kinds of films were as follows: disgust, fear < anger ($p < 0.001$) < neutrality, sadness ($p < 0.05$) < amusement, surprise ($p < 0.001$) < pleasure ($p < 0.001$). Positive films (such as pleasure, amusement, and surprise) elicited approach motivation, and negative films (such as sadness, anger, fear, and disgust) elicited avoidant motivation. It is worth mentioning that neutral films elicited avoidant motivation as sad.

Dominance Effects

A one-way repeated measure ANOVA revealed significant differences among dominance ratings [$F_{(7, 756)} = 24.494$, $p < 0.001$, $\eta^2 = 0.185$]. *Post-hoc* Bonferroni pairwise comparisons indicated that there were no significant differences between three negative emotions (fear, disgust and sadness) and no differences between three other negative emotions (disgust, sadness and anger); however, the dominance of fear was significantly lower than that of anger ($p < 0.05$). The dominance of positive (amusement, surprise and pleasure) and neutral emotions were significantly higher than that of negative emotions ($p < 0.05$). There were no significant differences between neutrality, surprise, amusement, and pleasure.

Target Emotions

The results of mean ratings for target emotion were showed in **Table 3**. Target emotion means the emotion which was elicited most strongly. For example, for sadness films, the rating of sadness was the rating of target emotion. One-way repeated measure ANOVA revealed significant differences between the ratings of target emotion and non-target emotion, all $p < 0.05$.

Table 4 shows a comparison of the results from the present study with that of Gross and Levenson (1995). Our data are the mean ratings for target emotion of the eight kinds of emotional film clips (see **Table 3**). For Gross and Levenson (1995) the mean ratings was of their best two films for each category (see their **Table 1**). Because we used a 1–9 point scale and Gross and Levenson used a 0–8 point scale we subtracted 1 point of all the results before the comparison. The results in **Table 4** showed the results after subtraction of our results.

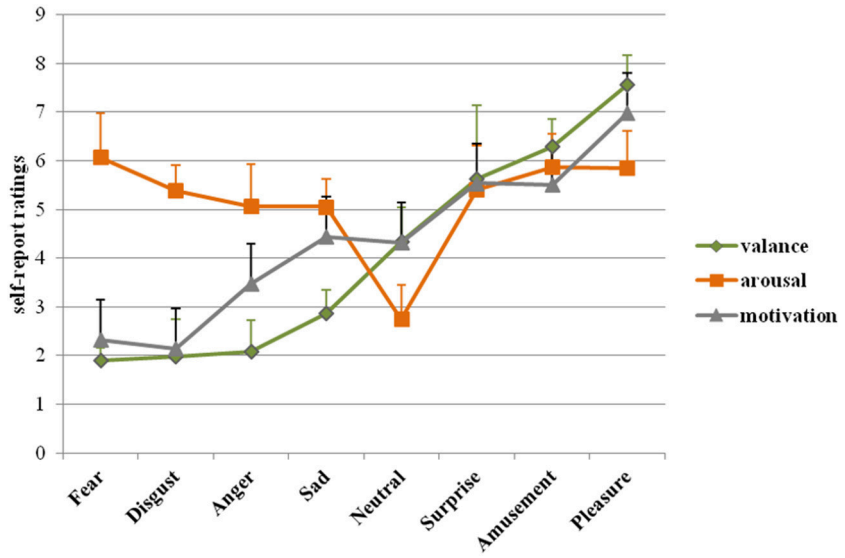

FIGURE 2 | The rank of each category on valence, arousal and motivation. (The rank is based on the results of valence.)

The Psychophysiological Responses

Table 1 presents the psychophysiological responses of heart rate and respiration rate of each film clip. **Table 2** presents a general description of per category.

Heart Rate (HR)

A one-way repeated measure ANOVA revealed significant differences in the heart rate data [$F_{(7, 756)} = 4.072$, $p < 0.001$, $\eta^2 = 0.036$]. *Post-hoc* Bonferroni pairwise comparisons indicated that the HR for neutrality film clips was significantly higher than those of sadness, anger, amusement, surprise and fear (all $p < 0.05$). There were no other differences.

Respiration Rate (RR)

For one group the RR data was lost due to equipment failure. Thus, there were missing data in each category of film clip (see **Table 1**).

A one-way repeated measure ANOVA revealed significant differences in the respiration rate data [$F_{(7, 455)} = 5.204$, $p < 0.001$, $\eta^2 = 0.074$]. *Post-hoc* Bonferroni pairwise comparisons indicated that the RR for amusement was significantly lower than those of sadness, anger and fear (all $p < 0.05$), and disgust was lower than fear ($p < 0.05$). There were no other significant differences.

Length Effect

Because the length of each film clip was different (from 58 to 590 s), we further analyzed whether the length factor could induce different effects in inducing valence, arousal, motivation, dominance, HR and RR. We used the median (155 s) as the boundary. The length shorter than 155 s were sorted as short length, the length longer than 155 s were sorted as long length. Independent sample *T*-test was used to test the length effect within each kind of emotion. The significance level was $p < 0.001$ after the Bonferroni's correction for multiple pairwise comparisons. The results only showed the signicant differences in surprise emotion. Short length of surprise emotional films elevated both higher valence (short: 5.968 ± 2.235, long: 3.300 ± 2.184) and motivation (short: 5.847 ± 2.533, long: 3.500 ± 2.418) than long length. There were no significant differences between short and long length in other kinds of emotional films in inducing valence, arousal, motivation, dominance, HR, and RR.

DISCUSSION

The present study showed the development of a new emotional film database with Asian actors where both the subjective (valence, arousal, motivation, and dominance) and physiological responses (HR and RR) of Asian participants were measured. It consisted of film clips with audio which depicted eight kinds of emotion (fear, disgust, anger, sadness, neutrality, surprise, amusement, and pleasure) similar to previous database studies (Gross and Levenson, 1995; Schaefer et al., 2010; Carvalho et al., 2012; Jenkins and Andrewes, 2012). The data (**Table 4**) showed the ratings of the target emotion in this film database were similar to Gross and Levenson (1995). Thus, it comprised a relatively well-developed standardized emotional film database. In addition, each category consisted of eight films, and each film in the same emotion had different scores on valence and arousal (see **Figure 1**), so researchers can select varying degrees of emotional films according to their own needs.

Self-reports from the participants indicated that each film clip elicited the target emotion (see **Tables 1**, **3**). As expected fear, disgust, anger, and sadness elicited negative emotions. Surprise, amusement and pleasure elicited positive emotions. The valence of neutral film clips was rated in the middle of the scale (mean score close to 5) and the arousal of neutrality was the lowest

TABLE 3 | Ratings of target emotion per category, *mean* (*SD*).

Film category	Sad	Angry	Amuse	Surprise	Fear	Disgusting	Pleased
Sadness	6.291 (0.750)	1.757 (0.536)	1.233 (0.181)	1.661 (0.276)	1.584 (0.270)	1.592 (0.284)	1.532 (0.376)
Anger	3.978 (1.469)	6.626 (0.633)	1.309 (0.258)	2.165 (0.733)	1.982 (0.733)	5.323 (0.876)	1.287 (0.210)
Amusement	1.130 (0.109)	1.394 (0.186)	6.955 (0.642)	1.860 (0.471)	1.272 (0.166)	1.664 (0.461)	4.163 (0.471)
Surprise	1.192 (0.211)	1.318 (0.301)	2.590 (0.466)	5.092 (0.935)	1.781 (0.859)	1.759 (0.632)	3.798 (1.193)
Fear	1.721 (0.265)	1.783 (0.281)	1.253 (0.176)	2.584 (0.316)	6.745 (0.468)	4.612 (0.542)	1.277 (0.211)
Disgust	1.937 (0.430)	2.961 (1.729)	1.845 (0.856)	2.941 (0.664)	3.833 (1.502)	6.315 (1.219)	1.479 (0.364)
Pleasure	1.255 (0.308)	1.147 (0.147)	2.968 (1.416)	1.795 (0.526)	1.134 (0.169)	1.223 (0.254)	6.597 (0.871)
Neutrality	1.161 (0.189)	1.191 (0.242)	1.230 (0.149)	1.701 (0.570)	1.196 (0.263)	1.692 (0.339)	2.176 (0.669)

(almost < 3), indicating some emotional neutrality. These data suggest the neutral films may be particularly appropriate for use as a control category.

For the valence rating, participants rated film clips of anger, fear, and disgust significantly lower than those depicting neutrality and positive emotions. However, within the negative emotions there were no differences between each other, suggesting the three kinds of emotional film clips in this database made participants experience the same feeling of unpleasantness. In contrast, the ratings of valence between film clips depicting positive emotions did differ: pleasure had the highest valence, pleasure films clips indeed made people feel happier than the amusement films clips, and surprise was rated less positive than that of amusement. Though the pleasure and amusement emotions were both positive, the content of the emotional stimulus may play more important role (Carvalho et al., 2012). As for the surprising emotion, they were rated as "Pleased." However, surprising emotion is well-known for its ambiguous property (Kim et al., 2004). It has to be clarify that the surprising emotional film clips in the present study showed the unusual things, for instance, magic, and uncredible skill. This kind of emotion was adapted from Gross and Levenson (1995). People may feel ambiguous at the beginning, but after they knew the principle they may suddenly realized and feel amazing and pleased. So the surprising emotion in this study was a little different from the studies about surprising expressions. Thus, the research on emotion needs to consider more than valence; rather, the content of the emotional stimulus should be taken into account.

The arousal dimension has been conceptualized as an index of the intensity of an emotional reaction (e.g., Schupp et al., 2004). In the present study neutral films had the lowest arousal compared to any other categories. Fear, amusement, and pleasure had higher levels of arousal than the sadness and anger films, but unlike Carvalho et al. (2012) and Lang et al. (1999), pleasure, amusement and fear did not differ from each other. This finding that film clips depicting sadness and anger film clips did not elicit higher levels of arousal than positive ones may be accounted for cultural differences. According to many cultural psychologists, people in Western cultures (especially Americans) tend to be high on individualism and in contrast, most Asian cultures emphasize collectivism, or prioritizing the group over the individual (Markus and Kitayama, 1991). For example, one study about Chinese Americans reported that less acculturated Chinese Americans speak significantly more than the others did about friends, family, and other social activities (Tsai et al., 2004). Positive film clips in this study all included happy interactions between lovers, family members, or friends. These stimuli may make people in collectivism cultures feel the greater happiness, resulting in higher ratings for arousal of positive emotions. This explanation would account for the difference in findings with previous research and the lack of difference in measures of arousal between negative and positive emotions in this study. Importantly the data suggest it is possible to produce film clips which elicit same levels of arousal for positive and negative films, removing a possible confound from research on emotions.

TABLE 4 | Ratings of target emotion compared this database with Gross and Levenson (1995).

	Sadness	Anger	Amusement	Surprise	Fear	Disgust	Pleasure
This database	5.291	5.626	5.955	4.092	5.745	5.315	5.597
Gross's	5.530	5.635	5.700	4.635	4.160	6.025	3.520

The third dimension measured was dominance, somewhat neglected, due to its variance being the least unique (e.g., Bradley and Lang, 1994) within the affective space, but it is worth measuring for further investigation (Carvalho et al., 2012). Bradley and Lang (1994) stated that the dominance dimension sometimes may be confusable. The main problem is what is really being rated: the stimulus itself or the subjective feeling it elicits. To avoid this confusion, in the present study the instructions to participants emphasized the elicited feeling. A lower degree of dominance represented that participants felt more dominated by the content of the emotional films. The positive and neutral movies had larger dominance scores than the negative ones. For the negative films, the fear clips had lower scores compared to anger. In short, participants reported higher levels of being dominated appear after negative films, especially fear ones, consistent with what was found in previous studies of emotional film databases (Carvalho et al., 2012). However, this finding is inconsistent with that from a study of affective pictures (Bradley and Lang, 2007), further emphasizing that variations in paradigms need to be accounted for in interpreting the results of studies of emotion.

This study also measured motivation, another under-studied variable in previous studies of emotional film databases. Links

between emotion and the motivation system have been studied (Elliot et al., 2013). Emotions can activate the approach or avoidance motivation systems (e.g., Lang et al., 1990, 1999). The data in the present study speak to this issue. Consistent with previous research (e.g., Frijda, 1988; Rolls, 2013; Panksepp, 2015) in this study, the negative emotion film clips (except sadness, which showed the same motivation as the neutral film clips) elicited the avoidance motivation (with motivation scores lower than 5) and the positive ones elicited the approach motivation (with motivation scores higher than 5). Like in the valence data, the film clips for pleasure and amusement were rated differently such that pleasure film clips elicited more approach motivation than amusement films. In contrast to the finding for the valence data, for the motivation scores there were reliable differences between film clips portraying negative emotions: sad films had higher motivation scores than anger films, and anger films had higher scores than disgust and fear films. One interpretation of this complex data set is that sadness may make people show more sympathy, so sad movies had low valence but high motivation scores. Anger is a negative emotion, but it often elicited the approach motivation (Harmon-Jones, 2003, 2004a,b); consistent with data from this study which showed that anger film clips also had low valence but high motivation scores.

One strength of this study was concurrent measurement of subjective and psycho-physiological responses. HR was significantly higher when participants viewed neutral emotional film clips than when viewing those depicting sadness, anger, amusement, surprise, and fear. That is to say, compared to neutral films, HR declined while watching emotional films. This finding is consistent with some previous results (Bradley et al., 2001; Sánchez-Navarro et al., 2006; Codispoti et al., 2008; Carvalho et al., 2012) but not with others (e.g., Kunzmann and Grühn, 2005 found the increased HR for sad movies in aged people). Kreibig (2010) has reviewed many studies about autonomic nervous system activity in emotion and found the great diverge of autonomic response patterns for certain emotions. She discussed each kind of emotions detailed in the review and found "HR was increased for negative (anger, anxiety, contamination related disgust, embarrassment, fear, crying sadness) and positive emotions (imagined anticipatory pleasure, happiness, joy) as well as for surprise. HR decreased in mutilation-related disgust, imminent-threat fear, non-crying sadness, acute sadness, affection, contentment, visual anticipatory pleasure, and suspense emotions that all involve an element of passivity, and may be taken to suggest vagal mediation." In consideration of these inconsistent findings, we thought the content of the emotional stimulus but not just the valence or arousal may play an important role in the physiological responses. Besides, different operations of the experiment (age and gender/sex of participants, length of stimulus, time of day/year of the test, etc.) may also be responsible for the diverge. Numerous conclusions remain tentative and more studies are still needed. We hope this database could offer more stimulus for future researchers to further explore the autonomic nervous system activity in emotion. To explain the results in this study, we would like to refer to Codispoti et al. (2008). They proposed that a decline in heart rate reflected orienting, sustained attention and action preparation, consistent with the finding that in the present study neutral film clips were less arousing than each of the emotion inducing film clips.

Few studies of emotional stimulus database have measured respiration rate. The respiration rate means how deeply and rapidly a person is breathing. In this study, amusement films elicited the lowest respiration rate, whereas fear elicited the highest. The fear, anger, and sadness films elicited higher RRs than the amusement films. Disgust films elicited lower RRs than fear films. The fear films made people breath quickly and deeply, indicating tense anticipation. These results were consistent with previous studies (Haag et al., 2004). Rapid and deep breathing can indicate excitement, such as anger or fear, but sometimes also joy. Rapid shallow breathing can indicate tense anticipation, including panic, fear or concentration. Slow and deep breathing indicates a relaxed resting state, whereas slow and shallow breathing can indicate states of withdrawal, passive states, such as depression or calm happiness (Haag et al., 2004).

The films in this database were all from Asian culture, purposely constructed to be a valid measure of emotional constructs in that cultural context. No erotic stimuli were included in any of the clips designed to elicit positive emotions. While in Western culture, erotic pictures or films have been used to elicit positive and high-arousal emotions (e.g., Carvalho et al., 2012), participants from Eastern culture have been reported to rate erotic stimulus as less arousing and less pleasant (Liu et al., 2009). In fact, Chinese participants rated the valence of naked people and sex lower than neutral stimulus (Liu et al., 2009). However, Eastern people rated warm relationships with others (e.g., clips No. 14–16 of pleasure stimuli) as the most positive and arousing. This category is often rated as a positive but low-arousal emotion in Western culture. One possible explanation for this difference is the collectivism in Eastern culture and individualism in Western culture (Earley, 1993). As for the fear emotion, the things that made people feel fear were totally different between the cultures. The fear film clips in this study excluded bloodiness, murder, and violence which sometimes make Eastern people feel disgusted rather than fearful. Rather we included clips from classical Asian ghost films, such as "A Wicked Ghost," as fear films. Although the content of fear films was different between that used in Western data bases, fear films were still rated the most negative and highly arousing emotion compared to other emotions in both cultures. In short, some types of emotional films created by Western researchers were not suitable for eliciting the same emotion or emotional intensity in Eastern participants. As a result, this database was developed.

Finally, there are some limitations that should be considered with caution. First, the HR and RR may not be enough to represent complex physiological patterns of nervous systems. Second, the length and the exciting parts of the films were different. This may bring about the potential problem that the time course of the emotion could not be easily determined. For example, the most exciting part of one film clip was at the end, and the physiological responses changed only at the end. However, the average physiological responses may be affected by the first half of a film clip. Third, the sample of participants in this study was small, with a restricted age range

(17–27 years old), they may not representative of the overall population, with a preponderance of females. Given known sex differences in emotion (Fischer et al., 2004), this may affect the results, though several previous studies also had this gender distribution (Schaefer et al., 2010; Carvalho et al., 2012). We have to say the current study can't be considered a normative study due to sample limitations. The present data requires replication, with larger samples and including, for instance, different range of ages, different nationalities as mentioned below, socioeconomic status and so on. Fourth, though the films were chosen from several Asian countries, the participants in this study were Chinese. Though studies found few or no cultural differences in emotional perception between Japanese and Chinese participants (Kawamura and Ohno, 2011), other researchers found that Japanese today are about as individually competitive as Americans (Bond, 2002; Oyserman et al., 2002). We still need more studies to test the cultural differences among Asian countries. The limitation of using films to elicit emotions has been discuss extensively (e.g., Fernández et al., 2012). Future studies could include (1) considering brain activity while watching these films, (2) enlarging the sample of participants in the nationalities, for example, age range, since huge number of researches have found that older people have a different approach to emotional stimuli compare to young people (e.g., Mammarella et al., 2012, 2016; Fairfield et al., 2013; Di Domenico et al., 2015, 2016), (3) using other methods to measure the autonomic nervous system, and (4) Comparing the differences in emotional responses between Western and Eastern culture. The current results were soley based on Asian population and therefore additional data based on Westerners should be collected to valid the usefulness of this dataset compared to the previous Western based stimulus sets. We just provide the stimulus in this study and we will collect more data using these stimulus. We also hope more researchers can use these stimulus to do more comparative studies, just like IAPS (Bradley and Lang, 2007), and this dataset can be used to compare research across laboratories or simply as a source of experimental materials.

CONCLUSION

The amount and category of emotional films in this database were considerable. The positive ones and negative ones had the same level of arousal, which can activate appetitive and defensive systems equally. This database may help Eastern researchers choose applicable emotional films for research. There were both subjective experience and physiological response in this database. Each category contained eight film clips and the eight films had different parameters from which researchers can choose, such as high and low arousal of pleasure. In addition, this database may be helpful for studies of cultural differences in emotions.

AUTHOR CONTRIBUTIONS

RZ and YD designed the study, MY and YD collected and analyzed the data, YD and RZ wrote the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01941/full#supplementary-material

The authors of the current database wish to state that they do not make any claim over the copyright of the film clips. That copyright is exclusively of the films rightful owners, which can be found in the Table S6 of supplementary material. The database film clips described in this article can be only used for scientific research and may not be used for any commercial purposes. If anyone wants to use the film clips rated in this study, one can request at rlzhou@nju.edu.cn for them. And you will be asked to confirm that it will be used solely for non-profit scientific research and that the database will not be reproduced or broadcasted in violation of international copyright laws.

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Linking the Positivity Effect in Attention with Affective Outcomes: Age Group Differences and the Role of Arousal

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Despite its assumed importance for emotional well-being, studies investigating the positivity effect (PE) in older adults' information processing rarely tested its relationship with immediate or general affective outcome measures like emotional reactivity or emotional well-being. Moreover, the arousal level of the to-be-processed emotional stimuli has rarely been taken into account as a moderator for the occurrence of the PE and its relationship with affective outcomes. Age group differences (young vs. old) in attention (i.e., fixation durations using eye tracking) and subjective emotional reactions (i.e., pleasantness ratings) were investigated in response to picture stimuli systematically varied in valence (positive vs. negative) and arousal (low vs. high). We examined whether there is a link between age group differences in fixation durations and affective outcomes (i.e., subjective emotional reactions as well as emotional well-being). Older compared to young adults fixated less on the most emotional part in negative but not in positive low-arousing pictures. This age difference did not occur under high arousal. While age group differences in fixation duration did not translate into age group differences in subjective emotional reactions, we found a positive relationship between fixation duration on negative low-arousing pictures and emotional well-being, i.e., negative affect. The present study replicated the well-known PE in attention and emotional reactivity. In line with the idea that the PE reflects top-down-driven processing of affective information, age group differences in fixation durations decreased under high arousal. The present findings are consistent with the idea that age-related changes in the processing of emotional information support older adults' general emotional well-being.

Keywords: eye tracking, emotional reactivity, emotion regulation, well-being paradox

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INTRODUCTION

Although older adults are thought to increasingly encounter losses in several life domains (Heckhausen et al., 1989; Baltes and Smith, 2003; Mustafić and Freund, 2012), they are still capable of maintaining relatively high levels of emotional well-being (Fiske et al., 2009; Charles and Carstensen, 2010; Wolitzky-Taylor et al., 2010; Scheibe and Carstensen, 2010; Carstensen et al., 2011). Socioemotional selectivity theory (SST; Carstensen et al., 1999, 2006; Carstensen, 2006), a prominent theory of emotional aging, posits that older adults are motivated to optimize their current affective experience and emotional well-being due to limits in future time

perspective. More recently, the so-called "positivity effect" has been introduced as an important mechanism to explain the maintenance of emotional well-being among older adults. The term "positivity effect" (PE) refers to "a relative preference in older adults (compared to younger adults) for positive over negative material in cognitive processing" (Reed and Carstensen, 2012, p. 4). Within the framework of SST it is argued that the PE in older adults' information processing reflects the recruitment of goal-directed, top-down driven processes in order to enhance, maintain or restore positive affective experience (Reed and Carstensen, 2012). Empirically, the PE has been particularly demonstrated in attention and memory using a wide range of experimental paradigms (e.g., eye tracking: Isaacowitz et al., 2006a,b; attention: Mather and Carstensen, 2003; and memory: Kennedy et al., 2004; Mikels et al., 2005; Mammarella et al., 2016; for a recent meta-analysis see Reed et al., 2014).

There is some evidence for the idea that the PE reflects cognitively controlled and thus resource demanding rather than automatic processes. Specifically, the PE has been shown to be enhanced in tasks supporting control-based processes (Mammarella et al., 2017). It was reduced or diminished among older adults with low cognitive functioning, when cognitive resources were experimentally depleted (Mather and Knight, 2005; Knight et al., 2007; Sasse et al., 2014), or during processing of high-arousing compared to low-arousing stimuli (Kensinger, 2008; Streubel and Kunzmann, 2011). Although the PE is thought to reflect the recruitment of goal-directed processes in order to optimize emotional well-being (e.g., Carstensen, 2006; Mather, 2012), the precise relationship between this age effect in cognitive processing and age-related changes in immediate or more general affective outcomes (i.e., subjective emotional reactions in response to the to-be-processed stimulus or emotional well-being) has rarely been studied (Isaacowitz and Blanchard-Fields, 2012).

In this study, we further investigated the PE in young and older adults by employing both measures of attention (i.e., fixation durations) and subjective emotional reactions (i.e., ratings of pleasantness and unpleasantness) in response to standardized positive and negative picture stimuli. By using these measures, we aimed to examine the precise relationship between age effects in attention, age effects in subjective emotional reactions, and age effects in general emotional well-being. We further examined a possible role of arousal for age group differences in attention and affective outcomes. To this end, we systematically varied the arousal level of the presented stimuli.

A common way to investigate the PE in attention is the registration of eye fixations (i.e., the duration of the eyes resting relatively stable) on (parts of) presented stimuli via eye-tracking. By using eye tracking, the PE has been demonstrated in a range of studies. In these studies, older compared to young adults fixated less on negative and more on positive faces (Isaacowitz et al., 2006a,b; Knight et al., 2007; Nikitin and Freund, 2011). Similarly, older adults fixated less on health messages with negative emotional content (Isaacowitz and Choi, 2012), and less on the most negatively judged part of unpleasant pictures (Noh et al., 2011). Furthermore, older adults demonstrating a gaze pattern predominantly to positive stimuli experienced less decrease in mood compared to older adults who did not exhibit such a preference (Isaacowitz et al., 2009b; Noh et al., 2011). Thus, several eye tracking studies provide evidence for the idea that age-related changes in the allocation of attention to emotional stimuli are indeed linked to changes in older adults' affective experience (Isaacowitz, 2012). In line with the idea that the PE in attention reflects resource demanding processes, the relationship between gaze preferences and mood changes in older adults has been observed only for subjects with high cognitive functioning (i.e., executive control; Isaacowitz et al., 2009b).

The assumption that arousal moderates the PE in older adults' information processing proceeds from the idea that distinct mechanisms are involved in the processing of low- and high-arousing emotional information. Whereas high-arousing stimuli primarily trigger automatic attentional capture to ensure prioritized processing (Dolan, 2002; Ferrari et al., 2008), enhanced processing of low-arousing stimuli involve top-down driven processes and thus require cognitive resources (Kensinger and Corkin, 2004; Mather and Knight, 2005; Knight et al., 2007). Given that the automatic processing of high-arousing information seems relatively preserved in old age (Mather and Knight, 2005), it may interfere with the goal-directed top-down driven information processing that underlies older adult's PE. The idea that particularly low arousal enables the engagement of resource-demanding top-down processes in older adults is also in line with the Strength and Vulnerability Integration (SAVI) model (Charles, 2010). SAVI suggests that older adults have greater difficulties in modulating high levels of arousal once these are experienced. Accordingly, studies examining age differences in affective information processing as well as emotional reactivity demonstrated the PE exclusively or more pronounced in response to low-arousing vs. high-arousing stimuli (Kensinger, 2008; Streubel and Kunzmann, 2011; Dolcos et al., 2014; Kappes and Bermeitinger, 2016). For instance, Kensinger (2008) studied the PE in memory and showed that older adults remembered more positive than negative words when these were rated low in arousal, while young adults demonstrated the reverse pattern. However, no age difference in memory-retrieval was observed for high-arousing positive vs. negative words. Streubel and Kunzmann (2011) studied age differences in subjective emotional reactions and provide further evidence that the PE attenuates in the processing of high-arousing information. In their study, older adults rated positive pictures as more pleasant than young adults did, and this effect was noticeably more pronounced when pictures were low in arousal. Moreover, older adults rated negative low-arousing pictures as less unpleasant than young adults did, but there was no age difference in pleasantness ratings for high-arousing negative pictures.

In order to confirm and extend the existing findings on the PE, we identified three aims that might be of worth and of special interest:

(1) To replicate the well-described PE in attention we studied differences in younger and older adults' eye fixations on positive and negative pictures chosen from the International Affective Picture System (IAPS; Lang

et al., 2008). More precisely, we examined age group differences in fixation duration on defined emotional areas of interest (AOI; i.e., parts of the pictures that were judged as particularly emotionally relevant) relative to non-AOI parts of the pictures.

(2) To investigate the relationship between the PE in attention and age group differences in immediate as well as more general affective outcome measures, we additionally assessed subjective emotional reactions in terms of pleasantness ratings in response to the pictures as well as general emotional well-being. Most important, we examined the correspondence of age group differences in both affective outcome measures with age group differences in AOI-related fixations.

(3) To test arousal as a potential moderator of age group differences in fixation durations, affective outcomes and the precise relationship between these variables, we systematically varied the arousal of the given stimuli by presenting low- and high-arousing positive and negative pictures. We formulated the following predictions:

H1: *Age group differences in AOI-related fixation duration moderated by arousal.* For low-arousing pictures older adults were expected to fixate a larger percentage of time on emotionally relevant AOIs in positive compared to negative pictures. For young adults we predicted a reverse pattern, i.e., longer AOI-related fixation duration in negative than positive low-arousing pictures. For high-arousing pictures, we hypothesized these age group differences to diminish (at least partly or completely).

H2: *Age group differences in subjective emotional responses moderated by arousal.* We hypothesized age group differences in fixation duration to be reflected in subjective emotional responses. Hence, for low-arousing pictures, older adults were expected to react with less unpleasantness to negative pictures and with more pleasantness to positive pictures than young adults. Regarding high-arousing pictures, these age group differences were assumed to be less pronounced or even non-existent.

H3: *Age group differences in emotional well-being.* Given previous findings on emotional well-being (e.g., Charles and Carstensen, 2010; Carstensen et al., 2011), we expected older adults to report less general negative affect and more positive affect than young adults.

H4: *Relationship between AOI-related fixation duration and affective outcomes moderated by arousal.* Given the idea that age-related differences in information processing reflect older adults' attempts to optimize their current affective experience, we expected that age group differences in AOI-related fixation duration are associated with age group differences in subjective emotional responses as well as emotional well-being. Assuming that arousal moderates the occurrence of age group differences in information processing, we expected the aforementioned relationships between fixation duration and affective outcomes to occur only for low-arousing pictures but not for high-arousing pictures.

MATERIALS AND METHODS

Participants

Twenty-one young adults ($N = 19$ women, 19–28 years, $M_{age} = 21.29 \pm 2.31$) and nineteen older adults ($N = 13$ women, 59–77 years, $M_{age} = 69.78 \pm 5.98$) participated in this study. We expected medium to large statistical effects for interactions between age group, valence and arousal based on previous findings regarding fixation duration (Isaacowitz et al., 2006a; Knight et al., 2007) and emotional reactivity (Streubel and Kunzmann, 2011). Unfortunately, G*Power (Erdfelder et al., 1996) is not suited to calculate a priori power analyses for designs with two within-subject factors and one between-subject factor. A power-analysis for a 2 × 2 design [e.g., age group (between) × valence (within)] indicated that we required $N = 16$ (large effect) to $N = 34$ (medium sized effect) participants in total to achieve 80% power when employing the traditional 0.05 criterion of statistical significance. For the correlational analyses G*Power indicated that we would need $N = 27$ to $N = 81$ participants to achieve 80% power to detect large to medium sized effects with 0.05 as criterion for statistical significance. Moreover, assuming large effect sizes for the mediational analysis, Fritz and MacKinnon (2007) suggest $N = 34$ to have 80% power for detecting a significant bias-corrected bootstrapped coefficient. The sample size accords with a priori power analyses for the expected large effect sizes. Still, we aimed at a larger sample to increase chances to detect only medium-sized effects. Unfortunately, the study had to be conducted in a quite narrow time slot and recruitment of (especially older) participants was also difficult. Participants were recruited at the university campus (older adults: guest auditor program for elder persons), adult education centers, via local newspaper advertisements, lists of former participants and student lists. All participants were highly (German *Abitur)* or intermediately (*Mittlere Reife*, equivalent to high school level) educated (young adults: 100% *Abitur*; older adults: 39% *Abitur*, 44% *Mittlere Reife*). While young adults received course credit for participation, older adults received no compensation. Young and older adults reported to be healthy, and to have normal or corrected-to-normal vision. Older adults judged their vision and hearing to be slightly worse than young adults (vision: $M_{young} = 4.6$, $M_{old} = 3.7$, $t(38) = 2.69$, $p < 0.05$; hearing: $M_{young} = 4.2$, $M_{old} = 3.5$, $t(38) = 3.84$, $p < 0.05$; all items ranging from "1" [*very bad*] to "5" [*very good*]). In addition, there were no significant age group differences with respect to self-reported mobility ($M_{young} = 4.4$, $M_{old} = 4.0$) or fitness ($M_{young} = 3.8$, $M_{old} = 3.3$). This study was carried out in accordance with the recommendations of the ethics committee of the German Psychological Society. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the local ethical committee of the University of Hildesheim.

Stimuli and Apparatus

Stimuli were 113 colored pictures selected from the International Affective Picture System (IAPS, Lang et al., 2008). In previous studies, non- or low-arousing stimuli ranged from a very low to a medium level of arousal (Kensinger, 2008; Streubel and

Kunzmann, 2011). For example, Kensinger (2008) classified stimuli as non-arousing when rated between 1 and 4.9 on a scale ranging from 1 (*low*) to 9 (*high-arousing*). To delineate the influence of arousal and to avoid the mixture of non-arousing (i.e., neutral) and low-/medium-arousing stimuli, we narrowed the arousal range for low-arousing stimuli from 2.0 to 4.5 in comparison to high-arousing (>4.5) positive and negative stimuli. Based on ratings assessed in younger and older German adults in prior studies (Grühn and Scheibe, 2008; Streubel and Kunzmann, 2011), pictures were selected and grouped into five affective stimulus-categories: *neutral* (e.g., domestic utensils; $M_{arousal} = 1.0$ to 2.0; $M_{valence} = 4.0$ to 6.0), *low-arousing positive* (e.g., family trips, nature; $M_{arousal} > 2.0$ to 4.5; $M_{valence} > 6.0$), *low-arousing negative* (e.g., insects, pollution; $M_{arousal} > 2.0$ to 4.5; $M_{valence} < 4.0$), *high-arousing positive* (e.g., erotica, skydiving; $M_{arousal} > 4.5$; $M_{valence} > 6.0$), and *high-arousing negative* (e.g., illness, death; $M_{arousal} > 4.5$; $M_{valence} < 4.0$). Each affective category contained 8 pictures. The neutral category contained a total of 32 pictures. All pictures were comparable in luminance and matched in arousal and valence levels for both age groups (see **Table 1** for descriptive statistics; see Appendix B for list of IAPS numbers).

We identified emotional AOIs of the pictures based on a separate online rating study, conducted on 134 German students who did not participate in the current study. Therefore, all 113 pictures were divided into two blocks. Pictures of block A ($N = 57$) were rated by 69 participants (52 women, $M_{age} = 22.25 \pm 4.41$ years); pictures of block B ($N = 56$) were rated by 65 participants (46 women, $M_{age} = 22.42 \pm 4.53$ years). A grid of 48 squares was superimposed on each picture (see Appendix A). Participants were asked to identify on each picture an area consisting of four contiguous squares that they judge as highly emotionally meaningful (i.e., as the most negative parts of negative pictures and the most positive part of positive pictures). Each picture allowed a total of 35 possible combinations of four contiguous squares. AOIs were identified based on the most frequently chosen combination of four coherent squares for each picture. As female participants were overrepresented in this sample (73% female), we weighted to adjust for the unequal gender distribution. Participants rated the valence for each of their selected AOIs on a scale ranging from "1" (*extremely unpleasant*) to "9" (*extremely pleasant;* see Appendix B).

Stimuli were displayed on a 24 inch TFT-monitor (1920 pixel × 1200 pixel, 60 Hz, 12 ms S/W). The background of the monitor was set to gray. Eye movements were recorded for the left monocular eye using an infrared high-speed eye tracking system (iViewX^{TM} Hi-Speed 1250 Hz System; SensoMotoric Instruments, Teltow, Germany) with high temporal (1250 Hz) and spatial resolution (0.25–0.5° visual arc). Recording of eye movements was controlled by a PC (Intel Core 2 Duo Processor, 2.66 GHz; system software: Windows XP, Version 2002), and by the recording software iViewX (Version 2.0.23b; SensoMotoric Instruments, Teltow, Germany). A network connection allowed for the exchange of stimulus-trigger between the stimulus computer and the recording system. In the beginning of the experiment, a calibration of the eye tracking system was conducted using a nine-point calibration matrix.

Procedure

Prior to the experiment, participants signed informed consent. To assess general emotional well-being, participants were asked to complete a German translation of the Positive and Negative Affect Schedule (PANAS; Krohne et al., 1996) at a laptop using E-prime 1.1 (Psychology Software Tools, Inc., Pittsburgh, PA, United States). To this end, participants indicated on a 5-point Likert-scale (ranging from 1 = *never* to 5 = *very often*) how frequently they had experienced each of the listed positive and negative emotions during the last year. The positive affect scale consisted of 10 positive emotions (e.g., interested, excited) and showed high internal consistency (Cronbach's $\alpha = 0.81$). The same held true for the 10 items of the negative affect scale (e.g., distressed, irritated; Cronbach's $\alpha = 0.78$).

Measurement of eye-movements and recording of immediate emotional responses took place in a sound-attenuated and dimly illuminated chamber (2 m × 4 m × 2.5 m). The diffuse illumination of the chamber was adopted to the luminance of the screen (50 cd/m^2). Participants sat in front of a monitor on a height-adjustable chair and used a height-adjustable chin-rest and a forehead support to ensure stable fixation on the screen. Viewing distance was 100 cm. Participants were informed that they would be viewing a slide show of photographs. They were instructed to view the images as if at home watching television or viewing photographs. Further, they were informed that they would be asked to report how they felt when viewing the picture. Pictures were presented centrally for a duration of 4 s and in a randomized order. To assess subjective emotional reactions, participants were asked, consecutively after each picture, to rate their feelings of pleasantness and arousal while viewing the picture via a digitized version of the Self-Assessment Manikin (SAM; Bradley and Lang, 1994). SAM depicts graphic figures representing different levels of experience of pleasantness and arousal, respectively. The anchors of both 9-point rating scales were labeled with "1" (*unpleasant* and *calm*, respectively) and "9" (*pleasant* and *exiting*, respectively). Participants responded by pressing defined keys on a standard numerical keyboard with the middle or index finger of their dominant hand. Before each picture, a white fixation cross (20 pixels) was presented centrally for a duration of 1 s and participants were instructed to relax and to clear their mind of any thoughts, emotions, or memories.

Eye Tracking Data Analysis

We analyzed eye tracking data using BeGaze 3.4.27 (SensoMotoric Instruments, Teltow, Germany). This analysis software allowed for an automatic detection and exclusion of blinks, and for the extraction of saccade-like events (SLE) and fixations using a velocity-based, high-speed event detection algorithm. Saccades were defined as SLE, when peak velocity exceeded a threshold of 80°/s in a time window comprising 20–80% of the duration of a SLE. Additionally, a saccade duration of at least 25 ms, followed by a fixation duration of at least 100 ms were required (Rayner, 1998; Manor and Gordon, 2003; Folta-Schoofs et al., 2015). Accordingly, fixations were defined as the time between the end of

TABLE 1 | Descriptive statistics: normative ratings of arousal and valence by stimulus category and age group.

		Young adults					Older adults			
		N	Minimum	Maximum	*M*	*SD*	Minimum	Maximum	*M*	*SD*
Neutral	Arousal	32	2.16	2.93	2.56	0.22	2.15	2.91	2.61	0.20
	Valence	32	4.56	5.96	5.40	0.36	4.85	6.00	5.61	0.28
Low-arousing positive	Arousal	8	3.73	4.15	3.91	0.17	3.82	4.10	3.95	0.11
	Valence	8	6.40	7.19	6.61	0.26	6.15	8.71	7.42	0.92
High-arousing positive	Arousal	8	4.78	5.41	5.07	0.20	4.65	5.53	5.09	0.35
	Valence	8	6.13	7.10	6.68	0.37	6.15	8.08	7.08	0.64
Low-arousing negative	Arousal	8	3.74	4.44	4.05	0.27	3.73	4.44	4.11	0.24
	Valence	8	2.43	3.92	3.38	0.62	2.72	3.59	3.30	0.27
High-arousing negative	Arousal	8	4.93	5.19	5.08	0.10	4.81	5.30	5.08	0.18
	Valence	8	3.07	3.89	3.41	0.27	2.93	3.92	3.49	0.37

one SLE and the beginning of the next one (Galley et al., 2015).

RESULTS

Arousal as a Moderator of Age Group Differences in AOI-Related Fixation Duration

In our sample of pictures, the neutral picture category was only included to exclude possible effects of habituation to emotional stimuli. Given that the hypotheses of this study did not refer to neutral pictures, data from this picture category had been excluded from all statistical analyses.

In a first step, we aggregated fixation duration across pictures of each picture category (low- and high-arousing negative vs. positive pictures). Second, to test age group differences in total fixation duration on the whole picture and to verify whether participants followed the instruction to look at the pictures, we conducted a mixed ANOVA with valence (negative vs. positive) and arousal (low vs. high) as within-subjects factors, age group (young vs. old) as between-subjects factor and total fixation duration on the whole picture as the dependent variable. There was a significant age group difference in total fixation duration, $F(1,38) = 12.49$, $p = 0.001$, $\eta_p^2 = 0.25$. Generally, older adults fixated shorter than young adults on the whole picture ($M_{old} = 3{,}046$ ms, $M_{young} = 3{,}433$ ms). Given that pictures were presented for a duration of 4 s, the resulting average fixation durations were considered as reasonably long to indicate that participants followed the instruction. No other main effects or interactions with age group were observed, but there was a significant interaction between valence and arousal, $F(1,38) = 7.92$, $p = 0.008$, $\eta_p^2 = 0.17$. Independent from their age, participants fixated high-arousing negative pictures ($M = 3{,}295$ ms) longer than low-arousing negative pictures ($M = 3{,}227$ ms). Contrary, they fixated low-arousing positive pictures ($M = 3{,}257$ ms) longer than high-arousing positive pictures ($M = 3{,}180$ ms). In order to control for age group differences in total fixation duration, we calculated AOI-related fixation duration as percentage of time spent on the emotionally relevant AOIs relative to time spent on the rest (non-AOI parts) of the corresponding picture.

