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New insights into stress coping and resilience

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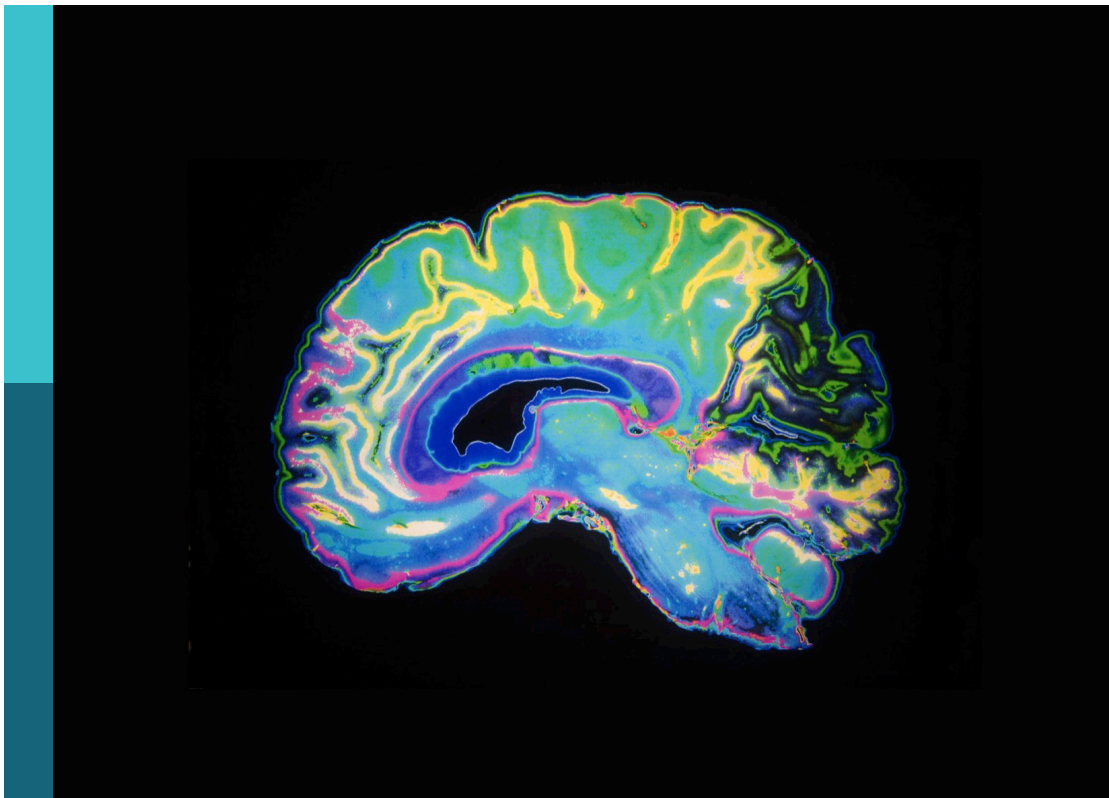

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New insights into stress coping and resilience

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Editorial: New insights into stress coping and resilience

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Editorial on the Research Topic
New insights into stress coping and resilience

Whereas the ability to solve problems before they occur is an essential skill, many problems, expected and unexpected, do prevail from time to time. These problems, known as "stressors", create difficult situations to people concerned, causing tension, worry, and occasionally overwhelming feelings. The latter is called "stress" or more accurately "stress responses". Adaptive stress responses help initiate effective problem coping mechanisms that remove the stressors or in some cases, adapt to unsolvable stressors. Maladaptive stress responses, including the development of helplessness and hopelessness, in contrast, lead to the disruption of normal homeostasis and increase the risk of stress-related pathology, including a variety of neurological and psychiatric disorders (Chen and Nakagawa, 2020). Importantly, a large proportion of individuals do not necessarily demonstrate maladaptive stress responses and develop stress-related pathology even when they encounter relatively strong stressors, indicating the existence of resilience (Feder et al., 2009; Kalisch et al., 2017). As a key personal asset in face of various stressors including disasters, accidents, crisis, and the ongoing COVID-19 pandemic, advancing our understanding of resilience, therefore, is a critical focus of investigation in psychology, psychiatry, and neuroscience. This Research Topic is a collection of 12 articles in these fields that help us gain novel insights into stress coping and resilience.

Consistent with the observation that positive expectancies are associated with resilience against trauma (Gallagher et al., 2020), Elhamiasl et al. found that negative expectancies or interpretations are associated with anxiety. Using an online task that consisted of 16 ambiguous health-related scenarios that can have both a safe and unsafe interpretation, Elhamiasl et al. found that illness-anxious individuals tend to make more negative interpretations of ambiguous body symptoms. This negative interpretation bias may be a key cognitive mechanism underlying illness anxiety and a potential interventional target for boosting resilience. Surzykiewicz et al. found that religious coping, or turning to religion for coping in stressful situations, may be another strategy for improving wellbeing. Matsuzaki et al. studied resilience in elementary and junior high school students and found that while some resilience factors such as stubbornness are still to be formed, factors including problem-solving, emotional regulation, and leadership common to adults already exist at this young age.

The COVID-19 pandemic represents a typical example of stressor and has been associated with worsened mental health (Chen et al., 2023). Several studies have tried to identify factors contributing to resilience under the pandemic. Maftei et al. reported that during the pandemic, adolescents' social media use as an active coping strategy may help improve wellbeing. Cognitive mechanisms of such benefits include associating social media with positive feelings and expectations of receiving gratification. Employing data from a birth cohort, Dalhof et al. reported that over the course of the COVID-19 pandemic, children showed increased emotional problems, which, however, were more emphasized in those with a mother having experiences of childhood maltreatment.

Whereas parental adverse childhood experiences may cause such vulnerability, parental involvement during childrearing helps cultivate resilience. Cheng et al. found that the when parents of children with autism experience more physical and mental symptoms during the pandemic, their family quality of life worsens. Via parental involvement, such as involvement in school activities, homework, extracurricular activities, hobbies and interests, and monitoring child's life details, however, parents can to some extent restore their family qualify of life. This is consistent with the findings that parent-child interactions, for instance, via conducting physical activities together, help improve family relations during the pandemic (Koga et al., 2023). Furthermore, Cheng et al. found that risk perception of infection and an optimistic attitude toward the pandemic (termed pragmatic hopefulness by the authors) also contribute to better family quality of life, via enhanced parental involvement.

As such, resilience exists not only at individual level, it also exists at family level. Family resilience involves activation of coping strategies at the family level via, for instance, communication and shared decision-making. Family resilience has been considered especially important for cancer patients and their families (Faccio et al., 2019). Within such a context, Almeida et al. evaluated the psychometric properties of the Portuguese version of the Family Resilience questionnaire—Short Form in women with breast cancer.

Four studies attempted to advance our understanding of the brain substrate of resilience with functional magnetic resonance imaging (fMRI). Sugiura et al. found that in response to negative emotional pictures, resilient individuals with traits of adaptive automatic emotion regulation tend to show decreased activation in the sensorimotor cortex as well as multiple cortical regions including the dorsal executive network and anterior cingulate. In contrast, non-resilient individuals tend to show increased activation in regions including the ventrolateral and dorsomedial prefrontal cortices. These findings indicate that automatic adaptive emotion regulation is characterized by automatic disengagement of deliberative processes, which is consistent with another line of evidence showing that contact with the natural environment achieves mood improving effects via relaxing the prefrontal cortex (Yamashita et al., 2021). Employing a thermal environmental stressor, Kawata et al. identified three components of coping behaviors, including motivational decline that reflects emotion-focusing coping, proactive response that indicates problem-focused coping, and active coping that reflects positive appreciation of the stressor. Using fMRI, they further identified neural correlates for two of these three components. Hirano et al. presented death-related words to older adults and found that leadership, one of eight resilience-related traits, was associated with reduced activation in the right inferior parietal lobule in response to such mortality threat. Setroikromo et al. investigated trauma-exposed Dutch police officers and found that resilient officers were characterized by reduced resting-state functional connectivity of the salience network with multiple prefrontal regions. The authors interpreted this pattern of brain activation as reflecting higher capacity for interoceptive awareness and internal-focused thought that helps initiate higher-order coping mechanisms.

The investigation of the biological mechanisms by which various treatments achieve therapeutic effects for neuropsychiatric diseases such as major depressive disorders may also advance our understanding of resilience. In a review paper, Lyu et al. provided an overview of acupuncture treatment for major depressive disorders and suggested that exosomes, extracellular vesicles released from cells for communication with other cells and transmission of molecules, may be a biological mechanism via which acupuncture works.

Taken together, this Research Topic has provided an excellent example of how the field of resilience can be advanced from different perspectives. We hope the novel insights gained by these articles help attract more researchers and accelerate investigation in this field.

Author contributions

Manuscript draft: CC. Manuscript revision and approval: all authors. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
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Resting-State Functional Connectivity Characteristics of Resilience to Traumatic Stress in Dutch Police Officers

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Background: Insights into the neurobiological basis of resilience can have important implications for the prevention and treatment of stress-related disorders, especially in populations that are subjected to high-stress environments. Evaluating large-scale resting-state networks (RSNs) can provide information regarding resilient specific brain function which may be useful in understanding resilience. This study aimed to explore functional connectivity patterns specific for (high) resilience in Dutch policemen after exposure to multiple work-related traumatic events. We investigated resting-state functional connectivity (RSFC) of the salience network (SN), limbic network, and the default-mode network (DMN).

Methods: Resting-state functional MRI scans were obtained from trauma-exposed executive personnel of the Dutch police force and non-trauma-exposed recruits from the police academy. Participants were divided into three groups: a resilient group (n = 31; trauma exposure; no psychopathology), a vulnerable group (n = 32; trauma exposure, psychopathology), and a control group (n = 19; no trauma exposure, no psychopathology). RSFC of the three networks of interest was compared between these groups, using an independent component analysis and a dual regression approach.

Results: We found decreased resilience-specific positive RSFC of the salience network with several prefrontal regions. The DMN and limbic network RFSC did not show resilience-specific patterns.

Conclusion: This study shows a differential RSFC specific for resilient police officers. This differential RSFC may be related to a greater capacity for internal-focused thought and interoceptive awareness, allowing more effective higher-order responses to stress in highly resilient individuals.

Keywords: MRI, stress, resilience, trauma, resting-state, police officers, functional connectivity

INTRODUCTION

The way individuals react and respond to extreme stress and adversity differs significantly. Some individuals may develop psychiatric disorders, such as anxiety or mood disorders, whereas others are considered more resilient, recovering from stressful experiences displaying no or only minimal symptoms of psychological distress and without functional impairment. Resilience can be conceptualized as "*a dynamic developmental process encompassing the attainment of positive adaptation within the context of significant threat, severe adversity, or trauma" (Cicchetti, 2010)*.

First responders such as police officers are more likely to experience traumatic events through the nature of their work. However, at the same time, a lower incidence of psychopathology is typically reported in this population (Skogstad et al., 2013; van der Velden et al., 2013). This makes first responders an interesting group to study mechanisms involved in resilience to traumatic stress.

Psychological factors involved in resilience have been studied extensively in first responders, military, and other populations and were found to include among other positive trauma-related reappraisal, emotional flexibility, social problem-solving, coping strategies, and personality traits (Luthar et al., 2000; Franklin et al., 2012). Studies have found a "resilient personality" to consist of a pattern of low neuroticism, an above average extroversion, openness, agreeableness, and conscientiousness (Campbell-Sills et al., 2006; Berry et al., 2007; Hjemdal et al., 2012). In addition, resilient individuals are generally optimistic and are characterized by high positive emotionality, possessing a specific explanatory style with coping strategies including positive reappraisal and acceptance (Southwick et al., 2005).

In contrast to the amount of data on the role of psychological factors, data on the neurobiology of resilience are still limited. Studies suggest the involvement of various neurotransmitter and hormone systems, genetic and epigenetic factors, and specific neurocircuitry (see review: Osorio et al., 2017). A previous review suggests that the neural circuitry of resilience includes among other key brain structures involved in emotion and stress regulation, e.g., the limbic network, rendering increased emotion regulation capacities in resilient individuals (van der Werff et al., 2013b). These key structures include the amygdala, insula, hypothalamus, hippocampus, and cortical structures such as the medial prefrontal cortex (mPFC) and the anterior cingulate cortex (ACC).

Neuroimaging has become an increasingly important tool to study neural correlates of behavior *in vivo*. Resting-state functional magnetic resonance imaging (RS-fMRI) relies on intrinsic brain activity, i.e., brain activity that is not induced by an external stimulus. When an individual is at rest, spontaneous low-frequency fluctuations in the blood oxygenation level-dependent (BOLD) response have been shown to temporally correlate between regions in large-scale functional brain networks also known as resting-state networks (RSNs) (Beckmann et al., 2005; Fox and Raichle, 2007; Smith et al., 2009). Thus, evaluating RSNs can provide information regarding inherent brain function that may help to identify network key to a resilient profile, which may be useful in further unraveling the neurobiology of resilience. Altered functional connectivity of the default-mode network (DMN) and the salience network (SN) have been linked to resilience as well as to stress-related psychopathology. The DMN is thought to be involved in self- and environmental referential mental activity, memory formation, and spontaneous thought. The DMN comprises the MPFC, the posterior cingulate cortex (PCC), precuneus, and the left and right inferior parietal lobules/angular gyrus (Smith et al., 2009; Mantini and Vanduffel, 2013). Altered DMN functional connectivity has been linked to the impact of early life stress (Whitfield-Gabrieli and Ford, 2012; Philip et al., 2013), as well as post-traumatic stress disorder (PTSD) (Lanius et al., 2010; Daniels et al., 2011). The SN is thought to play an important role in the integration of sensory information including the implementation of goal-directed tasks and consists of the dorsal anterior cingulate cortex (dACC) and bilateral insulae (Seeley et al., 2007). Altered SN functional connectivity has been linked to PTSD in veterans (Sripada et al., 2012) and resilience to childhood maltreatment (van der Werff et al., 2013a). In addition, SN modulation has been linked to DMN and central executive network (CEN) functioning, making proper SN functioning necessary for effective cognitive control (Bonnelle et al., 2012).

In this study, we aim to identify resting-state functional connectivity (RSFC) patterns specific for resilience in a unique sample of Dutch police officers. Previous studies mainly focused on the differences between resilient vs. non-resilient individuals which limits conclusions on resilient specific correlates (for an overview see: Koch et al., 2016). We therefore decided to compare resilient individuals (RES = trauma-exposed police officers without psychopathology) with two groups: a vulnerable group (VUL = trauma-exposed police officers with psychopathology) and a control group (CON = non-trauma-exposed police officers without psychopathology). We specifically included a wide variety of different trauma-related psychopathologies within the vulnerable group to be able to study resilience to trauma exposure in general rather than factors that protect against specific trauma-related psychopathologies.

In addition, previous studies that compare RSFC between resilient vs. non-resilient individuals has focused on connectivity patterns of circumscribed brain regions (e.g., seed-based analysis) instead of RSFC of functional systems that are linked to support core perceptual and cognitive processes (RSNs). We therefore chose to explore functional connectivity within large-scale RSNs as well as between large-scale RSNs and the rest of the brain.

Based on the existing literature, we focused on three RSNs comprising the limbic network, the DMN, and the SN. Based on the previous literature, we hypothesized that we would detect resilience-specific patterns in functional connectivity within the limbic, salience, and DMNs. In addition, we hypothesized that these differences in functional connectivity were correlated with resilient coping strategies.

MATERIALS AND METHODS

Participants

Trauma-exposed executive personnel of the Dutch police force and non-trauma-exposed recruits from the police academy were recruited through advertisements on the intranet of the Dutch police. About 149 participants signed up for the study and were subsequently screened for exclusion criteria. Participants were enrolled in the study if they did not meet the following exclusion criteria: (i) MRI contraindications, (ii) a history of neurological or other medical illness, (iii) the use of psychotropic medication other than stable use of selective serotonin reuptake inhibitors (SSRI) or infrequent benzodiazepines use (i.e., equivalent to 2 doses of 10 mg of oxazepam 3 times per week as a maximum and refrain from use 48 h before scanning), (iv) a history of childhood maltreatment (i.e., $<$ 18 years) was included as an exclusion criteria due to evidence of specific brain structural and functional characteristics related to childhood maltreatment as well as the relation of the experience of childhood maltreatment and the development of stress-related psychiatric disorders in later life, (v) a history of psychopathology with onset before work-related traumatic events, (vi) left-handedness, (vii) insufficient knowledge of the Dutch language, and (viii) smoking $>$ 5 cigarettes a day on average. After screening, 86 participants were invited to the hospital for data acquisition. A total of four participants were excluded from the study after quality checking the MRI data, due to motion-related noise. Therefore, the total sample size of this study was 82 participants. The participants were divided into three groups based on two criteria: (1). work-related trauma exposure as measured by the Police Life Events Schedule (PLES) and (2). Meeting criteria of one or more DSM-IV diagnoses either current or past according to the Mini-International Neuropsychiatric Interview (MINI). The RES group (N = 31) included individuals who experienced multiple work-related traumatic events, without the presence of a current or past DSM-IV diagnosis. The VUL group (N = 32) included individuals who experienced multiple work-related traumatic events, with the presence of one or more current or past DSM-IV diagnoses. The CON group (N = 19) included individuals recruited from the police academy without exposure to traumatic experiences and without the presence of a current or past DSM-IV diagnosis. The control group was recruited from the police academy to keep the groups as homogeneous as possible with respect to personality characteristics, which was deemed as more important than matching on age.

After explanation of the procedure, all participants signed informed consent. The study protocol was approved by the medical ethical committee of the Leiden University Medical Center under protocol number NL40761.058.12. The study was designed and conducted in accordance with the principles of the Declaration of Helsinki.

Behavioral Assessment

The assessment of past and current psychiatric disorders was determined using the MINI. The MINI is an interview used to assess the presence of the most common Axis 1 psychiatric disorders according to DSM-IV and ICD-10 criteria (van Vliet and de Beurs, 2007). The Montgomery-Asberg Depression Rating Scale (MADRS) is a 10-item diagnostic questionnaire used to measure the severity of depressive episodes in patients with mood disorders (Montgomery and Asberg, 1979). The Inventory of Depression Symptomatology (IDS) is a self-report questionnaire with 28 items, measuring the presence and severity of symptoms of depression (Rush et al., 1996). Internal consistencies (Cronbach's alpha) range from 0.76 to 0.94. The Beck's Anxiety Inventory (BAI) was administered to assess the severity of anxiety symptoms (Beck et al., 1988). The BAI consists of twenty-one questions regarding how the subject has been feeling in the last week, expressed as common symptoms of anxiety. Cronbach's alpha for the Dutch version of this inventory was found to be 0.82. Furthermore, the Harvard Trauma Questionnaire (HTQ) was assessed to evaluate the variety of trauma and the severity of the corresponding emotions. This questionnaire consists of 30 items that can be scored from 1 to 4 points with a Cronbach's alpha of 0.95 (Mollica et al., 1992). In addition, the degree of exposure to work-related life events was evaluated using the PLES. The PLES (Cronbach's alpha = 0.87) is a 37-item measure of the type and number of traumatic incidents by police officers and the degree to which they felt threatened, anxious, and helpless at each of the incidents (Carlier et al., 1997). The traumatic incidents listed within the PLES can be considered criterium A for PTSD according to DSM-V guidelines and include but are not limited to threatening situations with various weapons, as well as exposure to victims of crimes or accidents resulting in death or severe bodily injury. There are separate items depending whether the victim is a child, an adult, or a colleague.

The cognitive emotion regulation questionnaire (CERQ) (Garnefski et al., 2001) was assessed to determine individuals cognitive coping strategies, which is defined as "an individual's thoughts after having experienced a negative event." The nine cognitive emotion regulation strategies are as follows: (i) self-blame, (ii) other-blame, (iii) rumination, (iv) catastrophizing, (v) putting into perspective, (vi) positive refocusing, (vii) positive reappraisal, (viii) acceptance, and (ix) planning. The first four strategies are considered maladaptive, and the latter five adaptive. The Connor-Davidson Resilience Scale (CD-RISC) (Connor and Davidson, 2003), a self-report questionnaire, was used to assess individual's resilience level. The Connor-Davidson Resilience Scale (CD-RISC) comprises of 25 items, each rated on a 5-point scale (0–4), with higher scores reflecting greater resilience. The content of the scale features is among others: developing strategy with a clear goal or aim, action orientation, strong self- esteem/confidence, adaptability when coping with change, social problem-solving skills, humor in the face of stress, strengthening effect of stress, taking on responsibilities for dealing with stress, secure/stable affectional bonds, and previous experiences of success and achievement. The internal consistency for the full scale is Cronbach's alpha = 0.89.

Imaging Procedure

Scanning was performed on a Philips 3T MRI system (Philips Healthcare, Best, the Netherlands; software version 3.2.1), using a 32-channel head coil.

The following parameters were used to obtain a high resolution 3D T1-weighted image: repetition time = 9.8 ms, echo time = 4.6 ms, matrix size 256 × 256, voxel size 1.17 mm^3 × 1.17 mm^3 × 1.2 mm^3, 140 slices, with a scan duration of 4:56 min.

RS-fMRI scans were acquired using T2*-weighted gradient-echo echo-planar imaging with the following scan parameters: 200 whole-brain volumes; repetition time (TR) = 2,200 ms, echo time (TE) = 30 ms, flip angle = 80°, 38 slices, matrix size = 80 × 80, voxel size = 2.75 mm^3 × 2.75 mm^3 × 2.75 mm^3, with a scan duration of 7:28 min. All subjects were asked to close their eyes while staying awake and to lie as still as possible.

To facilitate registration of the functional image to standard space, a high-resolution T2*-weighted gradient-echo echo-planar imaging scan was required, with the following scan parameters TR = 2,200 ms, TE = 30 ms, flip angle = 80°, 84 axial slices, matrix size = 112 × 112, voxel size = 1.96 mm^3 × 1.96 mm^3 × 2 mm^3, no slice gap, scan duration = 46.2 s).

MRI Data Processing

All analyses were performed using FMRIB Software Library (FSL) (Smith et al., 2004), version 5.0.10. Preprocessing was carried out as described in the study of Pruim et al. (Pruim et al. (2015a,b)), in FSL's FMRI Expert Analysis Tool (FEAT), version 6.00. Thereafter, head motion correction was performed using MCFLIRT (subject movement > 3 mm in any direction, resulted in exclusion of the data from further analysis; N = 4 participants were excluded due to excessive head motion) (Jenkinson et al., 2002), followed by non-brain removal, and spatial smoothing with a Gaussian kernel of 6 mm^3 × 6 mm^3 × 6 mm^3 FWHM. The preprocessed RS images were registered into the corresponding brain extracted high-resolution T2*-weighted EPI image. The high-resolution T2*-weighted EPI image was then registered to the corresponding T1-weighted images and the T1-weighted images were registered to the MNI 152 standard space (2 mm isotropic). Registration into standard space was done after Automatic Removal Of Motion Artifacts based on independent component analysis (ICA-AROMA version 3.0-beta). ICA-AROMA automatically identifies and subsequently removes data-driven-derived components that represent motion-related artifacts, while preserving signal of interest. High pass temporal filtering (0.01 Hz) was done after denoising the fMRI data with ICA-AROMA. Thereafter, nuisance regression was performed, removing white matter (WM) and cerebrospinal fluid (CSF) signal.

Analysis of Resting-State Functional Connectivity

FMRIB Software Library's Multivariate Exploratory Linear Optimized Decomposition into Independent Components (MELODIC) tool was used to temporally concatenate all preprocessed data across subjects to create a single 4D dataset, which in turn was decomposed into 20 independent component analysis (ICA) components. These ICA components were visually inspected by two independent researchers and were selected by comparing the components with previously defined maps (Beckmann and Smith, 2004), resulting in the selection of three resting-state network of interest (**Figure 1**): the SN (A), the DMN (B), and the limbic network (C). Hereafter, dual regression was used to the set of spatial maps from the group-average analysis to generate subject-specific versions of the spatial maps and associated time series. The groups were then compared using a general linear model (GLM) including gender as confound regressor. To control for possible structural abnormalities and misregistration that could confound the differences in functional connectivity, gray matter values of each subject were included as a voxel-wise confound regressor in the GLM. Group differences were tested using permutation-based (5,000 permutations) non-parametric testing in a quadratic design. To control for family-wise error, threshold-free cluster enhancement (TFCE; Smith and Nichols, 2009) was applied and the threshold for significance was set on $p < 0.05$.

Correlation analyses for the difference in RSFC with CD-RISC as well as the subscales of the CERQ were performed with the use of Pearson's r or with Kendall's tau, when the data violated assumptions for parametric tests. All correlations were controlled for multiple comparisons using Bonferroni correction controlling for the number of (sub) scales tested, resulting in an adjusted p-value of 0.005.

RESULTS

Diagnoses in the VUL group consisted of one or more of the following: major depressive disorder (N = 27), anxiety disorder (N = 17), obsessive compulsive disorder (N = 2), posttraumatic stress disorder (N = 14), and substance abuse (N = 8). Furthermore, medication use in the VUL group was limited to stable use of either a SSRI (N = 7) or a non-selective SSRI (N = 1). Characteristics and between group statistics of the study population are reported in **Table 1**. There was a significant difference in age ($p < 0.001$) between the RES and CON group, due to younger cadets in the CON group. This difference in age was not found between the RES and VUL group ($p = 0.277$). Furthermore, there was a significant difference in gender ratio, with a higher male/female ratio in the RES group when compared to the CON group ($p = 0.033$).

The number of experienced work-related life events, measured with the PLES, was significantly higher in the RES group compared to the CON group ($p < 0.001$), but not compared to the VUL group ($p = 0.564$). One outlier was present in the VUL group, reporting 3,388 work-related life events by one individual, for details, refer to van der Werff et al. (2017) (24). After omission of this outlier, the difference between mean PLES scores of the RES and VUL group remained non-significant ($p = 0.709$). The trauma-related severity, measured with the

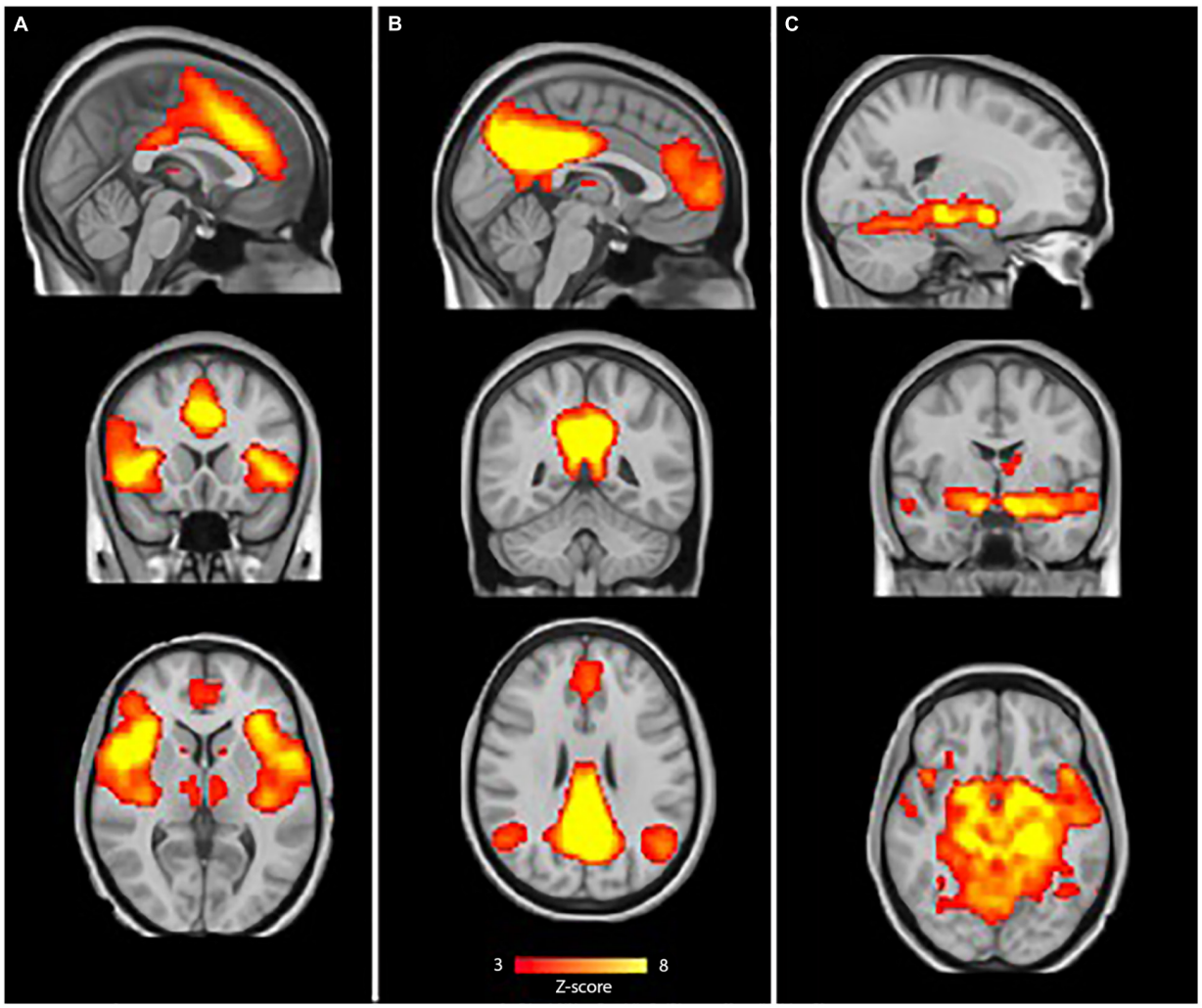

FIGURE 1 | Resting-state networks of interest. The sample-specific selected components for: **(A)** Salience network (SN), **(B)** default-mode network (DMN) and **(C)**. Limbic network. The color bar depicts Z-scores and runs from red (Z = 3) to yellow (Z = 8).