We examined age group differences in AOI-related fixation duration with a mixed ANOVA comprising valence (negative vs. positive) and arousal (low vs. high) as within-subjects factors and age group (young vs. old) as between-subjects factor. Significant main effects of valence and arousal as well as their interactions with age group were qualified by a significant 3-way interaction, $F(1,38) = 62.16$, $p < 0.001$, $\eta_p^2 = 0.62$ (see **Figure 1**). In order to dissect this interaction, we separately conducted mixed ANOVAs for low- and high-arousing pictures, followed up by paired *t*-tests for young and older adults, respectively. Both the ANOVAs for low- as well as high-arousing pictures revealed a significant valence-by-age group interaction, $F_{low}(1,38) = 60.85$, $p < 0.001$, $\eta_p^2 = 0.62$; $F_{high}(1,38) = 9.57$, $p < 0.001$, $\eta_p^2 = 0.20$. Consistent with our predictions for low-arousing pictures, *post hoc* comparisons revealed that older adults fixated emotionally relevant AOIs (in comparison to the rest of the picture) longer in positive than in negative pictures [$t(18) = -10.32$, $p < 0.001$; $M_{pos} = 51.9\%$, $M_{neg} = 32.4\%$]. In contrast, there was no significant difference in AOI-related fixation duration for low-arousing positive and negative pictures in young adults, [$t(20) = 0.76$, $p = 0.45$ ($M_{pos} = 49.2\%$, $M_{neg} = 50.6\%$]. As expected, this preference in AOI-related fixations for positive (vs. negative) pictures in older adults did not occur in response to high-arousing pictures. That is, older adults fixated emotionally relevant parts longer in negative than positive high-arousing pictures [$M_{pos} = 42.9\%$, $M_{neg} = 47.2\%$; $t(18) = 2.23$, $p = 0.042$], while young adults fixated proportionately longer on these AOIs in positive than negative high-arousing pictures [$M_{pos} = 46.1\%$, $M_{neg} = 41.5\%$; $t(20) = -2.17$, $p = 0.038$].

Age Group Differences in Affective Outcomes

Arousal as a Moderator of Age Group Differences in Subjective Emotional Responses

A mixed ANOVA with valence (positive vs. negative) and arousal (low vs. high) as within-subjects factors, age group (young

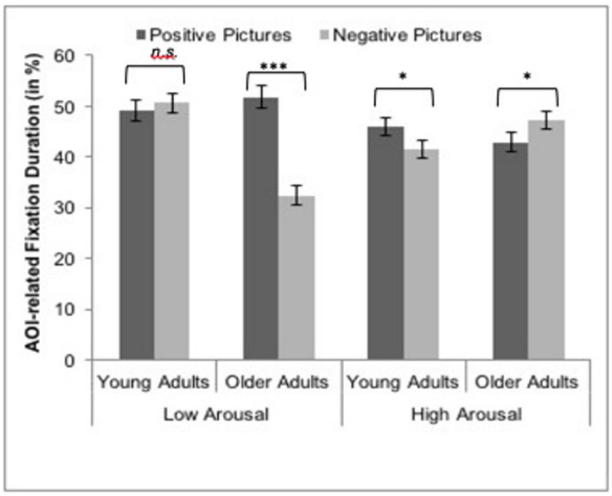

FIGURE 1 | Means (± standard errors) of young ($N = 21$) and older ($N = 19$) adults' AOI-related fixation duration (i.e., percentage of fixation duration on AOIs relative to the rest of the picture) for low- and high-arousing positive and negative pictures. *$p < 0.05$, ***$p < 0.001$.

vs. old) as between-subjects factor, and pleasantness ratings as the dependent variable revealed significant main effects of age group, $F(1,38) = 10.11$, $p = 0.003$, $\eta_p^2 = 0.21$, and valence, $F(1,38) = 529.27$, $p < 0.001$, $\eta_p^2 = 0.93$, qualified by significant interactions between age group and valence, $F(1,38) = 4.45$, $p = 0.041$, $\eta_p^2 = 0.11$, as well as age group and arousal, $F(1,38) = 5.36$, $p = 0.026$, $\eta_p^2 = 0.12$. Following-up on these interactions revealed that older compared to young adults experienced negative pictures as more pleasant [$M_{young} = 2.53$; $M_{old} = 3.43$, $t(38) = -3.92$, $p = 0.001$], whereas the age groups did not differ in their affective experience in response to positive pictures [$M_{young} = 6.88$; $M_{old} = 7.04$, $t(38) = -0.67$, $p = 0.51$; see **Figure 2**]. Moreover, both age groups experienced low-arousing pictures as similarly pleasant [$M_{young} = 4.89$; $M_{old} = 5.20$, $t(38) = -1.70$, $p = 0.098$]. In contrast, older compared to young adults rated high-arousing pictures as more pleasant [$M_{young} = 4.51$; $M_{old} = 5.28$, $t(38) = -3.61$, $p = 0.001$]. This was due to younger adults' lower rating of high-arousing compared to low-arousing pictures, $t(20) = 2.61$, $p = 0.017$.

Age Group Differences in Emotional Well-Being

T-tests for positive and negative affect revealed the expected age group difference for negative affect. That is, during the last year older adults experienced significantly less negative affect than young adults, $t(37) = 2.23$, $p = 0.032$ ($M_{old} = 2.27$, $M_{young} = 2.58$; $d_{Cohen} = -0.72$). The age groups did not significantly differ regarding positive affect, $t(37) = -1.31$, $p = 0.20$ ($M_{young} = 3.82$, $M_{old} = 4.02$).

Relationship between AOI-Related Fixation Duration and Affective Outcomes

To test the correspondence of age group differences in affective outcomes with age group differences in AOI-related fixation duration, we first calculated Pearson correlations separately for each picture category between AOI-related fixation duration and subjective emotional responses as well as between AOI-related fixation duration and emotional well-being (see **Table 2**). Regarding immediate emotional

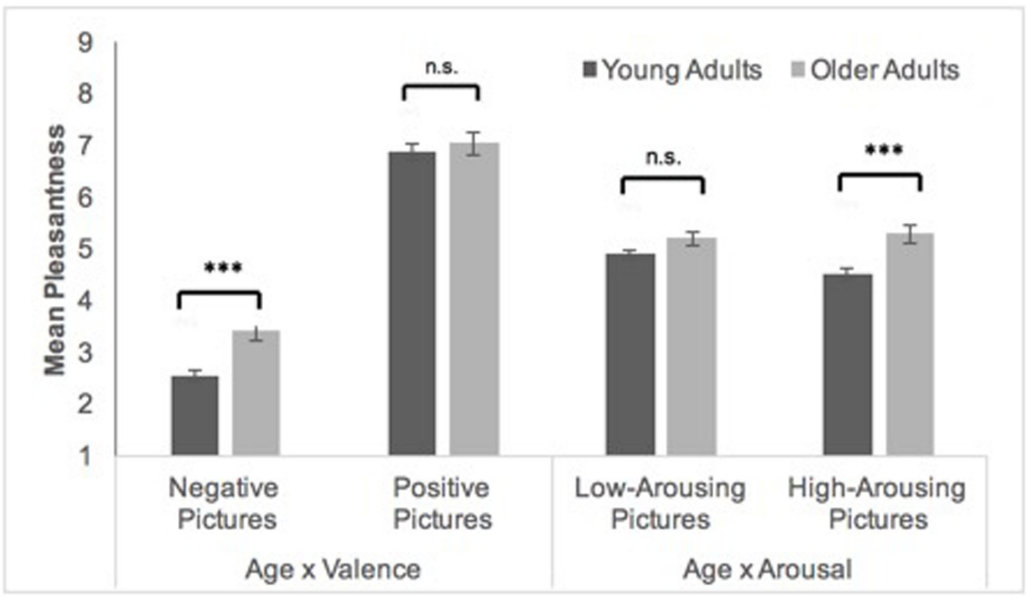

FIGURE 2 | Means (± standard errors) of young ($N = 21$) and older ($N = 19$) adults' pleasantness ratings for negative and positive pictures and for low- and high-arousing pictures. ***$p < 0.001$.

TABLE 2 | Correlations between AOI-related fixation duration, pleasantness ratings and emotional well-being by picture category.

	AOI-related fixation duration			
	Positive pictures		Negative pictures	
	Low-arousing	High-arousing	Low-arousing	High-arousing
Pleasantness ratings	0.03	0.11	−0.15	0.18
PA	−0.07	−0.13	−0.12	0.23
NA	−0.04	0.06	0.37*	−0.14

*PA, general positive affect; NA, general negative affect. *p < 0.05.*

responses, there were no significant relationships with AOI-related fixation duration, *p*s > 0.28. Because of an apparent lack of a significant relationship between fixation duration and subjective emotional responses, we did not conduct mediation analyses to test the role of age group differences in fixation duration for age group differences in subjective emotional responses.

An analysis of the relationship between fixation duration and emotional well-being revealed no significant relationship between fixation duration and positive affect. However, as expected, there was a significant correlation between the duration of AOI-related fixations on low-arousing negative pictures and negative affect, $r(38) = 0.37$, $p = 0.022$, which was not observed for high-arousing negative pictures [$r(38) = -0.14$, $p = 0.38$; $z = 2.24$, $p < 0.05$; Lee and Preacher, 2013]. That is, participants who fixated less long on the emotionally relevant AOIs of low-arousing negative pictures reported less negative affect during the last year. To test whether age group differences in negative affect were associated with age group differences in AOI-related fixation duration for low-arousing negative pictures, we conducted a mediation analysis employing PROCESS (Hayes, 2013; model 4) with age group as the predictor, AOI-related fixation duration as the mediator and negative affect as the criterion. As expected, the effect of age group on negative affect ($B = -0.31$, $p < 0.05$) decreased after inclusion of fixation duration and became non-significant ($B = -0.15$, $p = 0.46$); however, the indirect effect of age group via fixation duration was not significant ($B = -0.16$, 95% bootstrapped confidence interval = −0.45, 0.04; Sobel test: 1.07, $p = 0.28$).

Finally, we tested in an exploratory manner, whether both age groups differed significantly in the strength of the relationship between AOI-related fixation duration and affective outcome measures using software provided by Preacher (2002). Concerning general negative affect, young adults did not show any significant correlation with fixation duration. In contrast, older adults showed more pronounced positive correlations between negative affect and fixation duration at emotionally relevant AOIs on negative low-arousing pictures, $r(17) = 0.49$, $p = 0.038$. However, this age group difference did not reach significance [$r_{young}(19) = 0.23$, $p = 0.308$; $z = -1.60$, $p = 0.11$]. All other correlation coefficients in both age groups were non-significant (*p*s > 0.21).

DISCUSSION

The present study examined age group differences in the processing of emotional stimuli. Therefore, we employed high-speed eye tracking while young and older adults viewed positive and negative IAPS pictures that differed in their arousal. We investigated how the PE in attention, as indexed by age group differences in fixation duration during picture viewing, is related to immediate as well as more general affective outcome measures, that is, experience of pleasantness in response to emotional pictures and emotional well-being.

Age Group Differences in AOI-Related Fixation Duration Moderated by Arousal

In the present study, we replicated the well-known PE in fixation patterns during emotional picture viewing (Isaacowitz et al., 2006a,b). Additionally, the present results support and extend previous work on the PE in affective information processing (i.e., memory and emotional reactions, Kensinger, 2008; Streubel and Kunzmann, 2011; Mammarella et al., 2016), because they suggest that the PE in attention is reduced under conditions of high arousal. Consistent with our predictions, older adults fixated less on the most emotionally relevant parts in negative compared to positive low-arousing pictures, whereas young adults did not show such a difference under conditions of low arousal. In contrast, in response to high-arousing pictures, older adults fixated longer on the most emotionally relevant parts in negative than positive pictures, whereas young adults demonstrated the reversed pattern. Our findings emphasize the importance of arousal as a moderator for age differences in the processing of affective information.

Moreover, our findings contribute to an ongoing debate whether the PE can be considered to result from cognitively controlled processes (Mather and Knight, 2005; Reed and Carstensen, 2012), cognitive decline (Labouvie-Vief et al., 2010) or age-related impairments in amygdala function leading to reduced neural and affective responses to negative, but not to positive stimuli (Cacioppo et al., 2011). If the PE predominantly depends on cognitive decline, the PE is expected to become visible particularly when being confronted with high-arousing stimuli, because processing of negative stimuli taxes cognitive resources more (as compared to positive information) and should be particularly diminished under conditions of high arousal (see also Charles, 2010). Similarly, if the PE predominantly depends on impaired amygdala functions, it is also expected to be larger for high-arousing stimuli, because processing of these stimuli predominantly relies on information processing in limbic networks. Our findings better fit in with the idea that the PE is the result of top-down driven cognitive processes (Mather and Knight, 2005; Knight et al., 2007; Sasse et al., 2014; Kalenzaga et al., 2016; Mammarella et al., 2016, 2017). Implementation of these processes may be impeded in situations involving high arousal most likely resulting in the diminishment of the PE.

Age Group Differences in Affective Outcomes

Age Group Differences in Emotional Well-Being

Consistent with our predictions and previous findings (Charles and Carstensen, 2010; Carstensen et al., 2011; see review by Scheibe and Carstensen, 2010), older compared to young adults reported less general negative affect and a comparable extent of positive affect during the last year, supporting the assumption that emotional well-being remains relatively stable or even improves in older adulthood.

Arousal as a Moderator of Age Group Differences in Subjective Emotional Responses

Age group differences in immediate emotional responses to emotional pictures concur with these findings in that older compared to young adults experienced negative pictures as less unpleasant, whereas no age group difference for positive pictures occurred. Contrary to our hypothesis and findings from Streubel and Kunzmann (2011), this interaction between age group and valence was independent of the pictures' arousal level. One explanation for this inconsistency between both studies concerns differences in the mean arousal level of employed stimuli in both studies. Streubel and Kunzmann (2011) used high-arousing negative stimuli with higher mean arousal and low-arousing positive stimuli with lower mean arousal compared to the present study. The smaller difference between the mean arousal of the low- and high-arousing picture categories in the present study might have reduced the impact of arousal on age differences in emotional responses obtained by Streubel and Kunzmann (2011).

Another explanation concerns differences in the duration of stimulus presentation. Streubel and Kunzmann (2011) presented pictures longer (i.e., 6 s) than in the present study (4 s). As will be discussed in more detail in the section below, it might be possible, that it took a certain amount of time for cognitive regulation processes to "translate" into immediate benefits in emotional experiences that was not sufficiently allowed in the present study.

Relationship between Fixation Duration and Affective Outcome Measures Moderated by Arousal

There were no meaningful relationships between fixation duration on the most positive or most negative parts of the positive or negative pictures and subjective emotional reactions (i.e., pleasantness ratings) in response to the pictures. This lack of meaningful relationships between attention allocation during picture processing and immediate emotional reactivity suggests that differences in the processing of emotional information do not relate to differences in immediate emotional reactions – at least not always or not as fast. Thus, age group differences in fixation duration cannot account for age group differences in immediate emotional reactivity in the present study. It might be possible that 4 s of stimulus presentation are not sufficient for top-down information processing mechanisms to translate into emotional outcomes. Isaacowitz et al. (2009a) demonstrated that gaze preferences for neutral over angry faces in older adults only emerged after a time-interval of 3 s. However, they did not test the relationship between gaze patterns and immediate emotional outcomes. In the same vein, Allard and Kensinger (2014) suggested that older adults activated emotion regulatory processes (particularly reappraisal processes) only during the emotional peak of a film clip. Accordingly, it might take several seconds until emotion regulatory processes, as they might be reflected in fixation patterns, become mirrored in emotional responses (see also Scott et al., 2017, for an even longer time course for age differences to be observed).

The present findings regarding the relationship between fixation patterns and general affective outcome measures, i.e., emotional well-being, lend support for this interpretation. Consistent with our prediction, fixation durations on the most negative parts of negative pictures were positively associated with negative affect. As expected, the effect of age group in negative affect markedly decreased on a descriptive level when including fixation duration as predictor suggesting that age group differences in emotional well-being partially rely on attentional processes. However, the indirect effect of age group via fixation duration on negative affect turned out to be not significant, which may be due to the small sample size. Future studies are needed to strengthen this interpretation.

More importantly, we found the advantageous relationship between attentional avoidance of the most unpleasant parts of negative pictures and emotional well-being (i.e., less negative affect) only with respect to low-arousing material. Additionally, we tested whether the relationship between fixation duration and affective outcome measures differed between age groups and found that the positive relationship between fixation duration on negative low-arousing pictures and general negative affect only held within the older age group. These findings underline the assumption that low-arousing stimuli allow the implementation of top-down driven processes of a pro-hedonic orientation, while high-arousing stimuli evoke automatic processing and limit the implementation of top-down-driven processes presumably underlying the PE. Moreover, in line with a prior eye-tracking study our findings lend support for the idea that not only the PE *per se*, but also the "translation" of the PE in information processing into emotional outcomes (i.e., less negative or more positive affect) rely on resource demanding processes. In this study, only older adults with high cognitive functioning have been shown to benefit from a relative preference in fixation patterns for positive over negative pictures, in that they sustained positive mood during the experiment. In contrast, older adults with reduced cognitive functioning showed significant declines in mood even though they showed a similarly positive preference in fixation patterns (Isaacowitz et al., 2009b; Noh et al., 2011).

Furthermore, our findings suggest that the implementation of attentional avoidance is particularly beneficial in the older age group, given that fixation duration was unrelated to emotional well-being in younger adults. Alternative regulatory processes such as reappraisal might be more relevant or effective in the younger age group (Urry and Gross, 2010).

Caveats and Outlook

As discussed, the present findings suggest that age-related changes in the top-down driven processing of emotional

information might support older adults' emotional well-being. Future work is needed to better understand if and under which conditions age-related changes in affective information processing actually benefit immediate emotional experience. As discussed, the time between the assessment of attention allocation and emotional reactions might play an important role for regulatory processes to translate into emotional outcomes. It will be interesting to systematically vary the duration of stimulus presentation or employ online measures of emotional experience to assess the time course it needs for cognitive processes to be reflected in emotional responses. Additionally, the direction of the relationship between regulatory processes and emotional well-being cannot be determined with the present design. The inclusion of longitudinal measurements may help to understand the direction of the influence of regulatory processes on emotional well-being and vice versa.

A second limitation pointed out by Freund and Isaacowitz (2014) refers to the problem of employing extreme age group comparisons as an approximation to investigate age-related changes as they may lead to overestimation of age-related effects and are blind to changes in middle adulthood. Moreover, age is merely used as a proxy variable for underlying psychological processes (i.e., changes in the motivation to optimize one's current affective experience and emotional well-being) that cause the observed age group differences (e.g., in fixation patterns or emotional reactivity). Thus, we can only rely on previous studies (Xing and Isaacowitz, 2006; van Reekum et al., 2007) to infer that age-related differences in emotion regulation goals account for the observed age group differences in fixation patterns, as we did not directly assess or manipulate emotion regulatory goals.

Third, we did not directly assess potential cognitive impairment in the older adult group; thus, we cannot examine the influence of this factor. We refrained from including such a measure to keep the experimental session as short as possible. Given that this group of older participants consisted mainly of students of the guest auditor program for elder persons at the university or participants of the adult education center, we did not expect cognitive impairments. However, even if (mild) cognitive impairments were present in the sample, the testing of our hypotheses would be more conservative because – as we argue – cognitive resources would be necessary for the emergence of the positivity effect (in the present study at a low arousal level). Still, the inclusion of a measure of, for instance, executive functioning in future studies would be interesting to investigate possible interaction effects with the arousal level of stimuli.

Finally, the percentage of female participants is relatively high in the present study. Although Reed and Carstensen (2012) and Reed et al. (2014) do not report gender as a moderator of the PE, future studies should increase the number of male participants.

CONCLUSION

The results of the present study emphasize the role of stimulus-related arousal as a moderator of the PE in attention. Older adults paid less attention to low-arousing negative pictures than young adults but this difference reversed for high-arousing stimuli. While age group differences in attention allocation were unrelated to age group differences in immediate emotional responses in terms of pleasantness ratings, they were related to age differences in general negative affect. These findings lend support for the link between age-related changes in attentional processes during affective information processing (as expressed in the PE) and age-related stability of or even increase in emotional well-being.

AUTHOR CONTRIBUTIONS

CK, BS, and KF-S: Contributed in conception and design of the work. BS and KF-S: Contributed in writing code and implementing parts of the study in MatLAB. CK: Contributed in writing code and implementing parts of the study in e-prime and Unipark. KD: Collected the data. CK, BS, KD, and KF-S: Contributed in data analysis and interpretation of data. CK and BS: Contributed in drafting and revising work. KF-S and KD: Revised the work.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01877/full#supplementary-material

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Emotions and Steroid Secretion in Aging Men: A Multi—Study Report

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Although aging increases the risk of cognitive and socioemotional deterioration, it has also been shown to be accompanied by an increase in experienced positive emotions and a decrease in negative emotions. Steroid hormones and age-related alterations in secretion patterns have been suggested to play a crucial role in these age-related changes in emotional experience. Importantly, previous studies identified effects of neuroactive hormones on age-related alterations in emotional experience, which vary by sex and depression levels. Therefore, in three independent cross-sectional studies including a total of 776 men, we examined age-related differences in emotional experience and subsequently the moderation effect of steroid hormones. Sample one consisted of 271 self-reporting healthy (SRH) men aged between 40 and 75 years, while sample two comprised 121 men in the identical age range but only including vitally exhausted (VE) men. Sample three included 384 men aged between 25 and 78 years who reported having fathered (FA) at least one child. For the SRH men, age was negatively associated with anxiety symptoms and aggression, while negative trends emerged for depressive symptoms. In VE men, age was negatively associated with depressive symptoms and positively associated with aggression and positive emotions. For FA men, anxiety symptoms and aggression were negatively associated with age. Age trends of steroid hormones and identified moderation effects are reported. However, with adjustment for multiple comparisons, most of the significant associations fade and the reported associations need to be regarded as exploratory starting points for the further investigation of age-related alterations in emotional experience and their relation to steroid secretion. Overall, the results indicate that salivary cortisol might be a moderator of the association between age and symptoms of anxiety for SRH and VE men, while salivary testosterone seems to moderate the association between age and symptoms of anxiety or depression in VE and FA men, respectively. Both hair cortisol and progesterone seem to influence age-related alterations in anger experience. Age-related alterations in the hypothalamic-pituitary-adrenal (HPA) axis and the hypothalamic-pituitary-gonadal (HPG) axis emerge as promising avenues to further investigate the decrease in experienced negative emotions in aging men.

Keywords: aging, emotional experience, steroid secretion, testosterone, cortisol, anxiety, depression, vital exhaustion

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INTRODUCTION

Aging has been related to cognitive and socioemotional decline in several longitudinal studies (Carlo et al., 2000; Park and Bischof, 2013). Various cognitive and socioemotional functions undergo age-related changes, and although most functions deteriorate continuously with age (Ruffman et al., 2008), some show improvement. Emotional experience seems to be relatively unaffected by age or even appears to show an increase in terms of the total amount of experienced positive emotions (Carstensen et al., 2011) or general life satisfaction (Gana et al., 2013). With age, an increase in positive feelings such as, happiness, calmness, relaxedness, and enthusiasm, and simultaneously a significant decrease in negative feelings such as, boredom, fatigue, and a decreasing trend for anger have been reported (English et al., 2014). This age-related positivity effect in emotional experience favoring positive over negative stimuli has been well-documented in the past 15 years (Reed and Carstensen, 2012; Mammarella et al., 2016, 2017; Mather, 2016), and has important health implications since survival rates were shown to be related to positive affectivity in older individuals (Steptoe and Wardle, 2011). In line with these findings, Baer et al. reported a continuous decrease in the prevalence of depression with increasing age (Baer et al., 2013), while a progressive age-related downward trend in worry frequency in individuals with and without general anxiety disorders was demonstrated (Miloyan and Pachana, 2015). Wise reasoning is another psychological construct related to this positivity effect and it seems to increase with more life experiences (Grossmann et al., 2013). Furthermore, older individuals show preferences for positive low-arousal affect (calm, peaceful, relaxed) over positive high-arousal affect (excited, proud) matching with a state of wise reasoning (Scheibe et al., 2013). As other potential links between age and lower negative affect, increased acceptance of negative emotional experience or selective narrowing of social networks have been identified (Shallcross et al., 2013; English and Carstensen, 2014).

Neurobiological models indicate important biological underpinnings of age-related changes in emotion perception (Ruffman et al., 2008; Ebner and Fischer, 2014). Steroid hormones have been suggested to moderate the association between age and socioemotional functions (Ebner et al., 2014). A possible link between age-related hormonal changes and changes in emotional experience in aging individuals adds relevance to the examination of the moderating potential of the endocrine system in this research area (Walther and Ehlert, 2015; Schiller et al., 2016). In men over the age of 40 years, sex steroids (e.g., testosterone [T], dehydroepiandrosterone [DHEA], estradiol [E2]) continuously decline (Feldman et al., 2002; Frost et al., 2013; Walther et al., 2016), while cortisol (C) has been shown to increase with age (Karlamangla et al., 2013; Nater et al., 2013; Miller et al., 2016). However, T, as the end product of the hypothalamic-pituitary-gonadal (HPG) axis, has been positively related to aggression, dominance, and anger in men, while inverse associations have been shown for depressive and anxiety symptoms (Edinger and Frye, 2005; Wirth and Schultheiss, 2007; Carrier et al., 2015; Walther et al., 2017c). In contrast, higher levels of C, the primary effector of the biological stress response released via the hypothalamic-pituitary-adrenal (HPA) axis, have been associated with more depressive and anxious symptoms as well as higher scores for worrying (Ehlert et al., 2001; Takahashi et al., 2005; Mantella et al., 2008), although there is substantial conflicting literature indicating differences between symptoms of anxiety, anxiety disorders, and age as well as sex of examined subjects (Steudte et al., 2011; Yehuda and Seckl, 2011; Hek et al., 2013; Steudte-Schmiedgen et al., 2017). Therefore, an examination of potential associations between age-related changes in emotional experience and steroid secretion might yield crucial insights into the underlying neurobiology of this shift toward a more positive emotional experience with increasing age.

To examine the potential moderation effects of steroid secretion and age-related changes in emotional experience, we investigated three independent male samples with regard to steroid secretion and emotional experience. The first sample consisted of 271 self-reporting healthy (SRH) men between the ages of 40 and 75 from the Men's Health 40+ study (Walther et al., 2017a), while the second sample encompassed 121 men in the identical age range from the Men Stress 40+ study with a minimum score of 4 on the Maastricht Vital Exhaustion Questionnaire (MVEQ, Appels et al., 1987). Vital exhaustion (VE) is defined as a psychological state characterized by excessive fatigue, loss of vigor, increased irritability, and feelings of demoralization, while depressed mood, low self-esteem, or feelings of guilt, which are core symptoms of depression, are not predictive for VE (van Diest and Appels, 1991; Appels, 2004). Furthermore, VE has been shown to be associated with neuroticism, social anxiety, and hostility (van Zijderveld et al., 2013). In patients with chronic heart failure fatigue, cognitive-affective depressive symptoms, sleep difficulties, and a lack of concentration were predominantly observed (Smith et al., 2009). Finally, as previous studies revealed a significant influence of fatherhood on sex steroid secretion (Gettler et al., 2011; Perini et al., 2012), the third sample comprised 384 men aged between 25 and 78 years from a large-scale fatherhood study, only including men who reported having fathered at least one biological or non-biological child (Waldvogel and Ehlert, 2016). The comparison of these three samples is of major interest as sample 1 (SRH men) and sample 2 (VE men) compare men of the identical age range (40 to 75 years), very similar levels of socioeconomic status and environmental conditions and only differing by their perceived health status as either very healthy or vital exhausted. Exhaustion has been related to alterations in steroid secretion (Kudielka et al., 2006; Bellingrath et al., 2008; Snyder et al., 2016) and emotion experience (Koertge et al., 2007; Doyle et al., 2011) and therefore different associations between

Abbreviations: SRH, Self-reporting healthy; VE, Vital exhaustion; FA, fathers; T, Testosterone; C, Cortisol; DHEA, Dehydroepiandrosterone; P, Progesterone; E2, Estradiol; sC, salivary C; sT, salivary T; sDHEA, salivary DHEA; sP, salivary P; sE2, salivary E2; hT, hair T; hCrtsl, hair C; hDHEA, hair DHEA; hP, hair P; hCrtson, hair cortisone; HPA, hypothalamic-pituitary-adrenal; HPG, hypothalamic-pituitary-gonadal; BSI, Brief Symptom Inventory; PANAS, Positive and Negative Affect Schedule; BPAQ, Buss-Perry Aggression Questionnaire; MVEQ, Maastricht Vital Exhaustion Questionnaire.

steroid hormones and the age-related alterations in emotion experience are expected in VE men compared to SRH men. Furthermore, decreased androgen secretion has been reported in men after becoming a father and was associated with a decreased relationship quality due to missing tenderness (Gettler et al., 2011; Perini et al., 2012). These findings indicate that changes in circulating levels of androgens may be associated with "tend and befriend" behavior, what might contribute to better emotional experience with age (Van Anders, 2013). In the following, we describe the methods and findings of these three studies on the hormonal contribution to age-related changes in emotional perception. We conclude the report by integrating the findings into a comprehensive framework on the role of steroid secretion in age-related changes in emotional experience in men.

STUDY 1: MEN'S HEALTH 40+

Participants and Procedure

A total of 271 men between the ages of 40 and 75 years participated in the Men's Health 40+ study in the year 2014. They were recruited from the German-speaking part of Switzerland via flyers and web pages. The study only included SRH men, which was controlled for by the first question of the Short Form 36 (SF-36) Health Survey: "How would you describe your current health status?" (Brazier et al., 1992). 35.8% of the participants indicated the response option "very good," while 54.6 and 9.6% responded with "good" and "fair," respectively. None of the participants indicated the response options "bad" or "very bad." Participants had a mean age of 57.1 ($SD = 10.7$) years and a mean body mass index (BMI) of 25.4 ($SD = 3.4$). Only 8.2% of participants reported being regular smokers. In general, a relatively high socioeconomic status was observed, as reflected by the mean education level (88.1% higher secondary school or higher) and income level (48.3% earning more than CHF100,000/year what corresponds to 104'134 USD).

Participants independently completed psychometric questionnaires online. After completing the psychometric test battery, they were invited to a biological examination, where saliva and hair samples were obtained using standardized procedures. All participants provided written informed consent, and the study protocol was approved by the local Ethics Committee of the Faculty of Arts at the University of Zurich. Prior published data of this sample can be reviewed here (Walther et al., 2016, 2017a,b; Noser et al., 2017).

Psychometric Measures

The German version of the Brief Symptom Inventory—18 (BSI-18) was used to measure self-reported psychological distress focusing on symptoms of anxiety, depression, and somatization (Zabora et al., 2001; Franke et al., 2011). The questionnaire consists of 18 items distributed over the three subscales depression, anxiety, and somatization. Each subscale comprises six items rated on a 5-point Likert scale from 0 (not at all) to 4 (always) and participants were asked about symptoms experienced in the last 7 days. To obtain indicators of negative emotions, only the scales depression and anxiety were analyzed.

Aggression was measured via the German version of the Buss Perry Aggression Questionnaire (BPAQ) (Buss and Perry, 1992; Herzberg, 2003). The questionnaire comprises 29 items rated on a 5-point Likert scale from 1 (extremely uncharacteristic of me) to 5 (extremely characteristic of me) distributed over the four scales physical aggression, verbal aggression, anger, and hostility. All four scales were analyzed, as although only anger is a negative emotion in terms of subjective experience and social evaluation (Averill, 1982), aggressive behavior such as, physical or verbal aggression or hostile behavior can be considered a proxy for anger given that anger drives many, if not most, forms of aggression (Averill, 1982).

Endocrine Measures

Standardized saliva sampling took place starting at 8:00 am at the laboratory of the Psychological Institute of the University of Zurich. Participants were asked to fast overnight and to refrain from exercise or engaging in sexual activity for 24 h before testing. Moreover, they were requested not to brush their teeth or smoke and to only drink water on the morning before providing the saliva sample. Saliva was collected via a commercially available sampling device employing the passive drool method (SaliCaps, IBL International GmbH, Hamburg, Germany). Saliva samples were obtained during a 15-min time period and were stored at –20°C until required for biochemical analysis at the Biochemical Laboratory of the Institute of Psychology at the University of Zurich. All steroid hormones including salivary C (sC), salivary T (sT), salivary DHEA (sDHEA), salivary E2 (sE2), and salivary progesterone (sP) were quantified with standard enzyme immunoassays (retrievable under: http://www.ibl-international.com/ende/; Lewis, 2006; Chiappin et al., 2007). Intra- and inter-assay coefficients for the analyzed steroid hormones were below 10%, while sensitivity was 0.003 μg/dL for sC, 0.083 pg/ml for sT, or 0.6 pg/ml for sE2 according to Immuno-Biological Laboratories, Inc, IBL-America.

In addition, hair samples of T (hT), DHEA (hDHEA), P (hP), C (hCrtsl), and cortisone (hCrtson) were obtained from 211 participants to determine the concentrations of steroid hormones in hair. Therefore, 2 cm segments of hair from the posterior vertex proximal to the scalp were obtained, to reflect the steroid secretion of the last 2 months (assuming an average hair growth of 1 cm per month). For biochemical analysis with liquid chromatography-mass spectrometry, samples were sent to the Dresden Lab (Stalder and Kirschbaum, 2012; Gao et al., 2013, 2016; Stalder et al., 2017). Intra- and inter-assay coefficients for the analyzed steroid hormones were below 10%, while sensitivity was 0.5 pg/mg for C, 0.15 pg/mg for T, or 0.05 pg/mg for DHEA.

Covariates

Covariates included in the analyses were BMI, alcohol, or tobacco consumption, medication intake, general health status and health effort, recent physical activity, recent sexual activity, starting time of the examination, waking time of the participant, gum bleeding during the last days, and elevated stress during the last week. For hair steroids, the following covariates were additionally

controlled for: month of hair sampling, times of hair washing, hair color, artificial hair coloring, hair spray (excluding: waking time of the participant, elevated stress during the last week). We controlled for these covariates as they were previously reported to significantly influence steroid measurements in saliva or hair (Walther et al., 2016; Stalder et al., 2017).

Statistical Analysis

Pearson's zero-order correlations (r) were performed to examine the association between age and parameters for negative emotions and steroid hormones. Subsequently, partial correlation analyses were conducted including the introduced covariates. Next, separate moderation analyses were conducted for the association between age and negative emotions moderated by steroid hormones using PROCESS for SPSS (Hayes, 2013). Additionally, the potential covariates were included for the moderation analyses. All analyses were carried out using SPSS, version 23.0 (IBM SPSS Statistics, Armonk, NY, USA). The level of significance was set at $\alpha = 0.05$.

Results

Sample characteristics and descriptive statistics of salivary and hair analytes are summarized in **Table 1**. Pearson's correlation analyses showed significant associations between age (ranging from 40 to 75 years) and different psychometric indicators of negative emotions. The BSI-18 subscale anxiety was negatively associated with age ($r = -0.188$, $p = 0.001$), while for depression, only a negative trend emerged ($r = -0.098$, $p = 0.053$). With regard to the aggression questionnaire, age was significantly negatively associated with anger ($r = -0.166$, $p = 0.003$) and physical aggression ($r = -0.133$, $p = 0.014$), and positively associated with verbal aggression ($r = 0.113$, $p = 0.032$), but was not associated with hostility ($r = -0.019$, $p = 0.381$). Age was negatively associated with sT ($r = -0.345$, $p < 0.001$), sDHEA ($r = -0.385$, $p < 0.001$), sE2 ($r = -0.208$, $p < 0.001$) and sP ($r = -0.276$, $p < 0.001$) and positively associated with sC ($r = 0.145$, $p = 0.009$). Employing partial correlation analyses including the introduced set of covariates did not change associations with age (anxiety: $r_p = -0.191$, $p = 0.001$; depression: $r_p = -0.087$, $p = 0.079$; anger: $r_p = -0.108$, $p = 0.042$; physical aggression: $r_p = -0.116$, $p = 0.031$; verbal aggression: $r_p = 0.127$, $p = 0.021$; sT: $r_p = -0.236$, $p < 0.001$; sDHEA: $r_p = -0.301$, $p < 0.001$; sE2: $r_p = -0.191$, $p = 0.001$; sP: $r_p = -0.203$, $p = 0.001$; sC: $r_p = 0.128$, $p = 0.024$; see **Table 2**). However, for the hair steroids, a significant association with age only emerged for hT (hT: $r = -0.320$, $p < 0.001$), while all other hair steroids failed to show age-related associations (hCrtsl: $r = 0.038$, $p = 0.291$; hCrtson: $r = -0.016$, $p = 411$; hDHEA: $r = 0.030$, $p = 0.334$; hP: $r = -0.057$, $p = 0.204$). The pattern changed when including covariates into the correlation analyses, with partial correlation analyses revealing the following age-related associations with hair steroids: hCrtsl: $r_p = 0.139$, $p = 0.031$; hCrtson: $r_p = 0.100$, $p = 0.090$; hT: $r_p = -0.187$, $p = 0.006$; hP: $r_p = -0.118$, $p = 0.058$; hDHEA: $r_p = -0.026$, $p = 0.366$.

Moderation analyses for the association between age and parameters of negative emotional state including covariates are summarized in **Table 3**. The salivary analytes tested as moderators were sC, sT, sDHEA, sE2, and sP. A significant moderation effect of sC on the association between age and the BSI-18 anxiety scale emerged ($R^2 = 0.4146$, $p < 0.001$; B = −0.0036, SE = 0.0018, $p = 0.0453$, R^2 change = 0.0139). No other significant moderation effect emerged for the association between age and anxiety or depression for salivary analytes as moderators (see **Table 3**). For the association between age and aggression (physical and verbal), trends for moderation effects were observed for sP (Physical aggression: $R^2 = 0.1013$, $p = 0.084$, B = 0.0002, SE = 0001, $p = 0.0685$, R^2 change = 0.0124; Verbal aggression: $R^2 = 0.0687$, $p = 0.1140$; B = 0.0003, SE = 0.0002, $p = 0.0896$, R^2 change = 0.0139). No other moderation effects were observed (see **Table 3**).

For hair steroids, significant moderation effects of hCrtsl and hCrtson on the association between age and anger emerged (hCrtsl: $R^2 = 0.1992$, $p < 0.001$; B = 0.0010, SE = 0.0005, $p = 0.0360$, R^2 change = 0.0190; hCrtson: $R^2 = 0.2078$, $p < 0.001$; B = 0.0003, SE = 0002, $p = 0.0331$, R^2 change = 0.0191). Furthermore, the association between age and aggression (physical and verbal) was significantly moderated by hP (Physical aggression: $R^2 = 0.1502$, $p = 0.0139$; B = 0.0044, SE = 0.0020, $p = 0.0315$, R^2 change = 0.0209; Verbal aggression: $R^2 = 0.1449$, $p = 0.0197$; B = 0.0082, SE = 0.0029, $p = 0.0044$, R^2 change = 0.0372). No significant moderation effects emerged for the association between age and negative emotions for hT and hDHEA as moderators (see **Table 3**).

STUDY 2: MEN STRESS 40+

Participants and Procedure

The study was conducted in 2016 and comprised a total of 123 men between the ages of 40 and 75 years. Participants were recruited via web pages and by leaflets distributed in the city of Zurich. To be included in the study, participants had to be generally healthy and German-speaking. After initial inclusion, participants completed the MVEQ (see below) and only participants above a certain threshold score (≥4) for vital exhaustion remained in the study. The participants were characterized as mildly (4–10, $n = 48$), substantially (11–14, $n = 56$), or severely (15–18, $n = 20$) vitally exhausted (Appels et al., 1987; von Känel et al., 2004). The further procedure was the same as described in study 1, including the psychometric testing and a subsequent biological examination, in which saliva and hair samples were obtained under standardized conditions.

Participants had a mean age of 52.7 ($SD = 8.4$) years and a mean body mass index (BMI) of 25.8 ($SD = 3.9$). A total of 11.6% of participants reported being regular smokers. Similar to study 1, a relatively high socioeconomic status was observed, reflected by the mean education level (62.0% reported having a degree from a university or a university of applied sciences) and income level (50.0% earned more than CHF 117,000/year). All participants provided written informed consent, and the study protocol was approved by the Cantonal Ethics Committee of the Canton of Zurich.

TABLE 1 | Means and standard deviations or percentage frequencies of demographics, psychometric, and endocrine measures in the different studies.

	Study 1: Men's health 40+	Study 2: Men stress 40+	Study 3: Fatherhood
	N = 271	*N* = 121	*N* = 384
DEMOGRAPHICS			
Age	57.51 (10.74)	52.69 (8.35)	43.75 (10.72)
BMI	25.37 (3.06)	25.79 (3.86)	25.28 (3.57)
Smoking (%)	8.2	11.6	12.0
Alcohol (%)	79.6	80.2	85.9
Education (%)	88.1 ≥ higher secondary school	62.0 ≥ university or applied sciences degree	59.1 ≥ tertiary education
Income	48.3% > CHF 100,000/year	50.0% > CHF 117,000/year	CHF 7,565/month (an estimate of CHF 90,779/year)
BRIEF SYMPTOM INVENTORY (BSI)			
BSI—Anxiety	2.37 (2.67)	4.43 (3.02)	2.50 (2.59)
BSI—Depression	1.63 (2.69)	4.02 (3.59)	2.21 (3.07)
BSI—Aggression	–	–	2.12 (2.31)
BUSS PERRY AGGRESSION QUESTIONNAIRE (BPAQ)			
BPAQ—Physical	2.28 (0.41)	2.28 (0.39)	–
BPAQ—Verbal	2.37 (0.57)	2.56 (0.64)	–
BPAQ – Anger	2.21 (0.43)	2.11 (0.38)	–
BPAQ – Hostility	2.26 (0.46)	2.35 (0.46)	–
POSITIVE AND NEGATIVE AFFECT SCHEDULE (PANAS)			
PANAS—PA	–	31.44 (6.47)	–
PANAS—NA	–	21.55 (6.25)	–
SALIVARY ANALYTES			
sT (pg/ml)	67.37 (26.72)	65.80 (26.95)	56.20 (25.99)
sDHEA (pg/ml)	256.25 (224.26)	148.63 (154.27)	–
sE2 (pg/ml)	1.32 (0.999)	1.66 (0.91)	1.52 (1.46)
sP (pg/ml)	28.43 (18.79)	39.20 (42.81)	–
sC (nmol/L)	18.27 (8.16)	7.87 (4.17)	17.05 (8.95)
HAIR ANALYTES			
hT (pg/mg)	0.90 (0.76)	5.01 (6.98)	–
hDHEA (pg/mg)	1.07 (0.92)	16.89 (12.71)	–
hP (pg/mg)	1.86 (1.22)	2.07 (2.39)	–
hCrtson (pg/mg)	24.57 (16.39)	31.58 (28.58)	–
hCrtsl (pg/mg)	7.96 (6.32)	21.94 (29.84)	–

Table entries are means and, in parentheses, standard deviations, or percentage frequencies where noted. Absolut numbers vary slightly among different variables. T, Testosterone; C, Cortisol; DHEA, Dehydroepiandrosterone; P, Progesterone; E2, Estradiol; sC, salivary C; sT, salivary T; sDHEA, salivary DHEA; sP, salivary P; sE2, salivary E2; hT, hair T; hCrtsl, hair C; hDHEA, hair DHEA; hair P, hP; hair cortisone, hCrtson; BSI, Brief Symptom Inventory; PANAS, Positive and Negative Affect Schedule; BPAQ, Buss-Perry Aggression Questionnaire.

Psychometric Measures

This study also employed the BSI-18 and BPAQ as described above.

The short form of the German MVEQ (Kopp et al., 1998; Schnorpfeil et al., 2002) consists of nine items rated on a 3-point Likert scale (2 = yes, 1 = don't know, 0 = no). The VE score ranges from 0 to 18, with participants with a cut-off ≥ 4 being defined as vitally exhausted. The VE questionnaire showed good internal consistency, with Cronbach's alpha = 0.82.

The Positive and Negative Affect Schedule (PANAS) consists of 20 items rated on a 5-point Likert scale from 1 (very slightly or not at all) to 5 (extremely). Participants were asked how they feel at the moment and had to rate the 20 adjectives (e.g., angry, nervous, strong). The PANAS identifies two subscales, one for positive affect and one for negative affect. Cronbach's alpha is 0.88 for the positive affect subscale and 0.87 for the negative affect subscale.

Endocrine Measures

For this study, the same endocrine measures were analyzed as previously described in study 1, including salivary and hair steroids examined by the same laboratories and reporting similar intra- and inter-assay coefficients for salivary and hair analytes.

Covariates

To provide the highest possible overlap between analyses, covariates were identified which corresponded to the covariates described in study 1 to the highest possible degree. Similar to Study 1, covariates included were BMI, alcohol and tobacco consumption, medication intake, gum bleeding during the last

TABLE 2 | Partial correlations for age and emotion experience and steroid hormones.

	Study 1: Men's health 40+	Study 2: Men stress 40+	Study 3: Fatherhood
AGE			
Anxiety (BSI)	**−0.191**	0.110	**−0.113**
	0.001	0.131	**0.030**
Depression (BSI)	−0.087	−0.117	−0.011
	0.079[t]	0.116	0.831
Aggression (BSI)	–	–	**−0.175**
			0.001
Physical aggression (BPAQ)	**−0.116**	−0.160	–
	0.031	0.051[t]	
Verbal aggression (BPAQ)	**0.127**	**0.180**	–
	0.021	**0.033**	
Anger (BPAQ)	**−0.108**	0.131	–
	0.042	0.090[t]	
Hostility (BPAQ)	0.007	0.012	–
	0.458	0.453	
Positive affect (PANAS)	–	0.149	–
		0.064[t]	
Negative affect (PANAS)	–	0.001	–
		0.495	
sT	**−0.236**	**−0.246**	**−0.176**
	0.000	**0.006**	**0.001**
sDHEA	**−0.301**	**−0.338**	–
	0.000	**0.000**	
sE2	**−0.191**	0.008	**0.151**
	0.001	0.468	**0.004**
sP	**−0.203**	**−0.193**	–
	0.001	**0.024**	
sC	**0.128**	−0.125	−0.040
	0.024	0.101	0.441
hT	**−0.187**	**−0.283**	–
	0.006	**0.004**	
hDHEA	0.026	−0.133	–
	0.366	0.110	
hP	−0.118	−0.032	–
	0.058[t]	0.386	
hCrtson	0.100	−0.109	–
	0.090[t]	0.127	
hCrtsl	**0.139**	0.041	–
	0.031	0.336	

Upper values in the compartments represent correlation coefficients and values below represent level of significance. Bold correlations are significant at $p < 0.05$. T, Testosterone; C, Cortisol; DHEA, Dehydroepiandrosterone; P, Progesterone; E2, Estradiol; sC, salivary C; sT, salivary T; sDHEA, salivary DHEA; sP, salivary P; sE2, salivary E2; hT, hair T; hCrtsl, hair C; hDHEA, hair DHEA; hair P, hP; hair cortisone, hCrtson; BSI, Brief Symptom Inventory; PANAS, Positive and Negative Affect Schedule; BPAQ, Buss-Perry Aggression Questionnaire.

days, and elevated stress during the last week. Additional covariates were having a cold or infection during the last weeks and general health parameters such as, having a somatic disorder or having age-related symptoms.

Statistical Analysis

The statistical analyses, statistical software and significance level were the same as described for Study 1.

Results

Sample characteristics and descriptive statistics for salivary and hair analytes are summarized in **Table 1**. Pearson's correlation analyses showed significant associations between age and different psychometric indicators of negative emotions (see **Table 2**). The BSI-18 subscale depression was negatively associated with age ($r = -0.158$, $p = 0.042$), while no association emerged for anxiety ($r = 0.019$, $p = 0.418$). With regard to the aggression questionnaire, age was significantly positively associated with the subscales physical and verbal aggression (physical aggression: $r = 0.171$, $p = 0.030$; verbal aggression: $r = 0.180$, $p = 0.024$), but not with anger ($r = -0.006$, $p = 0.474$), or hostility ($r = -0.022$, $p = 0.407$). A positive age-related association emerged for positive affect ($r = 0.218$, $p = 0.008$), while no association was observed for negative affect ($r = -0.090$, $p = 0.163$). Age was negatively associated with sT ($r = -0.260$, $p = 0.002$), sDHEA ($r = -0.327$, $p < 0.001$) and sP ($r = -0.191$, $p = 0.018$) but not with sE2 ($r = 0.071$, $p = 0.220$), and as a trend with sC ($r = -0.121$, $p = 0.093$). When employing partial correlation analyses including the set of covariates introduced for study 1, associations with age did slightly change (anxiety: $r_p = -0.110$, $p = 0.131$; depression: $r_p = -0.117$, $p = 0.094$; anger: $r_p = 0.131$, $p = 0.090$; physical aggression: $r_p = 0.160$, $p = 0.051$; verbal aggression: $r_p = 0.180$, $p = 0.033$; positive affect: $r_p = 0.149$, $p = 0.064$; negative affect: $r_p = 0.001$, $p = 0.495$; sT: $r_p = -0.246$, $p = 0.006$; sDHEA: $r_p = -0.338$, $p < 0.001$; sE2: $r_p = 0.008$, $p = 0.468$; sP: $r_p = -0.193$, $p = 0.024$; sC: $r_p = -0.125$, $p = 0.101$; see **Table 2**). However, for the hair steroids, a significant association with age emerged only for hT (hT: $r = -0.169$, $p = 0.050$), and a negative trend emerged for hDHEA (hDHEA: $r = -0.153$, $p = 0.068$), while all other hair steroids failed to show age-related associations (hCrtsl: $r = -0.058$, $p = 0.264$; hCrtson: $r = -0.057$, $p = 267$; hP: $r = -0.102$, $p = 0.161$). The pattern changed when including covariates into the correlation analyses, with partial correlation analyses revealing the following age-related associations with hair steroids: hCrtsl: $r_p = 0.139$, $p = 0.031$; hCrtson: $r_p = 0.100$, $p = 0.090$; hT: $r_p = -0.187$, $p = 0.006$; hP: $r_p = -0.118$, $p = 0.058$; hDHEA: $r_p = -0.026$, $p = 0.366$.

Moderation analyses for the association between age and parameters of negative emotional state including covariates are summarized for all three studies in **Table 3**. Significant moderation effects of sC on the association between age and the BSI-18 anxiety emerged ($R^2 = 0.4062$, $p < 0.001$; B = −0.0152, SE = 0.0067, $p = 0.0262$, R^2 change = 0.0305), while a trend for negative affect (PANAS) was observed ($R^2 = 0.4051$, $p < 0.001$; B = −0.0242, SE = 0.0139, $p = 0.0859$, R^2 change = 0.0181). For sT, a significant negative moderation effect for the association between age and anxiety ($R^2 = 0.4022$, $p < 0.001$; B = −0.0027, SE = 0012, $p = 0.0225$, R^2 change = 0.0339) and a trend for depression ($R^2 = 0.4070$, $p < 0.001$; B = −0.0023, SE = 0.0014, $p = 0.100$, R^2 change = 0.0171) were observed. For sP and sDHEA, no moderation effects were observed, while for sE2, a positive trend for hostility ($R^2 = 0.3418$, $p = 0.001$; B = 0.1168, SE =

TABLE 3 | Moderation analyses for steroid hormones on the association between age and emotion experience.

	Study 1: Men's health 40+				Study 2: Men stress 40+				Study 3: Fatherhood			
	R^2	p-model	B	p-int	R^2	p-model	B	p-int	R^2	p-model	B	p-int
sT												
Age:BSI-Anxiety	0.1472	0.0016	−0.0005	0.3678	0.4022	0.0001	−0.0027	**0.0225***	0.1165	0.0000	0.0299	0.0511^{t}
Age:BSI-Depression	0.1081	0.0451	−0.0002	0.7650	0.4070	0.0001	−0.0023	0.1014	0.1461	0.0000	0.0412	**0.0210***
Age:BSI-Aggression	x	x	x	x	x	x	x	x	0.1319	0.0000	0.0025	0.8537
Age:BPAQ-Physical	0.0824	0.2390	0.0000	0.6071	0.2415	0.0950	−0.0013	0.4036	x	x	x	x
Age:BPAQ -Verbal	0.0874	0.1819	−0.0001	0.6327	0.2310	0.1292	0.0004	0.7787	x	x	x	x
Age:BPAQ -Anger	0.1111	0.0384	0.0001	0.4731	0.3362	0.0024	−0.0015	0.5085	x	x	x	x
Age:BPAQ-Hostility	0.1123	0.0352	0.0001	0.5675	0.3134	0.0068	0.0010	0.6443	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.3038	0.0102	0.0029	0.2817	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3762	0.0003	0.0001	0.9798	x	x	x	x
sDHEA												
Age:BSI-Anxiety	0.1512	0.0013	0.0000	0.5724	0.3998	0.0000	−0.0002	0.4071	x	x	x	x
Age:BSI-Depression	0.1107	0.0395	−0.0001	0.2686	0.3689	0.0003	−0.0001	0.7650	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ-Physical	0.0788	0.2954	0.0000	0.4515	0.3122	0.0046	0.0001	0.8676	x	x	x	x
Age:BPAQ -Verbal	0.1031	0.0715	0.0000	0.4544	0.2237	0.1280	0.0003	0.2902	x	x	x	x
Age:BPAQ -Anger	0.1123	0.0374	0.0000	0.4374	0.3318	0.0018	−0.0001	0.8520	x	x	x	x
Age:BPAQ -Hostility	0.0977	0.1022	0.0000	0.6535	0.2987	0.0084	0.0005	0.2392	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2924	0.0110	0.0002	0.6601	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3719	0.0002	−0.0001	0.8460	x	x	x	x
sE2												
Age:BSI-Anxiety	0.1494	0.0012	−0.0006	0.9681	0.3830	0.0001	−0.0408	0.2942	0.1024	0.0001	−0.0061	0.6223
Age:BSI-Depression	0.1176	0.0204	−0.0020	0.9045	0.3775	0.0002	−0.0348	0.4528	0.1179	0.0000	0.0012	0.9328
Age:BSI-Aggression	x	x	x	x	x	x	x	x	0.1268	0.0000	−0.0102	0.3485
Age:BPAQ -Physical	0.0808	0.2527	0.0005	0.8382	0.3605	0.0004	0.0860	0.0841^{t}	x	x	x	x
Age:BPAQ -Verbal	0.0845	0.2073	−0.0004	0.9136	0.2302	0.1054	0.0573	0.2342	x	x	x	x
Age:BPAQ -Anger	0.1064	0.0512	0.0000	0.9867	0.3414	0.0011	0.0675	0.3471	x	x	x	x
Age:BPAQ -Hostility	0.1001	0.0794	−0.0019	0.5024	0.3418	0.0011	0.1168	0.0922^{t}	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2922	0.0111	−0.0046	0.9589	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3710	0.0002	0.0427	0.5984	x	x	x	x
sP												
Age:BSI-Anxiety	0.1531	0.0012	−0.0009	0.2409	0.3841	0.0001	−0.0008	0.5020	x	x	x	x
Age:BSI-Depression	0.1002	0.0871	−0.0008	0.3010	0.3662	0.0003	−0.0001	0.9650	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ -Physical	0.1013	0.0848	0.0002	0.0685^{t}	0.2836	0.0157	0.0009	0.5872	x	x	x	x
Age:BPAQ -Verbal	0.0967	0.1140	0.0003	0.0896^{t}	0.2159	0.1598	0.0002	0.8790	x	x	x	x
Age:BPAQ -Anger	0.1166	0.0289	0.0001	0.5498	0.3415	0.0011	−0.0012	0.6108	x	x	x	x
Age:BPAQ -Hostility	0.1083	0.0530	0.0000	0.8764	0.2956	0.0097	0.0015	0.4960	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2943	0.0102	0.0000	0.9959	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3833	0.0001	−0.0039	0.1331	x	x	x	x
sC												
Age:BSI-Anxiety	0.1719	0.0002	−0.0036	**0.0453***	0.4062	0.0000	−0.0152	**0.0262***	0.1019	0.0001	−0.0038	0.8224
Age:BSI-Depression	0.0985	0.1017	−0.0015	0.4010	0.3701	0.0002	−0.0024	0.7761	0.1162	0.0000	0.0048	0.8103
Age:BSI-Aggression	x	x	x	x	x	x	x	x	0.1248	0.0000	−0.0057	0.6997
Age:BPAQ -Physical	0.0808	0.2854	0.0002	0.4820	0.3534	0.0006	−0.0130	0.1421	x	x	x	x
Age: BPAQ -Verbal	0.0886	0.1906	0.0007	0.0860^{t}	0.2137	0.1698	−0.0005	0.9574	x	x	x	x
Age:BPAQ -Anger	0.1226	0.0143	−0.0003	0.3036	0.3446	0.0010	−0.0172	0.1762	x	x	x	x
Age:BPAQ -Hostility	0.1046	0.0720	0.0003	0.3866	0.3099	0.0051	0.0050	0.6912	x	x	x	x

(Continued)

TABLE 3 | Continued

	Study 1: Men's health 40+				Study 2: Men stress 40+				Study 3: Fatherhood			
	R^2	p-model	B	p-int	R^2	p-model	B	p-int	R^2	p-model	B	p-int
Age:PANAS-PA	x	x	x	x	0.2888	0.0128	−0.0033	0.8346	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.4051	0.0000	−0.0242	0.0859^{t}	x	x	x	x
hT												
Age:BSI-Anxiety	0.1531	0.0145	0.0201	0.3482	0.3864	0.0001	0.0100	0.1873	x	x	x	x
Age:BSI-Depression	0.0943	0.3196	0.0089	0.6753	0.4157	0.0000	0.0059	0.4885	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ -Physical	0.1404	0.0337	0.0033	0.3176	0.2607	0.0167	0.0105	0.2772	x	x	x	x
Age:BPAQ-Verbal	0.0972	0.2917	−0.0005	0.9079	0.1250	0.5668	−0.0014	0.8852	x	x	x	x
Age:BPAQ-Anger	0.1833	0.0018	0.0028	0.3843	0.3372	0.0007	0.0047	0.7437	x	x	x	x
Age:BPAQ-Hostility	0.1376	0.0397	0.0018	0.6300	0.2867	0.0062	0.0067	0.6406	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2605	0.0168	0.0209	0.2536	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3719	0.0001	0.0394	**0.0168***	x	x	x	x
hDHEA												
Age:BSI-Anxiety	0.1333	0.0423	−0.0060	0.7751	0.3694	0.0003	−0.0032	0.3359	x	x	x	x
Age:BSI-Depression	0.1028	0.2085	−0.0088	0.6658	0.3934	0.0001	0.0009	0.8064	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ-Physical	0.1398	0.0296	0.0033	0.2984	0.3030	0.0050	0.0009	0.8242	x	x	x	x
Age:BPAQ-Verbal	0.1104	0.1505	−0.0008	0.8498	0.1290	0.6066	−0.0014	0.7512	x	x	x	x
Age:BPAQ-Anger	0.2003	0.0004	−0.0024	0.4477	0.3776	0.0002	0.0119	0.0526^{t}	x	x	x	x
Age:BPAQ-Hostility	0.1642	0.0058	−0.0009	0.8088	0.2989	0.0059	−0.0047	0.4513	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2830	0.0109	−0.0054	0.4867	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3444	0.0008	0.0061	0.3993	x	x	x	x
hP												
Age:BSI-Anxiety	0.1316	0.0435	0.0026	0.8499	0.3633	0.0003	0.0007	0.9762	x	x	x	x
Age:BSI-Depression	0.1012	0.2145	0.0199	0.1316	0.4058	0.0000	0.0187	0.4486	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ-Physical	0.1502	0.0139	0.0044	**0.0315***	0.2895	0.0086	−0.0100	0.7236	x	x	x	x
Age:BPAQ-Verbal	0.1449	0.0197	0.0082	**0.0044****	0.1263	0.6284	−0.0034	0.9045	x	x	x	x
Age:BPAQ-Anger	0.2147	0.0001	0.0023	0.2521	0.3509	0.0006	−0.0178	0.6646	x	x	x	x
Age:BPAQ-Hostility	0.1366	0.0334	0.0015	0.5164	0.3053	0.0046	−0.0294	0.4728	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2571	0.0276	−0.0023	0.6722	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3366	0.0012	−0.0136	0.7772	x	x	x	x
hCrtsn												
Age:BSI-Anxiety	0.1412	0.0239	−0.0008	0.4235	0.3307	0.0000	0.0010	0.4696	x	x	x	x
Age:BSI-Depression	0.1066	0.1676	−0.0011	0.2718	0.3304	0.0000	0.0004	0.7142	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ-Physical	0.1268	0.0598	0.0001	0.5739	0.3041	0.0001	−0.0008	6077	x	x	x	x
Age:BPAQ-Verbal	0.1060	0.1764	0.0000	0.9583	0.1974	0.0270	−0.0026	0.0817^{t}	x	x	x	x
Age:BPAQ-Anger	0.2078	0.0002	0.0003	**0.0331***	0.3385	0.0000	−0.0013	0.5499	x	x	x	x
Age:BPAQ-Hostility	0.1464	0.0179	0.0001	0.4087	0.2867	0.0003	−0.0037	0.0876^{t}	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2838	0.0004	0.0041	0.1319	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3489	0.0000	0.0005	0.8460	x	x	x	x
hCrtsl												
Age:BSI-Anxiety	0.1349	0.0400	−0.0019	0.5271	0.3386	0.0000	−0.0002	0.8469	x	x	x	x
Age:BSI-Depression	0.0994	0.2465	−0.0023	0.4144	0.3473	0.0000	0.0023	0.0773^{t}	x	x	x	x
Age:BSI-Aggression	x	x	x	x	x	x	x	x	x	x	x	x
Age:BPAQ-Physical	0.1257	0.0700	0.0002	0.6495	0.2709	0.0008	0.0000	0.9799	x	x	x	x
Age:BPAQ-Verbal	0.1055	0.1933	0.0002	0.7724	0.1842	0.0458	−0.0004	0.7913	x	x	x	x

(Continued)

TABLE 3 | Continued

	Study 1: Men's health 40+				Study 2: Men stress 40+				Study 3: Fatherhood			
	R^2	p-model	B	p-int	R^2	p-model	B	p-int	R^2	p-model	B	p-int
Age:BPAQ-Anger	0.1992	0.0004	0.0010	**0.0360***	0.2982	0.0002	−0.0011	0.3734	x	x	x	x
Age:BPAQ-Hostility	0.1455	0.0216	0.0005	0.3547	0.2384	0.0043	0.0001	0.9689	x	x	x	x
Age:PANAS-PA	x	x	x	x	0.2614	0.0013	0.0011	0.6576	x	x	x	x
Age:PANAS-NA	x	x	x	x	0.3349	0.0000	−0.0017	0.4653	x	x	x	x

$^{t}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$.

T, Testosterone; C, Cortisol; DHEA, Dehydroepiandrosterone; P, Progesterone; E2, Estradiol; sC, salivary C; sT, salivary T; sDHEA, salivary DHEA; sP, salivary P; sE2, salivary E2; hT, hair T; hCrtsl, hair C; hDHEA, hair DHEA; hair P, hP; hair cortisone, hCrtson; BSI, Brief Symptom Inventory; PANAS, Positive and Negative Affect Schedule; BPAQ, Buss-Perry Aggression Questionnaire.

0.0687, $p = 0.0922$, R^2 change = 0.0192) and physical aggression ($R^2 = 0.3605$, $p < 0.001$; B = 0.0860, SE = 0.0493, $p = 0.0841$, R^2 change = 0.0197) emerged.

For hCrtsl, no significant moderation effects emerged, but a trend was found for the BSI-18 depression scale (hCrtsl: $R^2 = 0.3473$, $p < 0.001$; B = 0.0023, SE = 0.0013, $p = 0.077$, R^2 change = 0.0196). For hCrtson, two trends for moderation effects resulted for the association of age with verbal aggression ($R^2 = 0.1974$, $p = 0.0270$; B = −0.0026, SE = 0.0015, $p = 0.0817$, R^2 change = 0.0234) and hostility ($R^2 = 0.2867$, $p < 0.001$; B = −0.0037, SE = 0.0022, $p = 0.0876$, R^2 change = 0.0200). Furthermore, for hT, a significant positive moderation effect emerged for the association between age and negative affect (PANAS) ($R^2 = 0.3719$, $p < 0.001$; B = 0.0394, SE = 0.0161, $p = 0.0168$, R^2 change = 0.0462). No moderation effects were observed for hP and hDHEA, although for hDHEA, there was a trend for an association between age and anger ($R^2 = 0.3776$, $p < 0.001$; B = 0.0119, SE = 0.0060, $p = 0.0526$, R^2 change = 0.0297, see **Table 3**).

STUDY 3: COSTS AND BENEFITS OF FATHERHOOD ACROSS THE LIFESPAN

Participants and Procedure

Study 3 was conducted in the year 2014. Participants for study 3 were recruited within the German-speaking countries of Central Europe (e.g., Austria, Germany, Switzerland) through announcements in daily newspapers, broadcast and online platforms, social networking sites, mailing lists of different family- or research-related organizations, and flyers displayed in public places such as, shopping malls or universities. Inclusion criteria were male sex, a minimum age of 18 years, and having assumed the paternal role for at least one biological or non-biological child in the course of a lifetime. All subjects gave informed consent prior to their study participation. The study protocol was approved by the local Ethics Committee of the Faculty of Arts, University of Zurich, Switzerland.

Data collection was implemented in two steps. First, all subjects completed an ($N = 2908$: original sample). Second, subjects were invited to participate in the follow-up study which included the assessment of salivary endocrine measures. A total of 425 participants subsequently provided saliva samples for the analysis of baseline values of steroid hormones. Of these, 11 subjects had to be excluded due to intake of drugs or anabolic steroids and 30 due to missing information on one of the included covariates, resulting in a final sample of 384 participants. Of those 343 men reported to have fathered only a biological child, while 7 reported to have fathered only a non-biological child and 34 reported to have fathered both. The different forms of fatherhood were not associated with different steroid hormone levels, what is in accordance with previous research (Gray et al., 2017). Participants had a mean age of 43.75 ($SD = 10.7$) years and a mean BMI of 25.3 ($SD = 3.6$). Twelve percentage of the participants reported being regular smokers. In general, a relatively high socioeconomic status was observed, as reflected by the mean education level, with 59% reporting having completed tertiary or higher education. Participants in the sample were relatively healthy, with 91% of participants rating their general health as "outstanding," "very good," or "good," and only 9% considering their health status to be "moderate" or "poor." Prior published data of this sample can be reviewed here (Ruppen et al., 2016; Waldvogel and Ehlert, 2016, 2017).

Psychometric Measures

Consistent with studies 1 and 2, self-reported psychological distress was measured using the German translation of the BSI-18 and subsequently focusing on anxiety and depression subscales as indicators of negative emotions (Spitzer et al., 2011).

Aggression was measured via the aggressiveness/hostility subscale of the German version of the Brief Symptom Inventory (BSI; Franke et al., 2011). This widely used, reliable, and valid self-report measure assesses symptoms of psychological distress on nine dimensions, including aggressiveness/hostility, during the past 7 days. The subscale aggressiveness/hostility consists of 5 items measuring symptoms of irritability, unbalanced mood or anger, up to strong aggressiveness and hostility on a 5-point Likert scale ranging from 0 (not at all) to 4 (extremely). The five items were aggregated into a sum score ranging from 0 to 20.

Endocrine Measures

Saliva sampling was carried out under standardized procedures during participants' daily routine on 2 consecutive working days directly after awakening. Saliva sampling materials, including two polypropylene tubes and detailed instructions of the sampling procedure were sent to the participants in advance by mail.

Participants were asked to refrain from alcoholic and caffeinated beverages, heavy exercise, and sexual activity for 12 h before testing. Moreover, they were instructed not to brush their teeth, chew gum, smoke, eat, or consume non-water beverages for 1 h prior to saliva collection. Mean sampling times were 6:38 a.m. on day 1 and 6:34 a.m. on day 2. The mean awakening time was 6:16 a.m. on both days. On the second sampling day, participants returned both of their samples to our laboratory, where they were immediately stored at −20°C until laboratory analysis at the Biochemical Laboratory of the Psychological Institute of the University of Zurich.

Saliva samples were collected by passive drool using ultra-pure polypropylene sampling devices (SaliCaps: IBL International GmbH, Hamburg, Germany). Steroid hormone concentration for sC, sT, and sE2 was determined in each sample via standard luminescence immunoassays using kits from IBL International GmbH, Hamburg, Germany. Inter- and intra-assay coefficients and analytical sensitivity were similar to in studies 1 and 2. After laboratory analyses, the two values for each participant were averaged to reduce noise in hormone values resulting from pulsatile secretion (Gray et al., 2004), thus providing a more reliable value of basal hormone concentrations.

Covariates

Similar to study 1, covariates included in the analyses were BMI, alcohol, and tobacco consumption, medication intake, general health status, recent physical activity, recent sexual activity, waking time of the participant, and gum bleeding during the last days. Additional covariate was the time of saliva sampling.

Statistical Analysis

Statistical analyses were conducted using SPSS, version 22.0 (IBM, Armonk, NY) and PROCESS for SPSS, version 2.15 (Hayes and Preacher, 2014). First, correlations between age and negative emotions or steroid hormones, respectively, were calculated using Spearman's rho due to skewed distribution of variables and relatively influential data points representing potential outliers. Spearman correlations are more robust against influential data points by calculating rank order correlations and thereby not including the actual difference between data points. Subsequently, partial correlations with the aforementioned covariates added. Next, similar to studies 1 and 2, moderation analyses were conducted for the association between age and negative emotions, moderated by steroid hormones while potential covariates were included. All statistical tests were two-tailed with statistical significance set at $p \leq 0.05$.

Results

Sample characteristics and descriptive statistics of dependent and independent variables are summarized in **Table 1**. Spearman's correlations showed significant associations between age and negative emotions. Age was negatively associated with aggression ($r = -0.117$, $p = 0.022$) and anxiety ($r = -0.105$, $p = 0.039$), while no association was found between age and depression ($r = 0.027$, $p = 0.597$). Additionally, age was negatively associated with sT ($r = -0.204$, $p < 0.001$) and sC ($r = -0.104$, $p = 0.042$), and positively associated with sE2 ($r = 0.147$, $p = 0.004$).

When considering covariates, associations between age and negative emotions only changed marginally, with aggression and anxiety still being negatively correlated and depression not being associated with age (aggression: $r_p = -0.175$, $p = 0.001$; anxiety: $r_p = -0.113$, $p = 0.030$; depression: $r_p = -0.011$, $p = 0.832$). Associations between age and steroid hormones partly changed after controlling for covariates. While remaining negatively correlated with sT ($r_p = -0.176$, $p = 0.001$) and positively correlated with sE2 ($r_p = 0.151$, $p = 0.004$), age was no longer associated with sC ($r_p = -0.040$, $p = 0.368$).

As presented in **Table 3**, moderation analyses for the associations between age and negative emotions, including covariates, revealed a trend toward sT moderating the association between age and anxiety ($R^2 = 0.117$, $p < 0.001$; B = 0.030, SE = 0.015, $p = 0.051$, R^2 change = 0.009). Further, the association between age and depression was found to be moderated by sT ($R^2 = 0.146$, $p < 0.001$; B = 0.041, SE = 0.018, $p = 0.021$, R^2 change = 0.012; **Table 3**). No other significant interaction effects for the considered steroids as moderators of the association between age and negative emotions could be revealed in this sample.

DISCUSSION

In this multi-study report, we intended to replicate findings of increased positive and a decreased negative emotional experience with increasing age (Carstensen et al., 2011; English et al., 2014). Moreover, we aimed to test whether acute levels of steroid hormones measured from saliva, or chronic levels of steroid hormones measured from hair, moderate age-related alterations in emotional experience. Therefore, we investigated emotional experience and steroid secretion in three independent samples of men, which differed with regard to health status, level of exhaustion, and parenthood.

Age and Emotions

Associations were identified between age and emotional experience in adult men. For the 271 SRH men, age was negatively associated with symptoms of anxiety and, as a trend, with symptoms of depression measured with the BSI-18. However, for the 121 VE men, no age-related association emerged for symptoms of anxiety and depression at first glance. For FA men, a negative association emerged between age and symptoms of anxiety (BSI-18) as well as general aggression (measured with the aggression subscale of the full version of the BSI); however, no association with depressive symptoms was observed. Interestingly, large cross-sectional epidemiological studies of Swiss citizens show an age-related increase in subclinical depression, while the percentage of persons with clinically diagnosed depression slightly decreases (Baer et al., 2013). Christensen and colleagues also reported direct age effects on the increase in symptoms of depression and anxiety in 2,622 participants aged between 18 and 79 (Christensen et al., 1999). These results stand in contrast to the finding of an age-related decline in worry frequency in 637 patients with generalized anxiety disorders aged 65 or older (Miloyan and Pachana, 2015). A recent longitudinal study including four large-scale nationwide datasets from different countries shed

some light on these contradictory findings by identifying a U-shaped trend for well-being, with a mid-life nadir around the age of 40 (Cheng et al., 2015). Carstensen et al. observed in a longitudinal study a positive curvilinear association between age and positive emotional experience until the age of 64, followed by a flattening of the slope (Carstensen et al., 2011). However, Gana et al. report in another longitudinal study including 899 older subjects (62–95 years) a linear relationship between age and life satisfaction (Gana et al., 2013). Our results for the SRH men are consistent with the assumption of a U-shaped development of positive emotional experience, as the youngest participants in our sample were aged 40. At this age, a nadir of positive emotional experience was shown; thus, a negative linear association of symptoms of anxiety and depression with age further underline such a U-shaped perspective. Furthermore, a negative association between symptoms of anxiety and age was also found in FA men. However, the lack of association for VE men indicates that subgroups suffering from VE might not show an age-related increase in positive emotional experience due to the well-investigated strong association between vital exhaustion and symptoms of anxiety and depression (McGowan et al., 2004; Rafael et al., 2014). The same picture emerged for measures of aggression, with a negative association between aggression measures and age being found in SRH and FA men, although verbal aggression significantly increased with age in SRH men. This might be due to the shift from internalizing negative feelings at younger ages to expressing more negative feelings at older ages. Such a shift could be an important mechanism through which more positive emotions are experienced with age, as studies have reported that the expression of negative emotions is associated with positive relationship outcomes, including elicitation of support, building of new close relationships, and heightening of intimacy in the closest of these relationships (Graham et al., 2008). However, for VE men, measures of aggression were generally positively associated with age, indicating increased anger experience with vital exhaustion, as previously reported (Keltikangas-Järvinen et al., 1996). Nevertheless, as a trend, VE men showed an age-related increase in positive emotions measured with the PANAS, but no decrease in negative affect.

These results are in line with the socioemotional selectivity theory (SST), which describes an increase in the selection of emotional experience with decreasing life expectancy (Carstensen et al., 2003). With increasing age, increased motivation to engage in emotionally meaningful relationships and activities is reported, as well as a preference for attention to and processing of positive over negative information (English and Carstensen, 2014). Evidence in support of this theory stems from a recent experimental study by Mattan et al., who describe a prioritization of self-relevant perspective-taking, despite generally poorer perspective-taking capacity, in older individuals (Mattan et al., 2017). In this experiment employing two visual perspective-taking paradigms, a shift toward a first-person (vs. a third-person) and a self-associated (vs. other-associated) perspective was observed with increasing age. Furthermore, another investigation of the prevalences of three specific emotional profiles (dissatisfied, happy, resilient) in age groups from 64 to 104 years revealed an age-related decrease in the dissatisfied emotional profile (Etxeberria et al., 2017). Moreover, at around the age of 84, a shift from the happy to the resilient emotional profile seems to occur, further supporting the observed positivity effect in the three examined samples of this report, with the age ranges from 40 to 75 years and 25 to 78 years. In addition, the positivity effect representing a favoring of information relevant to emotion-regulatory goals (predominantly goals related to well-being in older individuals) has been replicated in this study in the SRH men and in part FA men (Reed and Carstensen, 2012). The fact that this age-related positivity effect was not observed in VE men might be best explained by the association of vital exhaustion and reduced cognitive resources (Abd-elfattah et al., 2015). Reduced cognitive resources have previously been identified as the main factor reducing positivity (Reed and Carstensen, 2012). Therefore, VE individuals having less cognitive resources potentially do not show the same positivity effect compared to individuals with sufficient cognitive resources.

Age and Steroids

For the sex steroids T, DHEA, and P, a typical age-related decrease was observed in all three samples (Nankin et al., 1981; Feldman et al., 2002; Frost et al., 2013), with also an age-related decrease of E2 in the SRH men but no association with age in the VE men and the exception of an age-related increase in E2 for FA men, which has been reported previously (Berg and Wynne-Edwards, 2001; Gettler et al., 2011; Perini et al., 2012). However, it is important to remark that the sample of FA men was significantly younger and lower sex steroid levels in the FA men are therefore somewhat surprising. The effect of fatherhood might be responsible for this finding. Both sC and hCrtsl were only positively associated with age in SRH men, which is well-described for the general population in the literature (Karlamangla et al., 2013; Nater et al., 2013; Feller et al., 2014; Miller et al., 2016). However, HPA-axis dysregulation is well-established in mood disorders and its heterogeneous expression in hyper- and hypocortisolism might underlie the lack of association between C and age in VE men (Ehlert et al., 2001; Pariante, 2017; Walther et al., 2017c). The lack of association between age and C in FA men is somewhat surprising, although studies report a decline in C levels in expectant fathers (Berg and Wynne-Edwards, 2001), which might have confounded an age-related increase.

Exploratory Analyses and Correction for Multiple Testing

Exploratory analysis was conducted to detect potential associations between age-related alterations in emotional experience and age-related alterations in steroid secretion in men. This is the first study to investigate moderation effects of the steroids T, DHEA, E2, P, and C as well as cortisone on the age-related decrease in negative emotional experience and increase in positive emotional experience. As we used three independent samples, each with slightly different measures of emotional experience, first of all, we identified measures which were employed in all three studies, such as, the BSI subscales for symptoms of anxiety and depression. Furthermore, for the Men's Health 40+ and Men Stress 40+ studies, the aggression

questionnaire by Buss and Perry (1992) was used, while the study on costs and benefits of fatherhood across the lifespan used the subscale of the BSI on aggression (Spitzer et al., 2011). Therefore, a large number of tests had to be conducted to test every combination between steroid hormone (up to 10 measures) and measure for emotional experience (up to 9 measures) in each of the three samples. This yielded a total of (10 × 9 × 3–missings) 149 comparisons (see **Table 3**). The likelihood of finding a significant association by chance increases with the number of tests (type 1 error; rejecting H_0, when H_0 is correct). Alpha error accumulation with 149 comparisons using an alpha level of 0.05 would increase the probability of detecting a false-positive association from the standard 5 to 745%. Therefore, with 149 comparisons, seven to eight significant associations are expected to occur by chance. In fact, a total of nine significant moderation effects emerged. Importantly, adjusting for multiple comparisons reduces the statistical power of studies, a problem that is especially relevant for psychology, behavioral ecology, and animal studies, which usually try to identify small to medium effects due to the multifactorial nature of behavior (Nakagawa, 2004). This means that with correction for multiple testing, the type 2 or beta error rate increases (not rejecting H_0 when H_0 is false). Therefore, correction for multiple testing and blind adherence to particular p-values has been criticized under certain conditions such as, exploratory analyses, and researchers have called for a shift toward the inclusion of biological significance, effect sizes, and common sense (Cabin et al., 2017). In our case, when applying the Holm-Bonferroni method ($0.5 / (149 - 1 + 1)$) (Abdi, 2010), a minimum p-value of 0.000335 would be necessary to render an association significant. For the moderation analyses, the smallest p-value was 0.0044, indicating no moderation effects of steroid hormones on the association between age and emotional experience at all. However, an analysis of all moderation effects of salivary and hair steroids on age-related alterations in emotional experience yields interesting patterns, which merit further description. Therefore, we followed an exploratory approach, refraining from multiple correction and instead providing an overview of different associations and reporting the 149 comparisons, which may be of interest for further observational or experimental studies (see **Table 3**).