HTQ, was significantly lower in the RES group in comparison with the VUL group (p = 0.010), but not in comparison with the CON group (p = 0.159). Depression scores, measured with the IDS, were significantly lower (p = 0.013) in the RES compared to the VUL group, but higher (p = 0.017) when compared to the CON group. In addition, MADRS scores were significantly higher in the RES compared to the CON group (p = 0.006).

With regard to the cognitive emotion regulation strategies, the RES group had significant lower scores on the subscale acceptance compared to both the CON (p = 0.018) and the VUL groups (p = 0.011). In addition, the RES group scored significantly lower on the subscales other-blame (p = 0.026) and catastrophizing (p = 0.003) compared to the VUL, but not the CON group.

No significant differences between the RES and the VUL or CON group were found in BAI score or CD-RISC score.

Resting-State Functional Connectivity

The quadratic design identified four clusters showing a significant difference in RSFC with the SN between the RES group and the VUL group, and between the RES and CON group after FDR correction (**Figure 2**). The mean individual z-scores for these clusters were extracted from the subject-specific z-maps of the component representing the SN connectivity, which is depicted in the boxplot per (**Figures 2A–D**). When comparing the RES with VUL group as well as with the CON group, the mean individual z-scores showed a decrease in positive connectivity of the SN with: the right inferior frontal gyrus (BA44), right precentral gyrus/supplementary (pre)motor area (SMA) (BA 6), the right ventrolateral (BA44,45,47), and left lateral (BA10) parts of the PFC (**Table 2**).

There was no association between coping styles (measured with CERQ and CD-RISC) and the mean individual z-scores from the significant clusters in the RES group. Furthermore,

TABLE 1 | Characteristics of the study population.

	RES		VUL		CON		RES Vs. VUL	RES Vs. CON
	N		N		N		*P*-value	*P*-value
N	31		32		19			
Females/males	10/21		8/24		12/7		0.524[a]	**0.033[a]**
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***	***P*-value (Z or t-stat)**	***P*-value (Z or t-stat)**
Age	40.68	11.67	43.75	11.00	25.32	4.61	0.277[b] (*Z* = 1.09)	**<0.001[b] (*Z* = 4.70)**
IDS	36.39	6.82	43.94	12.65	32.58	5.32	**0.013[b] (*Z* = 2.48)**	**0.017[b] (*Z* = 2.40)**
BAI	24.00	2.73	26.31	6.56	23.94	3.00	0.183[b] (*Z* = 1.33)	0.841[b] (*Z* = 0.20)
MADRS	1.61	2.31	5.19	7.64	0.26	0.73	0.168[b] (*Z* = 1.38)	**0.006[b] (*Z* = 2.78)**
CD-RISC	98.23	11.92	92.25	14.44	103.89	9.57	0.079[c] (*t* = 1.79)	0.086[c] (*t* = 1.75)
HTQ	34.84	5.05	43.91	14.93	33.68	5.52	**0.010[b] (*Z* = 2.59)**	0.159[b] (*Z* = 1.41)
PLES (with outlier)	166.61	144.65	330.31	621.26	27.53	53.60	0.564[b] (*Z* = 0.577)	**<0.001[b] (*Z* = 4.61)**
PLES (outlier omission)	166.61	144.65	231.68	277.73	27.53	53.60	0.709[b] (*Z* = 0.37)	**<0.001[b] (*Z* = 4.61)**
CERQ: Self-blame	7.55	2.68	8.59	3.32	7.95	2.32	0.211[b] (*Z* = 1.25)	0.449[b] (*Z* = 0.76)
CERQ: Other-blame	5.74	1.79	7.16	2.58	5.42	1.71	**0.026[b] (*Z* = 2.23)**	0.575[b] (*Z* = 0.56)
CERQ: Rumination	10.06	3.82	12.06	6.82	8.79	3.39	0.183[b] (*Z* = 1.33)	0.248[b] (*Z* = 1.12)
CERQ: Catastrophizing	4.87	1.50	6.34	3.01	4.74	1.19	**0.003[b] (*Z* = 2.95)**	0.811[b] (*Z* = 0.24)
CERQ: Putting into perspective	11.71	4.02	11.31	3.42	13.05	3.54	0.674[c] (*t* = 0.423)	0.236[c] (*t* = 1.20)
CERQ: Positive refocusing	11.45	4.22	11.41	3.39	11.74	3.66	0.963[c] (*t* = 0.047)	0.809[c] (*t* = 0.24)
CERQ: Positive reappraisal	14.55	3.41	14.16	3.81	15.37	3.44	0.934[b] (*Z* = 0.083)	0.387[b] (*Z* = 0.86)
CERQ: Acceptance	10.42	2.84	12.44	3.14	12.68	3.30	**0.011[b] (*Z* = 2.56)**	**0.018[b] (*Z* = 2.36)**
CERQ: Planning	13.58	3.62	13.94	3.15	14.26	2.75	0.678[c] (*t* = 0.42)	0.484[c] (*t* = 0.71)

IDS, Inventory of depression symptomatology; BAI, Becks Anxiety Inventory; MADRS, Montgomery-Asberg Depression Rating Scale; CD-RISC, Connor-Davidson Resilience Scale; HTQ, Harvard Trauma Questionnaire; PLES, Police Life Events Schedule; CERQ, Cognitive Emotion Regulation Questionnaire.[a]Chi-square; [b]Mann Whitney U; [c]independent sample t–test.

Values considered to be statistically significant are displayed in Bold.

between group comparisons of the DMN and the limbic network did not show significant difference in RSFC.

DISCUSSION

In this study, we explored DMN, SN, and limbic network resting-state connectivity in a sample consisting of resilient Dutch police officers (i.e., trauma-exposed police officers who did not developed psychopathology), trauma-exposed police officers who developed psychopathology, and a non-exposed control group consisting of cadets from the Police Academy. We hypothesized that RES police officers would be characterized by specific RSFC patterns of the limbic, SN, and DMN networks. In addition, we hypothesized that differences in functional connectivity would be correlated with psychometric scores for resilience. In the RES group, we found a differential (i.e., decreased positive) connectivity of the SN with the inferior frontal gyrus (BA44), the precentral gyrus/supplementary (pre)motor area (SMA) (BA 6), ventrolateral (BA44,45,47), and lateral (BA10) parts of the PFC. It is important to note that we did not control for multiple comparisons across networks. All findings should therefore be considered explorative and should be interpreted with care.

There were no correlations between psychometric resilient characteristics and this resilience-specific RSFC pattern of the SN within the resilient group. Finally, we found no resilience-specific connectivity patterns for the DMN or limbic network.

The regions that showed a resilience-specific RSFC pattern with the SN typically have been associated with cognitive assessment of environmental stimuli and regulation of behavior and emotions (Farrow et al., 2012). For instance, lateral prefrontal regions have been implicated in cognitive control relevant to emotion, such as establishing increased attention control over expected threat-related distractors (Bishop et al., 2004). Of particular relevance, the lateral orbitofrontal cortex/ventrolateral PFC is thought to play a key role in the balance between the SN and CEN activities (Sridharan et al., 2008), with extensive interconnections to the amygdala as well as to the medial and lateral PFC (Dixon et al., 2017). In addition, the right ventrolateral prefrontal cortex is thought to be involved in judgment of relative salience. This judgment of the salience signal is then carried on to the premotor areas to implement response inhibition (Walther et al., 2011).

The SN plays a major role in the interactions between brain networks and one of its key roles, apart from the detection of salient internally or externally sensory information, is the integration of top-down appraisal and bottom-up information (Seeley et al., 2007) and the subsequent switching between activity of the DMN and CEN. Furthermore, it is thought that the SN initiates the CEN to respond to salient information for attentional shifts and to control execution (Menon and Uddin,

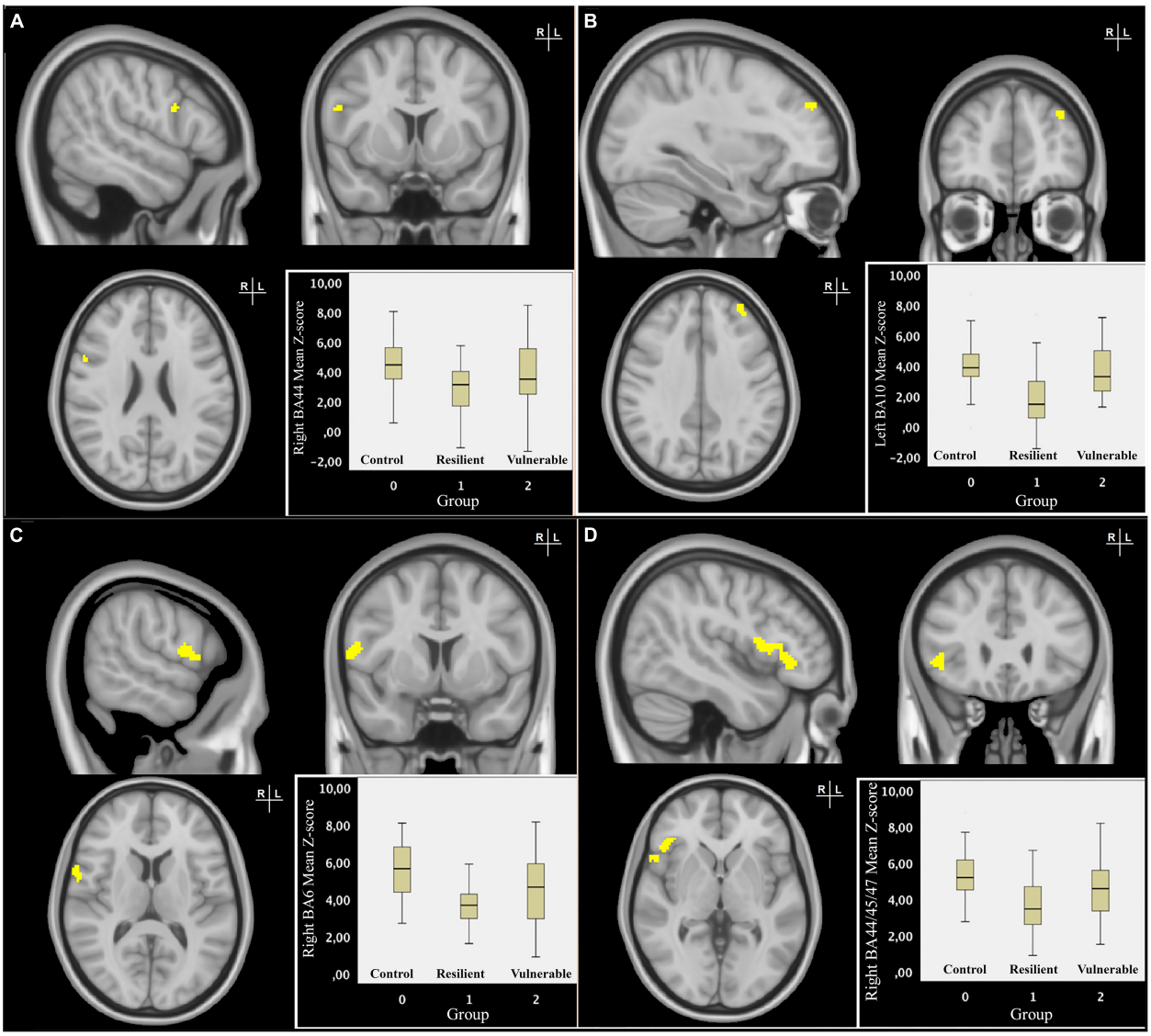

FIGURE 2 | Resilience-specific resting-state functional connectivity (RSFC) of the salience network (SN). Coronal, sagittal and transversal slices of the MNI-152 0.5 mm standard brain. The RES group showed significant differential RSFC of the right BA44 **(A)** and left BA10 **(B)** with the salience network compared to the VUL and CON group. The significant clusters were threshold at $p < 0.05$ and subsequently binarized in a mask. The boxplot displays mean individual z-scores of these clusters, depicted separately for each group. In radiological convention, the right side of the image corresponds to the left side of the brain. Coronal, sagittal, and transversal slices of the MNI-152 0.5 mm standard brain. The RES group showed significant differential RSFC of the right BA6 **(C)** and right BA44/45/47 **(D)** with the salience network compared to the VUL and CON groups. The significant clusters were threshold at $p < 0.05$ and subsequently binarized in a mask. The boxplot displays mean individual z-scores of these clusters, depicted separately for each group. In radiological convention, the right side of the image corresponds to the left side of the brain.

TABLE 2 | Characteristics of resilience-specific clusters of the salience network (SN).

Region	Brodmann area	Voxel size	Peak of activation (voxel) X, Y, Z	*P*-value
Inferior frontal gyrus (R)	44	10	68, 18, 48	0.025
Lateral prefrontal cortex (L)	10	29	87, 62, 53	0.019
Precentral gyrus/supplementary (pre)motor area (R)	6	118	67, 15, 42	0.025
Ventrolateral prefrontal cortex (R)	44, 45, 47	269	66, 21, 38	0.046

The size of the clusters is given using a threshold of 0.05.L, left; R, Right.

2010). The CEN mainly includes the dorsal lateral prefrontal cortex and the lateral parietal cortex, dorsomedial frontal/pre-SMA, and ventrolateral prefrontal cortex (Seeley et al., 2007). During rest, the SN and CEN are deactivated, which is thought to enable internally focused thought, interoceptive awareness, and processing (Sridharan et al., 2008). Taken together, the present result of a less positive RSFC between elements of the CEN (i.e., the ventrolateral/dorsolateral parts of the PFC) with the SN in both group comparisons (i.e., resilient vs. psychopathology and resilient vs. controls) suggests that this connectivity pattern is specific for resilience.

In line with the recent views on the role of the SN and the DMN, our findings may be interpreted as suggesting that resilient police officers have a greater capacity for internal-focused thought and interoceptive awareness, which would potentially enable higher-order processing of emotional information in the sequelae of traumatic events. Of interest, several studies in military personnel and top athletes have examined the effects of mindfulness based training (MFBT) on performance during very stressful situations and have also identified brain correlates of MFBT during task fMRI. The results showed that MFBT led to better performance in very stressful situations and to the changes in insula reactivity (a key region in the SN), and, in line with our findings, changes in the connectivity of the insula with prefrontal regions, notably the ACC. These changes were interpreted as allowing more effective higher-order responses to stress through more efficient interoceptive processing (Johnson et al., 2014; Haase et al., 2016). A more recent study also found increased within SN connectivity in an adolescent trauma-exposed control group further implying the role of the SN in resilience to trauma exposure (Sheynin et al., 2020).

Interestingly, this interoceptive processing capacity seems hampered in patients with PTSD as shown by a recent meta-analysis and systematic review of resting-state studies in PTSD (Koch et al., 2016) reporting that enhanced SN connectivity is associated with increased salience processing and hypervigilance in patients with PTSD. In addition, in another recent review (Akiki et al., 2017), PTSD was concluded to be associated with an overactive and hyperconnected SN during rest, suggesting hypervigilance in these patients at the cost of reduced awareness of internal-focused thoughts, interoceptive awareness, and autobiographical memory.

We did not find an association between coping styles, as measured with CERQ and CD-RISC, and strength of resilience-specific RSFC in the RES group. This could be due to our sample sizes and/or to the fact that these types of psychometric scales are often very heterogeneous in nature and hence do not "map" precisely on (resting-state) brain characteristics.

Contrary to our expectations, the DMN RSFC and limbic RFSC did not show resilience-specific patterns, perhaps because we examined three selected groups with similar baseline trait resilience levels. Finally, it is well possible that differences in functional activity within the limbic network might only be expressed when demands on cognition are high (i.e., during a stress paradigm or tasks).

To the best of our knowledge, this study was the first to investigate resilience-specific RSFC correlates in police officers and used a design with three groups that allows to identify resilience-specific correlates. Our study has also some potential limitations. First, our cross-sectional study design did not allow us to investigate causality, i.e., the role of differential RSFC in the development of resilience or as an acquired post-trauma characteristic. Longitudinal studies are needed to investigate this issue. Second, regarding our study sample, our findings should probably be regarded as specific to "highly resilient" populations, as police officers are, based on the stringent selection, and training, already more resilient to stress than the general population. Remarkably, depression symptomatology scores as measured with the MADRS differed between our RES group and the control group, suggesting a higher level of depressive symptoms within the RES group. However, both groups scored extremely low (mean MADRS score of the RES group = 1.61 and mean score of the control group = 0.26), suggesting an absence of depressive symptomatology in both groups. Differentiating between *"trait resilience levels"* can be addressed in future studies by adding a fourth, non-trauma-exposed healthy control group from the general population. In addition, we did not add age as a regressor due to the characteristics of the control group, which consists of young non-trauma-exposed police cadets. Furthermore, we did not correct for the number of networks investigated in this study, giving its explorative nature. In addition, our sample size could be considered a limitation. Finally, it remains unknown how the investigated networks relate to their function during tasks and how cognitive control mechanisms are mediated during active cognitive processing. Therefore, future studies should also incorporate task-based fMRI paradigms to investigate connectivity and coupling of brain networks under stress and during emotion regulation tasks or trauma scripted paradigms.

In summary, our explorative study shows a differential RSFC between the SN and key structures of the CEN specific for resilient police officers. This differential RSFC may be related to a greater capacity for internal-focused thought and interoceptive awareness, allowing more effective higher-order responses to stress in highly resilient individuals.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, SW, S.J.A.van_der_Werff@lumc.nl, upon reasonable request. For reasons of privacy the data cannot be made publicly available.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Medisch Ethische Toetsingscommissie (METC) (https://www.metc-ldd.nl/). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SW acquired the data. AS facilitated logistics surrounding participants. SW and SS organized the database and performed statistical analysis. SS wrote the first draft of the manuscript under supervision of SW and NV. All authors contributed to manuscript revision, read, and approved the submitted version and contributed to the conception and design of the study.

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Exploring the mediating effects of negative and positive religious coping between resilience and mental well-being

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Background: The purpose of the study was to examine more thoroughly the relationship between trait resilience and mental well-being. Although research demonstrates that this relationship is partially mediated by stress-related variables, no study has taken into account the mediating role of religious coping. We examined the mediating role of both variants of religious coping, positive and negative, along with specific strategies within the scope of religious coping strategies in a group of practicing Catholics.

Method: Participants were 317 people aged 19–60 years (M = 24.34; SD = 6.30). The respondents indicated their gender and age, and then completed the RS-14 (trait resilience), RCOPE (religious coping), and WEMWBS (mental well-being) scales.

Results: The results displayed a significant relationship between resilience and mental well-being (r = 0.67; $p < 0.001$). The relationship between resilience and positive religious coping was negligible (r = 0.09; p = 0.74), contrary to the relationship between resilience and negative coping that was significant but weak (r = −0.29; $p < 0.001$). Although the relationships between overall negative and positive religious coping with mental well-being were irrelevant, we found significant relationships between some strategies and mental well-being. The mediation analysis has demonstrated that the general negative religious coping and the strategies of demonic reappraisal, passive religious deferral, and spiritual discontent have enhanced the positive relationship between resilience and mental well-being. Contrary to expectation, positive strategies did not mediate the relationship between resilience and mental well-being, except religious practices (c' *path* totaled β = 0.66; t = 15.74, $p < 0.001$). The insignificant mediation effect can stem from the fact that the relationship between positive religious coping and stress is noticeable only in the long term. We controlled age and sex as statistically significant covariates so that the mediation effects obtained were devoid of the influence of those critical variables on the models.

Conclusion: This is the first study to investigate the role of religious coping as a mediator in the relationship between resilience and mental well-being.

KEYWORDS

wellbeing, resilience, religious coping, catholics, mental health

Introduction

For over three decades, numerous studies have shown that the trait of resilience significantly connects with broadly understood mental health and well-being. Research demonstrates that resilience relates negatively to the level of perceived stress, anger, hostility, generalized anxiety, depression, post-traumatic stress, and mental disorders (Beasley et al., 2003; Agaibi and Wilson, 2005; Campbell-Sills et al., 2006; Catalano et al., 2011; Ya et al., 2012; Wu et al., 2013; Surzykiewicz et al., 2019; Konaszewski et al., 2021a; Tamura et al., 2021) and positively to mental well-being, satisfaction with life, quality of life, positive adaptation, as well as physical and mental health (Armstrong et al., 2005; Friedli, 2009; Liu et al., 2013; Collishaw et al., 2016; Cosco et al., 2017). Research focused on exploring the relationship between resilience and well-being demonstrates that this relationship is at least partially mediated by perceived stress (Park et al., 2018), perceived stressors (Johnson et al., 2019), coping styles (Chen, 2016), stress-coping strategies (Kaczmarek et al., 2011), sense of social support (Zhang et al., 2017), hope (Satici, 2016), self-compassion (Kotera et al., 2020), Internet addiction (Mak et al., 2018), and depression (Lu et al., 2017). Among the studied mediators, stress-related variables are dominant, but at the same time, no study has taken into account the mediating role of religious coping. Our research aims to fill this gap. In this study, we extend the scope of our findings and analyze the potential mechanism linking the resilience feature with mental well-being, pointing to the mediating role of religious coping.

Religion constitutes an integral part of the lives of many people around the world (Zhang et al., 2017) and has a beneficial effect on their personal adaptation (Zarzycka and Zietek, 2019). A growing number of studies suggests that people often turn to various aspects of religion in stressful situations (Zinnbauer and Pargament, 1998; Koenig, 2009; Cassibba et al., 2014; Formoso-Suárez et al., 2022), in order to maintain a sense of control (Sasaki and Kim, 2011), regain mental balance after experiencing stress (Zinnbauer and Pargament, 1998), find meaning in life (Pargament, 1997) and maintain appropriate social relations (Páez et al., 2018). Research also demonstrates that people with high religious and spiritual commitment assess their lives more positively, despite all possible negative circumstances (Koenig, 2012, 2020). They possess a higher level of well-being and display lower scores within the sphere of perceived stress (Ramsay et al., 2019; Vishkin et al., 2019; Saud et al., 2020). Religion can also be a source of distress. An example in this area is religious struggles, which are described from the perspective of religious stress coping theory (Pargament et al., 2000, 2005). Religious struggles refer to forms of distress and conflict that involve religious and spiritual realities (Zinnbauer et al., 1999). Struggles occur when certain aspects of a person's current belief system, practices, or experiences become the center of negative thoughts and emotions, worry, or conflict (Exline, 2013; Exline et al., 2014). Research has shown that religious struggles and tensions negatively correlated with well-being, life satisfaction, quality of life, self-esteem, coping resources, internal locus of control, optimism, gratitude, prosocial sensitivity, and prosocial behavior (Koenig, 2012, 2020; Lucchetti and Lucchetti, 2014; Abdel-Khalek, 2019; Lucchetti et al., 2021; Konaszewski et al., 2022). In our opinion, in the context of the presented research results, it is worth taking a closer look at both the direct religious relationship between coping with mental well-being and the indirect role of religious coping in the relationship between resilience and mental well-being.

The holistic perspective on mental well-being

Research pertaining to psychological well-being highlights two research directions that can be distinguished, on the basis of theoretical assumptions and philosophical traditions: one concerns human happiness (hedonistic perspective; see e.g., Ryan and Deci, 2001), while the second is related to human potential (eudaimonic perspective; see e.g., Ryff and Singer, 1998). Moreover, numerous studies indicate that mental well-being is a multidimensional phenomenon that combines hedonistic and eudaimonic aspects (Stewart-Brown, 2013, 2016). In hedonistic terms, well-being consists of subjective happiness and refers to the experience of pleasure rather than dissatisfaction, including all judgments regarding the good and bad elements of life. This means that happiness cannot be reduced to physical hedonism, because it can be gained by achieving goals or worthwhile results in various fields (Diener et al., 1998; Diener, 2000). On the other hand, in the eudaimonic approach, the essence of well-being is associated with the idea of living in harmony with oneself. Eudaimonic well-being goes beyond the sense of pleasure in the life of an individual and encompasses a higher degree of psychosocial integration, broadly understood as a "good life" (Waterman, 1993). In turn, the holistic perspective assumes that mental well-being includes hedonistic (positive feelings, affects, emotions) and eudaimonic (positive functioning, mentality and relationships) dimensions (Stewart-Brown, 2013, 2016; Lyu et al., 2021). The hedonistic dimension relates to feelings, i.e., emotional well-being, and manifests itself, for example, in the form of positive and negative affects and satisfaction with life. Feelings are viewed as a state of mind that can vary depending on the situation, which is often beyond the control of an individual (Stewart-Brown, 2016). The eudaimonic dimension is related to the functioning of an individual, both on a personal and social level (e.g., mental or social well-being). This type of well-being is achieved through the

development of character traits and behaviors (Stewart-Brown, 2013, 2016).

Different concepts of resilience

Many life events affect well-being (Luhmann et al., 2012). Personality traits also have a significant impact on the level of well-being. A meta-analysis of research results demonstrated that neuroticism is most strongly related with well-being. Other traits, related to a lesser extent, include repressiveness, trust, emotional stability, locus of control, hardness, positive affect and self-esteem (DeNeve and Cooper, 1998). Resilience is also a trait linked to well-being. Resilience is described as an umbrella term, the symbolism of which expresses well the entirety of theoretical and research approaches in this area (Konaszewski, 2020). Depending on how it is described, explained, and delimited, different concepts of resilience can be distinguished: resilience as a trait, as a process, as a capability, or as an outcome. Defined as a dynamic process, resilience reflects relatively good adaptation, i.e., the positive adaptation of an individual despite the threats, adversities, or traumas they experience. This process involves the interplay of a spectrum of risk factors, vulnerabilities, and protective factors (Luthar et al., 2000; Masten, 2001; Wright and Masten, 2005; Windle et al., 2008; Windle, 2011). Resilience has also been defined as the ability to bounce back or recover from stress, to adapt to stressful circumstances, to not become ill despite significant adversity, and to function above the norm in spite of stress or adversity (Smith et al., 2008). In turn, Bonanno et al. (2011) view resilience as a pattern of outcomes after potentially traumatic events characterized by a stable trajectory of healthy mental and physical functioning. In this approach, resilience is the manifestation of emotional, behavioral, or health outcomes that meet or exceed normative developmental milestones, behavioral functioning, or emotional well-being despite exposure to significant life challenges (Hilliard et al., 2015).

Relationships between resilience as a personality trait and mental well-being

In our study resilience, understood as a personality trait, alleviates the negative effects of stress, promotes the ability to cope with changes or adversities and supports adaptation in difficult situations. Persons with high levels of resilience are able to adapt to overwhelming adversities and restore balance to life, avoiding the potentially harmful effects of stress. The strength of resilience is influenced by life circumstances and interventions undertaken (Wagnild and Young, 1993). Studies have demonstrated a significant positive relationship between resilience and both hedonistic and eudaimonistic well-being (Wagnild and Young, 1993; Abolghasemi and Varaniyab, 2010; Windle, 2011; Ya et al., 2012; He et al., 2013; Liu et al., 2013; Aiena et al., 2015; Di Fabio and Palazzeschi, 2015; Smith and Hollinger-Smith, 2015; Surzykiewicz et al., 2019). Moreover, resilience affects well-being not only directly but also indirectly through its impact on the ability to cope with stress. It makes it easier to mobilize oneself to take remedial actions in stressful situations.

Relationships between resilience as a personality trait and coping

Carver et al. (1989) emphasize the significant influence of resilience on coping; it determines the selection of specific coping strategies. Research demonstrates that the higher the resilience level, the wider the range of applied strategies (Bogar and Hulse-Killacky, 2006) and the greater the propensity to use problem-focused strategies and the lower the likeliness of using strategies focused on negative emotions and the need to discharge them (Boyden and Mann, 2005; Campbell-Sills et al., 2006; Chen, 2016; Konaszewski et al., 2019). As has already been indicated, research confirms the mediating role of coping in the relationship between resilience and well-being (Sojo and Guarino, 2011; Malkoç and Yalçin, 2015). As far as our knowledge goes, there have been no studies analyzing the mediating role of one of the important, especially in the case of believers and practitioners, ways of coping with difficult life situations, i.e., religious coping. This is why we believe it is worth exploring the relationships connecting religious coping, resilience, and well-being.

Positive and negative religious coping

In the last three decades, in terms of searching for sources of inner strength in difficult situations, theoretical concepts and scientific studies have confirmed the special role of religious coping (Pargament et al., 1990, 2000, 2001; VanderWeele, 2017; Weinberger-Litman et al., 2020). Religious coping is a multidimensional construct, with positive and negative aspects (Ano and Vasconcelles, 2005). Religious coping involves a number of cognitive and behavioral techniques aiding the individual to cope with or adapt to difficult life situations (Pargament et al., 2013). Positive religious coping is associated with the positive commitment of individual forces in the sphere of religion. Examples of positive coping include seeking religious and spiritual support, positive religious judgment, and the individual's interactions with God. The negative religious coping pattern manifests itself, *inter alia*, in dissatisfaction with God and the religious community, or negative feelings towards a given event,

perceived as God's punishment or as the actions of the devil (Krok, 2014, 2015).