Effects of Steroids on Age-Related Alterations in Emotional Experience

In the samples of SRH and VE men, a negative moderation effect of sC on the association between age and symptoms of anxiety emerged. Higher levels of sC were related to a buffered decrease in symptoms of anxiety with age resulting in stable or higher levels of anxiety experience with age. This is in accordance with a multitude of studies reporting higher levels of basal sC levels in patients with generalized anxiety disorder (Mantella et al., 2008) or other forms of anxiety disorders (Vreeburg et al., 2010). The anxiogenic effects of C administration are also well established (Ardayfio and Kim, 2006; Murray et al., 2008). Interestingly, this was not observed for fathers, with a diminished effect of C being found in FA men, or a floor effect due to lower levels of C due to fatherhood. However, the sampling method differed between the studies: For the SRH and VE men, saliva samples were obtained under standardized conditions during a biological examination performed by well-trained personal at 8:00 am. By contrast, FA men collected their saliva at home, mostly for the first time, which might be the reason for the differences between these groups. In addition, for hCrtsl and hCrtson (a metabolite of C), no moderation effects were detected for the association between age and symptoms of anxiety. However, this has been reported by previous studies investigating associations between patients with anxiety disorders and hCrstl (Steudte et al., 2011; Steudte-Schmiedgen et al., 2017).

sT was a significant moderator of the association between age and symptoms of depression in FA men, indicating an anti-depressant effect of T in the course of aging in these men. A multitude of studies have reported anti-depressant effects of T in mice (McHenry et al., 2014; Carrier et al., 2015), in different subgroups of men (Johnson et al., 2013; Walther et al., 2017c), and especially in older men (Snyder et al., 2016; Walther et al., 2016). However, for healthy men, a lack of association between depressive symptoms and T is often reported (Johnson et al., 2013), and a recently published review stated that evidence for the effectiveness of testosterone treatment in men with low T is lacking (Huo et al., 2016), thus potentially explaining the lack of moderation effect of T and symptoms of depression in SRH men. Furthermore, the lack of association in VE men, who primarily have low levels of vitality, might also be explained by the finding of Snyder et al. (2016) that T treatment in older men had no effect on vitality or physical performance. Nevertheless, salivary T moderated the association between age and symptoms of anxiety in the VE men, and hT moderated the association between age and negative affect. Previous research has demonstrated that T exerts anxiolytic effects (Mahmoud et al., 2016; Wainwright et al., 2016), and that these effects might be mediated in part by the aromatization to E2 (Carrier et al., 2015). However, no moderation effects of sE2 on age-related alterations in emotional experience were observed in any of the samples. Recent research showed that endogenous T mediated the association between cerebellar gray matter and measures of neuroticism, and that higher T levels were associated with lower scores for neurotic personality and larger cerebellar gray matter volumes (Schutter et al., 2017). This provides a cerebellum-oriented framework for the susceptibility to experience negative emotions and mood, moderated by T, thus further strengthening our findings regarding the moderation effect of T on age-related emotional experience.

No moderation effects emerged for DHEA, either for saliva sampling or hair sampling, which contributes further to the list of positive, negative, and null findings related to DHEA and mood or emotional experience in general (Kudielka et al., 1998; Wolf et al., 1998; Izawa et al., 2008; Heald et al., 2017).

With regard to aggression, sP just failed to show significant moderation effects on the age-related decrease in aggression in SRH men, although trends emerged. However, hP seems to exert significant moderation effects on the association between age and physical and verbal aggression in SRH men, but

not in the other samples of men. A similar picture can be observed for hCrtsl and hCrtson on the measures for anger. P is known to have stress-reducing effects and is associated with better mood ratings after psychosocial stress (Childs et al., 2010), as well as reduced cue-induced craving (Fox et al., 2013). However, the association between P and aggression seems to be negative, and in women, high levels of luteal P were associated with low levels of premenstrual aggressive behavior (Ziomkiewicz et al., 2012). For SRH men, physical aggression decreases with age while verbal aggression increases, and hP shows a positive moderation effect for both age-related alterations. Thus, we assume an intensifying effect of P on age-related alterations in aggression expression. Moreover, as verbal aggression has been suggested as a stress-relieving mechanism, higher P levels seem to contribute to a better (more positive) emotional experience with increasing age in healthy men.

In SRH men, hCrtsl and hCrtson were also significant moderators of the association between age and anger. As anger decreases with age in SRH men, higher levels of hCrtsl and hCrtson seem to intensify this association. Studies have linked aggression to increased levels of C in children, with findings of higher levels of C in boys after playing a violent video game (Gentile et al., 2017), increased levels of C in boys with an aggressive form of conduct disorder as well as chronic reactive aggression (Bokhoven et al., 2005), and in boys and girls who had been exposed to violence (Peckins et al., 2012). However, as C increases continuously with age, and has been shown to exert a regulatory function on emotion processing (Lam et al., 2009), it might have an intensifying effect on the age-related decrease in anger perception in healthy men.

Interaction of Steroid Hormones Affecting Emotional Experience

Steroid hormones act as a complex network of reciprocally inhibiting and facilitating agents. Therefore, researchers argue that inclusion and analysis of multiple steroid hormones in studies is of additional value and that combined factors such as, hormone ratios provide additional information about the interaction and balance between certain hormones (Sollberger and Ehlert, 2016). If not investigating hormone interactions but the effects of single hormones such as, cortisol in gender-mixed samples, there is also the recommendation to adjust for sex hormones because of their influencing effect on cortisol secretion (Juster et al., 2016). Furthermore, recent research presents evidence for a dual-hormone hypothesis on testosterone and cortisol. This hypothesis suggests that higher levels of testosterone increase dominance, aggressive, and mating behavior only, if cortisol is low and if, in turn, cortisol is present at high concentrations, higher levels of testosterone decrease the afore mentioned behaviors (Terburg et al., 2009; Mehta and Josephs, 2010; Van Anders, 2013). Therefore, in the presented study higher order moderations were calculated to check for potential interaction effects of steroid hormones on the association between age and emotional experience, but no significant associations emerged (data not shown).

Similarities and Differences between the Samples

On average, the three samples showed high levels of education and income. Therefore, the results from the three independent studies can primarily be generalized to men with a medium to high socioeconomic status. The sample from the Men's Health Study is, on average, 5 years older than the sample from the Men Stress Study, even though the two studies recruited men from the same age range. SRH and FA men showed similar levels of experienced anxiety and depression, while VE men reported higher levels of depressive and anxiety symptoms on average. However, SRH and VE men showed similar levels of experienced aggression. Based on the younger average age of the Men Stress Study sample, one might expect higher levels of sex steroids in the Men Stress Study due to age-related sex steroid decline. However, this was not observed for the salivary sex steroids, possibly due to the overall health status of the men from the Men Stress Study, who had elevated levels of vital exhaustion. Good general health has been shown to reduce or even prevent age-related sex steroid decline (Feldman et al., 2002; Sartorius et al., 2012; Walther et al., 2016), while mortality is associated with a decline in sex steroids (Hsu et al., 2016). Furthermore, a male-specific pattern for mood disorders has been suggested, with overall decreased androgen levels (Walther et al., 2017c), while for FA men, lower levels of androgens were expected due to fatherhood, as observed in the third sample (Perini et al., 2012; Waldvogel and Ehlert, 2016). However, for C, a conflicting picture emerged with regard to saliva and hair samples. However, as mentioned above the comparability of FA men with the SRH and VE men is limited due to the different age range and different sampling methods for the salivary analytes. Though FA men are in average younger than the SRH and VE men they show lower levels of sT. This might be explained by their role as a father, which is associated with reduced T levels and outweigh the effect of age. SRH and FA men showed similar levels of sC, while VE men showed relatively low levels of sC in comparison. This has previously been reported in patients with clinical burnout, for whom exhaustion plays a major role (Lennartsson et al., 2015). Furthermore, mean hCrtsl and hCrtson levels were higher in VE men than in SRH men, indicating that vital exhaustion is associated with elevated hair C and cortisone. This is in line with previous studies demonstrating higher levels of C in related conditions such as, burnout or depression (Ehlert et al., 2001; Menke et al., 2014; Pariante, 2017).

Similarities and Differences between Men and Women

The question whether similar effects would be observed in female samples based on the presented results is hard to answer because of three major differences between male and female endocrinology. First, women undergo endocrine changes during menopause in a much more condensed time period (average age of starting menopause is 51 years with an average duration of 4–10 years) and in a much more dramatic way compared to men (abrupt decline of estrogens and progesterones vs. continuous decline of androgens). Therefore,

women over 40 years can't be regarded as a homogeneous group with regard to their circulating sex hormone levels and subgroups of pre-, (peri-,) and post-menopausal women need to be examined separately in order to dissect the effects of steroid hormones for each subgroup individually as shown previously (Drobnjak et al., 2014). Second, circulating levels of sex steroids are significantly different between sexes showing for example up to 10 times higher androgen levels in males raising the question of physiological relevant hormone levels for certain steroids to act as neuroactive steroids. And third, during the fetal development the male and female brain are differentially programmed because of the different amounts of sex steroids secreted by the fetus and circulating in the womb (Seckl, 1998; Schore, 2017). Therefore, different levels of steroid hormones might have similar effects in men and women due to differential sensitivity to certain hormones represented by differences in steroid receptor distribution or function. However, since the menopausal transition is characterized by a decline of estrogen and progesterone it could be assumed that lower levels of estrogen and progesterone contribute to the observed changes in emotional experience. However, studies investigating estrogen and progesterone replacement in post-menopausal women contrast this hypothesis by reporting beneficial effects on mood with hormone replacement therapies (Fitzpatrick et al., 2000; Gleason et al., 2015). Therefore, studies investigating the moderating effects of steroid hormones on the age-related alterations in emotional experience in women are needed.

LIMITATIONS

Several limitations need to be taken into account when interpreting these results. The three studies employed cross-sectional designs and causal inferences cannot be drawn. Whether or not certain steroid hormones intensify age-related changes in emotional experience cannot be determined from the present findings. Only associations were identified, although these associations also need to be interpreted with caution, as we conducted a multitude of comparisons in an exclusively exploratory manner, without correction for multiple testing. Identified moderation effects might serve as initial starting points to further investigate the potential effects of steroids on age-related alterations in emotional experience using experimental designs. Furthermore, saliva sampling differed in one study, potentially increasing measurement error. Salivary analytes were obtained via a single measurement time point on a single day. However, salivary steroid hormones tend to vary significantly between days. Repeated measures on consecutive days would increase the robustness of the results and reduce between-day variance in steroid secretion. Furthermore, on average, psychometric measures were obtained 1 to 2 weeks before sampling of the hormone parameters. Experimental research designs measuring emotional experience in different age groups, manipulating hormone levels in a controlled manner, are needed to further test the revealed associations and identify causality.

CONCLUSION

Age-related alterations in emotional experience were identified in three independent samples of men. In support of the SST and the age-related positivity effect, a general shift toward more positive emotions was identified for SRH and FA men with increasing age, although this was not found for VE men, in whom detrimental effects of vital exhaustion on emotional experience in aging men emerged. Several potential moderation effects of steroid hormones were described, which merit further investigation. Since moderation effects faded after controlling for multiple comparisons, single significant results on emotional experience need to be replicated in experimental studies manipulating hormone levels systematically in different age groups before drawing final conclusions. Hormonal supplementation or the use of antagonists has been shown to support healthy aging in men and women (Lunenfeld et al., 2013; Walther and Ehlert, 2015; Hamoda et al., 2016), and might further support a successful aging process in men by intensifying the positivity shift with age. However, to date there is not sufficient empirical evidence for hormonal supplementation or antagonists facilitating the age-related positivity shift. Furthermore, the presented results are generalizable to adult males up to 75 years of age only while with respect to women, which differ substantially in basal steroid levels or secretion patterns from men, no conclusions can be drawn. Still, as emotional experience directly affects morbidity and mortality (Carney et al., 2002; Kiecolt-glaser et al., 2002; Carstensen et al., 2011; Steptoe and Wardle, 2011), it should be a public health goal to increase positive emotional experience. Therefore, more research is needed to elucidate the role of steroid hormones on the age-related shift toward more positive emotional experience.

AUTHOR CONTRIBUTIONS

AW, PW, EN, JR, and UE contributed equally to the design of the study and the data collection, analysis, and interpretation of the data. AW wrote the first draft of the manuscript. PW wrote the specific sections of study 3 and was leading for the representation of data in the tables. EN and JR edited subsequent versions of the manuscript. UE reviewed the manuscript during different stages of the process for intellectual content and edited the manuscript to its final version. All authors approved the final version of the manuscript.

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Age and Gender Differences in Facial Attractiveness, but Not Emotion Resemblance, Contribute to Age and Gender Stereotypes

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Considerable research has shown effects of facial appearance on trait impressions and group stereotypes. We extended those findings in two studies that investigated the contribution of resemblance to emotion expressions and attractiveness to younger adults (YA) and older adults (OA) age and gender stereotypes on the dimensions of warmth and competence. Using connectionist modeling of facial metrics of 240 neutral younger and older faces, Study 1 found that, neutral expression older faces or female faces showed greater structural resemblance to happy expressions and less resemblance to angry expressions than did younger or male faces, respectively. In addition, neutral female faces showed greater resemblance to surprise expressions. In Study 2, YA and OA rated the faces of Study 1 for attractiveness and for 4 traits that we aggregated on the dimensions of competence (competent, healthy) and warmth (trustworthy, not shrewd). We found that YA, but not OA, age stereotypes replicated previous research showing higher perceived warmth and lower perceived competence in older adults. In addition, previously documented gender stereotypes were moderated by face age for both YA and OA. The greater attractiveness of younger than older faces and female than male faces influenced age and gender stereotypes, including these deviations from prior research findings using category labels rather than faces. On the other hand, face age and face sex differences in emotion resemblance did not influence age or gender stereotypes, contrary to prediction. Our results provide a caveat to conclusions about age and gender stereotypes derived from responses to category labels, and they reveal the importance of assessing stereotypes with a methodology that is sensitive to influences of group differences in appearance that can exacerbate or mitigate stereotypes in more ecologically valid contexts. Although the gender differences in attractiveness in the present study may not have generalizability, the age differences likely do, and the fact that they can weaken the attribution of greater warmth and strengthen the attribution of lower competence to older than younger individuals has important practical implications.

Keywords: face perception, emotion resemblance, traits impression, connectionist models, aging, stereotypes, facial expression, attractiveness

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INTRODUCTION

Cultural wisdom instructs us not to judge a book by its cover. This warning suggests both that our natural inclination is to judge people by their appearance and also that doing so will lead to adverse effects. Both are true. On the first point, trait impressions from faces are fast and automatic, elicited by exposure as brief as 100 ms or less (Willis and Todorov, 2006). Moreover, there is remarkable consensus in trait impressions from faces that extends across diverse cultures (Zebrowitz et al., 2012) and shows similarities across the lifespan (Keating and Bai, 1986; Montepare and Zebrowitz-McArthur, 1989; Langlois et al., 1990; Zebrowitz et al., 2013; Cogsdill et al., 2014). The second point implied by the caution against judging people by their appearance is supported by evidence that this does yield adverse effects by contributing to race, gender, and age stereotypes. The fundamental dimensions underlying trait impressions are warmth and competence (Rosenberg et al., 1968), which capture both trait impressions from people's faces (Todorov et al., 2015) and group stereotypes (Cuddy et al., 2008). The present research investigated the contribution of variations in facial appearance to age and gender stereotypes on these dimensions, which has not been previously addressed.

Age Stereotypes and Contributions of Appearance

Age stereotypes are manifested in the attribution of similar traits to older vs. younger people in the absence of meaningful individuating information. There is considerable evidence for negative stereotypes of older people across many cultures (Nelson, 2002; Löckenhoff et al., 2009; North and Fiske, 2015). These include negative stereotypes regarding the competence of older adults, such as the perception that aging is associated with declines in competence at performing everyday tasks and new learning (Löckenhoff et al., 2009). Other research has conceptualized age stereotypes on the dimensions of warmth and competence (Cuddy and Fiske, 2002; Cuddy et al., 2005). This work found that trait impressions of older adults based on their category membership were more negative than impressions of younger adults on the dimension of competence, including the traits "skillful" and "able," but more positive on the dimension of warmth, including the traits "trustworthy" and "sincere." These results led to the conclusion that elderly people are stereotyped as "doddering, but dear" (Cuddy and Fiske, 2002). However, the question remains as to whether these age stereotypes generalize to those elicited by actual people rather than category labels. The present study begins to fill this gap in the literature.

A previous study that assessed impressions of photographs of neutral expression older and younger faces, rather than using category labels, found that older faces were judged less energetic and less growth-oriented (Ebner, 2008). Other reseearch using photographs has found positive as well as negative impressions of older people. Specifically, some photographs of older people evoked positive stereotypes while others evoked negative stereotypes (Brewer et al., 1981). However, the physical attributes that elicited the varying impressions of older adults were not identified in this work, and the stereotypes themselves were not explictly mapped onto the well-established competence and warmth dimensions of trait impressions. The present study addressed these issues.

Previous research examining stereotypes of the elderly also found that older adults were judged to be less attractive (Ebner, 2008; Löckenhoff et al., 2009), and other research has shown that age stereotypes are linked not simply to chronological age, but also to physical appearance. Specifically, unattractive physical qualities, such as wrinkling, gray hair, and baldness, are associated with more negative impressions of elderly faces (Hummert, 1994; Muscarella and Cunningham, 1996; Hummert et al., 1997). In addition, Zebrowitz et al. (2003) found that, compared with younger faces, older faces showed greater resemblance to faces with genetic anomalies and this contributed not only to impressions of older faces as less attractive, but also to impressions of them as less healthy, sociable, and intelligent than younger faces. More generally, the well documented attractiveness halo effect (Eagly et al., 1991) provides reason to believe that the lower attractiveness of older faces would augment negative stereotoypes, like incompetence, and weaken positive stereotypes, like warmth. Older and younger faces differ in many ways besides attractiveness. One that will be examined in the present research is a possible difference in their resemblance to emotion expressions. Research has documented an influence of emotion resemblance on impressions of warmth and competence (Zebrowitz et al., 2007, 2010) and, as discussed more fully below, there is reason to expect differences between younger and older faces.

Gender Stereotypes and Contributions of Appearance

The dimensions of warmth and competence capture gender stereotypes as well as age stereotypes, with men perceived as higher than women in competence, and women perceived as higher in warmth (Eagly and Steffen, 1984; Fiske et al., 2002; Cuddy et al., 2008). Although this work has examined stereotypes based on gender labels, other research has demonstrated that male-female differences in appearance contribute to the stereotypes. Indeed, Deaux and Lewis (1984) found that physical appearance was the single most influential component of sex-role stereotypes. Participants inferred traits that were consistent with a description of the target's body build even when those inferences were inconsistent with those associated with the target's gender label. Another study showed that sex stereotypes are also influenced by typical sex differences in facial appearance. Women's faces are more neotenous than men's (Enlow, 1990), and these variations in babyfaceness have a strong effect of gender stereotypes. When facial maturity was typical (babyfaced women, maturefaced men), the women were perceived as warmer and less competent than the men. However, when the male faces were manipulated to be babyfaced and the female faces to be maturefaced, the gender stereotyped attribution of warmth was eliminated and the women were perceived as more competent than the men (Friedman and Zebrowitz, 1992). As discussed in more detail below, babyfaceness is related to emotion resemblance (Marsh et al., 2005; Zebrowitz

et al., 2007), and research investigating differences in the emotion resemblance of neutral expression male and female faces has found that female faces are more similar than male faces to happy and surprised expressions and less similar to angry expressions (e.g., Becker et al., 2007; Zebrowitz et al., 2010).

The aim of the work to be reported here was to investigate how variations in facial appearance moderate age and gender stereotypes. In Study 1, using connectionist modeling, we assessed differences in the resemblance to emotion expressions of neutral expression younger and older male and female faces. We sought to determine whether an objective measure of emotion resemblance, free from cultural expectations, is related to age differences. In addition, we sought to replicate previous evidence for objective differences in the emotion resemblance of male vs. female faces and extend that evidence to older faces. In Study 2, we examined the contribution of face age and sex differences in emotion resemblance to YA and OA age and gender stereotypes. Furthemore, considering that previous studies found that lower facial attractiveness is associated with more negative impressions and that older adults tend to be judged less attractive, we also investigated the contribution of group differences in attractiveness to these age related stereotypes.

STUDY 1: FACE AGE AND SEX DIFFERENCES IN RESEMBLANCE TO EMOTION EXPRESSIONS

Study 1 investigated face age and sex differences in resemblance to happy, angry, and surprised expressions. We examined these expressions because, as discussed in more detail in the introduction to Study 2, each has previously been shown to influence impressions of warmth and competence, which are the two strongest components of age and gender stereotypes.

Previous research has documented similarities between facial expressions of emotion and neutral expression faces from various demographic groups. Faces of babies resemble surprise and fear expressions more than do faces of adults, and babies show less resemblance to anger, effects that have been demonstrated both by subjective ratings of the faces (Marsh et al., 2005) and by connectionist modeling using facial metrics (Zebrowitz et al., 2007). Consistent with evidence that women's faces are more neotenous than men's (Enlow, 1990), female faces are associated with surprise expressions and male faces with angry ones (Le Gal and Bruce, 2002; Becker et al., 2007; Zebrowitz et al., 2010). There is also some evidence that female neutral faces resemble happy expressions more than do male faces (Hess et al., 1997; Becker et al., 2007).

Whereas gender comparisons and age comparisons involving infants vs. adults have shown that emotion resemblance varies across these demographic groups, comparisons of older and younger adult faces are less clear. Research using subjective assessments of resemblance have found that neutral expression older faces are likely to be misperceived by younger raters as any one of several emotion expressions (Malatesta et al., 1987; Ebner, 2008; Freudenberg et al., 2015). Similarly, automated emotion recognition software (CERT) that registers the intensity of different facial action units yielded lower probability estimates that neutral expressions were neutral when posed in older than younger faces (Freudenberg et al., 2015). This research also found that older faces with neutral expressions were rated higher in anger, contempt, disgust, and happiness than younger faces, but lower in sadness, with no differences in perceptions of fear or surprise (Freudenberg et al., 2015).

The advantage of an objective measure, like CERT, is that it removes the influence of similarities between the *cultural meaning* of the demographic categories and the emotion expressions, such as the assumption that men are more likely to be angry than women (Hess et al., 1997), thus clearly identifying *structural similarities* between faces from certain demographic categories and those with certain emotion expressions. In the present study, we used connectionist modeling, which is also impervious to stereotyped assumptions about the emotion resemblance of different demographic groups. Whereas CERT registers facial action units associated with emotion expressions, connectionist modeling assesses whether facial metrics, such as eye height, nose width, and chin length reveal greater structural similarities between older than younger faces and certain emotion expressions. Such structural similarities could be occasioned by age-related bone resorption and/or it could be a by-product of textural changes. For example, sagging upper eyelids may make the eyes look smaller.

We derived our predictions for age differences in emotion resemblance from previous research that used connectionist modeling to investigate the resemblance of elderly and young adult faces to babies, finding elderly faces more similar to babies than young adult faces (Zebrowitz et al., 2003). Although it may be surprising to find that older adults are more baby-faced, age-associated bone loss causes elderly people to have small jaws, double chins, and jowls, just as babies do. Indeed, the characterization of elderly stereotypes as "doddering but dear" (Cuddy and Fiske, 2002) captures the incompetence and warmth that characterizes impressions of babies. Given that elderly faces resemble babies more than do young adult faces, and that baby faces resemble anger less than young adult faces (Marsh et al., 2005; Zebrowitz et al., 2007), we predicted that elderly faces would also resemble anger expressions less than young adult faces. Although our previous research found that faces of babies and young adults did not differ in resemblance to happy faces, this may have been due to the large eyes that characterize babies, in contrast to the squinting eyes of a smile that may be more characteristic of elderly adult eyes. This, coupled with evidence from CERT that older faces resemble happy expressions more, led us to predict that older faces would resemble happy expressions more than younger ones. In addition, we thought that, unlike babies with wide eyes, older faces may not resemble surprise faces more, even though babies, as compared with adults, do. Finally, we expected to replicate previous findings that female faces resemble happy and surprise expressions more than male faces do, with the reverse for angry faces, and we expected these results to be extended to older as well as younger faces.

Method

Connectionist models were trained to recognize the facial metrics of anger, happy, and surprise expressions in Caucasian male and female young adult training/test faces. The extent to which the models detected similarities to these emotions in neutral expression faces was then examined using a separate set of younger and older generalization faces.

Faces

Training/test faces

Training/test faces were taken from a previous study (Zebrowitz et al., 2007). They included digitized black and white portrait photos of 26 Caucasian men and 26 Caucasian women in their 20s or 30s, each of whom posed neutral, happy, angry, and surprise expressions. Previously reported validations of the database demonstrated significantly higher ratings of anger for angry faces than each of the other categories, higher ratings of happy for happy faces than each of the other categories, and higher ratings of surprise for surprise faces than each of the other categories (Zebrowitz et al., 2007).

Generalization faces

Generalization faces included 120 older and 120 younger neutral expression faces, with men and women equally represented within each age group. All faces were Caucasian. The entire set of 240 faces was selected from three different databases: 105 neutral expression faces (47 older faces) were selected from the FACES database (Ebner et al., 2010) which comprises digital high quality, front-view photographs of three different age groups; 8 neutral expression older faces were selected from the Humboldt face set (Fölster et al., 2015). The remaining 127 neutral expression faces (65 older faces) were selected from The Center for Vital Longevity Face Database (Minear and Park, 2004) created at the University of Michigan. The younger faces were photographed between 18 and 31 years of age ($M = 23.06$, $SD = 3.22$) and the older faces were photographed between 65 and 91 years of age ($M = 73.42$, $SD = 5.41$). We used four criteria for image selection: neutral expression, no head tilt, no eyeglasses, and no beards. To verify that faces had neutral expressions, four judges (2 males) provided smile ratings on a 5-point scale with endpoints labeled 1 = no smile and 5 = big smile. All faces were shown in gray-scale.

Following the procedure reported by Zebrowitz et al. (2007), in house software was used to mark 64 points on digitized images of each face from which facial metrics were computed using automatic procedures written in Visual Basic and Excel (**Figure 1**). After establishing reliability (>0.7) for points marked by two judges on a random subset of 24 faces for each category, one judge marked the remaining faces and those points were used to calculate the final facial metrics. Eighteen non-redundant facial metrics were selected as full facial inputs to the connectionist model. These included facial roundness plus the metrics shown in **Figure 1**. Facial roundness was computed by determining the average of the radii of two circles—one created by connecting facial points 31 right, 35 right, and 12, and another circle connecting facial points 31 left, 35 left and 12, with a smaller average radius signifying more roundness. To adjust for variations in distance from the camera, each facial metric was normalized by an additional metric, inter-pupil distance (E2) (Zebrowitz et al., 2007).

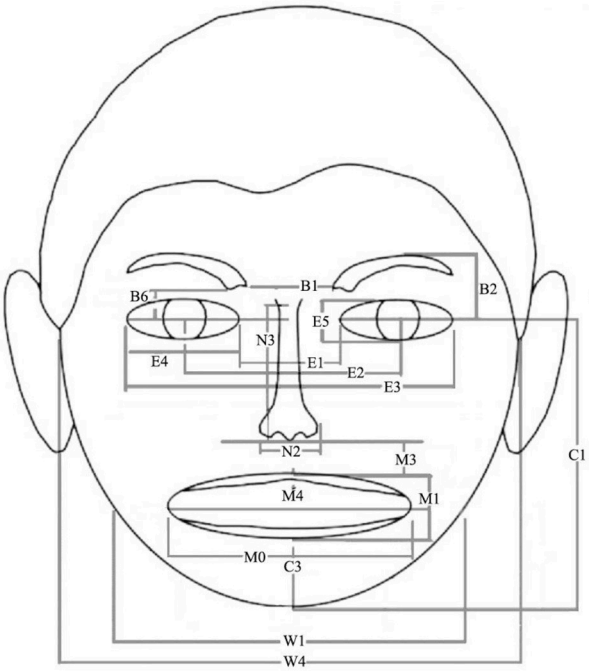

FIGURE 1 | Location of facial metrics used as inputs to the connectionist models trained on facial metrics. All metrics were normed by E2, interpupil distance. B1, Eyebrow separation; B2, Eyebrow height; B6, Distance from lower inner corner eyebrow and top of eye; E1, Eye separation; E2, Interpupil distance (used to normalize other measures); E3, Distance between outer corners of eyes; E4, Horizontal eye width; E5, Eye height; C1, Chin to pupil height; C3, Chin length; M0, Mouth width; M1, Lip thickness; M3, Distance from end of nose to middle top of upper lip; M4, Upper lip thickness; N2, Nose width; N3, Nose length; W1, Jaw width; W4, Face width.

Connectionist Modeling

The *total set* of faces used to train the network was composed of 208 faces (52 each for neutral, surprise, angry, happy expressions). Networks were trained to differentiate either happy from neutral faces, surprise from neutral faces, or angry from neutral faces. On each of 20 trials, 34 neutral and 34 emotion faces (either happy, surprise, or angry faces) were randomly selected from the total set to compose the *training set*, with a different random set of faces selected on each trial. The remaining 18 faces in each of the two categories composed the *test set*. The modeling had three phases. First, in the *training phase*, the 18 reliable facial metrics were provided as input to artificial neural networks that were trained with supervised learning to differentiate the 68 training faces (34 men), half with a neutral expression and half with an emotion expression. In the second or *test phase*, the trained network was tested on the set of 36 test faces (18 men) that differed in the emotion on which the network had been trained in order to establish that training was successful. In the third, *generalization phase*, the trained network was provided with input metrics from the 240 neutral expression generalization

faces, and the extent to which the output units responded to each of these faces was determined. These three phases were repeated for 20 trials to establish a reliable index of network activation by each face. Performing the entire procedure for networks trained to differentiate neutral expression faces from each of the three different emotion expressions generated three dependent variables for each generalization face: average activation across 20 trials of the happy output unit, the surprise output unit, and the angry output unit.

The connectionist models were standard back-propagation neural networks with one input layer, one hidden layer, and one output layer. Each input node projected to any or all of the hidden nodes and the hidden nodes projected to the two output units (neutral and one of the emotions). The input weight matrices connecting the layers consisted of numbers between –1 and 1. The output units were rescaled into graded values ranging from 0 to 100% activation. All units were nonlinear and mapped the weighted sum of their inputs to their output using a sigmoidal transfer function. The training parameters were 4 hidden nodes, 3,000 training epochs per trial, a 0.02 learning rate, and a 0.2 error goal.

Results

Reliability of Facial Metrics

High inter-judge agreement for the facial metrics of the emotion expression faces (cf. training and test set) was previously reported by Zebrowitz et al. (2007). The selected input metrics for the faces in the generalization set also showed high agreement both for the normalization interpapillary distance, $r = 0.92$, and the selected input metrics (>0.786; mean $r = 0.87$).

Network Training

Surprise-neutral networks

Training a network to differentiate surprise and neutral faces achieved 92.43% correct identification of the 68 training faces and 85.14% correct identification of the 36 test faces, averaged across 20 trials, with significantly higher activation of the surprise unit by surprise faces ($M = 82.82$, $SD = 17.30$) than neutral ones ($M = 18.18$, $SD = 12.38$), $F_{(1, 102)} = 479.79$, $p < 0.001$, $\eta^2 = 0.825$.

Anger-neutral networks

Training a network to differentiate angry and neutral faces achieved 88.31% correct identification of the 68 training faces and 72.78% correct identification of the 36 test faces, averaged across 20 trials with activation of the angry unit significantly higher for angry faces ($M = 73.97$, $SD = 24.69$) than for neutral ones ($M = 22.55$, $SD = 16.63$), $F_{(1, 102)} = 155.07$, $p < 0.001$, $\eta^2 = 0.603$. It should be noted that the less successful training of the anger- than the happy- or surprise-neural networks is consistent with human judges' ratings of the faces. Zebrowitz et al. (2007) found that the neutral faces were rated higher in anger than in happiness or surprise. Also, although neutral faces were rated the lowest of all expressions in surprise and happiness, they were rated second only to anger faces in anger, a finding that is consistent with other evidence concerning similar reactions to neutral and anger expressions (e.g., Vrana and Gross, 2004).

Happy-neutral networks

Training a network to differentiate happy and neutral faces achieved 92.75% correct identification of the 68 training faces and 86.39% correct identification of the 36 test faces, averaged across 20 trials with activation of the happy unit significantly higher for happy faces ($M = 79.89$, $SD = 16.60$) than for neutral ones ($M = 19.14$, $SD = 11.87$), $F_{(1, 102)} = 460.10$, $p < 0.001$, $\eta^2 = 0.819$.

Smile Ratings of Generalization Faces

A 2 (Face Age) × 2 (Face Sex) ANOVA on the smile ratings for these faces revealed no significant effect of face age ($M = 1.37$, $SD = 0.49$ and $M = 1.28$, $SD = 0.41$, for older adults and younger adults respectively), $F_{(1, 236)} = 2.36$, $p = 0.125$, $\eta^2 = 0.010$, no significant effect of face sex ($M = 1.30$, $SD = 0.48$ and $M = 1.33$, $SD = 0.42$, for men and women respectively), $F_{(1, 236)} = 0.22$, $p = 0.642$, $\eta^2 = 0.001$, and no significant face age × face sex interaction, $F_{(1, 236)} = 0.56$, $p = 0.453$, $\eta^2 = 0.002$. The final set of 240 faces (see footnote[1]) consisted of 120 Older faces (60 male) and 120 Younger faces (60 male).

Effects of Face Age and Sex on Emotion Resemblance

The means and *SD*s in **Table 1** shows how much neutral expression faces of each age and sex activated the network units trained to recognize angry, happy, and surprise faces. A higher activation of the network unit signifies higher resemblance of the face to the emotion for which the network is trained.

Surprise unit activation

Face Age had a no significant effect on activation of the network unit trained to recognize surprise faces, $F_{(1, 236)} = 1.44$, $p = 0.231$, $\eta^2 = 0.006$ ($M = 23.58$, $SD = 13.24$ and $M = 21.53$, $SD = 13.31$ for older and younger faces, respectively), while female faces activated this network unit ($M = 24.36$, $SD = 14.78$) significantly more than did male faces ($M = 20.76$, $SD = 11.38$), $F_{(1, 236)} = 4.44$, $p = 0.036$, $\eta^2 = 0.018$. There was no significant face age × face sex interaction, $F_{(1, 236)} = 0.22$, $p = 0.636$,

TABLE 1 | Effects of face age and sex on emotion resemblance.

Face	Surprise		Angry		Happy	
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***
Old	23.58	13.24	43.96	13.96	34.38	12.14
Young	21.53	13.31	53.99	16.88	17.26	8.47
$F_{(1, 236)}$	1.444		26.332****		166.424****	
Female	24.35	14.78	45.43	16.07	27.99	13.69
Male	20.76	11.38	52.53	15.71	23.65	13.04
$F_{(1, 236)}$	4.445*		13.190****		10.649***	

*N = 240, *p < 0.05, ***p < 0.005, ****p < 0.001.*

[1]Although the mean ratings of the faces confirmed that they had neutral expressions with no sex or age differences, we also examined activation for a subset of 191 faces that had mean smile ratings no greater than 1.50. The results were identical to the full set.

$\eta^2 = 0.001$. These results indicate that neutral expression female faces resemble surprise expressions more than do male faces.

Anger unit activation

Neutral expression younger faces activated the network unit trained to recognize angry faces ($M = 53.99$, $SD = 16.88$) significantly more than did older faces ($M = 43.96$, $SD = 13.96$), $F_{(1, 236)} = 26.33$, $p < 0.001$, $\eta^2 = 0.100$, and male faces activated this network unit ($M = 52.53$, $SD = 15.71$) significantly more than did female faces ($M = 45.43$, $SD = 16.07$), $F_{(1, 236)} = 13.19$, $p < 0.001$, $\eta^2 = 0.053$. There was no significant face age × face sex interaction, $F_{(1, 236)} = 0.12$, $p = 0.731$, $\eta^2 = 0.001$. These results indicate that neutral expression younger faces and male faces resemble anger more than do older faces and female faces, respectively.

Happy unit activation

Neutral expression older faces activated the network unit trained to recognize happy faces ($M = 34.39$, $SD = 12.14$) significantly more than did younger faces ($M = 17.26$, $SD = 8.47$), $F_{(1, 236)} = 166.42$, $p < 0.001$, $\eta^2 = 0.414$, and female faces activated this network unit ($M = 27.99$, $SD = 13.69$) significantly more than did male faces ($M = 23.65$, $SD = 13.04$), $F_{(1, 236)} = 10.65$, $p = 0.001$, $\eta^2 = 0.043$. There was no significant face age × face sex interaction, $F_{(1, 236)} = 0.57$, $p = 0.812$, $\eta^2 < 0.001$. These results indicate that neutral expression older faces and female faces resemble happy expressions more than do younger and male faces, respectively.

Discussion

Study 1 provides objective evidence for differences in the resemblance of older vs. younger and female vs. male neutral expression faces to particular emotions that are not vulnerable to biases introduced by age or gender stereotypes. Specifically, as predicted, the facial metrics of younger faces resemble anger expressions more than do those of older faces and the metrics of older faces resemble happy expressions more than do those of younger faces. Also as predicted, the facial metrics of male faces resemble anger expressions more and happy expressions less than do those of female faces, and male faces resemble surprise expressions less than do female faces.

The effects of face age on anger resemblance are consistent with previous evidence that older faces resemble babies more, since baby faces also show less resemblance to anger than do young adult faces (Zebrowitz et al., 2003). The effects of age on happy resemblance are consistent with recent evidence using a different method of assessing objective resemblance to emotion expressions, CERT (Freudenberg et al., 2015). Although baby faces show more resemblance to surprise than young adult faces, we did not find this effect for older faces, perhaps due to the effects of aging to reduce visible eye size in older adults. The effects of face sex on anger and happy resemblance are consistent with previous research (Hess et al., 1997; Becker et al., 2007; Zebrowitz et al., 2010). In addition, we found that these effects of face sex held true for both older and younger faces, and that the effects of face age held true for both male and female faces, questions that had not been addressed in previous research.

STUDY 2: THE CONTRIBUTION OF EMOTION RESEMBLANCE AND ATTRACTIVENESS TO AGE AND GENDER STEREOTYPES

In the second study, we used the network's estimate of the probability that each face is showing a particular emotional expression, to investigate the contribution of face age and sex differences in emotion resemblance to age and gender stereotypes, respectively. As noted earlier, emotion resemblance not only varies across demographic categories, but also it contributes to trait impressions and group stereotypes. Specifically, the adaptive value of responding appropriately to emotional expressions, such as avoiding an angry person or approaching a happy one, is overgeneralized to individuals whose facial structure merely resembles a particular emotional expression, with effects on trait impressions of those individuals that extend to group stereotypes (Zebrowitz and Collins, 1997; Zebrowitz et al., 2010; Zebrowitz and Montepare, 2014).

Neutral expression faces that show more resemblance to an angry expression, either as assessed by human raters (Montepare and Dobish, 2003) or by objective methods (Zebrowitz et al., 2007, 2010; Said et al., 2009) are perceived as lower on a warmth dimension and higher on a competence dimension, with opposite impressions of neutral faces showing greater resemblance to a happy expression. Neutral expression faces that show more objective resemblance to a surprise expression also are perceived as less competent and more warm than those with less resemblance to surprise (Zebrowitz et al., 2007). These effects have been documented for both YA and OA judges (Franklin and Zebrowitz, 2013), although resemblance has been assessed only for young adult faces. Pertinent to the current focus on effects of emotion resemblance on age and gender stereotypes, research also has shown that race differences in emotion resemblance contribute to race stereotypes (Zebrowitz et al., 2010).

As noted above, attractiveness also makes a strong contribution to impressions of warmth and competence (Eagly et al., 1991, and this has been documented for OA as well as YA (Zebrowitz et al., 2014). In Study 2 we investigated YA and OA age and gender stereotypes. We also predicted that face age and face sex differences in emotion resemblance and attractiveness would contribute to the stereotypes.

Age and Gender Stereotype Predictions

Consistent with the literature discussed earlier, we predicted that older faces and female faces would be judged more positively on a warmth dimension but more negatively on a competence dimension, as compared with younger and male faces, respectively. Research investigating whether these stereotypes vary with rater age have yielded mixed results. Some studies examining rater age differences failed to find differences in age stereotypes (e.g., Bailey, 1991; Erber and Rothberg, 1991), while others suggest that older adults (OA) have more positive attitudes toward aging and older faces than do younger adults (YA) (for reviews see Kite et al., 2005; Ebner, 2008). These results led us to predict that any differences between younger and older

raters would show more positive responses to older faces by the latter group. We did not predict any age differences in gender stereotypes, since research indicates similar effects across age (Nesbitt and Penn, 2000; Ebert et al., 2014; Siyanova-Chanturia et al., 2015; Strobach and Woszidio, 2015), although none of this work examined impressions from faces.

Emotion Resemblance Predictions

The age differences in emotion resemblance documented in Study 1 together with evidence that both happy and surprise resemblance increase perceived warmth,while anger resemblance decreases it (Zebrowitz et al., 2007, 2010) and that both anger and surprise resemblance decrease perceived competence (Zebrowitz et al., 2007, 2010) yielded the following predictions: (1) controlling the greater resemblance of older faces and female faces to happy expressions and their lesser resemblance to anger would weaken the perception of higher warmth in older and female faces compared with younger and male faces, respectively; (2) controlling older and female faces lesser resemblance to anger would weaken the perception of lower competence in older and female faces compared with younger and male faces, respectively; and (3) controlling female faces greater resemblance to surprise would weaken the perception of their greater warmth and the perception of their lower competence as compared with male faces.

Attractiveness Predictions

Previous evidence that older faces are less attractive (Zebrowitz et al., 2003; Ebner, 2008; Löckenhoff et al., 2009) led us to expect that they also would be perceived as less attractive than younger ones in our study. We further predicted that: (1) perceptions of greater warmth in older than younger adults would be strengthened when controlling the negative contribution of older adults lesser attractiveness to perceived warmth and (2) perceptions of lesser competence in older than younger adults would be weakened when controlling the negative contribution of older adults' lesser attractiveness to perceived competence. Finally, although we had no reason to expect the male and female faces to differ in attractiveness, any differences would yield similar expectations regarding the effects of controlling attractiveness on impressions of warmth and competence.