Relationships between positive and negative religious coping and mental well-being

An intensified stream of research on adaptive resources has emerged recently, with positive and negative religious coping having been recognized as important predictors of contentment, life satisfaction and quality of life (Koenig et al., 2012; Koenig, 2018; Oman, 2018). Numerous studies have also confirmed that religious coping is an important predictor of well-being (Burker et al., 2004; Rippentrop et al., 2005; Zwingmann et al., 2006; Trevino et al., 2010; Hawkes et al., 2021). The results obtained regarding the relationship of positive religious coping with well-being are less unambiguous than data demonstrating the mutual relationship between well-being and negative religious coping. Certain studies have demonstrated that positive religious coping is linked with a high level of well-being (Pargament et al., 2001; Cole, 2005; Wnuk, 2007; Scandrett and Mitchell, 2009). However, in other studies, the relationship between the two variables proved to be insignificant (Fitchett et al., 1999; Hebert et al., 2009; Krok, 2014). The data on negative religious coping and well-being are much more consistent. Negative religious coping has been linked with decreased quality of life, including poorer physical and social functioning, vitality and mental health (Pargament et al., 2001; Wnuk, 2007; Hebert et al., 2009; Scandrett and Mitchell, 2009; Krok, 2014; Taheri-Kharameh et al., 2016). Moreover, studies also show that particular categories of religious struggle and tensions are linked with high emotional distress, poorer indicators of health, and lower quality of life and well-being, both in the normal population and in various clinical trials (Exline, 2013; Zarzycka, 2017). Studies have demonstrated that religious doubts negatively correlated with well-being, with the effect stronger in younger people than in older people (Krause et al., 1999). A similar negative relationship pattern was observed between divine, demonic struggle, moral struggle, ultimate meaning struggle and well-being (Abu-Raiya et al., 2015; Zarzycka and Puchalska-Wasyl, 2019). Only certain studies presented the relationship between demonic struggle and well-being as insignificant and the relationship between moral struggle and well-being as positive (Zarzycka et al., 2020). And so, adjustment to specific religious and spiritual struggles may have a distinct role in predicting satisfaction with life and well-being (Wilt et al., 2016). It can therefore be concluded that the results of research in this area indicate a clearly defined negative relationship between well-being and negative religious coping. In contrast, relationships between positive religious coping and well-being are less consistent. This is why it is worth taking a closer look at the relationships between multidimensional well-being and individual strategies involved in positive and negative religious coping.

Purpose of the study

The purpose of the study was to gain insight into reciprocal relationships between trait resilience and mental well-being. We conducted mediation analysis due to the prominent role of mediating variables in psychological theory and research. Mediation analysis is considered an essential research tool, and it "*. . .is now almost mandatory for new social-psychology manuscripts*" (Bullock et al., 2010, p. 550). Although research demonstrates that the relationship between resilience and mental well-being is partially mediated by stress-related variables, no study has taken into account the mediating role of religious coping. Our research aims to fill this gap. In the study, we examine the mediating role of positive and negative religious coping in the relationship between trait resilience and mental well-being. Religious coping is remarkably crucial for practicing Catholics. Research on well-being and religious aspects is undertaken quite often in our times, but it does not take into account mental well-being as a whole. In line with the literature review presented above, a conclusion can be drawn that the research to date presents well-being in either hedonistic or eudaimonic terms. By focusing on a single dimension of well-being, research fails to yield conclusive results. This is why, in our opinion, it is worth introducing a multidimensional approach to well-being, combining hedonistic and eudaimonic aspects (Stewart-Brown, 2013, 2016), in order to describe the relationship between resilience, mental well-being, and religious coping in more detail. Furthermore, in the study, we analyze the mediating role of both variants of religious coping, i.e., positive and negative, along with specific strategies within the scope of religious coping strategies in a group of practising Catholics.

Method

Participants and procedure

The study was carried out in the winter of 2020 in Poland during the second wave of the COVID-19 pandemic, with the consent of the university ethics committee. Participants were 317 people aged 19–60 years (M = 24.34; SD = 6.30), including 75% women. Selecting the sample was purposeful. The research covered people identifying themselves as practising Catholics. No additional recruitment criteria were required. The invitation to participate in this study was sent using the academic websites of the University of Bialystok and Cardinal Stefan Wyszyński University in Warsaw. The link was sent to full-time and part-time students. The link to the survey

was active from December 1 to December 20. The Google Forms platform was used to collect data. Participants who expressed their willingness to take part in the study received a link to the online questionnaire, with an access password. Each participant provided their informed consent to anonymous participation in the study. After giving consent, the respondents indicated their gender and age, and then completed the RS-14 (trait resilience), RCOPE (religious coping), and WEMWBS (mental well-being) scales. All procedures performed in the study involving human participants were under the ethical standards of the Ethics Committee of the University of Bialystok in Bialystok. The survey was anonymous and did not require providing any personal data. More details are presented in **Table 1**.

Research tools

Trait resilience

For the measurement of *resilience*, understood as a personality trait, the *Resilience* Scale 14 (RS-14) by Wagnild and Young (1993) was used. This tool consists of 14 statements. Participants are asked to respond to each of them using a 7-point scale from 1: I disagree to 7: I agree. The distribution of points within the RS-14 scale is in the area of 14–98. Polish adaptation studies validated the original one-dimensional structure of the RS-14 (Surzykiewicz et al., 2019). The reliability of the scale, calculated using Cronbach's α coefficient, was α = 0.85 for the entire sample.

Religious coping

To measure religious coping we used the Polish version of the Religious Coping Questionnaire RCOPE (Pargament et al., 2000), which was adopted by Talik and Szewczyk (2008). The religious strategies under consideration represent a broad spectrum of the studied reality—they include positive and negative, passive, active, and interactive strategies relating to God and the Church. The complexity and multidimensionality of the phenomenon have been confirmed by the results of factor analysis. The Polish version of the RCOPE consists of 105 items on 16 scales, with both positive (9) and negative (7) religious strategies, but only 85 items are diagnostic. People respond to the items on a 4-point Likert scale, with their answers ranging from 0, "not at all" to 3, "a great deal". They assess the degree to which they make use of various religious coping strategies (positive: α = 0.91 and negative: α = 0.71). The scores are calculated from the 16 scales (Talik, 2009, 2011, 2013; Talik and Szewczyk, 2008). The positive religious strategies are as follows: Life Transformation (LT)—looking to religion for a radical change in life; seeking a new direction for life, α = 0.92; Active Religious Surrender (ARS)—voluntarily giving up control to God in order to cope, α = 0.89; Seeking Support from Priests/Members (SSM)—searching for comfort, prayers and spiritual support from priests or church members, α = 0.84; Religious Focus (RF)—engaging in religious activities to shift the focus from the stressor, α = 0.85; Collaborative Religious Coping (CRC)—partnership with God in problem solving, and redefining the stressor through religion as benevolent, α = 0.86; Pleading for Direct Intercession (PDI)—pleading to God for a miracle or divine intercession, α = 0.78; Spiritual Support (SS)—seeking and giving spiritual support to others, α = 0.82; Religious Practices (RP)—active practising of and faithfulness to religious principles, α = 0.86; and Benevolent Religious Reappraisal (BRR)—redefining the stressor through religion as benevolent and potentially beneficial, α = 0.85. The negative religious strategies are as follows: Punishing God Reappraisal (PGR)—redefining the stressor as a punishment from God for the individual's sins, α = 0.86; Self-directing Religious Coping (SRC)—coping without God's help, α = 0.83; Demonic Reappraisal (DR)—redefining the stressor as the act of the devil, α = 0.99; Passive Religious Deferral (PRD)—passive waiting for God to control the situation and solve the problem, α = 0.85; Spiritual Discontent (SD)expressing dissatisfaction and anger about God's relationship with the individual in a stressful situation, α = 0.84; Reappraisal of God's Power (RGP)—questioning God's power to influence the stressful situation, α = 0.66; and Religious Discontent (RD)—dissatisfaction with congregation members and questioning the Church's teaching, α = 0.71 (Talik and Szewczyk, 2008).

TABLE 1 Baseline characteristics of respondents.

Study groups		Women	Men
Sex	N (%)	237 (75)	80 (25)
Age	Mean (SD)	24.35 (6.75)	24.30 (4.73)
	Range	19–60	19–50
Country participating in the study		Poland	

Mental well-being

The Warwick-Edinburgh Mental Well-being Scale (WEMWBS) was applied to measure mental well-being (Stewart-Brown et al., 2011). In the view of the authors, psychological well-being covers the hedonistic and eudaimonic dimensions. States of happiness and satisfaction with life, positive psychological functioning, good relationships with others and self-realization/acceptance (Tennant et al., 2007; Stewart-Brown and Janmohamed, 2008). Participants were asked to respond to 14 items on a 5-point Likert scale: from 1 ("none of the time") to 5 ("all of the time"). The distribution of points within the WEMWBS scale is within the area of 14–70.

Polish adaptation studies validated the original one-dimensional structure of the WEMWBS (Konaszewski et al., 2021b). The reliability of the scale, calculated with Cronbach's α coefficient, turned out to be high and amounted to α = 0.92 across the entire sample.

Data analysis

An *a priori* G*Power 3.1. analysis was conducted to determine the suitable sample size. We used the suggested higher power criteria of 0.95 and a critical significance level of α of 0.05 to identify a medium effect size of $f^2 = 0.15$. The total number of variables is 18. G*Power analysis with the above-mentioned parameters would demand a sample of at least 208 participants. Pearson's correlation analysis was used to determine the relations between the variables. The mediation model was assessed using Hayes' Process macro. The significance level was determined at $p < 0.050$. Furthermore, the false discovery rate (FDR; Benjamini–Hochberg correction) method was used to minimalize the risk of making a type I error in multiple comparisons. The effect size was assessed based on R^2. Data analysis was conducted in IBM SPSS Statistics 26. The PROCESS macro in version 3.2 (Hayes, 2013) was applied to control whether the dimensions of RCOPE would mediate the relationship between trait resilience and mental well-being. Trait resilience acted as the independent variable and mental well-being as the dependent variable. Life Transformation, Active Religious Surrender, Seeking Support from Priests/Members, Religious Focus, Collaborative Religious Coping, Pleading for Direct Intercession, Spiritual Support, Religious Practices, Benevolent Religious Reappraisal, Punishing God Reappraisal, Self-directing Religious Coping, Demonic Reappraisal, Passive Religious Deferral, Spiritual Discontent, Reappraisal of God's Power and Religious Discontent were treated as mediating variables (separately). Consequently, we analyzed 14 single-level mediation models (Model no. 4), comprising three-variable systems. Age and sex were considered as potential covariates in all models and were retained if significantly related to mental well-being. The bootstrap estimates and 95% confidence intervals (CI) for the indirect effects were gained through the procedure of 5,000 bootstrapped samples.

Results

The average value of overall positive religious coping ($M = 76.59$; $SD = 26.12$) indicated a high degree of this type of coping within the studied group (seventh sten; Talik, 2013). On the other hand, the value of the mean of general negative religious coping ($M = 29.74$; $SD = 14.78$) demonstrated the average intensity of this variable within the studied group (sixth sten; Talik, 2013). As far as positive religious coping strategies go, the lowest values were recorded for seeking support from priests/members ($M = 6.09$, $SD = 3.90$), and the highest were recorded for religious practices ($M = 15.08$; $SD = 4.33$). In turn, in the group of negative strategies, the respondents rarely applied the religious discontent strategy ($M = 2.27$, $SD = 1.34$), with the most popular being self-directing religious coping ($M = 5.95$, $SD = 2.94$). The remaining descriptive results, as well as the results of the correlation analysis, are presented in **Table 1**.

The correlation analysis demonstrated that resilience significantly and positively combines with mental well-being and individual strategies of positive copings, such as active religious surrender, collaborative religious coping, spiritual support and religious practice. The relationship between resilience and positive coping was irrelevant. On the other hand, there was a significant relationship between resilience and the total score of negative religious coping. We also noticed significant negative relationships between resilience and punishing god reappraisal, demonic reappraisal, passive religious deferral, spiritual discontent and religious discontent. The relationships between negative and positive religious coping with mental well-being were irrelevant. Within the group of positive strategies of religious coping, three significant and positive associations with mental well-being were noted: collaborative religious coping, spiritual support and religious practices, whereas the group of negative strategies contained only two significant associations with mental well-being. The punishing god reappraisal and spiritual discontent strategies were connected negatively with mental well-being. The values of correlation coefficients are presented in **Table 2**; the analysis also takes into account the correlations between the individual religious coping strategies.

Bootstrap sampling analysis (5,000) with 95% confidence intervals displayed several significant partial mediators for the relationship between resilience and mental well-being. An important mediator was the total score of negative religious coping, three detailed strategies of negative coping (demonic reappraisal, passive religious deferral, spiritual discontent) and one strategy of positive religious coping (religious practices). The total effect (*c path*) amounted to $\beta = 0.68$ ($t = 16.35$, $p < 0.001$; $R^2 = 0.46$). In the case of the total score of negative religious coping, the regression coefficient of the independent variable on the mediator (*a path*) amounted to $\beta = -0.29$ ($t = -5.36$, $p < 0.001$; $R^2 = 0.10$). The mediator regression coefficient on the dependent variable with simultaneous control of the independent variable (*b path*) amounted to $\beta = 0.14$ ($t = 3.17$, $p = 0.002$; R^2 for the entire model = 0.48). Mediation increased the strength of the relationship between resilience and mental well-being in a direct effect (c' *path*) amounted to $\beta = 0.72$ ($t = 16.80$, $p < 0.001$). **Figure 1** shows the relationship between resilience and mental well-being with negative religious coping as a mediator (age and sex as covariates).

TABLE 2 Descriptive statistics and correlations (N = 317).

	Min	Max	M (SD)	RE	WB	LT	ARS	SSM	RF	CRC	PDI	SS	RP	BRR	PGR	SRC	DR	PRD	SD	RGP	PRC	RD
RE	21	98	74.63 (12.99)	1																		
WB	14	70	52.41 (9.68)	0.67***	1																	
LT	0	21	10.09 (5.39)	−0.04	−0.03	1																
ARS	0	15	8.68 (3.71)	0.12*	0.04	0.56***	1															
SSM	0	15	6.09 (3.90)	0.04	0.09	0.66***	0.50***	1														
RF	0	15	6.56 (3.56)	0.01	0.02	0.54***	0.52***	0.55***	1													
CRC	0	15	9.07 (3.12)	0.19***	0.14*	0.51***	0.68***	0.50***	0.51***	1												
PDI	0	12	7.08 (2.52)	0.05	0.08	0.53***	0.59***	0.47***	0.61***	0.60***	1											
SS	0	15	6.99 (3.63)	0.14*	0.15**	0.71***	0.56***	0.76***	0.58***	0.55***	0.53***	1										
RP	0	24	15.08 (4.33)	0.18***	0.24***	0.61***	0.58***	0.57***	0.48***	0.65***	0.52***	0.64***	1									
BRR	0	12	6.95 (2.78)	0.06	0.06	0.59***	0.62***	0.53***	0.58***	0.60***	0.52***	0.61***	0.63***	1								
PGR	0	15	5.32 (3.61)	−0.26***	−0.13*	0.34***	0.12*	0.19***	0.39***	0.05	0.38***	0.16**	0.08	0.15**	1							
SRC	0	15	5.95 (2.94)	−0.06	0.08	−0.22***	−0.31***	−0.16**	−0.07	−0.40***	−0.22***	−0.20***	−0.25***	−0.28***	0.20***	1						
DR	0	12	3.32 (2.88)	−0.21***	−0.04	0.42***	0.18***	0.43***	0.50***	0.22***	0.32***	0.39***	0.25***	0.26***	0.52***	0.07	1					
PRD	0	13	4.42 (3.36)	−0.25***	−0.06	0.51***	0.26***	0.56***	0.53***	0.25***	0.38***	0.45***	0.28***	0.37***	0.43***	0.09	0.59***	1				
SD	0	16	4.54 (3.91)	−0.32***	−0.13*	0.43***	0.10	0.33***	0.34***	−0.06	0.24***	0.28***	0.05	0.14*	0.64***	0.31***	0.55***	0.56***	1			
RGP	0	12	3.93 (2.74)	−0.09	0.07	0.18***	0.10	0.23***	0.24***	−0.01	0.26***	0.12*	0.05	0.03	0.51***	0.41***	0.37***	0.40***	0.58***	1		
RD	0	6	2.27 (1.34)	−0.19***	−0.09	0.13*	−0.10	0.03	0.02	−0.16**	0.05	0.08	−0.04	−0.05	0.33***	0.36***	0.22***	0.24***	0.54***	0.34***		
PRC	9	138	76.59 (26.12)	0.09	0.11	0.83***	0.78***	0.79***	0.74***	0.77***	0.73***	0.85***	0.81***	0.79***	0.26***	−0.29***	0.43***	0.51***	0.28***	0.17**	1	
NRC	2	79	29.74 (14.78)	−0.29***	−0.07	0.40***	0.09	0.36***	0.43***	0.01	0.31***	0.28***	0.09	0.16**	0.78***	0.47***	0.71***	0.71***	0.87***	0.74***	0.31***	0.55***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; RE, resilience; WB, mental well-being; LT, Life Transformation; ARS, Active Religious Surrender; SSM, Seeking Support from Priests/Members; RF, Religious Focus; CRC, Collaborative Religious Coping; PDI, Pleading for direct Intercession; SS, Spiritual Support; RP, Religious Practices; BRR, Benevolent Religious Reappraisal; PGR, Punishing God Reappraisal; SRC, Self-directing Religious Coping; DR, Demonic Reappraisal; PRD, Passive Religious Deferral; SD, Spiritual Discontent; RGP, Reappraisal of God's Power; RD, Religious Discontent; PRC, total score of Positive Religious Coping; NRC, total score of Negative Religious Coping.

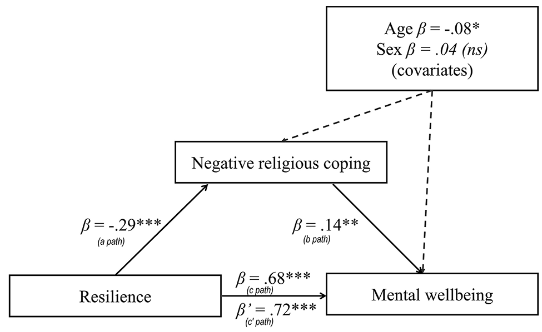

FIGURE 1
Negative religious coping as mediator in relationship between resilience and mental well-being (age and sex as covariates).

The *a path* for demonic reappraisal totaled $\beta = -0.21$ ($t = -3.85$, $p < 0.001$; $R^2 = 0.04$), *b path* totaled $\beta = 0.11$ ($t = 2.66$, $p = 0.008$; R^2 for the entire model = 0.47) with the *c′ path* totaling $\beta = 0.70$ ($t = 16.70$, $p < 0.001$). The *a path* for passive religious deferral totaled $\beta = -0.25$ ($t = -4.52$, $p < 0.001$; $R^2 = 0.06$), the *b path* totaled $\beta = 0.11$ ($t = 2.48$, $p = 0.014$; R^2 for the entire model = 0.47) and the *c′ path* totaled $\beta = 0.70$ ($t = 16.59$, $p < 0.001$). The *a path* for spiritual discontent totaled $\beta = -0.32$ ($t = -5.92$, $p < 0.001$; $R^2 = 0.10$), the *b path* totaled $\beta = 0.10$ ($t = 2.26$, $p = 0.025$; Benjamini–Hochberg adjusted p-value = 0.062; R^2 for the entire model = 0.47) and the *c′ path* totaled $\beta = 0.71$ ($t = 16.33$, $p < 0.001$). For the effects described, when we include the mediating variable, the relationship between resilience and mental well-being is intensified. This indicates the presence of suppression. In the remaining cases, negative forms of religious coping did not mediate the relationship between resilience and mental well-being in a statistically significant manner. General positive religious coping did not mediate the relationship between resilience and mental well-being. Taking into account the detailed strategies, one statistically significant mediation effect was obtained by religious practices, i.e., the *a path* totaled $\beta = 0.18$ ($t = 3.25$, $p = 0.001$; $R^2 = 0.03$), the *b path* totaled $\beta = 0.12$ ($t = 2.80$, $p = 0.006$; R^2 for the entire model = 0.48), and the *c′ path* totaled $\beta = 0.66$ ($t = 15.74$, $p < 0.001$). The other particular positive religious coping strategies did not mediate the relationship between resilience and mental well-being. The significance level for the effects is presented in Table 3.

Discussion

The purpose of the study was to examine the relationship between resilience and mental well-being. We extended the scope of analysis and examined both direct and indirect relationships between these variables. Similarly, like our

TABLE 3 The role of religious coping strategies on resilience and mental well-being (N = 317).

	a Path	b Path	c Path	c′ Path	Indirect effect and B (SE)	95% CI Lower upper
Positive religious coping						
RE → LT → WB	−0.04	−0.01	0.68***	0.68***	0.0001 (0.0029)	−0.0057; 0.0070
RE → ARS → WB	0.12**	−0.04	0.68***	0.68***	−0.0055 (0.0061)	−0.0195; 0.0056
RE → SSM → WB	0.04	0.07	0.68***	0.67***	0.0029 (0.0045)	−0.0048; 0.0135
RE → RF → WB	0.01	0.01	0.68***	0.68***	0.0001 (0.0024)	−0.0048; 0.0056
RE → CRC → WB	0.19***	0.01	0.68***	0.68***	0.0025 (0.0086)	−0.0140; 0.0214
RE → PDI → WB	0.05	0.05	0.68***	0.68***	0.0022 (0.0044)	−0.0053; 0.0130
RE → SS → WB	0.14**	0.05	0.68***	0.67***	0.0069 (0.0070)	−0.0043; 0.0237
RE → RP → WB	**0.18****	**0.12****	**0.68*****	**0.66*****	**0.0212 (0.0119)**	**0.0019; 0.0475**
RE → BRR → WB	0.06	0.02	0.68***	0.68***	0.0011 (0.0040)	−0.0047; 0.0118
RE → PRC → WB	0.09	0.04	0.68***	0.68***	0.0038 (0.0054)	−0.0048; 0.0173
Negative religious coping						
RE → PGR → WB	−0.26***	0.05	0.68***	69***	−0.0116 (0.0128)	−0.0406; 0.0106
RE → SRC → WB	−0.06	0.11**	0.68***	0.68***	−0.0059 (0.0073)	−0.0227; 0.0072
RE → DR → WB	**−0.21*****	**0.11****	**0.68*****	**70*****	**−0.0238 (0.0120)**	**−0.0510; −0.0044**
RE → PRD → WB	**−0.25*****	**0.11****	**0.68*****	**70*****	**−0.0257 (0.0129)**	**−0.0551; −0.0045**
RE → SD → WB	**−0.32*****	**0.10**[a]**	**0.68*****	**71*****	**−0.0309 (0.0171)**	**−0.0663; −0.0004**
RE → RGP → WB	−0.09	0.13**	0.68***	0.69***	−0.0111 (0.0090)	−0.0313; 0.0035
RE → RD → WB	−0.19***	0.03	0.68***	0.68***	−0.0047 (0.0090)	−0.0243; 0.0125
RE → NRC → WB	**−0.29*****	**0.14****	**0.68*****	**72*****	**−0.0389 (0.0163)**	**−0.0744; −0.0111**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; [a]not significant using an FDR of 0.05; RE, resilience; WB, mental well-being; LT, Life Transformation; ARS, Active Religious Surrender; SSM, Seeking Support from Priests/Members; RF, Religious Focus; CRC, Collaborative Religious Coping; PDI, Pleading for direct Intercession; SS, Spiritual Support; RP, Religious Practices; BRR, Benevolent Religious Reappraisal; PRC, total score of Positive Religious Coping; PGR, Punishing God Reappraisal; SRC, Self-directing Religious Coping; DR, Demonic Reappraisal; PRD, Passive Religious Deferral; SD, Spiritual Discontent; RGP, Reappraisal of God's Power; RD, Religious Discontent; NRC, total score of Negative Religious Coping; a path, effect of the independent variable on the mediator; b path, effect of the mediator on the dependent variable; c path, effect of the independent variable on the dependent variable; c′ path, direct effect of the independent variable on the dependent variable while controlling for the mediator. Effects are adjusted for age and sex.

predecessors, we focused on mediating role of stress-related variables and examined the mediating role of religious coping. That mechanism has not been explored yet, to the best of our knowledge. The aim of this study was to demonstrate the mediating role of positive and negative religious coping in the relationship between the trait of resilience and mental well-being. Our study analyzed both the mediating role of both types of religious coping, as well as particular strategies in the group of practising Catholics. As Pargament (1992) points out, ways of religious coping are interrelated; when faced with difficult situations, individuals may apply many positive and negative strategies. The results of our research indicate that the respondents when in difficult situations, used positive religious coping more willingly than negative coping. The average value of religious coping indicated a high peak in positive coping and moderate results in the case of negative coping. The most frequently used positive strategy was religious practices, and the least frequent was seeking support from priests/members. High scores in religious practices might be considered not only as a useful coping strategy but also as an expression of being religious for Polish Catholics. Low scores on seeking support from priests may be related to restricted immediate access to them during the COVID-19 pandemic. In turn, self-directing religious coping was the strategy most often used in the group of negative strategies, with religious discontent as the least frequent. A clear propensity to use positive strategies can be seen as a personal resource for practising Catholics. On the other hand, the use of negative religious coping strategies can be linked with a relatively stable tendency to experience tensions related to matters of faith and one's relationship with God (Zarzycka, 2017). It should also be taken into account that negative religious coping can be triggered when the level of difficulties experienced by the individual is so great that it exceeds the resources that were sufficient to deal with everyday problems (Hreciński, 2017).

Relationships between resilience, religious coping, and mental well-being

The obtained results displayed a significant relationship between resilience and mental well-being. Similarly to the studies of our predecessors, our research also demonstrated that the higher the intensity of resilience, the higher the level of mental well-being (Abolghasemi and Varaniyab, 2010; Ya et al., 2012; He et al., 2013; Liu et al., 2013; Aiena et al., 2015; Di Fabio and Palazzeschi, 2015; Smith and Hollinger-Smith, 2015; Surzykiewicz et al., 2019; Konaszewski et al., 2021a). The relationship between resilience and general negative religious coping was also important but low. The results confirmed the negative nature of this relationship (McIntire and Duncan, 2013; Rezapur-Shahkolai et al., 2017; Konaszewski et al., 2020). The results obtained regarding the relationship between resilience and negative religious coping are consistent with previous research that has shown that the higher the level of resilience, the lower the tendency to use strategies focused on negative emotions and the need to discharge them (Boyden and Mann, 2005; Campbell-Sills et al., 2006; Chen, 2016; Konaszewski et al., 2019). Thus, it can be concluded that resilience is related to the tendency to view difficult events in terms of God's punishment, religious passivity, or experiencing dissatisfaction

with God and the church. In other words, the tendency to use negative religious coping is associated with reduced levels of resilience resources and therefore is consistent with previous research (Pargament et al., 1990, 2000, 2001; Fallot and Heckman, 2005). To perceive God as a punisher, to experience abandonment by God, and "spiritually desert" experiences closely relate to phases of spiritual dryness (Büssing et al., 2013, 2021). Research demonstrates that feelings of spiritual dryness are associated with perceived stress, depression, anxiety, and emotional exhaustion (Büssing et al., 2013). Experiencing spiritual dryness is also linked to poor mental well-being. A study conducted during the COVID-19 pandemic among Iranian Muslims showed that spiritual dryness is moderately related to lower life satisfaction and marginally related to poor well-being (Büssing et al., 2021). Furthermore, spiritual dryness can lead to either a loss of faith or spiritual growth (Büssing et al., 2020).

In the study the relationship between resilience and general positive religious coping was irrelevant. Similar relationships were established, among others, in studies by Jans-Beken (2019) and Konaszewski et al. (2020). The lack of relationship between the variables may be due to the fact that resilience represents an active, problem-solving approach to stressful situations, while positive religious coping represents a more passive, avoidance-oriented approach, such as 'focusing on religion to stop worrying about my problems, or "surrendering to God's will."' This does not imply that positive religious coping only includes an avoidant approach to difficult situations.

Although the relationship between overall negative religious coping and mental well-being was negligible, we found a significant and negative relationship between mental well-being and two component strategies: punishing god reappraisal and spiritual discontent. And so, the results of our study have not confirmed the findings existing so far, indicating that negative religious coping is generally associated with decreased well-being (Pargament et al., 2001; Wnuk, 2007; Hebert et al., 2009; Scandrett and Mitchell, 2009; Krok, 2014; Taheri-Kharameh et al., 2016). Although the mechanisms underlying the described relationships have not been clearly established, one possibility is that punishing God's reappraisal and spiritual discontent may decrease well-being by reducing people's efforts to stay healthy while serving as a trigger for risky behaviors. Park et al. (2009) showed that negative religious coping was associated with lower medication adherence and medication use, as well as higher levels of alcohol use among patients. In addition, although some individuals agree with the belief that God is forgiving, at the same time their personal experiences are associated with a sense of unforgiveness on the part of God. Feeling unforgiveness triggers fear of God's punishment, which results in reduced well-being (Zarzycka, 2017). Also, experiencing doubt in terms of faith is not foreign to members of religious communities (Krause et al., 1999). It can be inferred that struggles involving spiritual discontent are associated with poorer psychological functioning. This relationship pattern has been repeated in many studies, and as the results of longitudinal studies suggest that this relationship may weaken over time (Zarzycka, 2017). Also in the case of overall positive coping, we have not noticed any significant relationship between this variable and mental well-being. Only three strategies (collaborative religious coping, spiritual support and religious practices) have shown positive relationships with mental well-being. The results of our studies indicate that the holistic concept of mental well-being may not prove helpful in the analysis of the relationship with religious coping, due to its hedonistic dimension, which focused more on seeking pleasure and positive experiences and high satisfaction with life than on the individual's involvement in dealing with existential challenges posed by life (Keyes et al., 2002).