Method

Participants

Five groups of 20 OA and 20 YA, with equal numbers of men and women in each group, participated in the study for a total of 100 OA and 100 YA individuals. YA were students recruited from University of Chieti, Italy while OA were recruited from the local community. The study was approved by the local departmental ethical committee. All participants were volunteers and provided their written informed consent.

Each group was asked to rate the 240 faces used in Study 1 on just one of five dimensions: competence; health; naivete; trustworthiness and attractiveness. Although the average age of the OA and YA participants differed slightly across rater groups no age differences between groups were found for either OA raters, $F_{(4, 95)} = 0.97$, $p = 0.426$, $\eta^2 = 0.039$, or YA raters, $F_{(4, 95)} = 1.70$, $p = 0.157$, $\eta^2 = 0.067$.

Procedure

Each of the 240 faces used in Study 1 was rated on a 7-point scale for competence (1—not at all competent/per nulla competente; 7—very competent/molto competente); health (1—not at all healthy/ per nulla sano; 7—very healthy/molto sano); shrewedness (1—very naïve/molto ingenuo; 7—very shrewd/molto furbo); trustworthiness (1—not at all trustworthy/per nulla affidabile; 7—very trustworthy/molto affidabile) and attractiveness (1—not at all attractive/per nulla attraente; 7—very attractive/molto attraente). The rating task was administered using OpenSesame version 0.27.3, a graphical open-source experiment builder for the social sciences. Each face was randomly presented for 2 s after which the rating scale appeared. Once participants made their rating, a new face was shown. The experiment lasted approximately 15 min. Inter-Rater Reliability for YA and OA across the 5 ratings are shown in **Table 2**.

Results

Factor Analyses of Trait Impressions

We performed separate factor analyses on OA and YA ratings of the faces, excluding attractiveness, to confirm the 2-dimensional "competence" and "warmth" dimensions documented in previous research. The results for YA were as expected, with competence and health loading on one factor and trustworthy and shrewd (opposite loading) on the second factor. The results for OA deviated from past research that has focused largely on factor structures for YA. Competence, health, and trustworthy ratings all loaded highest on one factor, with shrewd ratings loading on the second factor (**Table 3**). Since trustworthy ratings loaded on the second factor more strongly than did competence or health ratings, we created the same trait composites for YA and OA to facilitate comparisons across rater age. The "warmth" composite was computed by summing ratings of trustworthy and reverse scores ratings of shrewd; and the "competence" composite was computed by summing ratings of competence and health. Inter-Rater Reliability for YA and OA for the 2 composite scores are shown in **Table 2**.

ANOVAs on Trait Composites and Attractiveness

To identify age and gender stereotypes and their moderation by rater age, we performed rater age × face age × face sex ANOVAs on the competence and warmth composites, with rater age a within face variable. We performed the same analysis on attractiveness ratings to ascertain whether our predictions regarding effects of attractiveness on age stereotypes were warranted. To enhance readability, all main effect and interaction means are shown in **Table 4** rather than in the text. Interactions are also depicted in figures.

Warmth composite

A main effect of face age revealed that, contrary to prediction, younger faces were rated as warmer than older faces, $F_{(1, 236)} = 21.20$, $p < 0.001$, $\eta^2 = 0.082$. However, a significant

TABLE 2 | Inter-rater reliability.

		α	$ICC_{(2, k)}$	95% CI		*F*	*df*1	*df*2	*p*
				Lower	Upper				
YA	Competence	0.686	0.654	0.587	0.714	3.182	239	4541	<0.001
	Health	0.935	0.926	0.911	0.940	15.311	239	4541	<0.001
	Shrewdness	0.745	0.724	0.671	0.773	3.919	239	4541	<0.001
	Trustworthiness	0.824	0.790	0.745	0.830	5.687	239	4541	<0.001
	Attractiveness	0.935	0.903	0.873	0.926	15.396	239	4541	<0.001
	Warmth composite	0.827	0.802	0.761	0.838	5.793	239	4541	<0.001
	Competence composite	0.921	0.912	0.895	0.928	12.658	239	4541	<0.001
OA	Competence	0.906	0.892	0.869	0.912	10.628	239	4541	<0.001
	Health	0.917	0.890	0.861	0.913	12.083	239	4541	<0.001
	Shrewdness	0.635	0.611	0.537	0.678	2.742	239	4541	<0.001
	Trustworthiness	0.830	0.798	0.755	0.836	5.891	239	4541	<0.001
	Attractiveness	0.896	0.853	0.812	0.886	9.604	239	4541	<0.001
	Warmth composite	0.842	0.829	0.795	0.859	6.343	239	4541	<0.001
	Competence composite	0.953	0.912	0.895	0.928	12.658	239	4541	<0.001

Two-way random effects model. Intraclass correlation coefficients using an absolute agreement definition. ICC average measures.

TABLE 3 | Factor Analyses of trait impressions.

	YA		OA	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**
Competence	0.935	−0.103	0.941	−0.230
Health	0.840	0.173	0.937	−0.153
Shrewdness	0.404	0.815	−0.226	0.967
Trustworthiness	0.524	−0.769	0.821	−0.464

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

face age × rater age interaction, $F_{(1, 236)} = 125.77$, $p < 0.001$, $\eta^2 = 0.348$, revealed that this effect was moderated by rater age. It held true for older raters, $p < 0.001$, contrary to the expectation that OA might respond more positively to older faces, while younger raters attributed greater warmth to older faces than younger faces $p = 0.044$, consistent with previous research findings. The face age × rater age interaction further revealed a surprising other-age favoritism, with OA rating younger faces as warmer than YA did, with the reverse effect of rater age for older faces (**Figure 2**). Finally, a face age × face sex interaction, $F_{(1, 236)} = 26.47$, $p < 0.001$, $\eta^2 = 0.101$, revealed that the perception of greater warmth in younger than older faces was significant for female faces, $p < 0.001$, but not for male faces, $p = 0.703$ (**Figure 3**).

A significant effect of face sex, $F_{(1, 236)} = 24.01$, $p < 0.001$, $\eta^2 = 0.092$, reflected the perception of greater warmth in female than male faces, as predicted. However, this effect was moderated by the above noted interaction with face age, which revealed that the overall tendency to rate female faces as warmer than male faces was significant for younger faces, $p < 0.001$ but not older ones, $p = 0.863$. Finally, a significant main effect of rater age, $F_{(1, 236)} = 4.41$, $p = 0.037$, $\eta^2 = 0.018$ revealed that OA had higher scores on the warmth composite than YA. The interaction effects of rater age × face sex and rater age × face sex × face age were not significant, respective $Fs_{(1, 236)} = 0.75$ and 0.87, $ps = 0.386$ and 0.353, $\eta^2 = 0.003$ and 0.004.

Competence composite

A main effect of face age revealed that, as predicted, younger faces were rated as more competent than older faces $F_{(1, 236)} = 622.77$, $p < 0.001$, $\eta^2 = 0.725$. A significant face age × rater age interaction, $F_{(1, 236)} = 109.71$, $p < 0.001$, $\eta^2 = 0.317$ revealed that this effect was stronger for OA. However, the perception of greater competence in younger faces was highly significant for both groups, $ps < 0.001$ (**Figure 4**). What accounted for the interaction was an own-age favoritism, with YA rating younger faces as more competent than did OA, $p < 0.001$, and the reverse effect of rater age for older faces, $p = 0.015$.The perception of younger faces as more competent than older ones also held true for both male and female faces despite a significant face age × face sex interaction $F_{(1, 236)} = 14.45$, $p < 0.001$, $\eta^2 = 0.058$, reflecting a stronger age effect for female faces, although the effects for both male and female faces were highly significant, both $ps < 0.001$ (**Figure 5**).

Contrary to prediction, there was no significant effect of face sex on the competence composite scores, $F_{(1, 236)} = 1.11$, $p = 0.292$, $\eta^2 = 0.005$. However, the face sex × face age interaction noted above revealed that younger women received higher scores than younger men $p < 0.001$, contrary to prediction, while older women received lower scores than older men, $p = 0.003$, as predicted. This interaction was qualified by a significant rater age × face age × face sex interaction, $F_{(1, 236)} = 9.67$, $p < 0.001$, $\eta^2 = 0.039$, which revealed that the unexpected tendency for younger women to be rated as higher in competence than younger men held true for OA, $p = 0.006$., but not YA, $p = 0.438$, while the predicted perception of

TABLE 4 | Older and younger adults' rating scores Face Age × Face Sex × Rater Age.

		Face age (FA)		Face sex (FS)		Rater age (RA)		FA * FS			
								YF		OF	
		YF	OF	F	M	YA	OA	F	M	F	M
Warmth	M	8.51	8.02	8.52	8.00	8.19	8.33	9.04	7.98	8.01	8.03
	SD	1.12	1.07	1.11	1.08	1.03	1.21	0.94	1.03	1.03	1.12
Competence	M	10.09	7.33	8.65	8.77	8.55	8.87	10.24	9.94	7.07	7.60
	SD	1.08	0.89	1.86	1.52	1.46	1.89	0.98	1.15	0.95	0.75
Attractiveness	M	4.19	2.88	3.63	3.43	2.90	4.17	4.41	3.96	2.86	2.91
	SD	1.08	0.76	1.17	1.10	0.97	0.91	0.98	1.13	0.76	0.77

		FA * RA				FS * RA			
		YF		OF		F		M	
		YA	OA	YA	OA	YA	OA	YA	OA
Warmth	M	8.07	8.95	8.32	7.72	8.42	8.62	7.96	8.05
	SD	0.88	1.13	1.52	0.90	0.91	1.28	1.09	1.06
Competence	M	9.69	10.49	7.41	7.26	8.48	8.83	8.63	8.91
	SD	0.93	1.07	0.89	0.90	1.56	2.10	1.35	1.67
Attractiveness	M	3.53	4.84	2.27	3.50	3.03	4.24	2.77	4.10
	SD	0.95	0.74	0.46	0.44	0.90	0.94	0.87	0.87

		FA * FS * RA							
		YF				OF			
		F		M		F		M	
		YA	OA	YA	OA	YA	OA	YA	OA
Warmth	M	8.54	9.53	7.60	8.36	8.31	7.70	8.33	7.73
	SD	0.71	0.89	0.78	1.11	1.07	0.89	1.24	0.92
Competence	M	9.75	10.72	9.63	10.25	7.20	6.93	7.63	7.58
	SD	0.80	0.90	1.04	1.17	0.98	0.89	0.73	0.78
Attractiveness	M	3.79	5.03	3.27	4.65	2.26	3.45	2.27	3.55
	SD	0.90	0.57	0.93	0.85	0.51	0.43	0.42	0.44

older women as less competent than older men held true for both OA and YA, respective *ps* < 0.001 and 0.010 (**Figure 6**). Finally, a significant effect of rater age, $F_{(1, 236)} = 48.91$, $p < 0.001$, $\eta^2 = 0.172$, revealed that OA had higher scores on the competence composite than YA. The rater age × face sex interaction was not significant, $F_{(1, 236)} = 0.56$, $p = 0.456$, $\eta^2 = 0.002$.

Attractiveness

A main effect of face age revealed that, as predicted, older faces were rated as less attractive than younger faces, $F_{(1, 236)} = 270.49$, $p < 0.001$, $\eta^2 = 0.534$. This effect did not vary with rater age $F_{(1, 236)} = 1.66$, $p = 0.199$, $\eta^2 = 0.007$. It also held true for male faces, and female faces, both *ps* < 0.001, despite a significant face age × sex interaction $F_{(1, 236)} = 10.04$, $p < 0.005$, $\eta^2 = 0.041$, which reflected a larger age difference for female faces (**Figure 7**).

An unexpected finding was that female faces were rated as more attractive than male faces, $F_{(1, 236)} = 6.33$, $p < 0.05$, $\eta^2 = 0.026$, and the face age × sex interaction noted above revealed that this was true for younger faces, $p < 0.001$, but not older ones, $p = 0.645$. Finally, a significant effect of rater age, $F_{(1, 236)} = 1{,}525.40$, $p < 0.001$, $\eta^2 = 0.866$, revealed that OA gave higher attractiveness ratings than YA. The rater age × face age effect was not significant, $F_{(1, 236)} = 1.66$, $p = 0.199$, $\eta^2 = 0.007$, and neither was the rater age × face age effect, $F_{(1, 236)} = 3.19$, $p = 0.075$, $\eta^2 = 0.013$, or the triple order interaction, $F_{(1, 236)} = 0.15$, $p = 0.702$, $\eta^2 = 0.001$.

Summary

YA ratings were higher for older than younger faces on the warmth composite and lower for older than younger faces on the competence composite, consistent with the age stereotype "doddering but dear" documented in previous research. Like YA, OA ratings were lower for older than younger faces on the competence composite. However, they were also lower for older faces on the warmth composite, contrary to prediction. Whereas age stereotypes were moderated by rater age, sex stereotypes were moderated by face age. YA and OA ratings were higher for female than male faces on the warmth composite, as predicted, but this held true only for younger faces. In addition, whereas both YA and OA ratings were higher for male than female faces on the competence composite, this held true only for older faces. YA did not show this sex stereotype for younger faces and OA perceived younger women as more competent than younger men. As predicted, older faces were judged less attractive than younger ones. Unexpectedly, male faces were also judged less attractive than female faces, which means that we can examine the contribution of facial attractiveness to the gender stereotypes we've observed. Finally, OA gave more positive ratings than YA on the warmth and competence composites and attractiveness, consistent with other evidence for an OA positivity effect that includes trait impressions (Carstensen and Mikels, 2005; Zebrowitz et al., 2013; Mammarella et al., 2016, 2017). However, greater OA positivity was shown only for younger faces on the warmth composite and only for older faces on the competence composite.

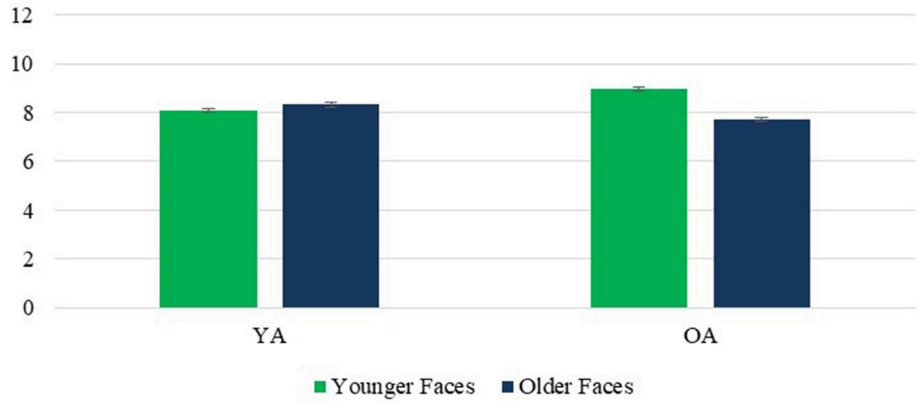

FIGURE 2 | Warmth: Face Age × Rater Age interaction. Error bars are SE.

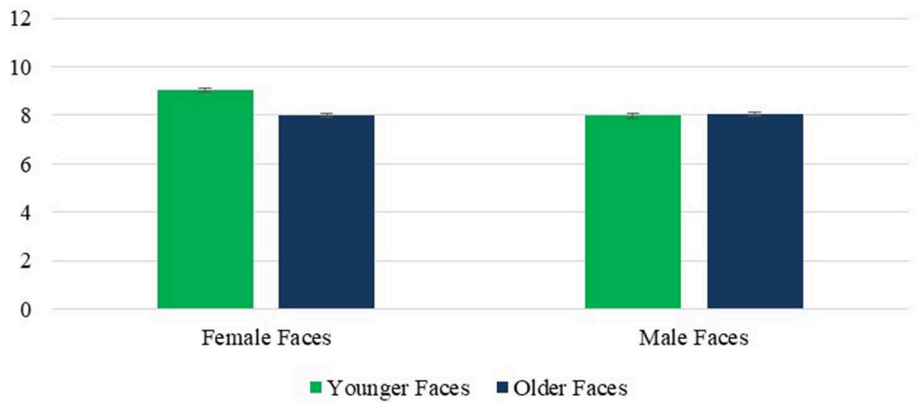

FIGURE 3 | Warmth: Face Age × Face Sex interaction. Error bars are SE.

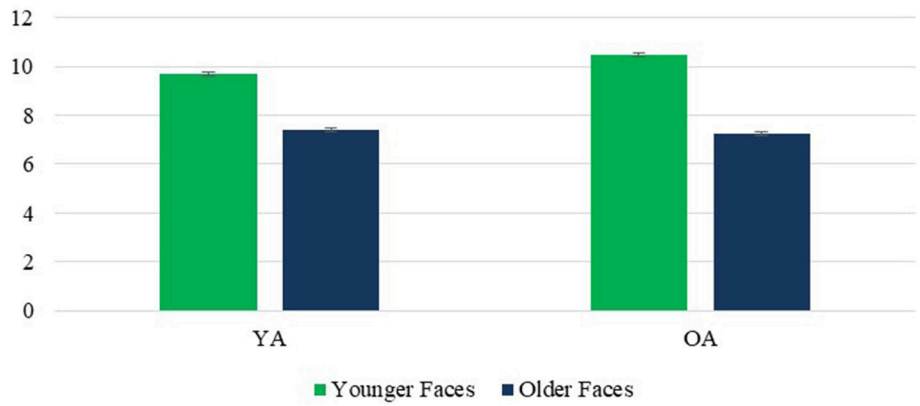

FIGURE 4 | Competence: Face Age × Rater Age interaction. Error bars are SE.

Regressions Predicting Scores on the Trait Composites

We performed separate regression analyses on the warmth and competence composites for OA and YA to determine the contribution of emotion resemblance and attractiveness to their age and gender stereotypes. Step 1 of the regressions entered face age and face sex. Step 2 entered resemblance to happy, angry, and surprised faces. Step 3 entered face

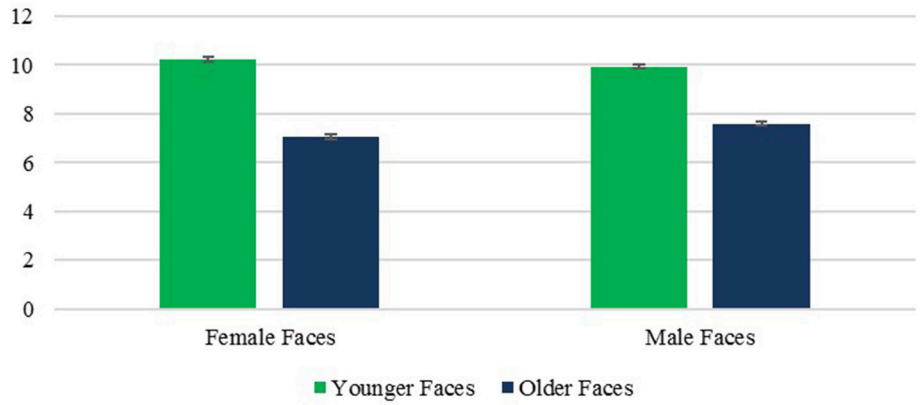

FIGURE 5 | Competence: Face Age × Face Sex interaction. Error bars are SE.

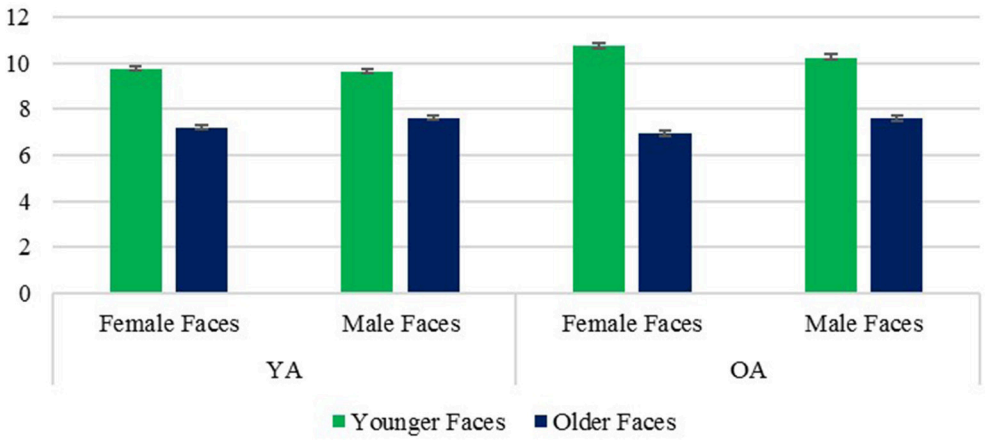

FIGURE 6 | Competence: Face Age × Face Sex × Rater Age interaction. Error bars are SE.

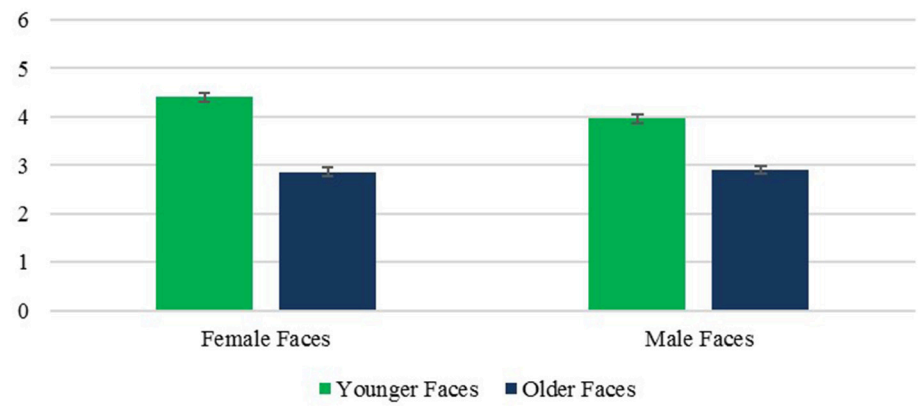

FIGURE 7 | Attractiveness: Face Age × Face Sex interaction. Error bars are SE.

attractiveness. To facilitate readability, the regression results are presented in **Table 5** (warmth composite) and **Table 6** (competence composite) rather than in the text, where statistics are limited to comparisons of the change in the βs for face age and sex from one step to the next.

TABLE 5 | Summary of regression analysis for variables predicting warmth.

	Variable	Step 1							Step 2							Step 3						
							Correlation							Correlation							Correlation	
		B	SE B	β	t	p	Partial	Semi-partial	B	SE B	β	t	p	Partial	Semi-partial	B	SE B	β	t	p	Partial	Semi-partial
YA	Face Age	0.254	0.13	0.124	1.97	0.050	0.127	0.124	0.234	0.17	0.114	1.37	0.172	0.890	0.085	0.635	0.19	0.309	3.31	0.001	0.212	0.198
	Face Sex	0.460	0.13	0.224	9.56	0.000	−0.225	−0.224	0.396	0.13	0.193	2.97	0.003	−0.190	−0.184	0.283	0.13	0.138	2.14	0.033	−0.139	−0.128
	Happy								−0.003	0.01	−0.038	−0.46	0.648	−0.030	−0.028	−0.002	0.01	−0.027	−0.34	0.733	−0.022	−0.020
	Angry								−0.004	0.01	−0.068	−0.95	0.341	−0.062	−0.059	−0.007	0.00	−0.114	−1.63	0.105	−0.106	−0.097
	Surprise								0.013	0.01	0.164	2.45	0.015	0.158	0.152	0.012	0.01	0.159	2.46	0.015	0.159	0.147
	Attractiveness															0.352	0.09	0.333	4.11	0.000	0.260	0.246
	R^2				0.065							0.103							0.163			
	R^2 Change				0.065							0.038							0.061			
	F for R^2 Change				8.281							3.266							16.879			
	df				2,237							3,234							1,233			
	p				0.000							0.022							0.000			
OA	Face Age	−1.226	0.13	−0.509	−9.49	0.000	−0.525	−0.509	−1.201	0.17	−0.499	−6.91	0.000	−0.412	−0.372	0.356	0.16	0.148	2.22	0.028	0.144	0.085
	Face Sex	0.575	0.13	0.239	4.44	0.000	−0.277	−0.239	0.597	0.14	0.248	4.39	0.000	−0.276	−0.237	0.359	0.10	0.149	3.67	0.000	−0.234	−0.140
	Happy								0.002	0.01	0.017	0.24	0.811	0.016	0.013	−0.002	0.01	−0.027	−0.53	0.599	−0.034	−0.020
	Angry								0.006	0.01	0.078	1.26	0.208	0.082	0.068	−0.006	0.00	−0.079	−1.74	0.084	−0.113	−0.066
	Surprise								0.003	0.01	0.037	0.64	0.525	0.042	0.034	0.004	0.00	0.049	1.19	0.234	0.078	0.046
	Attractiveness															1.197	0.08	0.901	15.19	0.000	0.705	0.581
	R^2				0.316							0.321							0.659			
	R^2Change				0.316							0.005							0.338			
	F for R^2 Change				54.859							0.561							230.646			
	Df				2,237							3,234							1,233			
	p				0.000							0.641							0.000			

Higher scores for face age signify that older faces are rated higher and higher scores for face sex indicate that female faces are rated higher.

TABLE 6 | Summary of regression analysis for variables predicting competence.

	Variable	Step 1							Step 2							Step 3						
							Correlation							Correlation								Correlation	
		B	SE B	β	t	p	Partial	Semi–partial	B	SE B	β	t	p	Partial	Semi–partial	B	SE B	β	T	p	Partial	Semi–partial
YA	Face Age	−2.277	0.12	−0.783	−19.43	0.000	−0.784	−0.783	−2.225	0.16	−0.765	−14.17	0.000	−0.680	−0.571	−1.203	0.13	−0.413	−9.46	0.000	−0.527	−0.265
	Face Sex	−0.150	0.12	−0.052	−1.28	0.201	0.083	0.052	−0.102	0.12	−0.035	−0.83	0.407	0.054	0.033	−0.390	0.09	−0.134	−4.46	0.000	0.280	0.125
	Happy								0.001	0.01	0.007	0.12	0.902	0.008	0.005	0.003	0.00	0.025	0.68	0.499	0.044	0.019
	Angry								0.006	0.00	0.066	1.41	0.159	0.092	0.057	−0.001	0.00	−0.016	−0.50	0.616	−0.033	−0.014
	Surprise								−0.003	0.01	−0.025	−0.57	0.571	−0.037	−0.023	−0.004	0.00	−0.034	−1.11	0.267	−0.073	−0.031
	Attractiveness															0.895	0.06	0.599	15.79	0.000	0.719	0.443
	R^2				0.615							0.621							0.817			
	R^2 Change				0.615							0.005							0.196			
	F for change in R^2				189.593							1.088							249.286			
	df				2,237							3,234							1,233			
	p				0.000							0.355							0.000			
OA	Face Age	−3.230	0.13	−0.854	−25.31	0.000	−0.854	−0.854	−3.161	0.17	−0.836	−18.63	0.000	−7.773	−0.624	−1.439	0.13	−0.380	−10.83	0.000	−0.579	−0.218
	Face Sex	−0.083	0.13	−0.022	−0.65	0.519	0.042	0.022	−0.010	0.13	−0.003	−0.08	0.940	0.005	0.003	−0.274	0.08	−0.072	−3.38	0.001	0.216	0.068
	Happy								0.001	0.01	0.010	0.21	0.831	0.014	0.007	−0.003	0.00	−0.021	−0.80	0.426	−0.052	−0.016
	Angry								0.008	0.01	0.067	1.74	0.083	0.113	0.058	−0.005	0.00	−0.043	−1.82	0.070	−0.118	−0.037
	Surprise								−0.006	0.01	−0.044	−1.23	0.221	−0.080	−0.041	−0.005	0.00	−0.036	−1.64	0.102	−0.107	−0.033
	Attractiveness															1.325	0.07	0.635	20.30	0.000	0.799	0.409
	R^2				0.730							0.738							0.905			
	R^2 Change				0.730							0.008							0.168			
	F for change in R^2				320.505							2.281							412.202			
	df				2,237							3,234							1,233			
	p				0.000							0.080							0.000			

Higher scores for face age signify that older faces are rated higher and higher scores for face sex indicate that female faces are rated higher.

Warmth composite: YA

The tendency for YA ratings to be higher for older than younger faces on the warmth composite, lost significance when emotion resemblance indices were entered into the equation at Step 2, but this change in the age effect was not significant, $t = 0.093$ $p = 0.92$ (see Weaver and Wuensch, 2013). Higher YA ratings of female than male faces on the warmth composite, remained significant at Step 2, and the change in the sex effect was not significant, $t = 0.35$ $p = 0.727$. However, the R^2 change at Step 2 was significant, reflecting a significant positive effect of surprise resemblance on perceived warmth. Although the effect of surprise resemblance was consistent with previous research findings, it did not influence the age or gender stereotypes shown on the warmth composite. Contrary to prediction, happy and anger resemblance had no significant effects on YA ratings on the warmth composite.

Adding attractiveness into the equation at Step 3 produced a significant R^2 change. Not only was attractiveness a significant predictor of YA perceived warmth, but also including it in the model restored and strengthened the original effect of face age that had lost significance at Step 2, However, this increase in the β was not significant as compared with Step 2, $t = 1.57$, $p = 0.116$ or Step 1, $t = 1.65$, $p = 0.098$. Including attractiveness also had no significant influence on the effect of face sex, $t = 0.44$ $p = 0.658$. Resemblance to surprise continued to predict greater perceived warmth with attractiveness in the model, and the effects of resemblance to happy and angry expressions remained non-significant.

Warmth composite: OA

The tendency for OA to rate younger faces higher in warmth than older ones remained significant when emotion resemblance indices were entered into the equation at Step 2, and there was no significant change in the face age effect, $t = 0.12$, $p = 0.907$. Similarly, the tendency for OA to rate female faces higher in warmth than male faces remained significant at Step 2, and there was no significant change in the face sex effect, $t = 0.11$, $p = 0.908$. The R^2 change also was not significant. Contrary to prediction, none of the emotion resemblance indicators predicted impressions of warmth.

Adding attractiveness into the equation at Step 3 produced a significant R^2 change. Not only was attractiveness a significant predictor of perceived warmth, but also including it in the model reversed the perception of younger faces as warmer than older ones, yielding the pattern consistent with predictions, and this change in the β was significant, $t = 3.70$, $p < 0.001$. Although including attractiveness in the model also weakened the greater perceived warmth of female faces, as predicted, this change was not significant, $t = 1.38$ $p = 0.168$. Finally, there was a marginally significant negative effect of anger resemblance on perceived warmth at Step 3, consistent with predictions. However, there were no effects for resemblance to happy or surprise expressions.

Competence composite: YA

The significant tendency for YA to perceive higher competence in younger than older faces remained significant when the emotion resemblance indices were entered at Step 2, and the age effect did not change significantly, $t = 0.05$, $p = 0.950$. Perceptions of competence did not vary with face sex, and this remained true at Step 2. The R^2 change at Step 2 also was not significant, and contrary to prediction, none of the emotion resemblance indicators predicted impressions of competence.

Adding attractiveness at Step 3 produced a significant R^2 change., Not only did attractiveness have a significant positive effect on perceived competence, but also the negative effect of age on perceived competence was weaker with attractiveness in the model, as predicted, and this change in the β was significant, $t = 4.96$, $p < 0.001$. In addition, consistent with predictions, a significant effect emerged for face sex, showing higher perceived competence in male than female faces, and this change in the β was marginally significant, $t = 1.92$, $p = 0.056$. All of the emotion resemblance effects on perceived competence remained non-significant at Step 3.

Competence composite: OA

The significant tendency for OA to rate younger faces as more competent than older ones remained significant when the emotion resemblance indices were entered at Step 2, and the age effect did not change significantly, $t = 0.32$, $p = 0.747$. OA perceptions of competence did not vary with face sex, and this remained true at Step 2, The R^2 change at Step 2 was not significant, and contrary to prediction, none of the emotion resemblance indicators predicted impressions of competence.

Adding attractiveness at Step 3 produced a significance R^2 change. Not only did attractiveness have a significant positive effect on perceived competence, but also the positive effect of age on competence impressions was weakened with attractiveness in the model, as predicted, and this decrease in the β was significant, $t = 8.05$, $p < 0.001$. In addition, with the higher attractiveness of female than male faces controlled, a significant effect emerged for face sex, with higher perceived competence in male than female faces, and this change in the β was marginally significant, $t = 1.73$, $p = 0.085$. The emotion resemblance effects on perceived competence remained non-significant at step 3.

Summary

Controlling for emotion resemblance did not influence the effects of face age or face sex on perceived warmth and competence. However, surprise resemblance did increase YA impressions of warmth across all faces, and anger resemblance marginally decreased OA warmth impressions, while none of the emotion resemblance indices affected impressions of competence[2]. In addition, in contrast to the null effects of

[2]In addition to the effects of surprise on warmth impressions across all faces with face age and sex controlled, we found several significant or marginally effects of emotion resemblance within the age/sex categories, which we summarize below for the interested reader. The direction of the effects was often variable across levels of face age and sex as well as across rater age. One notable difference was that anger resemblance enhanced perceived competence for young faces but reduced it for old faces. *Young female faces*: Anger resemblance showed a positive relationship to OA competence ratings, $r_{(60)} = 0.282$, $p = 0.029$ and surprise resemblance showed a marginal negative relationship, $r_{(60)} = -0.250$, $p = 0.054$. *Young male faces*: anger resemblance showed a positive relationship to OA and YA competence ratings, respective $rs_{(60)} = 0.378$ and 0.419, $ps = 0.003$ and 0.001, anger resemblance also showed a positive relationship to OA warmth

emotion resemblance on age and gender stereotypes, controlling attractiveness, which was greater in younger than older and female than male faces, had a significant influence. In the case of age stereotypes, controlling attractiveness replaced OA perception of greater warmth in younger than older faces, with the perception of greater warmth in older faces, a significant reversal. Controlling attractiveness also significantly decreased YA and OA impressions of greater competence in the younger faces. In the case of gender stereotypes, it was only when controlling the greater attractiveness of female than male faces, that YA and OA showed greater perceived competence in male than female faces, changes that were marginally significant.

Discussion

Age and Gender Stereotypes

Previous research showing less favorable evaluations of older than younger individuals on a competence dimension, with the reverse on a warmth dimension (Cuddy et al., 2008) were confirmed by the trait impressions of YA in our study. Whereas YA thus perceived older faces as "doddering but dear," OA judged younger faces more favorably on the warmth composite, rather than older faces. As discussed below, this reversal of the effect predicted from previous research was driven by the greater attractiveness of the younger faces, which was not a salient cue in research examining age stereotypes from category labels (Cuddy and Fiske, 2002; Fiske et al., 2002; Cuddy et al., 2008). Our results suggest that the YA stereotype of older faces as warmer is robust in the face of their lesser attractiveness, whereas the OA stereotype is not.

The trait impressions of both YA and OA confirmed previous research showing gender stereotypes paralleling age stereotypes, with less favorable evaluations of women than men on a competence dimension and the reverse on a warmth dimension (Fiske et al., 2002; Cuddy et al., 2008). However, these effects were moderated by face age, with higher female warmth scores shown only for younger faces and lower female competence scores shown only for older faces. As discussed below, the greater attractiveness of younger female than male faces contributed to these effects.

We did not select male and female faces with the intention of creating variation in attractiveness. Whether the gender differences we found for younger but not older faces in our sample generalize to a more representative sample is worthy of further investigation. If they are representative, this would have implications for understanding changes in gender stereotypes across age. It should be noted that only a handful of previous studies have examined age and gender stereotypes as a function of the person's position on the other dimension, and to our knowledge none have done so using impressions of faces (for a review, see Andreoletti et al., 2015). Our results urge caution in generalizing from YA age and gender stereotypes of younger faces to older faces or older raters.

Contribution of Emotion Resemblance to Age and Gender Stereotypes

Face age and sex differences in emotion resemblance had no effect on age or gender stereotypes as evidenced by no changes in the effects of age and gender on perceived warmth and competence when controlling emotion resemblance. One possible explanation for our null results is that differences in the emotion resemblance of older vs. younger adults or women vs. men that were detected by the connectionist models were not strong enough to override the influence of other facial information provided in the photographs. Another possible explanation is that the emotion resemblance differences were not strong enough to override the influence of cultural stereotypes unrelated to appearance. Notably, however, previous research found that structural resemblance to emotions did moderate race stereotypes (Zebrowitz et al., 2010). The divergent results may reflect a stronger influence of variations in attractiveness among faces in the present study than those varying in race.

Although emotion resemblance did not contribute to age or gender stereotypes, we did find effects of emotion resemblance on trait impressions across all faces. Specifically, surprise resemblance increased YA ratings of faces on the warmth composite, and anger resemblance marginally decreased OA ratings, thus establishing the validity of these predictors. These effects of emotion resemblance extend previous research that included only younger faces, although YA and OA perceivers showed both effects in one study (Zebrowitz et al., 2007, 2010; Franklin and Zebrowitz, 2013).

Contribution of Attractiveness to Age and Gender Stereotypes

Age differences in attractiveness contributed to age stereotypes on both the warmth and competence dimensions. The unexpected tendency for younger faces to be judged warmer by OA was significantly reversed with attractiveness controlled, indicating that statistically equating the attractiveness of younger and older faces uncovered this OA positive stereotype of older individuals which was shown by YA without controlling attractiveness. In the case of competence stereotypes, the higher scores for younger faces by both YA and OA became significantly weaker with attractiveness controlled, indicating that the higher attractiveness of younger than older faces contributed to this negative stereotype of older individuals.

Gender differences in attractiveness in our study also contributed to gender stereotypes. In the case of competence stereotypes, there were no significant effects of face sex until attractiveness was controlled, yielding significantly higher perceived competence of male faces by both YA and OA, changes that were marginally significant. This indicates that the greater attractiveness of women than men in the present study masked a tendency to perceive men as more competent. Similarly,

ratings, $r_{(60)} = 0.300$, $p = 0.020$, while surprise resemblance showed a positive relationship to YA warmth ratings, $r_{(60)} = 0.333$, $p = 0.009$. *Old female faces:* Anger resemblance showed a negative relationship to YA warmth ratings, $r_{(60)} = -0.300$, $p = 0.020$, and surprise resemblance showed a positive relationship, $r_{(60)} = 0.446$, $p < 0.001$. Surprise resemblance also showed a marginal negative relationship to OA competence ratings, $r_{(60)} = -0.228$, $p = 0.080$. *Old male faces:* Anger resemblance showed a negative relationship to competence ratings, that was significant for YA, $r_{(60)} = -0.290$, $p = 0.025$, and marginal for OA, $r_{(60)} = -0.220$, $p = 0.091$. Although these findings are beyond the scope of the hypotheses we tested, the warrant further investigation.

the tendency for both YA and OA to judge female faces as warmer was weakened with the greater attractiveness of women statistically controlled, although changes in these effects were not significant.

The effects of attractiveness on age stereotypes is consistent with previous research that found that older faces' greater resemblance to unattractive, anomalous faces partly explained the tendency to rate them as less sociable, warm and healthy than younger faces (Zebrowitz et al., 2003). The present results also demonstrate that this evidence for a contribution of age differences in attractiveness to YA negative age stereotypes generalizes to OA judges and to a much larger sample of faces. Furthermore, the present findings show that these effects of age differences in attractiveness on age stereotypes are independent of differences in the emotion resemblance of younger and older faces, which were controlled in the regression models.

Although it is unclear whether the greater attractiveness of younger female than male faces in our study has any generalizability to other samples, it is likely that most samples of older faces will be perceived as less attractive than younger ones. As such, our results have important implications for addressing age biases. In particular, our finding that age differences in attractiveness make a substantial contribution to negative stereotypes of older people's competence is consistent with evidence that age-appearance has a stronger effect on simulated personnel decisions than does chronological age (Kaufmann et al., 2016). This appearance bias is particularly troubling given evidence that attractiveness is not a reliable cue to the competence of older people. Although it was related to self-reported physical fitness in older people, it was unrelated to their reasoning or short term memory, albeit positively related for younger people (Zebrowitz et al., 2014). These results suggest that policies to combat age discrimination in the workplace should prioritize selection processes that keep personnel officers blind to applicants' appearance as long as possible. Although this may seem far-fetched, the fact is that major symphony orchestras have implemented audition procedures in which the applicant performs behind a screen so that the judges are ignorant of demographic characteristics (Goldin and Rouse, 2000). Our finding that age differences in attractiveness also have effects on the perception of greater warmth in older than younger adults may also have important practical implications

SUMMARY AND IMPLICATIONS

Our results document age differences in the resemblance of neutral expression faces to emotion expressions and extend previous evidence for gender differences to include older faces. However, emotion resemblance did not contribute to age or gender stereotypes, although it did influence impressions of warmth across all faces. Our results also extend previous evidence that YA perceive older adults and women as warmer and less competent than younger adults and men, respectively. Specifically, we found variations in age stereotypes across perceiver age and variations in gender stereotypes across face age. These moderating effects provide a caveat to conclusions from the large body of stereotype research that generalizes from YA impressions and ignores cross-cutting demographic categories. Our results also provide a caveat to conclusions about age and gender stereotypes derived from responses to category labels. Our assessment of stereotypes from trait impressions of faces as opposed to category labels revealed significant impacts of age and gender differences in attractiveness, as evidenced by changes in the stereotypes with attractiveness controlled. Specifically, the lower attractiveness of older faces weakened OA perceptions of their greater warmth as compared with younger faces and strengthened both YA and OA perceptions of their lesser competence. Similarly, the greater attractiveness of female faces in our study weakened their lesser perceived competence as compared with male faces. These results reveal the importance of assessing stereotypes with a methodology that is sensitive to influences of group differences in appearance that can exacerbate or mitigate stereotypes in more ecologically valid contexts. Positive stereotypes of older adults' warmth may have little effect in contexts where their lower attractiveness is salient, whereas negative stereotypes of older adults' competence may be exacerbated in such contexts.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the ethical committee of the University of Chieti with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the University of Chieti committee.