The mediating effects of negative and positive religious coping between resilience and mental well-being

The analysis of mediation has demonstrated that taking into account within the model of the general negative religious coping and the strategies of demonic reappraisal, passive religious deferral, and spiritual discontent have intensified the positive relationship between resilience and mental well-being, which point to the appearance of the suppression phenomenon. We controlled age and sex as statistically significant covariates in our analyzes, so that the mediation effects obtained were devoid of the influence of those critical variables on the models. It is a well-established fact that religious struggle and negative coping can harm mental health (Ellison et al., 2010; Exline, 2013; Wilt et al., 2016), although studies by Zarzycka and Zietek (2019) demonstrated that demonic and moral religious struggles can promote well-being, as they can be a source of positive changes and lead to spiritual growth. Demonic re-evaluation means accepting a stressful situation as Satan's work. More specifically, demonic evaluation is a belief that the devil or other demonic forces have a direct or indirect influence on someone or something (Talik and Szewczyk, 2008). The ability to attribute negative events to evil forces may facilitate some people in gaining a sense of support from their faith, as it allows them to protect their image of God and their relationship with God (Zarzycka and Zietek, 2019).

Religious passivity and dissatisfaction with God also enhance the effect that resilience has on well-being. Research on the function of faith can be helpful in understanding this result. Many people firmly believe in a passive attitude, in which expectations are emphasized for God to take control of the situation; shifting responsibility for solving the problem to God

will help in a stressful situation. On the other hand, expressing dissatisfaction and anger mainly towards the attitude of God and the Church towards a person in a stressful situation (feelings of abandonment, rejection, of being unloved) may lead to the mobilization of forces helpful in difficult situations. It is consistent with the idea that religion offers individuals several ways to maintain and increase their sense of well-being and the possibility of spiritual growth and development (Spilka et al., 1985). This perspective, present in the work by Batson et al. (1993) on religious exploration, is based in part on the assumption that religious doubt is beneficial and leads to a deeper and more meaningful faith. Also, Tillich (1957) argues that various strategies and struggles that may be described as negative are not inherently wrong. Doubt and dissatisfaction are not the opposite of faith; rather, they are part of it.

Research results suggest that, in the case of well-being, negative strategies should be ascribed significant importance. It can be concluded that general negatively focused strategies, including demonic reappraisal, passive religious deferral, and spiritual discontent are an important part of faith (Hunsberger et al., 1996, 2002; Kooistra and Pargament, 1999). It would be difficult to imagine a deeply religious person who has no moments of doubt, dissatisfaction, or passivity about their religious beliefs. This struggle can be considered an effort to preserve or transform an endangered spirituality. The struggles themselves may focus on the expression of suffering, anger, dissatisfaction, fear, and disorientation (Zarzycka, 2017). While numerous studies confirm the negative relationship between religious coping and well-being, quality of life and health studies also exist that have not confirmed it (Hunsberger et al., 2002), while still others have found positive relationships (Krause and Wulff, 2004; Exline et al., 2014). Faced with such inconsistent data, it is legitimate to ask about the mechanisms by which we can explain the relationships between resilience, coping strategies, and well-being. We have come to the conclusion that the impact of resilience on mental well-being, through negative religious coping strategies, depends on how we treat them. This is demonstrated by some psychological theories, for example by Erikson, Kohlberg, or Dąbrowski, focusing on positive disintegration; the function of moral conflicts or crises inherent in development. They are a transitional phase that can lead to both regression as well as maturity and increased well-being (e.g., Erikson, 1968; Kohlberg, 1976; Dąbrowski, 1979). Our findings suggest that resilience increases well-being through negative coping, considering low negative coping as an immediate effect (a reactive process). This finding confirms that demonic reappraisal, passive religious deferral, and spiritual discontent can be part of a healthy process and suggests that negative coping enhances the relationship between resilience and mental well-being (Batson and Schoenrade, 1991; Exline et al., 2014; Zarzycka and Zietek, 2019).

Our analysis found that overall positive religious coping did not mediate the relationship between resilience and mental well-being. After taking detailed strategies into account, one statistically significant mediation effect was obtained by religious practices. Faithfulness to religious practices involves actively practising and faithfully adhering to the teachings of one's religion (steering away from false teachings). The relationship between resilience and mental well-being diminished when this coping strategy was taken into account. In the remaining cases, it was not noted that positive strategies mediate the relationship between resilience and mental well-being. This result is inconsistent with our expectations based on the theory and the results of previous studies (Pargament et al., 2001; Wnuk, 2007; Scandrett and Mitchell, 2009). In our study, we made the assumption that positive religious counseling should enhance the resilience effect on well-being within a group of practising Catholics. The observed lack of mediation effect can be explained by referring to the results of the meta-analysis by Ano and Vasconcelles (2005), which demonstrated that the relationship between positive religious coping and stress is noticeable only in the long term. The results of this study may therefore suggest that a positive appeal to religion protects against long-term consequences of difficulties. Undoubtedly, further exploration in this area is advisable.

Finally, it should be noted that the percentile bootstrap confidence intervals for indirect effects calculated by PROCESS are preferred for testing models with a large number of potential mediators and do not require additional adjustments (Taylor et al., 2008; Yzerbyt et al., 2018). Furthermore, in multiple comparisons, the authors suggest leaving a 95% confidence level for all confidence intervals in output at 5,000 number of bootstrap samples. On the other hand, because of the risk of making a Type I error, it is common to use corrections for multiple comparisons, which reduce the nominal significance level of each test by a specified correction. The disadvantage of such solutions is lowering the power of the test, i.e., increasing the risk of making a type II error. FDR is preferred in exploratory studies (Hochberg and Benjamini, 1990). After including this method in our study, the relationship between spiritual discontent and well-being while controlling for resilience proved to be statistically insignificant. The above indicates a questionable mediation effect. If so, this result should be interpreted with caution, and the analysis should be repeated in future studies without using multiple comparisons. The Benjamini-Hochberg correction did not affect the other revealed relationship effects.

Practical implications

Our findings offer indications for the development of resilience- and coping-based interventions to protect the mental health and well-being of individuals. The results of this

study generally indicate that the development of psychological resources is able to help protect mental health from negative coping. Resources such as resilience can be increased through psychological intervention and treatment programs (Ritchie et al., 2014).

Limitations

In our study, we have focused on the mediating role of religious coping in the relationship between resilience and mental well-being. For the purposes of further research, an attempt should be made to verify the mediating role of religious struggles and tensions. It is also worth taking into account the level of religiosity and religious centrality in the analyzes, as both of these factors can be potential moderators of the relationship between resilience and well-being. Our study has its limitations. The main limitation of the study is its transverse character, excluding any conclusions regarding the cause-and-effect relationships. Mediation analysis is able to test the significance and perhaps the effect size of a hypothetical mediator, assuming it is the actual mediator. On the other hand, mediation analysis cannot determine whether a variable is a unique (sole) mediator, and significant mediation tests do not provide sufficient evidence to support the causal role played by the intervening variable (mediator) in the model being tested. Longitudinal studies are necessary to assess resilience and the religious coping function of well-being, health, and overall frame of mind. Another limitation is related to the time period in which the study was conducted and the characteristics of the studied sample. The data were collected during the second wave of the COVID-19 pandemic and this may have influenced the findings. Moreover, the participants of our study were people aged 19–60 years, but with a clear predominance of young people. Research demonstrates that the depth of religiosity changes with age, and therefore it can be observed that positive religious coping is more often used by older people (Pargament, 1997). Therefore, further research should consider a moderated mediation analysis to compare the relationship between resilience, religious coping, and well-being among younger and older (over 35 years of age) individuals due to the greater religiosity of the latter.

Conclusion

This is the first study to investigate the role of religious coping as a mediator in the relationship between resilience and mental well-being. The obtained results demonstrate the occurrence of the suppression effect in the case of general negative religious coping and its three components. Negative religious coping, demonic reappraisal, passive religious deferral, and spiritual discontent enhance the relationship between resilience and mental well-being. Research has demonstrated no significant mediation effect on overall positive religious coping. Among the components of overall positive coping, only one strategy, i.e., religious practices, had a significant effect. The effect of resilience on mental well-being was diminished by the use of religious practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Faculty of Education of the University of Białystok in Białystok. The patients/participants provided their written informed consent to participate in this study.

Author contributions

KK, SS, MN, and JS: methodology, formal analysis, writing—original draft preparation, writing—review and editing. KK: investigation. JS, KK, and MN: project administration and funding acquisition. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Parents' pandemic stress, parental involvement, and family quality of life for children with autism

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Background: Research has shown that parents of children with autism spectrum disorder (ASD) suffered high levels of stress during the COVID-19 pandemic and faced poor family quality of life (FQOL). However, little is known about the inherent dynamic interaction between pandemic stress and FQOL, especially in the Chinese cultural context.

Aims: This study provides preliminary evidence by examining the relationships among pandemic stress, parental involvement, and FQOL for children with autism in mainland China.

Method: A total of 709 parents of children with autism completed measures of FQOL, parental involvement, and pandemic stress. Structural equation modeling was employed to examine the interrelations among these variables.

Results: Pandemic stress has direct effect and indirect effect mediated by parental involvement on FQOL. Two dimensions of pandemic stress had a direct effect on FQOL ($\beta1 = 0.11$; $\beta2 = -0.55$) and three dimensions had an indirect effect on FQOL through parental involvement ($\beta1 = -0.097$; $\beta2 = 0.257$; $\beta3 = 0.114$).

Conclusion: Stress related to the COVID-19 pandemic affects family quality of life for children with autism in complex ways. Policies may be developed to enhance parental *pragmatic hopefulness* in the anti-epidemic victory and alleviate negative *physical and mental reactions* caused by the pandemic.

KEYWORDS

family quality of life (FQOL), pandemic stress, parental involvement, children with autism, China

Introduction

It has been almost 3 years since the novel coronavirus was first discovered and the COVID-19 pandemic began in Wuhan, China, and so far, the pandemic shows no signs of ending. The pandemic has resulted in numerous adjustments to daily life for children and their caregivers, including children with ASD (autism spectrum disorder) and their parents. ASD is a pervasive developmental disability characterized by social-communication and interaction deficits, restricted and repetitive patterns of behavior, and significant functional impairments (1).

Providing care for children with autism exposes their families to high levels of psychological stress and a lower quality of life for families (2). The adjustments to the COVID-19 pandemic, such as stay-at-home orders and remote learning, have impacted caregivers' wellbeing (3, 4) and, in the case of families of children with autism, further reduced family quality of life (FQOL) (5). Although studies have shown that FQOL for children with autism was affected by the COVID-19 pandemic (5), few have examined COVID-19's impact on families with autistic children from a multifactorial holistic perspective. This study provides preliminary evidence of the relationships among pandemic stress, parental involvement, and FQOL for children with autism in mainland China.

Studies concerning family quality of life for children with autism

The concept of FQOL has been used to assess family adjustment outcomes for children with autism and is increasingly attracting the attention of researchers worldwide (6, 7). Several studies have shown that FQOL for children with autism is lower than for families of children with other disabilities (8, 9), making the study of FQOL for children with autism particularly important for social welfare.

Previous research has focused on exploring children with autism's overall FQOL and its possible predictors. These predictors focus on the child with ASD's: (1) individual level (6, 7, 10), (2) family level (6, 7, 11–14), and (3) social support level (15, 16).

The severity of symptoms in children with autism negatively predicts their FQOL (6, 7, 10). In addition to social support (15, 16), family cohesion (7), parental stress (11), and parental involvement (12) are associated with FQOL, indicating it is the result of multiple factors.

Although there is still a lack of representative large-scale epidemiological surveys on children with autism in China, the number of children being diagnosed with autism is increasing. Meanwhile, Chinese families experience high stress levels and low FQOL (17). These families experience high levels of parenting stress, financial burden, and limited family support (18). Hence, further investigating FQOL among children with autism in China is worthwhile.

Parental stress related to ASD and its association with FQOL

Previous findings suggested that parental stress is greater for parents of children with autism than for those of typically developing children and children with other disability types (19–21). In the existing studies, parental stress, as an independent variable, affects the lives and growth of many children with autism and their parents. The relationship between parental stress and FQOL has received much attention, and some studies have demonstrated parental stress' lasting impact on children with autism's FQOL (22).

The current research on parental stress related to ASD and FQOL comprises three main aspects. The first aspect concerns their current state; parents of children with autism tend to have higher levels of parental stress and lower levels of FQOL [e.g., (8, 23, 24)]. The second aspect concerns the outcome assessments of parental stress, with some studies involving FQOL as an important parental stress outcome in assessing autistic children's families' overall satisfaction [e.g., (9)].

The third aspect regards their causal analysis. For instance, Likhitweerawong et al. (25) identified that, among 61 and 63 Thai caregivers of children with and without ASD, respectively, higher parental stress correlated moderately with lower authoritative, higher authoritarian, and higher permissive parenting styles, while a negative correlation was found between authoritarian and permissive parenting styles and children with ASD's quality of life. Pozo et al. (7) found that among 118 Spanish parents (59 mothers and 59 fathers) with a child with ASD, behavior problems negatively affected FQOL indirectly (through sense of coherence). The severity of the disorder and social support levels played significant roles in FQOL models for both fathers and mothers, whereas coping played differentiated roles in their FQOL. Through a meta-analysis of 29 studies (N = 4,864), Wang et al. (26) found that among caregivers for autism, social support partially mediated the relationship between coping (positive and negative) and family quality of life.

During the COVID-19 pandemic, people have stayed home and socially isolated themselves to avoid contracting the virus (27). Existing studies have demonstrated that while isolation somewhat reduces the risk of virus transmission, it also brings anxiety and psychological stress (28–30). In particular, parents affected by the pandemic who are raising infants or children with disabilities receive lower levels of social support and are at greater risk of psychological distress (3, 31–33).