AUTHOR CONTRIBUTIONS

Data collection: RP; Data analyses: RP, LZ; Conceptualization: LZ, RA, RK, UH, RP; Writing RP, LZ.

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Age-Based Positivity Effects in Imagining and Recalling Future Positive and Negative Autobiographical Events

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Thoughts about the future reflect personal goals, and projections into the future enrich our emotional life. Researchers have taken an interest in determining whether the tendency to remember more positive than negative emotional events observed when recalling past events also appears when remembering imagined future events. The objective of this study was to examine the age-based positivity effect of recall for future positive and negative autobiographical events in young and older adults. Representative future events were first established to develop the cues used to prompt personal future events. In the production task, the participants were presented with eight positive and eight negative random future events of young or older adults as a model and the corresponding cues to generate their own positive and negative future autobiographical events. In the recall task, the participants recovered as many experiences as they could of the model and the positive and negative events produced by themselves. The participants correctly recalled more positive than negative events and committed more errors for negative than positive events, showing a clear tendency in both young and older adults to recall future imagined events as positive. Regarding age, the young adults recalled more events than the older participants whilst the older participants in particular showed better recall of their own imagined future events than the model's events, and committed more errors when recalling the model's events than their own imagined events. Regarding the positivity effect in incorrect recall, more than half of the errors were valence changes, most of these being from negative to positive events, and these valence changes were more pronounced in the older than in the younger adults. In general, there were fewer differences between young and older adults in the recall of positive events in comparison with negative events. Our findings suggest that people are well disposed toward recalling positive imagined future events and preserve a positive emotional state, suppressing negative memories.

Keywords: autobiographical memory, future events, positive and negative experiences, positivity effect, young and older adults

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INTRODUCTION

Episodic memory not only includes past experiences, but is also the vehicle that allows us to travel mentally through time from the past and into the future (Tulving, 1985). Thinking about past experiences and imagining the future are common occurrences in our daily thoughts, conversations, and social relations. In recent years both cognitive psychology and the neurosciences

have taken an interest in understanding whether the projection of oneself—the episodic thoughts of future experiences—shares characteristics with the episodic recall of past events (for reviews, see Schacter et al., 2007; Szpunar, 2010). Finnbogadóttir and Berntsen (2013) investigated the frequency and valence of spontaneously arising experiences and they found that involuntary future projections were as frequent as the involuntary retrieval of past events. They observed that more positive events were reported than negative experiences (see also Berntsen and Rubin, 2002; Newby-Clark and Ross, 2003; Berntsen and Jacobsen, 2008), and that this preference for positive events was greater for future than for past events. It has also been observed that older adults tend to remember positively the past (Kennedy et al., 2004), and subjectively rate past and imagined future events more positively than younger adults (Gallo et al., 2011).

Although the majority of past experiences and future thoughts include trivial and unemotional events (e.g., thinking about the day's activities or reviewing the shopping list), positive and negative emotional experiences are what give meaning to our lives and they provide us with our own identity (Conway and Pleydell-Pearce, 2000; García-Bajos and Migueles, 2013; Demblon and D'Argembeau, 2017). Thinking about future events can be as relevant to present life as evoking past autobiographical experiences. In fact, to recreate the future we use our knowledge and past experiences. Mental simulations of future experiences are often concerned with emotionally arousing events and virtually nothing is known about memory for these simulations or the impact of their emotional valence on thoughts about the future in young and older adults. The aim of this study, therefore, was to examine whether there are differences in the recall of future positive and negative autobiographical events between young and older adults. That is, to examine age-based positivity effects in imagining and recalling imagined future events.

The term positivity refers to the preference for positive information as opposed to negative content in attention and memory tasks, an effect that is accentuated with age (Carstensen and Mikels, 2005; Mather and Carstensen, 2005; Schryer and Ross, 2014). The positivity effect concerns the relative difference between older and younger people in attention to and memory for positive as opposed to negative material (see Reed and Carstensen, 2012). Young adults show enhanced memory for both positive and negative information, and often have a tendency to process and remember negative information more thoroughly than positive information (for a discussion, see Baumeister et al., 2001). Compared with young adults, older people remember more positive than negative content, or show reduced memory for negative information when attending to visual materials such as scenes, affective pictures, or faces (Charles et al., 2003; Reed et al., 2014; Mammarella et al., 2016). For instance, it has been observed that older people spend more time attending to positive faces that reflect feelings of joy than negative faces that express anger or sadness (Mather and Carstensen, 2003). This positivity effect has also been observed in memory for word lists (Shamaskin et al., 2010), long-term autobiographical experiences (Kennedy et al., 2004), or in tasks that involve working memory (Mikels et al., 2005). Gallo et al. (2011) even found that older adults subjectively rated retrieved autobiographical past events or imagined future events more positively than younger adults, demonstrating an age-related positivity effect. However, the opposite pattern of results has also been found (e.g., Grühn et al., 2005), or in some cases negligible differences have been observed between young and older adults in the processing of emotional information (for a review see Reed and Carstensen, 2012). The variability in both the size and nature of the positivity effect in remembering suggest that there are factors that have received little attention that could moderate the effect, such as encoding conditions and information content (Hess et al., 2013). Reed et al. (2014) conducted a systematic meta-analysis of 100 empirical studies of the positivity effect. All the studies compared positive and negative emotional material in young and older adults, which allowed for an analysis of the interaction between emotional valence and aging. The results indicated that the positivity effect is clear and consistent, particularly when processing constraints are not imposed on participants and natural information is processed.

An important factor in the memory of positive and negative emotional experiences is self-referencing (e.g., Gutchess et al., 2007; Leshikar et al., 2015). Therefore, in this study we examined the memory of autobiographical future emotional events related to the participants themselves and those of other people that, in addition, share (or not) age with the participants of the experiment. Recovering, generating, or producing self events require deeper and more elaborate processing than when simply reading about the experiences of others (Symons and Johnson, 1997), and both young and older adults can benefit of depth of processing (Lalanne et al., 2013). Therefore, personal events will be remembered better than those of other people. In addition, this more elaborate processing may modulate the positivity effect in recalling imagined future events. It has been shown that both young and older adults can benefit from self-referenced items (Gutchess et al., 2007; Lalanne et al., 2013), that self-referencing does not restore the memory of older adults to the level of young adults (Gutchess et al., 2007), and that self-reference effect can be more marginal for older adults (Lalanne et al., 2013). Furthermore, inconsistent with a positivity effect in aging, Leshikar et al. (2015) found that self-referencing increased recollection memory for positive items in both young and older adults, but further study is needed in this area. We also examined the impact of a possible identification of the participants with the experiences of the reference model. Thus, personal information or the experiences of people who share age, life scripts, life cycle, concerns and illusions, may receive additional attentional resources. In other words, self-referential processing, which involves encoding information in relation to oneself, can improve the memory of the future events of other people (Gutchess et al., 2007; Leshikar et al., 2015) and also modulate the positivity effect. Therefore, additional objectives of the present study were to examine the impact of self-reference and identification with other people's experiences in the positivity effect.

Why do older people show a tendency to favor positive information over negative information? Although the underlying cognitive mechanisms of the positivity effect are not fully understood, several alternatives have been considered in the search for explanations. The *Socio-emotional Selectivity Theory*

(SST; Carstensen, 2006) emphasizes an age-related increase in the accessibility of positive information. This theory posits that with increased age, the priorities and motivations of a person shift according to their future prospects. The fact that future prospects become narrow over time and the fragility of life is appreciated leads to a prioritization of current objectives that are related to self-satisfaction. In other words, older adults deploy cognitive control mechanisms to avoid negative information and to seek positive, emotionally rewarding information. Prioritizing the positive means that when it comes to coding information, paying attention, or remembering facts, there is a preference for what is deemed to be pleasant and positive. Other theories emphasize cognitive mechanisms (e.g., Spaniol et al., 2008) and neural processes (Kensinger and Schacter, 2008; Mammarella et al., 2017) to explain the age × valence interaction. Studies of young adults have shown that inhibitory mechanisms may help keep negative thoughts and episodes from coming to mind, promoting a positive bias (e.g., Giebl et al., 2016; García-Bajos and Migueles, 2017), and studies with young and older adults reveal that older adults recruit cognitive control processes to strengthen positive and diminish negative information (e.g., Mather and Knight, 2005; Knight et al., 2007), or older people automatically prefer and process positive information because it is less complex than negative content (Labouvie-Vief et al., 2010; Wurm, 2011). Szpunar et al. (2012) suggest that one basis of the preference for positive information may be the *fading affect bias* (Walker et al., 1997), whereby information related to negative emotions tends to fade more rapidly than that related to positive emotions, which results in a tendency to remember the positive. Consistent with this interpretation, Berntsen et al. (2011) observed that older people remembered and judged positive experiences as being more central to their life and identity than negative or traumatic experiences.

Although errors have been analyzed in the positivity effect, showing that older participants show an optimism bias and recall more false positive than false negative information (e.g., Fernandes et al., 2008), one aspect that is rarely studied in the phenomenon of positivity effect in memory is the nature of errors. The majority of the studies have focused on the production of events, the description of experiences, phenomenological evaluations, or correct recall (Reed et al., 2014). The properties of memories and the types of memory errors people commit offer a window into the organization of memory (Schacter, 1999). Could signs of this bias in favor of positive over negative information in later life also be detected in memory errors? It has been found that older adults are more prone than younger adults to make everyday memory errors (Ossher et al., 2013; Devitt and Schacter, 2016). The limitations of the elderly appear in the memory of information that requires attentional and cognitive resources (Craik and McDowd, 1987; Danckert and Craik, 2013), such as specific facts or concrete details. In addition, future thinking in older adults is characterized by a lack of specificity of imagined events and by an equal or even higher subjective experience in comparison with younger adults (Jumentier et al., 2017). However, it has been observed that age differences in memory are reduced or even eliminated when participants process emotional or affective information (May et al., 2005). Thus, an additional goal of this study was to examine the nature of the errors shown in young and old adults, to determine whether their impact is greater on positive or negative content, and to also identify the types of errors that are made in the recall of imagined future events. For this, we distinguished between commission errors, source errors, and emotional valence changes. Commission errors, when the participants contribute their own or others' events that are not present in the coding phase, may be connected to prior knowledge (Migueles and García-Bajos, 2012), life scripts (Rubin and Berntsen, 2003), or forms of semantic memory that can be used to guide one's anticipated future (Grysman et al., 2015). Source errors—in which an error is made regarding the subject or action of an event—can be an index of the lack of specificity of processing the origin of the information (Danckert and Craik, 2013; Jumentier et al., 2017) and should depend on the recollection of specific details about the earlier generated events (Gallo et al., 2011). And more relevant to the effect of positivity in the memory of future events would be changes in emotional valence, where negative events are remembered as positive.

In short, in our daily lives we frequently think of future positive and negative emotional events. Because of the interest in understanding the effects of aging on episodic future memory, in this study we examined the positivity effect and differences in recall between young and older adults for self and other future events. We also examined errors, since they are indicators of memory processes and limitations, and may be manifest in positivity or negativity biases in the recall of emotional future events.

MATERIALS AND METHODS

Participants

The final sample of participants in the experiment consisted of a total of 136 students from the University of the Basque Country. Of these, there were 68 young adults aged between18 and 30 years ($M = 20.37$; $SD = 2.16$), which included 59 women and 9 men, all of which were psychology students. The 68 older participants were aged between 55 and 75 years ($M = 65.13$; $SD = 4.02$), 48 of which were females and 20 males. These old participants were enrolled in a university degree in human sciences. **Table 1** displays the characteristics of the participants. There were no differences between the young and older adults in the years of completed formal studies, $t(134) = -94$, $p = 0.35$, $d = 0.02$, or perceived health, Mann–Whitney test, $Z = -1.84$, $p = 0.07$. Young adults showed greater semantic fluency in the animal production task for 1 min, $t(134) = 5.79$, $p < 0.001$, $d = 0.21$, and greater processing speed in the Wechsler Adult's digit symbol-coding task Intelligence Scale (WAIS, Wechsler, 1997/1999) for 2 min, $t(134) = 10.33$, $p < 0.001$, $d = 0.36$, in comparison with the older adults. In contrast, the older participants achieved higher scores than the young adults, $t(134) = 2.65$, $p < 0.01$, $d = 0.17$, in a 4-min verbal comprehension task composed of 50 items, each of which included four synonyms (Thurstone, 1938/1996). To examine whether the significant differences in cognitive abilities between the young and older participants influenced the

TABLE 1 | Participant characteristics (*SDs* in parentheses).

	Age	Years of education	Health[a]	Semantic fluency[b]	Verbal comprehension[c]	Speed of processing[d]
Young	20.37 (2.16)	15.50 (0.82)	4.32 (0.58)	18.18 (2.75)	34.12 (6.50)	86.35 (14.25)
Older	65.13 (4.02)	15.85 (2.98)	4.15 (0.55	14.71 (4.11)	38.85 (7.69)	59.88 (15.61)

[a]*Participants rated their state of health on a scale from 1 (very bad) to 5 (very good).* [b]*1 min of animal names.* [c]*PMA Verbal factor (Thurstone, 1938/1996).* [d]*Digit symbol-coding task (Wechsler, 1997/1999).*

main findings of the study on future events production, correct recall or errors, a set of ANCOVAs (Analyses of Covariance), were conducted with semantic fluency, processing speed and verbal comprehension as covariables. The results showed that semantic fluency, processing speed or verbal comprehension did not interact significantly ($p > 0.05$ cases) with any of the factors studied: age group, model age, emotional valence, experiences recalled or type of errors.

Materials

For the experiment, each participant was presented with 16 future experiences, eight positive and eight negative (**Table 2**) randomly organized. To manipulate the model age (young or old) as a between-participants factor to generate self-events, the 68 young adults and the 68 older participants were randomly divided in two subgroups of 34 participants each. In addition, two examples were selected to control for primacy and recency effects, which also served to help participants understand the task. Future experiences had been obtained from a previous normative study using 600 participants of similar characteristics to those of the current study, but none of them subsequently participated in the present experiment. This sample was composed of 300 youngsters aged between 18 and 30 years ($M = 20.46$, $SD = 2.38$), of which 243 were females and 57 males. The 300 older participants were aged between 56 and 80 years ($M = 66.59$, $SD = 5.09$), of which 212 were females and 88 males. All participants produced, for 8 min, future events. Of these, 100 young and older participants produced positive thoughts or experiences, 100 produced negative thoughts, and the remaining 100 did not receive instructions about the valence. Based on the experiences obtained, eight frequent positive and eight negative events were selected, generated by more than 20% of young or older adults. The 16 future events selected served as models for the participants in the experiment to generate their own future events or thoughts. Half of the young participants received young model events, whereas the other half received old model events, the same being true for older participants. Whether the model came from young or old adults, retrieval cues (a procedure based on Migueles and García-Bajos, 2015 and García-Bajos and Migueles, 2017) were selected to help participants produce their own future events or experiences, that could be positive (e.g., Travel to...) and negative (e.g., Fear of...).

TABLE 2 | The 16 future autobiographical events, eight positive and eight negative, of the young and old model age (in italics the older events, when they were different from the young model events).

Future autobiographical events
POSITIVE
Example. **Attend** a concert/*play*
Do a master's degree/*computing course*
Travel to Paris/*Italy*
Having a good time at parties
Meet my future partner/*my children's partner*
Have children/*grandchildren*
Get along with family
Buy myself a house/*another house*
Live by myself/*independently*
NEGATIVE
Not being able to finish the degree/*finish the university courses*
Fear of not finding a job/*my children not finding a job*
Contracting a serious illness
Arguing with my friends
Losing my job/*cognitive abilities*
Disappoint my parents/*children*
Death of people close to me
Suffer an accident
Example. **Having problems** financially/*reaching the end of the month*

Half of the young participants received young model events, whereas the other half received old model events, the same being true for older participants. The retrieval cues for the task of production of own experiences are in bold characters.

Design

The present study employed a 2 (participants age: young or old) × 2 (model age to generate self-events: young or old) × 2 (emotional valence: positive and negative), mixed factorial design with between-participants factors being the age of the participants and the age of the model to generate one's own future experiences, whilst the within-participants variable was the emotional valence of the events. The correct recall and errors were measured for the recall of the positive and negative experiences of the model and those generated personally by each participant. Three types of errors were evaluated: commission errors, source errors, and valence changes.

Procedure

Before starting the experiment, written informed consent was obtained from all participants. This study was carried out in accordance with the American Psychological Association standards for ethical treatment of participants, the Declaration of Helsinki, and was approved by the Ethics Committee of the University of the Basque Country UPV/EHU. Participants were first informed that the experiment dealt with the memory of positive and negative autobiographical experiences that are expected to occur in the future. They then filled out a personal

information sheet, which included age, gender, education, and health status.

The experiment was conducted in three phases. The first phase focused on the task of producing future autobiographical experiences, followed by the second phase that included tests to measure participants' cognitive abilities and, finally, the third phase consisted of the final recall task. The duration of the experiment was approximately 45 min.

To obtain the autobiographical experiences of the participants, a sheet was designed with the instructions in the heading and with two columns. The instructions were read by the experimenter and by each participant when receiving the material. The instructions were:

> "When we think of the future we imagine positive and negative experiences that can occur in the near or distant future. We asked young and older university students to list their future thoughts and would like to contrast them with yours. Write your own positive or negative thoughts."

The first column contained the 16 experiences obtained in the previous study with young psychology students or elderly human sciences students. The experiences of young and old served to counterbalance the model age so that the participants, young and old, generated their own experiences. At the head of the first column of the model experiences a 5 × 2.5 cm color photograph was placed with young or older students with headings *Psychology Students* or *Human Sciences Students* at the top of the photograph. To match the characteristics of the participants of the experiment, both photographs included white western female and male students in academic contexts; one photograph (young adults) representing undergraduate students in their twenties and the other photograph (old adults) elderly students in their sixties to seventies. The second column heading was an orange picture of a silhouette of the bust of a person on with the title *Me*. Below was a list with the cues of the 16 experiences, eight positive and eight negative (**Table 2**) presented randomly, but in the same order as the experiences of the model. The participants of the experiment, young and old, had in the first column the experiences of the model (young students or older students) and had to write in the second column their own future experiences. An example was included at the beginning and end of the lists in each column. Participants had 8 min to examine the experiences of the model, young or old, and use the cues to complete their own experiences. Therefore they had to generate 16 own experiences, eight positive and eight negative. They were told to work at their own pace and to try to complete all the cues.

Between the production task and the final recall three cognitive tests were intercalated. These also served as distractor tasks to fill the 15-min interval between the production tasks and the final recall task. The participants completed a 1-min verbal fluency test on animals, followed by a 4-min verbal comprehension test composed of 50 items containing 4-synonym groups, and finally a 2-min digit-symbol-coding task.

For the final recall task, the participants—young and old—were given a sheet with two blank columns, headed only by the same photos included in the production phase. They were told that they had 8 min to write in the order they wished, both the 16 future experiences of the model, young or old, and the 16 experiences of their own.

RESULTS

In the production task, it was taken into account that the participants had completed at least 14 of the 16 experiences. Those participants who had not correctly remembered at least two experiences of the model and two self experiences were also discarded. Two researchers independently evaluated the participants' responses to the production and recall tasks, and there were no discrepancies between them.

Production of Future Events

The success rate for the production of the 16 future events, eight positive and eight negative, was 98.91%. To analyze the events produced by the participants, a 2 (group age: young, older) × 2 (model age: young or older) × 2 (emotional valence: positive, negative) ANOVA was conducted. The factors model age, $F(1,132) = 1.11$, $p = 0.74$, $\eta_p^2 = 0.001$, and emotional valence, $F(1,132) = 0.48$, $p = 0.49$, $\eta_p^2 = 0.004$, were not significant, whereas the group factor, $F(1,132) = 6.98$, $p = 0.009$, $\eta_p^2 = 0.05$, and the interaction group × valence, $F(1,132) = 4.36$, $p = 0.039$, $\eta_p^2 = 0.03$, were significant. The number of events produced was higher in the young ($M = 15.94$, $SD = 0.29$, range 14–16) than in the older participants ($M = 15.71$, $SD = 0.67$, range 14–16). In the *post hoc* comparisons conducted to explore the group × valence interaction, the Bonferroni test revealed that there were no differences between the production of positive and negative experiences in young people (7.94, 8.00, $p > 0.05$) or in the elderly (7.91, 7.79; $p > 0.05$). In the production of positive experiences no differences were found between the young and older participants (7.94, 7.91; $p > 0.05$), but the older adults produced fewer negative experiences than the younger ones (7.79 < 8.00, $p = 0.03$). Therefore, although older people produced fewer experiences than young people, this limitation only affected negative, but not positive experiences. Thus, although the effect size was small, we found a positivity effect in the elderly in the task of producing self future events.

Correct Recall

Of the 16 experiences of the model or of their own that the participants could remember, the young people correctly remembered between 3 and 15 ($M = 9.01$, $SD = 2.43$) experiences and the older people between 2 and 12 ($M = 6.32$, $SD = 2.09$) experiences. The percentage of experiences correctly recalled was greater than 50% in the recall of one's own experiences ($M = 53\%$, $SD = 16.35$), $t(135) = 2.00$, $p < 0.05$, $d = 0.17$, and less than 50% in the recall of the model experiences ($M = 43\%$, $SD = 16.56$), $t(135) = -4.92$, $p = 0.001$, $d = 0.42$. **Table 3** displays the proportion of positive and negative experiences of the model and self-events that were correctly recalled by young and older adults.

In order to analyze the number of experiences correctly recalled, a 2 (age group: young or older) × 2 (model age: young or older) × 2 (emotional valence: positive and negative) × 2 (experiences recalled: model and self) ANOVA

TABLE 3 | Mean proportion of correct recall of future positive and negative autobiographical events (*SDs* in parentheses) of both the model and own experiences in young and older adults.

Participants	Young		Older	
Model age	**Young**	**Older**	**Young**	**Older**
Model events recall				
Positive	0.62 (0.14)	0.54 (0.16)	0.40 (0.17)	0.40 (0.18)
Negative	0.48 (0.20)	0.44 (0.20)	0.24 (0.14)	0.32 (0.20)
Self events recall				
Positive	0.65 (0.18)	0.65 (0.15)	0.52 (0.19)	0.57 (0.19)
Negative	0.55 (0.21)	0.56 (0.20)	0.35 (0.19)	0.36 (0.24)

was conducted. The factors age group, $F(1,132) = 62.81$, $p < 0.001$, $\eta_p^2 = 0.32$, experiences recalled (model and self), $F(1,132) = 67.32$, $p < 0.001$, $\eta_p^2 = 0.34$, and emotional valence, $F(1,132) = 55.86$, $p < 0.001$, $\eta_p^2 = 0.30$, were all significant. As in the production task, young participants ($M = 0.56$) remembered a greater proportion of experiences than the older participants ($M = 0.40$). Relative to the young and old participants, globally, own imagined experiences ($M = 0.53$) were better remembered than the experiences of the model ($M = 0.43$) and more positive experiences ($M = 0.55$) than negative experiences ($M = 0.41$) were recalled. The model age factor, $F(1,132) = 0.04$, $p = 0.85$, $\eta_p^2 = 0.01$, and the interaction between age group × model age, $F(1,132) = 1.87$, $p = 0.17$, $\eta_p^2 = 0.01$, were not significant. Thus, having a model with experiences provided by people of the same or different age, young or old, had no impact on recall.

Only the interaction between age group x experiences recalled (model or self) x valence, $F(1,132) = 5.40$, $p = 0.022$, $\eta_p^2 = 0.04$, was significant. *Post hoc* comparisons were performed using the Bonferroni test. We found (**Figure 1**) that the differences between young and old were smaller for the recall of their own positive experiences (0.65 −0.56 = 0.09) in comparison with their own negative experiences (0.56 −0.36 = 0.20), positive model experiences (0.58 −0.40 = 0.18) and negative experiences (0.46 −0.28 = 0.18), with $p < 0.05$ in all comparisons. Thus, as in the production task, in correct recall we also find an age-based positivity effect. In addition, in older people the differences between the recall of positive and negative experiences were greater when the experiences were their own (0.55 −0.35 = 0.20) as opposed to the model experiences (0.40 −0.28 = 0.12), $t(67) = 2.03$, $p < 0.05$, $d = 0.26$, whereas in the young there were no significant differences between recall of positive and negative experiences between recall of model experiences (0.58 −0.46 = 0.12) and own experiences (0.65 −0.56 = 0.09), $t(67) = -1.10$, $p = 0.27$, $d = 0.12$. Therefore, not only do the participants remember their own experiences better than those of the model, the older participants are more positively biased than the younger participants, but only when asked to recall their own experiences.

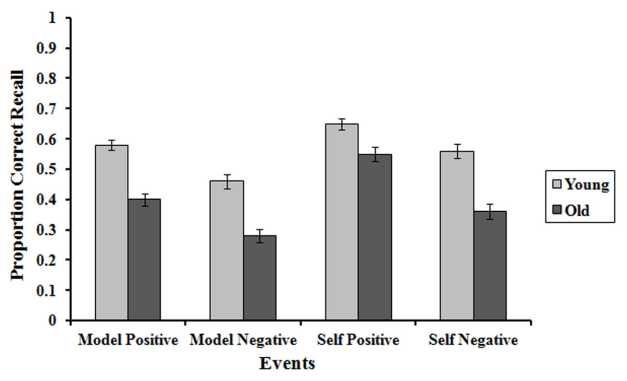

FIGURE 1 | Proportion of correct recall of the positive and negative future events of both the model and own experiences in young and older adults. Error bars represent standard errors.

Errors

Three types of errors were taken into account for the recall task. Commission errors were analyzed, in which the participants recalled experiences or content that was neither in the model nor in the experiences they had produced themselves. Source errors, where they mistook in the recall task the model and their own experiences (e.g., remembering as own experience to travel to Paris, when it was only a model experience) or attributed subjects and actions incorrectly (e.g., if they had produced to discuss with their sister-in-law, remembering to discuss with their brothers), and errors of valence change, which consisted of remembering negative experiences as being positive (e.g., a negative event such as not being able to finish the course being remembered as positive, i.e., finishing the course) or remembering positive experiences as having negative valence (e.g., the positive event of buying a new house being remembered negatively, such as not being able to buy a new house). The types of errors were always independent of one another.

The young participants incorrectly recalled an average of 0.85 experiences ($SD = 0.84$, range 0–4) and the older participants a mean of 0.92 experiences ($SD = 1.09$, range 0–7). The mean number of errors was less than 1 in the recall of self events ($M = 0.82$, $SD = 0.90$), $t(135) = -2.39$, $p = 0.018$, $d = 0.21$, and there were no significant differences in the recall of model experiences ($M = 0.95$, $SD = 1.05$), $t(135) = -0.57$, $p = 0.57$, $d = 0.05$. **Table 4** presents the results of errors in the recall of the positive and negative experiences of both the model and self events in the young and older adults.

In order to analyze the errors, we conducted a 2 (age group: young or older) × 2 (model age: young or older) × 2 (emotional valence: positive and negative) × 2 (experiences recalled: model and self) × 3 (type of errors: commission, source, and valence change) ANOVA. The factors age group, $F(1,132) = 0.35$, $p = 0.56$, $\eta_p^2 = 0.003$, model age (young, older), $F(1,132) = 0.03$, $p = 0.87$, $\eta_p^2 = 0.001$, and experiences recalled (model, self), $F(1,132) = 2.09$, $p = 0.15$, $\eta_p^2 = 0.02$, were not significant, whereas there were significant effects of the emotional valence, $F(1,132) = 53.15$, $p < 0.001$, $\eta_p^2 = 0.29$, and in the type of errors, $F(2,132) = 23.80$, $p < 0.001$, $\eta_p^2 = 0.15$. There were more errors when recalling negative experiences ($M = 0.70$) than

TABLE 4 | Mean number of errors in the recall of future positive and negative events from the model and own events in young and older adults (*SDs* in parentheses).

Participants	Young		Older	
Experiences	**Positive**	**Negative**	**Positive**	**Negative**
Model events recall				
Commission errors	0.13 (0.38)	0.15 (0.43)	0.07 (0.26)	0.06 (0.24)
Source errors	0.07 (0.26)	0.28 (0.57)	0.07 (0.26)	0.10 (0.31)
Valence change	0.03 (0.17)	0.32 (0.58)	0.06 (0.24)	0.56 (1.07)
Self events recall				
Commission errors	0.06 (0.29)	0.09 (0.29)	0.03 (0.17)	0.06 (0.24)
Source errors	0.09 (0.29)	0.09 (0.29)	0.03 (0.17)	0.07 (0.26)
Valence change	0.03 (0.17)	0.35 (0.54)	0.07 (0.26)	0.66 (0.89)

positive experiences ($M = 0.18$). The *post hoc* comparisons using the Bonferroni test showed that there were more valence change errors ($M = 0.52$) than source errors ($M = 0.20$) and commission errors ($M = 0.16$), with $p < 0.001$ values in both comparisons. There were no significant differences between source errors and commission errors.

The interactions age group × error type, $F(2,132) = 9.12$, $p < 0.001$, $\eta_p^2 = 0.07$, and valence × error type, $F(2,132) = 27.70$, $p < 0.001$, $\eta_p^2 = 0.17$, were significant. The younger participants showed more source errors than the older participants ($0.26 > 0.14$, $p < 0.05$), whilst the older participants made more valence change errors than the younger participants ($0.68 > 0.37$, $p < .01$). There were no significant differences in commission errors between the young and old participants (0.21, 0.11, $p = 0.06$) (**Figure 2**). There were more source errors in the recall of negative experiences than the positive ones ($0.14 > 0.07$, $p < 0.05$) and valence changes ($0.47 > 0.05$, $p < 0.001$), but there were no significant differences between positive and negative experiences in terms of commission errors (0.9, 0.7, $p > 0.05$). Also significant was the interaction group × valence × errors, $F(2,132) = 3.61$, $p < 0.05$, $\eta_p^2 = 0.03$ (**Figure 3**). The differences in errors between young and old were restricted to negative experiences. Only in the recall of negative experiences did the younger participants show more source errors than the older group ($0.18 > 0.09$, $p < 0.05$), whilst the older participants made more valence change errors than the younger participants ($0.61 > 0.34$, $p < 0.05$). The change in the value of negative to positive experiences was twice as great in the elderly as in the young. Therefore, the errors also reveal an age-based positivity effect.

Also significant was the interaction model age × valence × experiences recalled (model or self) × errors, $F(3,132) = 3.21$, $p = 0.023$, $\eta_p^2 = 0.03$. There were more source errors in the recall of the experiences of the model than in the own experiences ($0.22 > 0.06$, $p < 0.01$) and more changes of negative to positive valence in the recall of the own experiences than in the recall of the model experiences ($0.56 > 0.34$, $p < 0.05$). The source errors in the recall of the model experiences show that the encoding of the model was more superficial than that of the own experiences. However, valence errors show that age-based positivity effects are applied more frequently to the own experiences than to those of the model. Thus, whilst self-referencing favors memory it also fosters biases of emotional self-adaptation toward positivity.

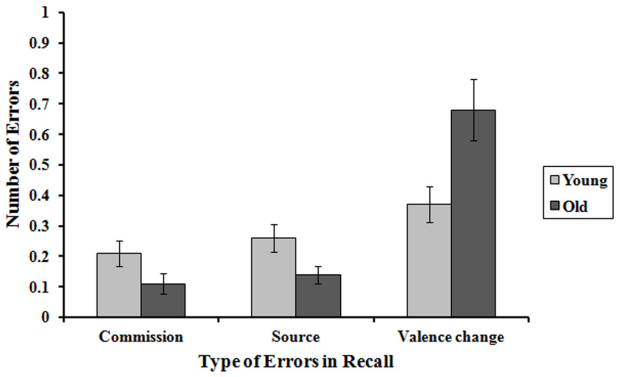

FIGURE 2 | Mean number of errors in the recall of future events in young and old adults. Error bars represent standard errors.

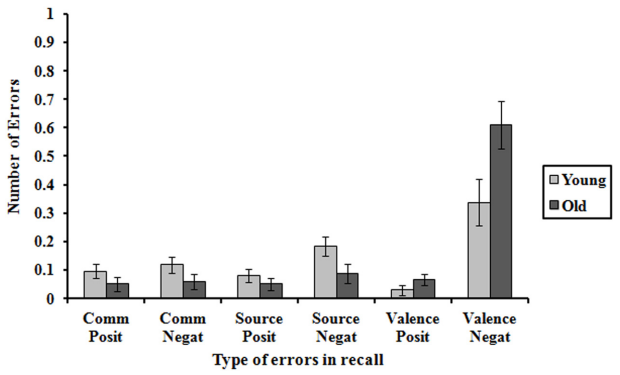

FIGURE 3 | Mean number of commission errors, source errors, and change of valence errors in the recall of positive and negative future events in young and older adults. Error bars represent standard errors.

DISCUSSION

The central objective of this study was to examine age-based positivity effects in the recall of emotional future events. The participants, young and older adults, were presented with a model of future experiences provided by a previous study in young and old adults and had to generate their own future experiences from positive and negative retrieval cues. Although the participants knew that it was a memory experiment, they were never told that they had to study the experiences or that they would have to remember them later. That is, they had no restrictions or complex instructions to follow. It has been observed that the positivity effect is more pronounced in studies that do not constrain cognitive processing and allow the participants' preferences to appear more spontaneously (Reed et al., 2014). Therefore, whilst incidental processing can reduce the level of recall (Schlagman et al., 2009), these are the ideal conditions under which the

positivity effect, the interaction between age (young vs. old) and emotional valence (positive vs. negative), can naturally emerge. As expected, both our young and older participants remembered more positive than negative events, showing a clear optimism bias about the future. In addition, age-based positivity effects were evident in the older participants, since on both the production and recall tasks the elderly group was relatively more resistant to the recall of negative events (Charles et al., 2003). Further, when examining errors the older group transformed twice as many negative future events into positive experiences. Our results are consistent with the Socio-emotional Selectivity Theory (SST; Carstensen, 2006), which emphasizes the importance of prioritizing information related those aspects that generate wellbeing and balance. Although studies are needed to determine the role of inhibitory mechanisms in the positivity effect, findings with young adults in autobiographical memory suggest that people tend to reduce, suppress or block the accessibility of negative thoughts and events (Giebl et al., 2016; García-Bajos and Migueles, 2017).

An interesting aspect of the present study is that it compares young and old participants that share certain characteristics. In particular, all participants, young and old, were university students, a characteristic that homogenizes variables such as culture or socioeconomic status. In this experiment, despite the possible diversity in vital and generational experiences, there were no differences between young and old in terms of years of formal education. The age limit of the older participants was capped at 75 years to prevent high levels of cognitive impairment. Young and old people with serious medical or psychological problems, such as cancer or depression, were also excluded. Older people tend to perceive their health to be worse than young people (Pinquart, 2001) but, after applying these selection criteria, there were no significant differences between the young and older participants in their overall health in this study. Nonetheless, when cognitive abilities are compared, the common limitations associated with aging appear. In the present study three cognitive aspects were evaluated. Young adults showed greater semantic fluency than older adults in a production task of exemplar categories. The older participants had higher scores in verbal comprehension than the young adults when tested on a synonyms task. And older people were at a disadvantage compared with young people when tested on a digit-symbol coding task, which involves greater cognitive abilities, working memory, and processing speed. These results are in agreement with the findings of other studies on cognitive aging, which significantly affects the speed of processing and working memory, but not world knowledge (Park et al., 2002).

In this study we analyzed the positivity effect both in the production task and in the correct and incorrect responses on the recall task. In all three measures we found a preference for the positive contents to the detriment of the most negative contents. As in many studies on episodic future thinking (e.g., Kwan et al., 2010; Gallo et al., 2011), a cueing technique was used to obtain future autobiographical events. Although several studies point out that future events produced in response to experimentally provided cues are of a different nature compared with self-generated future events (Neroni et al., 2016), the cues used in this experiment came from a previous normative study, providing cues to generate relevant emotional facts for each age group. This procedure allowed us to examine the correct recall and the nature of the errors of personal emotional events and those of others of the same age or a different age. In the production task, although the size of the effect was small, the younger participants produced more future events than the elderly group. This result, however, was restricted to negative experiences, because there were no significant differences between the young and old participants in the production of positive events. Therefore, older adults produced fewer negative events than the younger group, which indicates a positivity effect on the task of producing future events in the elderly. With increasing age, motivational priorities change, and a preference for positive information over negative information emerges (Carstensen and Mikels, 2005; Mather and Carstensen, 2005; Schryer and Ross, 2014). Older people have greater accessibility to positive future thoughts, and give priority to thoughts that generate satisfaction or emotional balance. In fact, during the production phase the older participants expressed that they had difficulty imagining negative future events and that they preferred to think positively.

In the recall task, as in the production task, young adults remembered, regardless of emotional valence, more future experiences than the older participants. One of the more consistent findings in the cognitive aging literature is that, compared with younger adults, older adults provide less information and are less accurate. The deterioration in performance in episodic memory tasks, as used in the present study, has been observed in a range of situations including word lists, sentences, fragments of prose, faces, drawings, photographs, or daily life situations (see Salthouse, 1991; Bäckman et al., 2000; and Park et al., 2002, for reviews). In addition, the limitations related to aging are accentuated on tasks of free recall where there are no external cues, and which require self-initiation and the use of retrieval strategies (Craik, 2005). Our results support the notion of a negative effect of aging on the recall of imagined future events.

What was the impact of remembering one's own or others' experiences? Participants recalled more self events than those of the model, regardless of whether the model was young psychology students or older students. As shown in previous studies, both young and older adults can benefit from self-referenced items (Gutchess et al., 2007; Lalanne et al., 2013). The task of generating one's own experiences involves a deeper level of processing than simply reading the experiences provided by other people, and it is known that more elaborate processing leads to better performance on memory tasks (Craik and Lockhart, 1972; Craik, 2002). Therefore, the processing of the model could be more superficial, based on the simple reading of the experiences without elaboration, whereas producing own personal experiences entails more in-depth processing. Both young and older adults can benefit of depth of processing (Lalanne et al., 2013). In addition, the experiences generated by the participants themselves were aspects of personal relevance, and represented plausible and highly significant events that could occur in the near future (D'Argembeau et al., 2012), and events that are relevant to the self are better remembered than the

experiences of other people (Gutchess et al., 2007; Carson et al., 2016).

The self is a meaningful construct that is linked to motivational and social aspects that become increasingly relevant with age (Gutchess et al., 2007). Encoding information with reference to the self can be a natural and familiar strategy for the elderly, which can help to reduce the cognitive processing burden and minimize differences when compared with the performance of young people (Castel, 2005; Gutchess et al., 2007). Thus, relating information to oneself could be an effective encoding strategy that helps to process the information in a meaningful, elaborate, and organized way (see Klein and Loftus, 1988; Leshikar et al., 2015). Contrary to the idea that self-reference effect can be more marginal for older than younger adults (Lalanne et al., 2013), the opposite pattern of results was observed in the present experiment. Further, and contrary to the inconsistent results with a positivity effect in aging found by Leshikar et al. (2015), that self-referencing increased recollection memory for positive items in both young and older adults, a significant positivity effect was evident in the present experiment in the recall of own imagined future events. In fact, the impact of the self was more relevant in older people, particularly when dealing with the positive social-emotional information to which they are motivated to pay special attention. These ideas are supported by the fact that the differences between young and old were less evident in the recall of positive experiences than negative experiences, both for those experiences related to the self and those of the model. Another result consistent with the relevance of self-reference processing and positivity effect is that in older people the differences between the recall of positive and negative experiences were greater for the recall of self future events than those of the model, while in the young people these differences did not appear. Working with the experiences of other people of the same generation or a different generation, whilst it could also have triggered processes of self-referencing and identification as individuals attempt to understand the mental state of others (Hess et al., 2013), was not a relevant variable, possibly because they did not perceive the experiences of the model as being relevant or as pertaining to themselves, or because older adults did not identify with the model of their chronological age (e.g., Rubin and Berntsen, 2006).

Relatively few studies have documented the types of errors made in recall in young and older adults. Compared with younger adults, older adults are impaired in their ability to accurately recall perceptual and conceptual based source information but age differences are reduced or even eliminated when participants process emotional or affective information (May et al., 2005). In this experiment three types of errors were taken into account. First, we examined commission errors, which are due to own elaborations, deductions or reconstructive processes based on typical aspects, stereotypes, or knowledge schemas for such events. Second, we considered source attribution errors, which are due to erroneous subject/action exchanges, and which may depend on the level of processing. For this reason, the attribution errors were more likely in the recall of the model than in the recall of one's own imagined future events. Age-related differences in source errors were restricted to the recall of negative events and, contrary to predictions of age-related decline in source accuracy based on recognition tasks (see May et al., 2005; Gallo et al., 2011), young adults had more source errors than older adults. This result may be derived from the worse recall of negative events in older adults. Third, we looked at the valence change errors. The change from negative to positive valence in recall was more pronounced in the recall of one's own experiences than those of the model. This effect is due to a tendency toward self-adaptation that biases our perspective toward positive events. We are motivated, particularly the elderly, to process information that generates emotional satisfaction and we have a desire to attain a level of emotional wellbeing (Carstensen, 2006). Transforming the negative, which disturbs or worries us, into something positive is an example of this bias. Our results are in line with Fernandes et al. (2008) study. They measured memory for words, pictures and autobiographical material in young and older adults and on all three recall tasks older adults erroneously recalled more positive than false negative memories, showing that older reconstruct the past to accentuate the positive. Even so, consistent with the idea that free recall tasks generate few errors, the average number of errors was less than one per participant in this experiment, as occurs, for instance, in the recall of emotional eyewitness events (e.g., García-Bajos et al., 2012). Nonetheless, the information they provide is very significant because it illustrates the processes involved and the biases derived from constructing and remembering positive and negative future events.

In our results we found that there were more valence change errors than source or commission errors. The positive to negative valence change represented only 9% of all valence changes, while the change from negative to positive events was 91%. Therefore, the most characteristic error was the tendency to favor positive content over negative content in the recall of future events. There were more source errors in negative events than positive events for the model experiences; this difference, however, was less evident for the own experiences, which could indicate that negative events involving others could receive a more superficial and less detailed level of processing, and therefore the connection between subject and action is lost more easily. Contrary to what happens on recognition tasks that generate high proportions of false alarms, commission errors were infrequent in recall and there were no significant differences between young and older participants or between positive and negative events in this regard.

With respect to age differences, the most important errors were the changes in valence from negative to positive events, which were twice as frequent in the older participants in comparison with the younger ones. Therefore, in this experiment, as in the production and the correct recollection of future events, examining the errors also reveals a strong age-based positivity effect in the elderly. One striking feature is that positivity effects are more often applied to one's own experiences than to those of the model. That is, self-referencing favors memory (Klein and Loftus, 1988; Gutchess et al., 2007), but also encourages biases to avoid the negative and to have a vision of emotional self-adaptation that favors positivity.

CONCLUSION

The results of this study show a consistent optimism bias in the memory of future events, that is, we have a greater tendency to remember positive experiences than negative experiences. Thus, imagining the future may have synergistic value for our everyday emotional state. Compared with younger people, older people show a positivity effect, a greater preference for positive content that brings them wellbeing, balance and personal satisfaction. But our data also show another adaptive characteristic of memory, i.e., the rejection of the emotionally negative. People tend not to think about the negative things that may come to them in the future and that generate anguish, fear, or sadness. Our data suggest that older people are particularly prone to avoid negative experiences of the mind and to even transform them into more emotionally pleasant ideas. Because of its social relevance and potential applicability to clinical settings, it will be a challenge for future research to examine which variables encourage positivity when imagining the future, along with the real impact of this effect on everyday life.

AUTHOR CONTRIBUTIONS

All the authors contributed to the project of this research. MM and EG-B conceived, designed and prepared the materials for the experiment. MM and AA performed the experiment and collected the data. EG-B and MM scored the tasks and EG-B analyzed the data. EG-B and MM wrote the manuscript. All the authors revised critically the paper for important intellectual content, approved the manuscript for publication, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Thin-Slice Measurement of Wisdom

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Objective Measurement of Wisdom within a short period of time is vital for both the public interest (e.g., understanding a presidential election) and research (e.g., testing factors that facilitate wisdom development). A measurement of emotion associated with wisdom would be especially informative; therefore, a novel Thin-Slice measurement of wisdom was developed based on the Berlin Paradigm. For about 2 min, participants imagined the lens of a camera as the eyes of their friend/teacher whom they advised about a life dilemma. Verbal response and facial expression were both recorded by a camera: verbal responses were then rated on both the Berlin Wisdom criteria and newly developed Chinese wisdom criteria; facial expressions were analyzed by the software iMotion FACET module. Results showed acceptable inter-rater and inter-item reliability for this novel paradigm. Moreover, both wisdom ratings were not significantly correlated with Social desirability, and the Berlin wisdom rating was significantly negatively correlated with Neuroticism; feeling of surprise was significantly positively correlated with both wisdom criteria ratings. Our results provide the first evidence of this Thin-slice Wisdom Paradigm's reliability, its immunity to social desirability, and its validity for assessing candidates' wisdom within a short timeframe. Although still awaiting further development, this novel Paradigm contributes to an emerging Universal Wisdom Paradigm applicable across cultures.

Keywords: Thin-slice, measurement of wisdom, Thin-slice wisdom Paradigm, Berlin Wisdom Paradigm, Universal Wisdom Paradigm

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INTRODUCTION

Political leaders (e.g., Lincoln, Mao Zedong) are among the most frequently nominated wisdom exemplars in both Western and Eastern cultures although both political systems and wisdom criteria vary across different cultures (Hu et al., 2016; Weststrate et al., 2016). However, these lay people's nomination may be influenced by irrational factors, e.g., political leaders' facial attractiveness (Zebrowitz et al., 2015). Therefore, a vital issue for democracy is to measure wisdom objectively, especially within a short period of time. In fact, rapid objective measurement of personal wisdom is also important for wisdom experts who hope to promote wisdom development. However, to date, wisdom research has been limited by methods that rely on self-report (e.g., Ardelt's three-dimensional wisdom scale) and verbal think-aloud procedures (e.g., Berlin Wisdom Paradigm) that allow people to give socially desirable answers.

A method that allows real-time emotion assessment by human raters, or even artificial intelligence, may minimize the chance for social desirability and thus be a more objective measure of wisdom. In fact, emotion plays an important role in the development and utilization of wisdom (Sternberg and Jordan, 2005; Ardelt and Ferrari, 2014). A recent review reported that emotional homeostasis was commonly cited as a component of wisdom (Bangen et al., 2013). However, very few empirical studies have been conducted on the emotional aspect of wisdom.

Kunzmann and Baltes (2003) measured participants' self-report of affective feelings and found negative correlations of wisdom score to negative and pleasant feelings in the past year and thus proposed studying the relationship between wisdom and actual emotional reactions to specific emotion-arousing events. Recently, Thomas and Kunzmann (2013) extended the Berlin scenario to real-life video clips of marital conflicts; however, they relied on the participants' verbal report to measure emotional reactions, which is equally vulnerable to social desirability, especially when asked to describe or explain their thoughts and behavior, rather than simply verbalizing their silent thoughts about the problem (Ericsson and Simon, 1993).

The traditional Berlin Wisdom Paradigm assessed participants' responses to hypothetical life-scenario situations usually irrelevant to their personal life and thus less emotionally engaging than real life situations (Baltes and Staudinger, 2000). For example, "In reflecting over their lives, people sometimes realize that they have not achieved what they had once planned to achieve. What should one/they do and consider?" (Staudinger and Baltes, 1996, p. 762). Participants reflected on these questions for a while before they responded by thinking aloud. Their responses were recorded, transcribed, and finally rated by 10 well-trained raters on five Berlin wisdom criteria: Declarative knowledge, procedural knowledge, value relativism, lifespan contextualism and management of uncertainty (Staudinger et al., 1994).

Ardelt (2004) critiqued the Berlin Wisdom Paradigm's definition of wisdom as expert knowledge, arguing that wisdom cannot exist independently of individual people. Based on Clayton and Birren's definition of wisdom, Ardelt (2003, 2004) proposed that wisdom involves the integration of cognitive, reflective, and affective personality qualities. Ardelt developed a 39 items self-report/self-assessment scale to measure wisdom on these three dimensions, not unlike many assessments of personality traits (e.g., Eysenck Personality Traits Scale [1975]). For each item, participants indicate on a 5-point response scale from "Definitely true of myself" or "strongly agree" to "Definitely not true of myself" or "strongly disagree" (Ardelt, 2003, 2004).

Although these two Western wisdom paradigms are well-known and have been used internationally, studies have shown that cultures differ in how wisdom is understood (e.g., Ferrari et al., 2011; Brezina and Oudenhoven, 2012; Hu et al., 2016). In general, Eastern understanding of wisdom emphasizes both analysis and synthesis, whereas Western understandings of wisdom generally emphasize analysis (Takahashi and Bordia, 2000). Western researchers studying wisdom are arguably influenced by Western culture and have mainly studied Western participants growing up in a Western cultural background (for reviews, see: Sternberg and Jordan, 2005; Bangen et al., 2013; Glück et al., 2013); therefore, their scientific models of wisdom may not be relevant for other cultural groups.

Bang and Zhou (2014) argued that prototypical Chinese wisdom was generally congruent with that in Ardelt's wisdom model, and conducted a survey among Chinese young adults using Ardelt's three-dimensional wisdom scale. However, factor analysis failed to identify the three dimensional model proposed by Ardelt, and instead found a 4-dimensional structure involving "non-dualistic thinking," "perspective-taking," "non-resentment," and "empathy." In fact, our previous survey with 97 Chinese adults (46 males, aged from 18 to 23 years, $M = 19.71$, $SD = 1.19$ years) also failed to identify the three dimensional model proposed by Ardelt, the model in the 12-Item Abbreviated Three-Dimensional Wisdom Scale (Thomas et al., 2015), or the four-factor structure proposed by Bang and Zhou (2014) (For the details of our survey, see the Supplementary Tables.).

Moreover, the Lie/Social desirability score (measured within Eysenck personality scale) was significantly positively correlated with Ardelt wisdom score ($r = 0.26$, $p = 0.037$), confirming Ericsson and Simon's (1993) and Staudinger and Glück's (2011) proposition that self-reported measurement of psychological constructs may be influenced by self-serving bias and inaccurate self-perception. In fact, a positive correlation between impression management and scores on some items in the Ardelt (2003) three-dimensional wisdom scale was already demonstrated in a previous study (Taylor et al., 2011).

Considering above theoretical rationales and empirical findings, we conducted this study to develop a measurement of wisdom that would allow measurement of real-time emotional reactions and be suitable for cross-culture studies. A performance-based measurement was developed by adapting the Berlin Wisdom Paradigm.

The traditional Berlin Wisdom Paradigm relies on an objective third-person perspective when measuring wisdom performance, using vignettes potentially irrelevant to participants' personal lives. Mickler and Staudinger (2008) extended the original Berlin paradigm and argued that 'general wisdom' as measured in the traditional Berlin Wisdom Paradigm differed from Personal Wisdom, considered an individual's insight into his or her own life. However, again following Ericsson and Simon (1993), there is good reason to believe that their first-person perspective wisdom performance measure may be as vulnerable to social desirability and inaccuracy in self-judgment as is Ardelt's measure. For this reason, we adopted a position between these two extremes and developed a second-person perspective wisdom performance measure, in which participants imagined the lens of a camera as the eyes of their friend/teacher whom they advised about pre-designated life dilemmas framed in the Berlin wisdom vignettes.

Our 2nd person task is not meant to replicate the Berlin paradigm tasks but to adapt them to this new approach. The original Berlin paradigm used vague problems to elicit participant's meta-level thinking rather than their concrete advice, which is one of the key aspect critics like Ardelt (2004) have leveled against it. Our aim is to strike a balance between general 3rd person considerations provoked by the original Berlin paradigm and 1st person approaches that are more emotionally

engaging but also liable to social desirability bias. Ericsson and Simon (1993) underlined that research participants were simply verbalizing the information they attend to while generating an answer to a problem (which is what happens in the 2nd person method) instead of describing, explaining, justifying, or rationalizing their actions (which is what happens in the 1st and 3rd person methods), and thus the 2nd person method may be less vulnerable to social desirability bias.

We expected that talking to an imagined friend when left alone in a quiet room should be less affected by social desirability, compared with thinking-aloud about oneself being a friend. Although the task of speaking to a camera as if another person may seem unnatural, and so not ecologically valid, it is actually modeled on the 'empty chair' technique developed in the Gestalt therapy that has been empirically proven to be of therapeutic value despite its artificiality, because it evokes a much deeper and authentic response to life problems (Paivio and Greenberg, 1995; Wagner-Moore, 2004) —and therefore, we suggest, one probably less subject to social desirability—than simply describing or explaining what must be done (as required in the original Berlin paradigm) or oneself as a friend (as in Staudinger's personal wisdom paradigm). It is for this reason, too, that we can expect the emotions generated and captured by the camera to be an important non-verbal indicator meaningfully associated with wisdom. In fact, many Thin-slice studies have demonstrated the accuracies in ratings of personality and intelligence from videotaped episodes that lasted only for a few minutes or even seconds; an accuracy in intelligence rating not influenced by stereotypes of gender and age (Ambady and Rosenthal, 1993; Borkenau et al., 2004).

Furthermore, the traditional Berlin wisdom vignettes are implicitly based on Western cultural contexts that may not be suitable for measuring wisdom among the Chinese. A previous study extending the Berlin paradigm has already demonstrated that wise reasoning about fundamental life issues is related to the relevance of problems in individuals' own lives (Thomas and Kunzmann, 2013). Thus, wisdom vignettes based on Chinese social and cultural life might be more ecologically valid than the original Berlin vignettes for Chinese participants. For these reasons, two culturally appropriate scenarios were used in our paradigm: "a friend's unrealizable dream," a relatively common life scenario for contemporary Chinese adults; and "a teacher's unrealized dream," adapted from a classic Berlin scenario.

Since the Berlin wisdom Criteria also may not be perfectly applicable to Chinese participants, a Chinese Wisdom Criteria (see **Table 1** for details) was developed based on our previous study exploring Chinese implicit theory of wisdom (Hu et al., 2016): 50 older Chinese (age 60–84 years) and 50 younger (age 20–30 years) participants first nominated personal acquaintances and historical figures as wisdom exemplars and then gave their own definition of wisdom from which five latent factors were identified. In order to compare the Berlin criteria and our Chinese criteria, our participants' responses were rated on both sets of criteria by 20 well-trained raters.

In addition, facial expressions during each wisdom response were videotaped and then analyzed for emotional reactions. The effect of emotion on physical expression is faster, more automatic, less controlled and thus less contaminated by social desirability than that on verbal speech. In fact, Paul Ekman and Friesen (2003) argue that authentic emotions behind facial expressions can be detected through combined analyses of multiple facial muscular actions of transient subtle micro-expressions. Following Kunzmann and Baltes (2003), we hypothesized that emotional reactions (i.e., positive and negative emotion) of individuals with wisdom—understood within the Berlin Paradigm as expertise in the fundamental pragmatics of life—should be more prevalent than that of individuals without this life expertise.

Finally, in order to test whether the participants' tendency toward social desirability would affect their wisdom performances, in light of general personality traits, they completed the Eysenck Personality scale before taking our wisdom measurement.

Hypotheses

The wisdom vignettes based on Chinese social and cultural life should be more reliable than the Berlin vignette adapted for Chinese participants when assessing wisdom performance in China. Nevertheless, the wisdom rating on the Chinese wisdom criteria should be positively correlated with the Berlin Wisdom criteria, due to similarities between the Berlin wisdom model and Chinese implicit theory of wisdom that reflect broad cultural universals about wisdom. Positive and negative emotional reactions during the wisdom performance should be more prevalent in responses rated as wiser. Finally, social desirability score should not be significantly correlated with either the Berlin or the Chinese wisdom rating.

MATERIALS AND METHODS

All procedures used in the current study were approved by the Ethic Committees at Zhejiang Normal University and the University of Toronto. Sample size was selected to allow for quantitative analyses with Type I error rate set at 0.05. Written consent was not obtained from our participants, because they had given their recorded verbal consent to participate, and given their names and contact information before finishing our survey; moreover, we had explained the nature of our study, assured them they could stop at any time without penalty, and ensured that their personal information would be kept private. This consent procedure was approved by the Ethic Committees.

Participants

Thirty undergraduate students (12 males) at Zhejiang Normal University aged from 18 to 21 ($M = 19.10$, $SD = 0.75$) participated in this study. All subjects were native Chinese speakers and had normal or corrected-to-normal vision. Each participant was compensated 20 RMB (about 3 United States dollars).

Material

The Chinese version of shortened Eysenck personality scale (Qian et al., 2000) measures Psychoticism, Extroversion,

TABLE 1 | Chinese wisdom criteria and their definitions.

Wisdom component	Definition	Sample quotations
Cognitive engagement	Motivation to engage in cognition and reflection about the external world and the internal mind; skill in such cognition, and the outcome of these cognitive processes.	"They (singers) may not be as happy as they appear to be". "There is no standard criterion to measure whether you realize your dream or not". "You have educated us diligently and contributed much, and yet you say 'life is meaningless,' which I can sympathize with: your once busy life has suddenly become idle".
Practical engagement	Motivation and ability to successfully put into practice the outcome of cognitive engagement.	"You could teach singing to the elders in your neighborhood". "You could participate in some competitions for singers, and improve your singing". "You need more practice. Even if your skill in singing would improve in the future, it would take a long time".
Social engagement	Motivation and ability to engage with others for the goodness of everyone.	"Your song brings happiness to us, your friends". "You need to consider your family". "You need to consider others' potential negative opinion if you still want to become a singer". "You could tell us students about your dream, and we will realize it for you".
Spirituality of disengagement	Disengage oneself from civilization and worldly issues and return to the primitive nature or "Buddha": the ultimate truth.	"If you are only seeking fame, social status and wealth (through becoming a singer), I would advise you to quit" "If you realize your dream, you may suddenly feel life is meaningless".
Positive mindset	In face of the hardship in life, exert oneself to overcome the difficulty and improve oneself, through satisfaction with life.	"Competition in today's society is so fierce that if your mental strength is firm enough I would encourage you to fearlessly strive for your dream". "If you keep seeking your dream, you may feel your life is meaningful, even if it is never realized".

Neuroticism/emotional instability, and Lie/Social desirability scales: Psychoticism is the tendency to develop psychotic symptoms or anti-social behavior; Extraversion is the tendency to be active in social activities; Neuroticism measures individuals' emotional instability and the tendency to develop negative feelings; the Lie scale contains questions about which individuals tend to lie due to social desirability. Reliability tests revealed that Cronbach's alpha for these subscales was mixed: Neuroticism: 0.75; Extroversion: 0.71; Lie/Social desirability: 0.59; and Psychoticism: 0.21.

Berlin Style Wisdom Vignettes

Two fundamental life scenarios were printed on an A4 paper: (1) The "life review problem" adapted from a Berlin scenario: *"Imagine one of your teachers suddenly feels life is meaningless because he has not realized a dream he always had since his youth. What would you say to him?"*; and (2) the "Life plan problem" was invented by the first author as potentially more common in real lives of contemporary Chinese students, while remaining true to the Berlin Wisdom Paradigm action-theoretical approach, in which wisdom is involved in life planning, management and review: *"Imagine one of your friends dreams of becoming a singer, but he is really bad at singing and is not young anymore; if he asked you how he sings, what would you say to him?"*

Answers were scored analogously to the ***Berlin Manual instructions (Staudinger et al., 1994)***, ignoring several aspects of the original Berlin manual instructions due to the particulars of our research setting; in particular, the think-aloud procedure was not used, given our 2nd-person approach to measuring wisdom, and thus the sections related to the think-aloud procedure training were replaced with an analogous 2nd-person practice task. Furthermore, ***Chinese wisdom criteria*** were developed based on a previous study on implicit theory of wisdom among Chinese (Hu et al., 2016).

In addition, we used a ***laptop with a camera*** that captured 29 frames per second of emotional reactions, which were later analyzed in the ***iMotions – Attention Tool FACET module (version 2.1)***. Previous studies have confirmed a link between the facial affect data of the FACET module to established peripheral arousal measures such as event-related potentials (ERP), heart rate variability (HRV), and galvanic skin response (GSR) (Amico et al., 2016).

Procedure

Participants finished the Eysenck personality scale about one or 2 months before taking our Thin-slice wisdom measurement.

The participants completed the two vignette scenario assessments in a quiet laboratory room individually. They were instructed to read the vignettes printed on an A4 paper while sitting in an armchair, with the laptop camera set about 30 cm away from their face. The participants were asked to imagine the camera as the eyes of their friend/teacher and talked to "him/her" while their responses were videotaped by the camera. Before the formal task, participants underwent a practice task (i.e., talking to a friend who had become bankrupt) to become accustomed to the unusual situation of talking to a camera. In order to mimic a natural situation, there was no set time limit for participant responses. During both the reflection and answer time, the experimenter left the laboratory room so that the participants could feel less constrained in their performance.

Data Analysis

Wisdom Ratings

Twenty graduate students in the Department of Psychology at Zhejiang Normal University capable of reading academic papers in psychology written in Chinese and English were recruited and trained according to the Berlin Wisdom Manual. Each rater was compensated 200 RMB (about $30 United States). Ten raters (7 females, ages 23–27, Mean age = 24, $SD = 1.33$) were randomly chosen to rate the videotaped responses on the Berlin Wisdom criteria; another 10 raters (6 females, ages 24–28, Mean age = 26, $SD = 1.20$) rated the videotaped responses on the Chinese wisdom criteria. To prevent mutual influence from the ratings on different criteria ("halo effect"), each rater rated videos on only one criterion; in order to calculate the inter-rater reliability, two raters rated each criterion.

Our raters were adequately trained according to the manual (e.g., scale anchoring, rating each transcript independently rather than ranking them, using training videos). All raters engaged in a practice wisdom rating (rating a videotape of the first author's advice concerning the advantages and disadvantages for a Chinese student to study abroad for a doctorate degree) before rating the participants' videotaped performance. Each rater rated the videotaped performance in random order. Participants' responses ranged from 14 to 502 seconds ($M = 88$ s).

Facial Expression Analysis

The Attention Tool FACET calculates the probable occurrence of seven basic emotions (joy, sadness, anger, contempt, fear, surprise, and disgust) and three general valences (negative, positive, and neutral). This system first identifies and locates the face in each frame of the video; and then automatically measures basic facial Action Units (AU) listed in the well-established Facial Action Coding System (FACS), a comprehensive, compositional, and anatomically based facial muscular movement analysis system (Ekman and Rosenberg, 1997). Quoting the FACET module Manual, "It is useful to think of facial expressions as words and of AUs as the letters that make up those words. For example, one of the most common expressions of fear contains a combination of AU1 [Brow Raiser Frontalis], AU2 [Outer Brow Raiser Frontalis], AU4 [Brow Lowerer Depressor Glabellae], and AU5 [Upper Lid Raiser Levator Palpebrae Superioris]."

FACET module provided an evidence value for each emotion category on each frame of each video. The aggregate time of the positive evidence frames for a category of emotion per video was used as an ideal estimation of the aggregate time of that emotion, since the chance that a frame was mistaken as emotional equals the chance that an emotional frame failed to be identified.

In order to compare the aggregate time of an emotion across responses of varying duration, we calculated the "proportional time of emotion" by dividing the number of positive evidence frames by the total number of frames within a video, excluding ineffectively analyzed frames. For example, the response of one female participant for the first Berlin-Style Wisdom vignette lasted for about 88 s and generated 2565 effectively analyzed frames of which 27 were positive on surprise; thus, the proportional time of surprise was 27 divided by 2565, or about 1.05% percent.

RESULTS

Reliability of the Berlin and Chinese Wisdom Ratings

In the life plan problem, "a friend's unrealizable dream," the reliability between the two raters was analyzed for each criterion and inter-rater reliability was acceptable for all the Berlin criteria (Cronbach's Alpha > 0.60). Overall Cronbach's alpha for the Berlin paradigm was computed by treating the 10 individual ratings as items, Cronbach's Alpha > 0.70. Therefore, these ratings were averaged to get the final Berlin Wisdom rating, ranging from 1.80 to 5.10 ($M = 3.19$, $SD = 0.91$).

Inter-rater reliability was acceptable for all the Chinese criteria, except for the Chinese wisdom criterion "Spirituality of disengagement," which was probably difficult for the student raters to comprehend; two middle-aged raters were then recruited to rate the participants' performances in the life plan problem on "Spirituality of disengagement": One was a 35-year-old male associate professor in Psychology at Zhejiang Normal University; the other was a 33-year-old male editor for Zhejiang University Publisher. They were not financially rewarded for their ratings, but were promised a research report of this study. Inter-rater reliability for this new rating was acceptable (Cronbach's alpha = 0.83), therefore, the average rating from these middle-aged raters was adopted as the final rating on "Spirituality of disengagement." Overall Cronbach's alpha for the Chinese criteria ratings was computed by treating the 10 individual ratings as items, Cronbach's Alpha > 0.70. These ratings were then averaged to get the final Chinese Wisdom rating, ranging from 2.90 to 6.00 ($M = 4.37$, $SD = 0.67$).

In the life plan problem "a friend's unrealizable dream," the Berlin Wisdom rating was significantly positively correlated with the Chinese Wisdom rating, $r = 0.73$, $p < 0.001$. Pearson correlations among and between the ratings on each of the Berlin and Chinese wisdom criteria in the life plan problem are shown in **Table 2**.

Because "Positive Mindset" was negatively correlated with the ratings on other wisdom criteria overall, this wisdom component was removed from our model, and the Chinese wisdom rating was calculated by averaging the ratings on the other four Chinese wisdom criteria, ranging from 3.13 to 6.25 ($M = 4.43$, $SD = 0.79$). This newly calculated Chinese wisdom rating was significantly positively correlated with the Berlin wisdom rating, $r = 0.87$, $p < 0.001$. For the following analyses, this Chinese wisdom rating based on the model of cognitive, practical, social engagements and spirituality of disengagement was adopted.

In the life review problem ("a teacher's unrealized dream"), inter-rater reliability was not acceptable for most of the Berlin and Chinese criteria; therefore, no wisdom rating was calculated for this problem.

TABLE 2 | Correlations for ratings on the Berlin and Chinese wisdom criteria.

Wisdom criteria	Practical engagement	Positive mindset	Social engagement	Spirituality of disengagement	Factual knowledge	Procedural knowledge	Contextualism	Value relativism	Uncertainty
Cognitive engagement	0.51**	−0.17	0.73**	0.50**	0.66**	0.74**	0.77**	0.68**	0.76**
Practical engagement		0.54**	0.46*	0.18	0.42*	0.43*	0.19	0.22	0.50**
Positive mindset			−0.17	−0.35	−0.09	−0.34	−0.47**	−0.40*	−0.12
Social engagement				0.44*	0.86**	0.84**	0.71**	0.58**	0.67**
Spirituality of disengagement					0.41*	0.50**	0.64**	0.40*	0.43*
Factual knowledge						0.78**	0.73**	0.54**	0.58**
Procedural knowledge							0.79**	0.67**	0.72**
Contextualism								0.74**	0.69**
Value relativism									0.58**

*$p < 0.05$, **$p < 0.01$.

Relationship between Emotion Reactivity and Wisdom Performance

Twenty-nine participants' effectively measured frames were more than 84% of the total frames in the videos ($M = 99.11\%$, $SD = 2.58\%$). [The facial expression of one participant was not effectively measured (54.59%), probably because she did not look directly at the camera]. Therefore, data of these 29 participants were included in the following analyses. The proportional time of each category of emotion in each scenario was listed in **Table 3**. Paired sample t-tests revealed no significant difference in any category of emotion between the performances in life plan and life review problems.

In order to test whether participants' emotion reactivity was related to their wisdom performance, Spearman correlation analyses[1] were conducted between the proportional time of each emotion (seven basic emotion categories and three valences) and the Berlin and Chinese Wisdom ratings. Results showed that the proportional time of surprise was significantly positively correlated with both the Berlin and Chinese Wisdom ratings (See the Supplementary Figures for the scatterplots); other correlations were not significant (see **Table 4**).

Relationship between Emotion Reactivity and Response Length

Response length was considered a meaningful outcome of the wisdom performance in a previous study (Mickler and Staudinger, 2008), therefore, Spearman correlation analyses were conducted to examine the relationship between emotion reactivity and response length. Proportional time of surprise was significantly positively correlated with response length in both life dilemma tests: "a friend's unrealizable dream" ($rho = 0.41$, $p = 0.029$) and "a teacher's unrealized dream" ($rho = 0.46$, $p = 0.013$).

Correlations with Social Desirability

Pearson correlation analysis revealed that neither the proportional time of emotion, nor the wisdom ratings were significantly correlated with Social desirability score, all $p > 0.05$. Nevertheless, the Berlin Wisdom rating was significantly negatively correlated with "Neuroticism," $r = -0.47$, $p = 0.024$ ($N = 23$).

DISCUSSION

Our results showed acceptable inter-rater and inter-item reliabilities for our Thin-Slice Wisdom Paradigm. Moreover, this novel approach's minimization of social reliability was partially confirmed by the null correlation between the wisdom ratings and Social desirability score in the Eysenck Personality scale. Of course, participants still knew that they were talking to a camera and that their responses might be evaluated, so their responses might still differ from what they would actually say in a real-life situation. Nevertheless, our novel paradigm provides

[1]The distribution of an emotion's proportional time is not normal, thus Pearson correlation analyses were not suitable.

TABLE 3 | Proportional time of emotion during the participants' performance in different scenarios (unit: percent).

	A friend's unrealizable dream				A teacher's unrealized dream			
Emotion	**Minimum**	**Maximum**	**Mean**	***SD***	**Minimum**	**Maximum**	**Mean**	***SD***
Joy	0.0	91.4	9.5	18.1	0.0	34.4	6.1	4.5
Anger	0.0	93.7	17.0	24.5	0.0	100.0	14.3	28.0
Surprise	0.0	65.7	5.9	12.8	0.0	66.3	4.1	13.3
Fear	0.0	60.4	15.8	21.3	0.0	75.7	15.9	20.7
Contempt	0.0	74.1	10.4	18.7	0.0	78.7	10.0	16.6
Disgust	0.0	100.0	33.3	36.1	0.0	100.0	30.4	35.1
Sadness	0.0	61.0	12.3	19.1	0.0	80.5	14.1	22.8
Neutral	0.0	100.0	48.6	28.6	0.0	100.0	50.4	29.7
Positive	0.0	93.8	21.1	25.5	0.0	53.3	16.6	15.1
Negative	0.8	100.0	70.8	30.7	0.8	99.9	72.2	30.4

a more ecological approach capturing more emotional aspects, compared with other methods.

The Roles of Wisdom Criteria and Wisdom Vignette in Performance Measurement

The Berlin wisdom rating was highly consistent with the Chinese Wisdom rating. In fact, previous studies have demonstrated that wisdom rating by raters' own understanding of a wise response (Global Wisdom Rating) is highly consistent with ratings on the Berlin criteria (Staudinger et al., 1992; Zacher et al., 2015). Taken together, these results suggested that performance measures of wisdom are relatively robust across different rating systems. On the other hand, the "life review problem" vignette adapted from the Berlin wisdom vignette was not reliable, perhaps because advising a retiring teacher is an unusual life scenario for Chinese undergraduate students. Therefore, designing appropriate vignettes with which participants have experience was arguably much more important than selecting culturally specific wisdom criteria for wisdom measurement across different cultures.

Although only one Chinese wisdom criterion "Cognitive engagement" is related to the Berlin wisdom criteria, the Chinese wisdom ratings were mostly significantly positively correlated with the Berlin wisdom ratings (see **Table 2**), probably because wisdom is a perfect integration of different psychological components—as demonstrated by the significant positive correlations among different Chinese wisdom components—and thus the level of one wisdom component (e.g., cognitive engagement) can predict the levels of other wisdom components (e.g., practical engagement, social engagement).

The Role of Experience in Wisdom Rating

In the life review problem, "a teacher's unrealized dream," inter-rater reliability was unacceptable on almost every wisdom criterion, perhaps because these undergraduate students had no experience of advising a teacher on any life problem, something potentially considered improper in Chinese culture. Likewise, although inter-rater reliability was unacceptable between the student raters on the Chinese wisdom criterion "Spirituality of disengagement," it was acceptable between middle-aged academic raters; this suggests that raters' life experience is important for accurate rating on an elusive criteria about a profound life philosophy, one that may require a certain amount of life experience to understand. In fact, previous researchers have suggested that even well-trained student raters were not as good as middle-aged academics raters, with inter-rater correlations among student raters being lower than those among middle-aged academic raters (Glück et al., 2013).

TABLE 4 | Spearman correlations of Chinese and Berlin wisdom ratings with different emotions during the scenario "A friend's unrealizable dream."

	Chinese	**Berlin**
Joy	0.12	0.00
Anger	−0.18	−0.04
Surprise	0.55**	0.50**
Fear	0.23	0.33
Contempt	0.05	0.06
Disgust	−0.05	−0.08
Sadness	0.14	0.09
Neutral	−0.06	−0.08
Positive	0.16	0.02
Negative	−0.21	−0.09

*$p < 0.05$, **$p < 0.01$.

"Spirituality of disengagement" may be implicated in the implicit theory of wisdom among the middle-aged and older raters but not student raters, making comprehension of "Spirituality of disengagement" more difficult for them. Still, the ratings of these middle-aged raters were moderately positively correlated with one student rater, respectively, $r = 0.44$, $r = 0.55$, but not the other, all $r < 0.15$. Therefore, some student raters may have a more developed implicit theory of wisdom, that allows them to comprehend this wisdom criterion just as do the middle-aged academic raters.

Emotion, Wisdom, and Aging

The significantly negative correlation between neuroticism and Berlin wisdom rating was consistent with the common theory that emotional homeostasis is a subcomponent of wisdom (Bangen et al., 2013). Moreover, with this Thin-slice Wisdom Measurement we found a significant positive correlation between surprise and wisdom when discussing a hypothetical scenario. Although our sample was not large, our effect size was fairly large: both *rho* > 0.50 (between the wisdom ratings and proportional time of surprise). With a larger sample size, it would have been more likely to detect a significant correlation.

Feeling of surprise may be the beginning of wisdom. Individuals usually do not question or ponder their original thoughts until they feel surprised by unexpected information: either from external environment or from their internal reaction to their own thoughts. Since feeling surprised is positively correlated with feeling of difficulty—something considered important for metacognition (Touroutoglou and Efklides, 2010), itself believed to be important for wisdom (Sternberg, 2001)—surprise may incite individuals to wonder about and then to reflect upon their original thoughts, thereby arriving at a deeper understanding of what is being discussed. Perhaps a greater feeling of surprise provokes greater cognitive effort, as demonstrated by the significant correlation between response length and feeling of surprise in our results.

By contrast, "Positive Mindset" was generally negatively correlated with wisdom ratings on other criteria (see **Table 2**), especially with the Berlin Criteria of "Contextualism" and "Value Relativism" ($r = -0.47$, $r = -0.40$, all $ps < 0.05$); thus, "Positive Mindset" may not be a valid component of Chinese wisdom. Wiser individuals are probably more willing to process negative information, even if this undermines their positive feelings. By contrast, less wise individuals are more willing to process and recall the positive information, a "positivity bias" that might increase when getting older, evidenced by previous studies on emotion recognition and memory (Baddeley et al., 2015; Di Domenico et al., 2015; Altamura et al., 2016). Wiser individuals may have less "positivity bias" as they age, and thus show less positive emotion when addressing difficult life problems.

Relevance for Cross-Cultural Studies of Wisdom

In general, our studies provided intriguing results for wisdom researchers who plan to conduct cross-cultural studies of wisdom, suggesting the need to consider cultural differences in both the conception and structure of wisdom. As revealed in our studies, the Berlin wisdom vignette may not be applicable to participants from non-Western cultures. Nevertheless, we should expect some universal aspects of wisdom to be shared by all human beings, since some fundamental life problems are shared by people in every nation (e.g., the life plan problem of an "unrealizable dream").

An ambitious but meaningful project may be to identify common life problems through a review of autobiographies across different cultures, perhaps of wisdom exemplars. We hypothesize that similarities in fundamental life problems across cultures should predominate, despite some cultural differences. Moreover, even though people in different cultures may respond differently to these fundamental life problems, we expect some latent universal criteria to be evident in their performance; a wise response to such universal life problem may be considered wise across different cultures and explain the timelessness and near-universal appeal of some historical wisdom exemplars like Buddha.

In cross-cultural wisdom research projects, performance-based wisdom measurement is probably a more appropriate method for effectively identifying universal and culturally specific wisdom components and criteria. Videotaped wisdom performance of participants can be rated on different systems of wisdom criteria, based on different wisdom models. For example, wisdom criteria could be developed from Ardelt's three-dimensional wisdom model and participants' wisdom performance in different nations rated on Ardelt's wisdom dimensions, just as they were on the Berlin wisdom criteria and our Chinese wisdom criteria. Eventually, researchers could use factor analysis to identify the common factors and combine these wisdom criteria into universal criteria, thereby contributing to the development of a Universal Wisdom Model and Paradigm.

Perhaps the most important innovation in our study was the Thin-slice wisdom measurement: rating videotaped wisdom performances in which participants performed as if they were really addressing some fundamental life problem by talking to someone personally familiar to them. Although such a performance was fictional, as in Gestalt therapy, performers' habitual thinking, emotion, and action should reveal a habitual Gestalt and expressed through their emotional reactions.

Non-verbal wisdom components are necessarily missing in transcript responses commonly used to assess wisdom performance, therefore, examining a person's emotional expression associated with their speech seems a more authentic way to assess wisdom performance. In fact, insight and homeostasis conveyed in the facial expressions of wisdom exemplars' (e.g., Buddha) advice-giving may be integral to the expression of wisdom across cultures.

Limitations

Our participants were all Chinese undergraduate students; the Ardelt's scale might work better assessing older Chinese adults. Also, facial expression analysis technology is still under development, just as any computer technology. In addition, our Chinese Wisdom Paradigm is not without its own limitations. For example, our Thin-slice Wisdom Measurement is still not an entirely ecological measure: The participants were talking to a camera, which was unnatural for them. Furthermore, participants might offer different advice to different listeners. Likewise, a larger set of scenarios involving different life problems would provide a more comprehensive and reliable measurement of wisdom. Finally, although relatively small, a sample size of 30 is a typical size for this methodology given the enormous amount of data generated by each subject and each of the 20 raters. A more economical paradigm would be needed for a larger sample.

CONCLUSION

In general, our results provided the first evidence for the Thin-slice Wisdom Paradigm's reliability, minimization of social desirability, and validity for quickly assessing candidates' wisdom. A more developed Thin-slice Wisdom Measurement could serve both the public interest (e.g., understanding a presidential election) and research needs (e.g., testing factors facilitating wisdom development). Although the Thin-slice Wisdom Paradigm is admittedly still rudimentary and awaiting further development, we hope our fledgling attempt to develop this novel measurement paradigm will contribute to wisdom studies in different cultures through its innovative approach to assessing wisdom performance.

AUTHOR CONTRIBUTIONS

CH, MF, and EW contributed to the conceptualization of this study. CH designed the study, analyzed the data, and wrote this research report. QW conducted the study and collected the data.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.01378/full#supplementary-material

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GENERAL COMMENTARY
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Commentary: Experience Sampling Methodology reveals similarities in the experience of passage of time in young and elderly adults

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Keywords: aging, Experience Sampling Methodology, passage of time, time

A commentary on

Experience Sampling Methodology reveals similarities in the experience of passage of time in young and elderly adults
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Few studies have investigated differences in judgments of passage of time between younger and older adults, and the results seem contradictory. Generally, people report that time goes faster as they get older (Lemlich, 1975) which is due to the pressure of perceived time (Janssen et al., 2013). However, Wittmann and Lehnhoff (2005) and Friedman and Janssen (2010) found no clear differences of how passage of time perception changes with aging.

The article by Droit-Volet and Wearden (2015) investigated this issue by using the Experience Sampling Methodology (ESM) technique and combining, for the first time, the assessment of the direct experience of the flow of time in everyday life in both younger and older adults. The study involved 15 younger adults and 14 older adults. Both groups conducted the experiment through the "Experience Sampling Methodology" (ESM) method, which involves submitting a questionnaire to participants at different times of the day using a smartphone provided by the experimenters, and asking them questions regarding the passage of time at different periods of the day. Although this method has been used in other studies regarding the evaluation of perception of time (Conti, 2001; Larson and von Eye, 2006), and it is frequently used in health psychology (e.g., Schwartz and Stone, 1998; Myin-Germeys et al., 2009), the use of it in cognitive psychology is unusual. Participants were also asked questions about the passage of time over longer periods of time (this week, this month, or this year), if they felt that time passed more quickly now than when they were younger or if they felt that time passes more quickly as people get older. The data obtained were analyzed in relation to additional variables, including: the affective state of the participants (positive vs. negative), the level of arousal, the relaxation, the difficulty of the activity, and the degree of attention invested in the activities. Although the passage of time in every-day life was significantly related to affective states and the degree of attention invested in their activities, the results showed no significant difference between the two groups regarding the answers to questions about the passage of time. Interestingly, both groups felt that time passes more quickly as they get older and that time passes faster in the present than when they were younger. Further investigation and different modalities of data collection will be needed in the future to determine whether or not more complex factors, such as the "reference effect," played a crucial role. In fact, the lack of differences between older and younger adults may have been influenced by the tendency of individuals to make judgments in relation to a salient comparison group rather than in absolute terms when responding to the self-report and

peer-report questionnaires (e.g., Youyou et al., 2017). Both, younger and older adults may have probably compared, consciously or unconsciously, the passage of the last day/week/month/year based on their own criteria (i.e., their own recent experience of passage of time which varied between the two groups).

Compared to previous ones, this study emphasizes the innovative use of the ESM method. This method, unlike the paper and pencil questionnaires, offers the possibility of obtaining ecologically large data sets infiltrating in the participants' everyday life to determine directly how they perceive the passage of time (Mehl and Conner, 2012). In the article by Droit-Volet and Wearden there is no measure of the direct experience that participants have on the passage of time on specific daily life activities, but rather the general impression of how time seems to flow in everyday life. In future investigations, this interesting data regarding the impression could be accompanied by an objective and real measurement of the time spent in a certain activity carried out by the participants, to evaluate not only how time has passed (e.g., slow vs. fast) but also how much time has actually passed (e.g., in s, min, h). In particular, the activity carried out by the participant at the time of evaluation could play a very significant role not only in terms of the difficulty of the activity itself, or in the degree of attention invested in it, but also in terms of its affective value (Carstensen et al., 1999; Innamorati et al., 2013; Di Domenico et al., 2015, 2016; Zebrowitz et al., 2015). Based on the extensive literature on emotions and aging (for a review see Fairfield et al., 2015b; Mammarella et al., 2016a), affective contents may affect the performance of participants in different domains including memory, language, and perception (Fairfield et al., 2015a; Altamura et al., 2016; Mammarella et al., 2016b, 2017; Palumbo et al., 2017a,b). In this regard, the study of Droit-Volet et al. consider the overall emotional state of the participant in general (but this may not be determined by the type of activity carried out at that time, but by several other factors). This is related to the fact that, as indicated by the authors, it was not possible to systematically check all the activities carried out by the participants on a daily basis, because they were too varied, but perhaps it would have been advisable to control the inherent value in these activities (Carstensen, 2006) asking the participants to rate the valence of their activities on a scale ranging from very negative to very positive. This would have allowed to divide the activities in positive, negative, and neutral to investigate not only the role of the valence in the perception of the passage of time but also the interaction between affective state and the valence of the activity on experience of passage of time. It is important to remark that in the study of Droit-Volet et al. the authors only measured the affective state of the participants and, although the affective state may play an important role in the perception of passage of time, it is not possible to exclude its independence from the valence of the actions carried out. It is possible, in fact, that a subject with a certain affective state may report that time goes faster when performs positive actions compared to negative ones or vice versa.

In summary, the study of Droit-Volet et al. Emphasizes the innovative use of the ESM method in dealing with issues of cognitive psychology ecologically by taking into account a controversial issue regarding the possible change in the age-related perception of time.

In future research, it may be interesting to investigate, through the use of ecological studies or with more simple and objective paradigm, the role played by emotional factors and therefore not only the general emotional state of the participants but also the value of the activities carried out. More objective studies may include the use of the Mismatch Negativity paradigm (e.g., Chen et al., 2010) to investigate differences between younger and older adults in the perception of time using, for example, neutral, positive, or negative auditory and visual stimuli.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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ORIGINAL RESEARCH
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Neural Temporal Dynamics of Facial Emotion Processing: Age Effects and Relationship to Cognitive Function

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This study used event-related potentials (ERPs) to investigate the effects of age on neural temporal dynamics of processing task-relevant facial expressions and their relationship to cognitive functions. Negative (sad, afraid, angry, and disgusted), positive (happy), and neutral faces were presented to 30 older and 31 young participants who performed a facial emotion categorization task. Behavioral and ERP indices of facial emotion processing were analyzed. An enhanced N170 for negative faces, in addition to intact right-hemispheric N170 for positive faces, was observed in older adults relative to their younger counterparts. Moreover, older adults demonstrated an attenuated within-group N170 laterality effect for neutral faces, while younger adults showed the opposite pattern. Furthermore, older adults exhibited sustained temporo-occipital negativity deflection over the time range of 200–500 ms post-stimulus, while young adults showed posterior positivity and subsequent emotion-specific frontal negativity deflections. In older adults, decreased accuracy for labeling negative faces was positively correlated with Montreal Cognitive Assessment Scores, and accuracy for labeling neutral faces was negatively correlated with age. These findings suggest that older people may exert more effort in structural encoding for negative faces and there are different response patterns for the categorization of different facial emotions. Cognitive functioning may be related to facial emotion categorization deficits observed in older adults. This may not be attributable to positivity effects: it may represent a selective deficit for the processing of negative facial expressions in older adults.

Keywords: aging, cognitive function, event-related potential, N170, emotion

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INTRODUCTION

Facial emotion processing is affected by aging (Di Domenico et al., 2015) and clinical conditions (Gur et al., 2007; Weiss et al., 2008; Wieser et al., 2012; Altamura et al., 2016). Numerous behavioral studies have identified age-related decline of labeling negative facial expressions and a preservation in labeling happy expressions (Isaacowitz et al., 2007; Ruffman et al., 2008; Horning et al., 2012; West et al., 2012; Kessels et al., 2014). Neuroimaging data have also found decline of neural activities to negative stimuli with age, and a relatively invariant response to positive stimuli across the adult life span (Gunning-Dixon et al., 2003; Tessitore et al., 2005; Fischer et al., 2010).

It is argued that there is an attention (Mather and Carstensen, 2003) and memory (Charles et al., 2003) biases toward positive versus negative stimuli in older adults, so called the "positivity effect" (Mather, 2012; Nashiro et al., 2012). From a neurobiological perspective, the interaction between noradrenergic activity and emotional memory enhancement in older adults is considered relevant (Mammarella et al., 2016). This perspective has extended to the perception and identification of another's expression (Bucks et al., 2008; Isaacowitz et al., 2009; Kaszniak and Menchola, 2012). A competing perspective for explaining age-related changes in labeling negative expressions has been argued as a general decline of cognitive function (Suzuki and Akiyama, 2013) or neurological atrophy in specific brain regions (Calder et al., 2003).

The processing of facial expression information is fast and efficient (Vuilleumier, 2005), and may lead to substantial temporal dispersion of evoked responses that enable 'high-level' regions to respond with surprisingly short latencies (Kawasaki et al., 2001; Pessoa and Adolphs, 2010). With resolution in the order of milliseconds, event-related potentials (ERP) are candidates to be excellent neural markers of the early involvement of perceptual face knowledge (Rossion, 2014). Affective facial stimuli elicit particular ERP components (Eimer and Holmes, 2007; Luo et al., 2010; Leleu et al., 2015), such as: (a) the P1, a positive potential with peak latency from 70 to 130 ms after stimulus onset over the occipital brain scalp sites, indicating selective spatial attention toward emotional cues (Luck et al., 2000; Bekhtereva et al., 2015); (b) the N170, a prominent negative waveform over the occipito-temporal scalp sites, with a peak at approximately 170 ms post-stimulus, representing an early neural marker involved in the pre-categorical structural encoding of an emotional face (Rossion, 2014); (c) the posterior P2, a positive deflection observed over the occipito-temporal regions at approximately 200–280 ms post-stimulus (Latinus and Taylor, 2006; Brenner et al., 2014), which has been suggested to be a kind of stimulus-driven call for processing resources (van Hooff et al., 2011); and (d) the N250, an affect-related negative component peaking at approximately 250 ms post-stimulus over the occipito-temporal scalp sites (Streit et al., 2000; Williams et al., 2006).

Event-related potential studies have used diverse paradigms to examine age-related changes of facial emotion processing, including passive viewing (Smith et al., 2005; Hilimire et al., 2014; Mienaltowski et al., 2015) and emotion recognition memory tasks (Schefter et al., 2012). Hilimire et al. (2014) suggest that there is an age-related shift away from negative faces toward positive faces within an early (110–130 ms) and late (225–350 ms) period in a checkerboard probe go/no-go task requiring passive processing of task-irrelevant emotional faces. However, another previous study of young adults showed that the processing of negative faces was increased at early perceptual stages only task-irrelevantly (e.g., passive viewing), whereas happy faces received enhanced processing only task-relevantly (e.g., naming the emotional expression) (Rellecke et al., 2012). To further test the effect of age on facial emotion processing, it would be necessary to manipulate the relevance to the task of the facial expressions. This would allow researchers to determine whether older adults demonstrate enhanced processing of positive expressions during explicit facial emotion identification tasks, and whether greater processing in response to positive faces is associated with stronger cognitive functioning.

The goal of the present study was to revisit the effect of age on particular ERP components using facial emotion categorization paradigm. To shed light on the controversy regarding the mechanism underlying these age effects, correlations between cognitive functions and brain responsivity to specific emotional faces, as well as the correlations between cognitive functions and performance of labeling facial emotions, were also explored. We used a reference sample of healthy younger adults to test the specificity of the effects in an older population. Given the existence of two directly competing perspectives discussed above, no specific directional hypothesis was possible. If available cognitive resources may be voluntarily engaged, accounting for the positivity effects observed in older adults (Isaacowitz et al., 2009), we hypothesized that higher cognitive abilities should be associated with reduced or enhanced neural responsivity to specific emotional faces. If impaired performance on labeling negative facial expressions is an unintended consequence of a general decline of cognitive function associated with old age (Suzuki and Akiyama, 2013), we anticipated that weaker cognitive abilities might show a correlation with decreased performance in labeling negative faces in older adults (but not young adults), but not necessarily in labeling positive faces.

MATERIALS AND METHODS

Participants

Thirty healthy older adults (58–79 years of age; 17 female) and 31 young adults (22–26 years of age; 19 female) were recruited. All participants were right-handed and had normal or corrected-to-normal vision and normal hearing. A battery of neuropsychological tests, including the Montreal Cognitive Assessment (MoCA), the Auditory Verbal Learning Test (AVLT), the Logical Memory Test (LMT), and the forward and backward digit span test, were used to confirm that participants were within normal ranges for cognitive functioning according to published norms (Guo et al., 2009). Meanwhile, older adults completed the Instrumental Activities of Daily Living scale (IADL) and the Geriatric Depression Scale (GDS), while young adults completed the Center for Epidemiologic Studies Depression Scale (CES-D).

For both groups, inclusion criteria were the absence of self-reported history of neuropsychological impairment or any disorder affecting the central nervous system, no previous head injury, and not currently being treated for depression or anxiety. Exclusion criteria were (a) impaired general cognition and activities of daily living; (b) subjective memory impairment, and scoring more than 1.5 standard deviations below the age and education-adjusted mean on the immediate or delayed AVLT or LMT; and (c) a GDS score $>$ 20 for older adults (Chan, 1996); and (d) a CES-D score $>$ 28 for young adults (Cheng et al., 2006). Participants' characteristics are shown in **Table 1**.

Participants were recruited from the Southern Medical University (Guangzhou, China) and the nearby community

TABLE 1 | Participants characteristics.

Items	Older adults ($n = 30$)		Young adults ($n = 31$)	
	Mean	***SD***	**Mean**	***SD***
Age (range) (years)	67.77 (58–79)	6.54	23.52 (22–25)***	0.85
Sex (male, %)	13 (43%)	/	16 (52%)	/
Education (years)	12.83	2.72	16.74***	0.44
MoCA scores	27.27	1.62	29.39***	0.76
AVLT scores (immediate)	8.77	1.76	10.89***	1.26
AVLT scores (delayed)	8.17	1.49	10.90***	1.16
LMT scores (immediate)	10.05	2.29	12.32***	1.48
LMT scores (delayed)	7.98	2.78	11.61***	1.36
Longest digit forward scores	7.64	0.90	9.35***	1.14
Longest digit backward scores	4.82	0.80	7.87***	1.15
Semantic fluency scores	20.20	5.14	23.26*	4.17
IADL scores	12.93	1.74	/	/
GDS scores	6.73	3.91	/	/
CES-D scores	/	/	8.97	6.2

*MoCA, the Montreal Cognitive Assessment; AVLT, the Auditory Verbal Learning Test; LMT, the Logical Memory Subtests; IADL, the Instrumental Activities of Daily Living Scale; GDS, Geriatric Depression Scale; CES-D, Center for Epidemiologic Studies Depression Scale. SD, standard deviation; *$p < 0.05$; ***$p < 0.001$.*

via advertisements, and received monetary compensation. All participants provided written informed consent in accordance with the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of Nanfang Hospital of Southern Medical University (NFEC-201511-K2).

Stimuli and Task

Ninety-six digitally reworked black-and-white face photographs were selected from the Chinese Facial Affective Picture System database (Luo et al., 2010). The faces expressed positive (happiness, 32 pictures), neutral (32 pictures), and negative (32 pictures; fear, anger, sadness and disgust, eight pictures each) emotions, and were balanced for gender and matched for luminance and contrast grade. Only closed-mouth expressions were used. Positive and negative faces were equated in terms of emotional intensity ($t = -1.34$, $p = 0.187$). Mean emotional intensity was 5.85 (SEM = 0.27) and 6.29 (SEM = 0.18) for positive and negative faces. Each face was seen by each participant once. The pictures used in the practice stage were different from those used in the formal experiment.

The stimuli were presented in random order for 500 ms each, against a black background subtending a visual angle of about 11° to 15° at a distance of 75 cm. Participants were instructed to classify the displayed facial expressions from a multiple-choice scale containing the names of the six facial expressions as discrete categories arranged horizontally on the screen. The scale appeared on the screen after a delay of 1000 ms (to avoid confounding motor effects), and was presented until a classification had been made, or for a maximum of 8000 ms. A random interval of 1600–2200 ms was set between the participants' response and the onset of the next trial. Emotions were classified by clicking the corresponding label of the scale with a computer mouse. The task paradigm has been described in a previous study (Woelwer et al., 2012).

Event-Related Potentials

EEG data were collected from 32 electrodes (impedance $< 5\ k\Omega$), in accordance with the extended 10/20 system. Recordings were made with a Brain-Amp-DC amplifier and controlled through Brain Vision Recorder 2.0 (sampling rate: 250 Hz; recording reference: left mastoid) (Brain Products, Munich, Germany). Data were analyzed by Brain Vision Analyzer 2.0 (Brain Products) and filtered offline (band-pass 0.1–70 Hz with a 50-Hz notch filter; re-calculated to Cz reference), corrected for horizontal and vertical ocular artifacts, and baseline corrected to 200 ms pre-stimulus. Trials with a transition threshold of 50 μV (sample to sample) or an amplitude criterion of more than ±80 μV were automatically rejected.

TABLE 2 | Between-group differences in performance of facial emotion categorization task.

Variables	Older adults ($n = 30$)		Young adults ($n = 31$)		*t*	*p*	t^a	p^a
	Mean	***SD***	**Mean**	***SD***				
ACC (%)								
Positive	85	−13	89	−8	−1.53	0.131		
Neutral	86	−16	92	−10	−1.52	0.134		
Negative	56	−14	75	−10	−6.20	0.000		
Practice phase	93	−8	95	−6	−1.67	0.167		
RT (milliseconds)								
Positive	849.11	−323.52	686.07	−280.88	2.51	0.036	1.61	0.113
Neutral	847.22	−375.89	668.09	−267.06	2.10	0.040	1.59	0.118
Negative	1726.09	−547.90	1221.44	−368.57	4.23	0.000	1.61	0.003
Practice phase	1539.50	−741.43	891.12	−339.53	4.81	0.000		

Abbreviations: RT, reaction time; ACC, accuracy rate; MD, mean difference; SD, standard deviation; [a]Yielded from one-way ANOVA adjusted by reaction time in the practice phase.

The procedure was confirmed by visually checking the remaining trials for artifacts. The number of artifact-free trials did not differ between groups [($F_{1,59} = 0.81$, $p = 0.78$), mean number of artifact-free trials per valence: positive faces = 31.97 ($SD = 0.18$), neutral faces = 31.97 ($SD = 0.18$), and negative faces = 31.93 ($SD = 0.37$) in older adults; positive faces = 31.94 ($SD = 0.36$), neutral faces = 31.90 ($SD = 0.54$), and negative faces = 32.19 ($SD = 0.18$) in young adults].

The amplitudes (measured as peak-to-baseline values) of the P100 (70–130 ms) and the N170 (130–200 ms) were averaged from occipital (O1 and O2) and parietal (averaged across P3/P7 and P4/P8, respectively) scalp sites, respectively. The time-windows were chosen by visually inspecting the time course of each component. Peaks of the components were measured within a ±30 ms window centered on the maximum of the grand-average means (Itier and Taylor, 2004). To further test whether there is a positive deflection to task-relevant happy faces in older adults within the time-window of P100, the ERP data were also re-calculated according to the average reference (average of all scalp electrodes), and reanalyzed using the method reported by Hilimire et al. (2014).

It was difficult to quantitatively compare the P2 and N250 components between the two age groups, because the older adults demonstrated a clearly delayed P2 (older adults: 270–330 ms; young adults: 200–260 ms) and near-absent N250 (or that which was merged into the later component). Therefore, we qualitatively compared the between-groups differences in brain responsivity after the N170 based on the topographical maps corresponding to the duration from 200 to 500 ms post-stimulus. Multiple re-entrant feedback signals along various regions of the visual ventral stream are thought to be surprisingly fast, with each processing stage adding approximately 10 ms to the overall latency (Pessoa and Adolphs, 2010). As the shortest possible time bin for the present topographical maps was 16 ms, the spline interpolated topographical maps of scalp voltage across 32 electrodes over the period from 200 to 500 ms post-stimulus were computed in consecutive 16-ms bins.

Statistical Analyses

Event-related potentials were analyzed separately for signal amplitude at the corresponding electrodes and entered into repeated-measures ANOVAs with the Greenhouse-Geisser epsilon correction in case of violation of sphericity. The between-participant variable was "Group" (older adults vs. young adults), and the within-group variables were "Hemisphere" (two levels: left and right) and "Emotion" (three levels: positive, neutral, and negative). In case of a significant interaction including Group and Emotion, *post hoc* tests were calculated using Bonferroni correction to account for multiple testing. Independent-sample *t*-tests and chi-square tests assessed differences in demographic variables between the groups.

The multiple linear regression analyses (forward procedure) were performed to statistically test the correlations between cognitive functions and ERPs, as well as the correlations between cognitive functions and performances, for both groups. In the first regression analysis, amplitudes of P100 and N170 were introduced as the dependent variable, respectively. Scores of MoCA, AVLT, LMT, forward and backward digit span, semantic fluency, and age were introduced as the independent variables. In the second regression analysis, performance data (accuracy rates for negative, positive, and neutral faces) were introduced as dependent variable, respectively. Independent variables were the same as in the previous analysis.

RESULTS

Behavioral Results

Regarding accuracy, a repeated-measure ANOVA yielded a Group × Emotion interaction ($F_{2,118} = 11.32$, $P < 0.001$, $\eta_p^2 = 0.16$). The older adults performed less accurately in labeling negative faces than young adults ($t = -6.20$, $P < 0.001$), while their performance for positive and neutral faces remained no significant group difference ($P > 0.10$). Within-group accuracy for labeling negative faces were significantly lower than those for labeling positive faces (older adults: $t = -10.59$, $P < 0.001$; young adults: $t = -8.25$, $P < 0.001$) and neutral faces (older adults: $t = -8.87$, $P < 0.001$; young adults: $t = -6.84$, $P < 0.001$) in both groups.

Reaction time mirrored the pattern of accuracy in the Group × Emotion interaction ($F_{2,118} = 9.47$, $p = 0.001$, $\eta_p^2 = 0.14$). After adjusting for reaction time in the practice phase before the formal experiment, older adults were slower to label negative faces ($F_{1,58} = 9.92$, $p = 0.003$, $\eta_p^2 = 0.15$) relative to young adults, while their performance for labeling positive and neutral faces remained no significant difference ($p > 0.10$). Detailed behavioral results are reported in **Table 2**.

Electrophysiological Results

As for P100 amplitudes, none of the interactions that included Group × Emotion were statistically significant ($F < 1$). Descriptive statistics for ERP variables are in Supplementary Tables S1, S2.

As for N170 amplitudes, a significant Group × Hemisphere × Emotion interaction was observed ($F_{2,118} = 3.08$, $P = 0.05$, $\eta_p^2 = 0.05$). Group differences were detected for left hemisphere (negative faces: $t = -3.31$, $P = 0.002$; positive faces: $t = -3.29$, $P = 0.002$; and neutral faces: $t = -4.00$, $P < 0.001$), and right hemisphere (negative faces: $t = -2.24$, $P = 0.003$; and neutral faces: $t = -2.12$, $P = 0.04$). No group difference was found for right-hemispheric N170 amplitudes elicited by positive faces ($P > 0.10$).

Bonferroni corrected *post hoc* tests showed that there was no significant within-group emotion effect in older adults. In contrast, young adults demonstrated that the N170 elicited by emotional faces were larger than those elicited by neutral faces (negative vs. neutral: $t = -2.99$, $P = 0.02$; positive vs. neutral: $t = -2.90$, $P = 0.02$) at the left hemisphere, and N170 elicited by positive faces was larger than those elicited by neutral faces ($t = -2.94$, $P = 0.02$) at the right hemisphere. Moreover, within-group analysis in older adults showed that the right-hemispheric N170 was significant larger than left-hemispheric N170 for emotional faces (negative faces: $t = -2.34$, $P = 0.026$; positive faces: $t = -2.61$, $P = 0.014$), while the N170 laterality

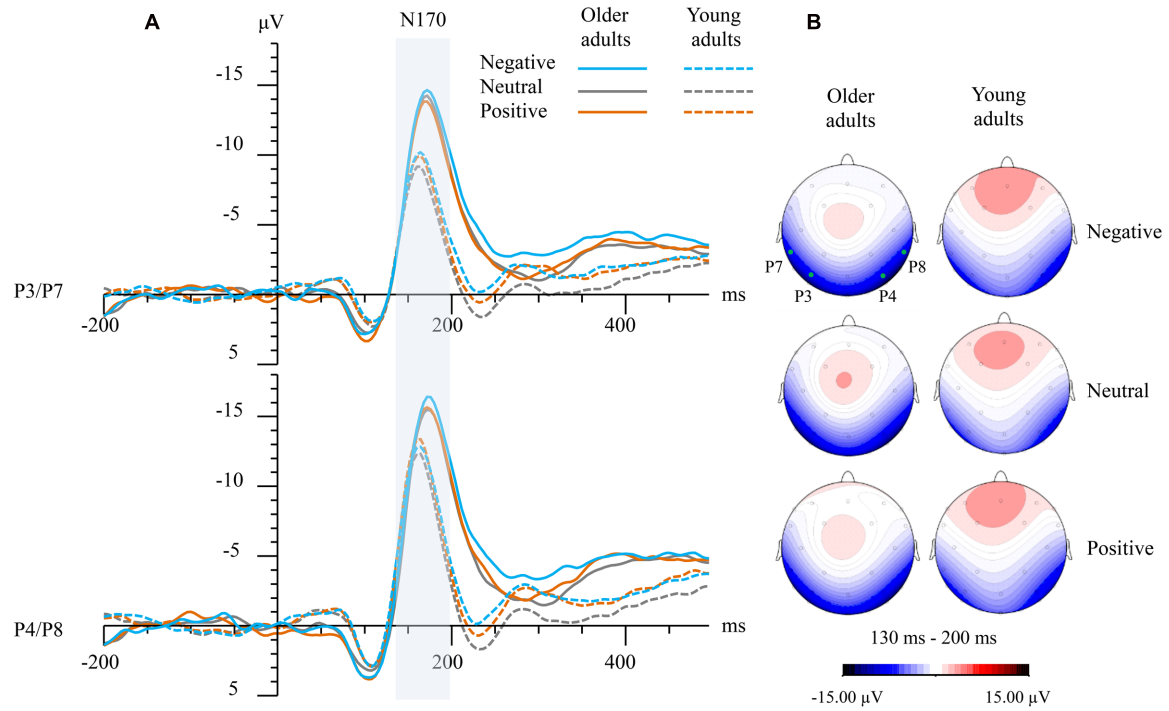

FIGURE 1 | (A) Grand-averaged event-related potential (ERP) waveforms elicited at left (averaged from P3 and P7) and right temporo-occipital electrodes (averaged from P4 and P8) for both groups and emotions. The vertical bar marks the time-windows that were analyzed as N170 in both age groups. **(B)** Topographical maps showing top view of scalp distributions over the N170 time-window for negative faces (top), neutral faces (medium), and positive faces (bottom). Note: the solid green points indicate the scalp electrodes where the P3, P4, P7, and P8 were located.

effect was not significant for neutral faces ($P = 0.07$). On the contrary, the N170 laterality effect has observed for all emotions in young adults (negative faces: $t = -5.93$, $p < 0.001$; neutral faces: $t = -5.54$, $P < 0.001$; positive faces: $t = -4.69$, $P < 0.001$). See also **Figure 1**.

Older adults exhibited a sustained temporo-occipital negativity deflection (mainly at posterior electrodes) over the time range of 200–500 ms post-stimulus. By contrast, young adults showed clear posterior positivity and subsequent frontal negativity deflection (mainly at anterior electrodes). Moreover, the frontal negativity deflections observed in young adults were thrice enhanced (scalp voltage gradually increasing thrice) for negative faces and twice enhanced (scalp voltage gradually increasing twice) for neutral and positive faces between 256 and 500 ms post-stimulus (see **Figure 2**).

Correlations between Cognitive Functions, Task Performance, and ERPs

No correlations were observed between cognitive functions (scores of MoCA, AVLT, LMT, forward and backward digit span, semantic fluency) and ERPs (amplitudes of P100 and N170) in either group ($P > 0.05$). For the correlations between cognitive functions and task performances (expressed as accuracy for labeling negative, positive, and neutral faces) in older adults, decreased accuracy for labeling negative faces was correlated with lower MoCA scores (adjusted $R^2 = 0.15$, standardized Beta = 0.42, $P = 0.020$; **Figure 3A**), and decreased accuracy for labeling neutral faces was correlated with advanced age (adjusted $R^2 = 0.21$, standardized Beta = -0.49, $P = 0.006$; **Figure 3B**). In young adults, decreased accuracy for labeling negative faces was correlated with lower backward digit span (adjusted $R^2 = 0.15$, standardized Beta = 0.42, $P = 0.019$; **Figure 3C**).

DISCUSSION

Facial Emotion Labeling Performance

A large sample internet-based explicit emotion identification study suggests an inverted U-shaped trajectory over 6–91 years with highest identification accuracy in the middle decades (20–49 years) and a progressive decline over 50–91 years (Williams et al., 2009). The behavioral results in the present study are highly similar to this kind of trajectory (Ruffman et al., 2008; Kessels et al., 2014), wherein reduced accuracy and slower speed for identification of negative faces and relatively preserved identification of positive and neutral faces are observed in older adults. It is possible that emotion labeling of negative facial emotions is more difficult than that of positive and neutral faces. In contrast, happy faces are easier to recognize because other positive emotions are absent as possible distractors (Kessels et al., 2014), and a smile may be a shortcut for quick and accurate categorization (Beltran and Calvo, 2015).

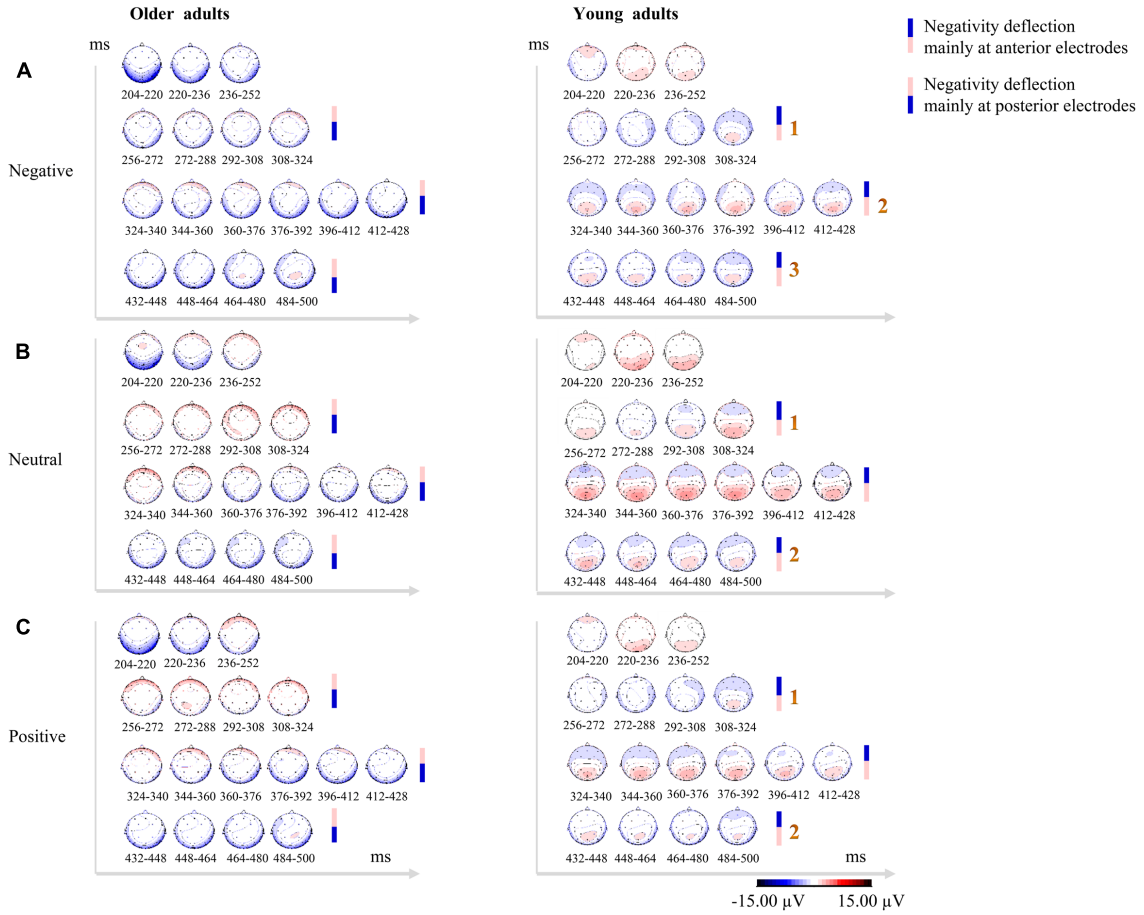

FIGURE 2 | Topographical maps in consecutive 16-ms bins over the time range of 200–500 ms post-stimulus showing qualitative between-group differences in scalp distributions across 32 electrodes for negative faces **(A)**, neutral faces **(B)**, and positive faces **(C)**. Older adults exhibited sustained temporo-occipital negativity deflections (mainly at posterior electrodes), while young adults showed clear posterior positivity over P2 time-window and subsequent frontal negativity deflections (mainly at anterior electrodes). The negativity deflections in young adults were thrice enhanced (scalp voltage gradually increasing thrice) for negative faces, and twice enhanced (scalp voltage gradually increasing twice) for neutral and positive faces. Enhanced positivity for the stimuli is shown in red, while blue indicates enhanced negativity for the stimuli. The scale (–15/+15 μV) has been adapted to better display the topographical similarities and differences.

Event-Related Potentials

The P100 has previously been associated with attention-related enhancements of processing intrinsically salient stimuli (Di Russo et al., 2003). In the present study, an insignificant group difference in P100 amplitudes suggests that early detection of facial emotions remains relatively intact in the older adults. We did not observe an attention bias toward positive or away from negative faces over the P100 time-window in the present study. A recent ERP study reported an age-related stronger positive deflection for task-irrelevant happy faces at frontal scalp sites over the time-window of P100, when performing a checkerboard probe go/no-go task (Hilimire et al., 2014). We also re-calculated the ERP data using the method reported by Hilimire et al. (2014), but no positive deflection was observed. One of the potential explanations for this inconsistence is that task relevance may manipulate the effect of on facial emotion processing.

The N170 component has excellent test-retest reliability, and obtaining as few as 10 or 20 artifact-free trials per condition for each participant may be sufficient to attain adequate reliability (Huffmeijer et al., 2014). The N170 is linked to pre-categorical structural encoding of emotional faces, where generated holistic internal face representations are used by subsequent finer-grained processing of expression categorization (Calvo and Beltran, 2014; Rossion, 2014; Bekhtereva et al., 2015). In line with our behavioral results, the present study revealed that the N170 amplitudes elicited by negative faces were enhanced in older adults relative to their younger counterparts, while the group difference in right-hemispheric N170 elicited by positive faces was non-significant, reflecting that older adults may exert more effort in structural encoding of facial features in negative faces, while their structural encoding of positive faces may be relatively preserved. Recent visual evoked potential studies suggest that emotional cue extraction for faces might be completed within the N170 phase (Bekhtereva et al., 2015), and N170 amplitudes could distinguish emotional faces from neutral faces in younger adults (Zhang et al., 2013). Accordingly, compromised within-group

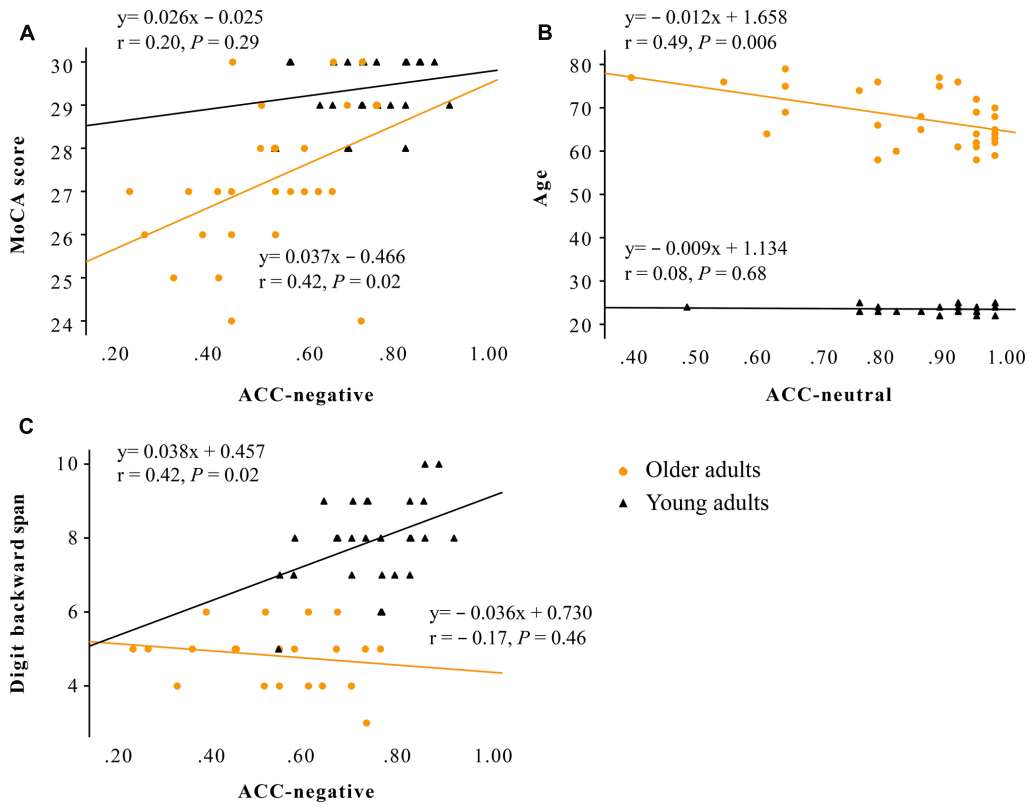

FIGURE 3 | Scatter plot showing that: **(A)** decreased accuracy for labeling negative faces was correlated with lower MoCA scores only in older adults (adjusted R^2 = 0.15, standardized Beta = 0.42, P = 0.020); **(B)** decreased accuracy for labeling neutral faces was correlated with advanced age only in older adults (adjusted R^2 = 0.21, standardized Beta = −0.49, P = 0.006); **(C)** decreased accuracy for negative faces was correlated with lower backward digit span only in young adults (adjusted R^2 = 0.15, standardized Beta = 0.42, P = 0.019). Older adults are marked with circles, and younger adults are marked with triangles. Note: ACC, accuracy rate; MoCA, the Montreal Cognitive Assessment.

emotion effect on N170 amplitudes observed in our older adult participants may go some way to explaining the decreased differentiation of emotional faces from neutral faces in older adults.

Interestingly, the present study also observed decreased hemispheric laterality effect for the N170 elicited by neutral faces in older adults. In contrast, young adults exhibited an obvious N170 laterality effect for all facial emotions. It has been suggested that facial expression processing is both holistic and analytic (Tanaka et al., 2012). Holistic processing is thought to be preferentially executed by the right hemisphere, whereas the left hemisphere is regarded as more involved in part-based processing (Ramon and Rossion, 2012). The left-hemispheric N170 was previously found to be greater for featural relative to configural changes (Calvo and Beltran, 2014), whereas the right-hemispheric N170 shows the opposite pattern (Scott, 2006). Therefore, the non-significant group difference in right-hemispheric N170 for positive faces observed in the present study may suggest that the holistic processing of positive faces remains relatively intact in the older adults, while attenuated N170 laterality effect for neutral faces may reflect compensatory engagement of additional regions during pre-categorical structural encoding of facial emotions in older adults.

As a result of the obvious phase delay of the P2, and near-absent N250 in older adults, it was difficult to quantitatively compare the P2 and the N250 between two age groups. By using the topographical maps in consecutive 16-ms bins over the time range of 200–500 ms post-stimulus to qualitatively compare between-group difference in scalp distributions for three valence conditions, the present study revealed a sustained temporo-occipital negativity deflection in older adults and frontal negativity deflections in young adults over this time range. Moreover, the frontal negativity deflections in young adults were thrice enhanced in response to negative faces and twice enhanced in response to neutral and positive faces. These findings suggest that two age groups may have recruited different frontal-parietal networks during the facial emotion labeling task, and exert different strategies for processing facial expressions.

Correlations of Cognitive Functions, Task Performance, and ERPs

Prefrontal and temporal-lobe structures that are important in recognizing and naming facial emotional stimuli in general (Kober et al., 2008; Ruffman et al., 2008) were found to be the earliest and most strongly affected by advancing age (Petit-Taboue et al., 1998). These brain regions are implicated in

conceptualization (categorical perception of discrete emotions), language (representation of feature-based information for abstract categories), and executive attention (volitional attention and working memory), suggesting that more "cognitive" functions play a routine role in constructing perceptions of facial emotions (Lindquist and Barrett, 2012), especially when one explicitly evaluates and holds affective information in mind to categorize it.

In line with it, the present study found that older adults' impaired performance for labeling negative faces was associated with decreased MoCA scores, suggesting that cognitive functions may contribute to impaired identification of negative faces in older adults. Moreover, older adults' performance for labeling neutral faces was found to be negatively associated with age. This may partially explain the decreased N170 laterality effect for neutral faces observed in our older adult participants. Furthermore, cognitive functioning was not correlated with any early neural responses to emotional faces, suggesting that older adults may not voluntarily or involuntarily employ cognitive resources to modulate emotion perception during early visual processing of task-relevant emotional faces.

Limitations

Limitations of this study should be considered and verified. First, we combined total artifact-free trials into the ERP analysis, instead of just taking correct trials, because of the significant group difference in accuracy for the task. The **Supplementary Figure S1** showed that the waveform of the correct trials in older adults was overlap with that of the total trials, but slightly higher than that of the incorrect trials. The combination may allow better understanding of actual early processing of a valence-specific emotion in older adults. Second, the pictures used in the present study were mainly younger faces, which may introduce the concern of "own-age bias" in face processing (Ebner et al., 2011). However, the processing of negative faces has also been reported to override age-of-face effects in facial expression identification tasks (Ebner et al., 2013). Further studies should be designed to use stimuli depicting both young and older adults.

CONCLUSION

The present findings showed that older people may exert more effort during structural encoding and different response patterns during emotional decoding of facial expressions, especially for negative faces. Therefore, aging might be associated with a selective deficit in processing negative facial expressions. Further investigations in this area may facilitate the detection of at-risk individuals in the early stage of mild cognitive impairment and enable targeted early interventions.

AUTHOR CONTRIBUTIONS

XL designed the study, collected and analyzed the data, and drafted the manuscript. KW contributed to the experiment design and data interpretation. KL participated in the participants' enrollment and cognitive assessment. XZ and RC conceived of and designed the study, and reviewed the manuscript. All authors have read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.01110/full#supplementary-material

FIGURE S1 | The supplementary figure showing that the waveform of the correct trials was overlap with that of the total trials, but slightly higher than that of the incorrect trials.

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