The relationship between parental stress and FQOL is of great academic interest. Studies exploring the relationship between the two could help to reduce stress and improve FQOL for children with autism and their families during COVID-19. Some studies have analyzed parental stress as an influential factor in family relationships, regulation, and social support in the COVID-19 epidemic context (34–36). However, to the authors' best knowledge, no studies have focused on the relationship between pandemic stress and FQOL of children with autism. Thus, identifying and discussing the role of COVID-19-pandemic-related stress in parents of children with autism's FQOL is worthwhile.

Parental involvement as an intermediary

Research on parental involvement originated with Englund et al.s' (37) study, which noted a positive relationship between parental involvement and children's school performance. Existing studies summarize the basic content and common forms of parental involvement, which mainly include the child's education plan, intervention plan, and educational career planning (38–40), as well as participation after communication with the intervention team and participation with the child in implementing the program (41, 42).

Parents need to spend more time and energy caring for children with autism, so it is essential to study parental involvement and related factors, which are important parts of developmental and therapeutic strategies for children with autism and particularly critical in the child's early development, education, and therapeutic interventions (43, 44). Parental involvement with children with autism covers a wide range of areas, including participating in the child's development, learning, and treatment and actively interacting with teachers and physicians (45, 46). Increasingly, parents of children with autism are becoming involved in their child's activities and interventions, participating in homework tutoring, parent training, and the design and implementation of intervention processes (29, 47–49). In this process, it is possible to gain a more comprehensive understanding of the effectiveness of engagement behaviors and thus better design and implement them when considering family outcomes, using FQOL as an indicator (50, 51).

It has been confirmed that parental involvement in the care and education of children with autism can have a positive impact on the child's behavioral styles, character personality, future development, and family relationships and interactions (52–54). Some studies have focused on the impact of parental psychological stress on parental involvement in children with autism, showing that increased parenting stress and decreased supportive behaviors and child care lead to decreased parental involvement (55, 56).

Some existing studies have confirmed the relationship between parental stress and involvement (57, 58), while others have demonstrated that parental involvement can influence FQOL (12, 59). In China, studies have found that parents of children with autism have higher parental psychological stress and are less actively involved in parenting than parents of normal children and children with other disabilities (60, 61). Thus, it is valuable to explore whether parental involvement mediates the relationship between pandemic stress and FQOL.

The present research

The purpose of this study was to enrich the research on the relationships among pandemic stress, parental involvement, and FQOL for children with autism. Two research questions were proposed: (1) What are the current status of pandemic stress, parental involvement, and FQOL for children with autism in China? (2) What are the relationships among pandemic stress, parental involvement, and FQOL? Based on previous studies, two hypotheses were made. The first was that pandemic stress would directly predict FQOL. The second was that pandemic stress would indirectly predict FQOL, mediated by parental involvement.

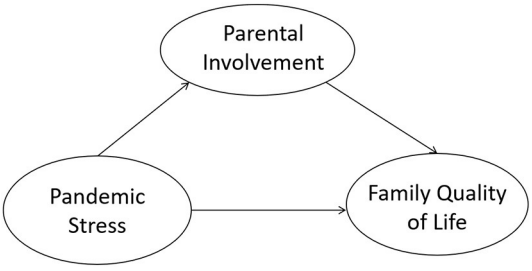

FIGURE 1
Hypothetical model.

A review of the current literature and research hypotheses suggested that pandemic stress would predict FQOL through direct and indirect pathways, with parental involvement mediating the latter. This study's proposed hypothetical model is shown in Figure 1.

Methods

Procedures

As the study did not have direct access to a list of children with autism in China, it used schools as a hub to introduce the online questionnaire to principals of special public schools serving children under the age of 22 with autism, in 31 provinces, autonomous regions, and municipalities. The principals then introduced and distributed the questionnaire to their students' parents, encouraging them to participate in this research.

All participants in the study completed the questionnaire online, which usually took about 20 min. All participants uploaded an informed consent form stating that participation was voluntary and that all information collected through the questionnaire would be kept strictly confidential and used for academic research only. All demographic information was anonymized. Upon completing the questionnaire, participants were randomly given an online bonus package, with a one-third chance of winning, to show the researchers' appreciation for their participation. It is worth noting that the data was collected when children were able to attend classes a bit in person/hybrid learning.

Participants

Eight hundred and one families of children with autism completed the survey. Since the present research target children with autism, and those with autism usually lag behind the normal population across diverse developmental domains, we selected families with children aged ≤22 years as our sample, resulting in a final sample of 761 families. Removing outliers left 709 participants, 16% male and 84% female. Parents were mostly 31–50 years old. Their education was mostly at the bachelor's degree level or above. Most of the children with autism are 8–17 years old, mostly primary school students. About 40 % of the family reported a monthly income of <5,000 yuan (equivalent to 710 US dollars), below the poverty threshold (the level deemed necessary to achieve an adequate standard of living in China). Table 1 shows the demographic information of the children and their parents.

TABLE 1 Participant descriptive statistics.

Variables	*n*	%
PARENT		
Gender		
Male	113	15.9%
Female	596	84.1%
Age		
18–25	5	0.7%
26–30	31	4.4%
31–40	330	46.5%
41–50	292	41.2%
51–60	42	5.9%
>60	9	1.3%
Education		
<High school	99	14.0%
Polytechnic school or high school	122	17.2%
Mechanical degree or bachelor degree	197	27.8%
>Bachelor degree	291	41.0%
Monthly household income (Yuan)		
<5 K	268	37.8%
5–10 K	233	32.9%
10–20 K	114	16.1%
>20 K	94	13.3%
Number of children		
1	359	50.6%
2	321	45.3%
3	29	4.1%
CHILDREN		
Age		
<7	226	31.9%
8–17	410	57.8%
18–22	73	10.3%
Education		
Not enrolled	139	19.6%
Kindergarten	108	15.2%
Primary schools	308	43.4%
Junior high school	92	13.0%
polytechnic school or high school	54	7.6%
Specialist or undergraduate	8	1.1%

Measures

A demographic sheet and three inventories were adopted in this study. The demographic sheet included questions to gather respondents' personal information (i.e., gender, age, employment status, educational level, family structure, monthly household income, number of children) and their children with disabilities (i.e., age, educational level). The three inventories were as follows.

Beach center family quality of life scale

The Beach Center Family Quality of Life Scale is a 25-item self-report measure used to examine parents' perceived Family Quality of Life [FQOL, (62)] *via* a five-point Likert-type scale (1 = very unsuitable, 2 = unsuitable, 3 = neither unsuitable nor suitable, 4 = suitable, and 5 = very suitable).

It has five subscales: (1) family interaction, reflecting the level of interaction between family members (six items); a sample item is "My family enjoys spending time together"; (2) family care and support, reflecting the level of care and attention given to raising children (six items); a sample item is "My family helps children learn to be independent"; (3) emotional happiness, reflecting the level of emotional happiness of the family (four items); a sample item for emotional happiness is "My family has friends or others to provide support"; (4) material happiness, reflecting the family's level of material wellbeing (five items); a sample item is "My family has transportation to get where they need to go"; and (5) disability-related support, reflecting the level of disability-related support received by the family (four items); a sample item is "My family member with a disability has support to accomplish goals at home".

This scale was developed in English, translated into Chinese for this study, and then back-translated into English. In addition, the third question, "My family works together to solve problems", and eighth question, "My family members help the children with school work and activities", were removed from the original scale, considering the study's purpose and the local context, leaving 23 items.

After removing 52 outliers, the researchers performed a confirmatory factor analysis (CFA) on the scale for validation.

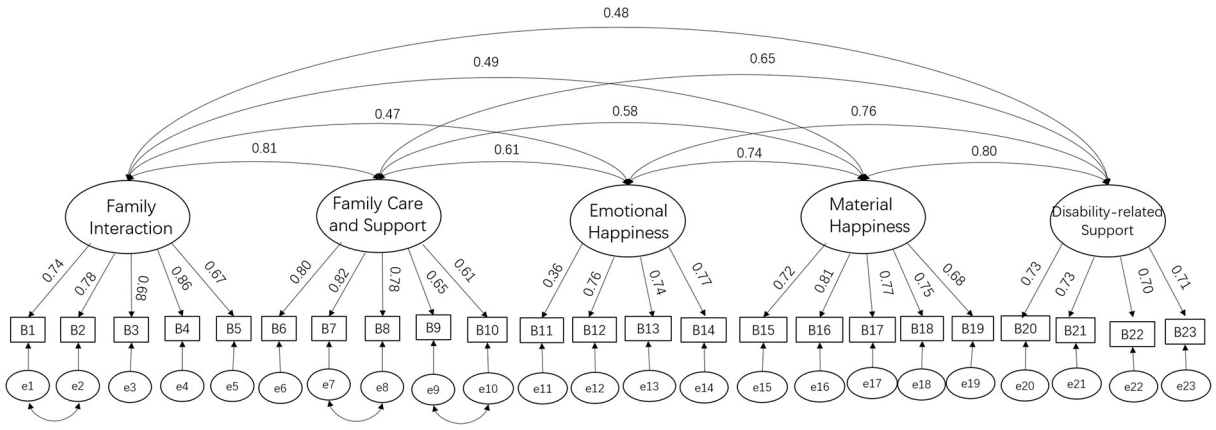

FIGURE 2
Confirmatory factor analysis of family quality of life.

The reliability and validity of the scale meet the requirements of psychometric indicators and showed good reliability and validity. As shown in Figure 2, the overall Cronbach's alpha value for the scale in this study was 0.94, with the five factors having alpha values of 0.89, 0.85, 0.75, 0.86, and 0.81, respectively, indicating a good level of internal consistency for the entire survey instrument and the five factors. The CFA results for the scale showed that the CMIN/DF was 4.41, RMSEA (Root Mean Square Error of Approximation) was 0.07, CFI (comparative fit index) was 0.92, AGFI (adjusted goodness-of-fit index) was 0.86, IFI (incremental fit index) was 0.92, and TLI (Tucker-Lewis index) was 0.91, all good indicators. The modified scale had a better fit and more desirable data than the Hoffman-designed scale.

Pandemic stress scale

The Psychological Stress Questionnaire (63) is a newly developed measurement that examines stress related to the COVID-19 pandemic using a five-point Likert scale. It contains nine items reflecting three factors identified by Wang J. et al. (63). The first factor is risk awareness, reflecting subjects' self-assessment of the level of risk in their environment (three items). A sample item is "What do you think is the risk of exposure to infection in your work environment?" The second factor is physical and mental response, revealing subjects' reactions to stress in the current environment (four items). A sample item is "Do you need professional psychological guidance?" The third factor relates to optimistic Hope, reflecting subjects' confidence in overcoming the pandemic and their optimism about the current pandemic attitude (two items). A sample item is "Are You confident in this anti-epidemic victory?" The "anti-epidemic victory" refers to the spread of COVID-19 across the globe, where through the widespread availability of the vaccine and the success of anti-epidemic measures, governments remove the last legal restrictions and citizens can achieve freedom of movement across regions (64).

Since latent variables need to be explained by at least three or more observed variables (65), and one factor of the Psychological Stress Scale contains only two items and is unsuitable for CFA, exploratory factor analysis (EFA) was conducted to validate the Psychological Stress Scale.

Factor analysis is appropriate when the KMO (Kaiser-Meyer-Olkin) > 0.60 and Bartlett's spherical test is statistically significant (66). Results showed that KMO $= 0.83$ and Bartlett sig < 0.05, indicating that the scale was suitable for EFA. Three factors were yielded *via* the component matrix. The first was *risk perception and concern* (items 2, 3, 4, 5, and 6), describing parents of children with autism's pandemic-related risk perceptions and concerns. A sample item is "you concerned about being infected during your work". The second is *pragmatic hopefulness* (items 1 and 9), describing respondents' degree of rational attitude toward the pandemic and hope of an anti-epidemic victory. A sample item is "You are confident in this anti-epidemic victory". The third is *physical and mental reaction* (items 7 and 8), describing respondents' physical and mental responses to the pandemic. A sample item was "you need professional psychological guidance".

The Cronbach's alpha value of the modified scale was 0.77, indicating the whole survey instrument and the *risk perception and concern* section had good internal consistency. After maximum variance rotation, the coefficients ranged from 0.74 to 0.89 for the five risk perception and concern items, from 0.48 to 0.88 for the two *pragmatic hopefulness* items, and from −0.69 to 0.77 for the two *physical and mental reaction* items. The coefficient of item 7 was negative, while the coefficients of the other items were all positive; the item 7 scores were assigned in the reverse direction to ensure that the effect direction was

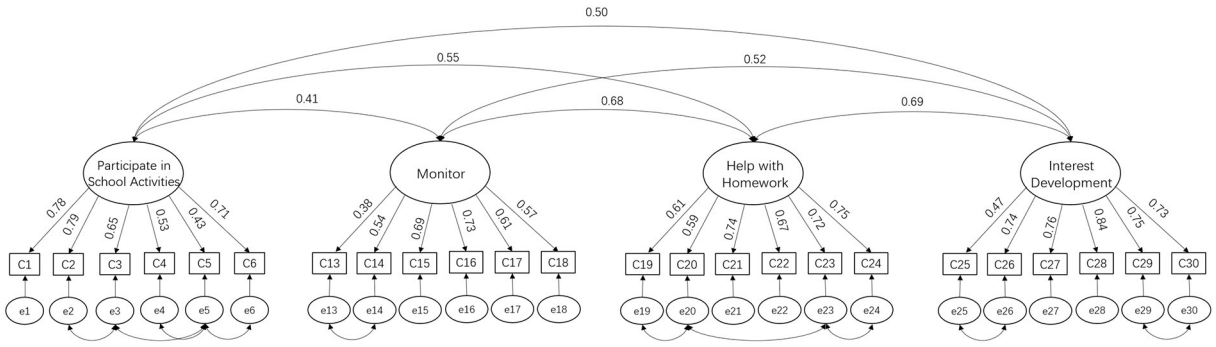

FIGURE 3
Confimatory factor analysis of parental involvement.

consistent among all items. Based on the scale designed by J. Wang, this study adapted the structure of the EFA method model, which was an attempt to develop a pandemic stress scale, and the indicators were better than the original scale.

Parental involvement scale

The study drew on the Parental Involvement Scale used by Georgiou and Tourva (67), which consists of five factors: (1) involvement in school activities, reflecting how closely subjects interact with their children's school (six items). A sample item for *participation in school activities* was "Going to my child's school to talk to teachers"; (2) anxiety and overprotection, revealing specific behaviors of anxiety and overprotection in subjects' parenting (six items). A sample item was "Worrying that something bad might happen to my child"; (3) monitoring, revealing subjects' privacy and life details (six items). A sample item for *monitoring* was "Wondering who your child's friends are"; (4) homework help, reflecting subjects' involvement in their child's classroom tutoring and academic development (six items). A sample item for *homework help* is "Getting to know your child's school systematically"; and (5) interest development-extracurricular activities, reflecting subjects' involvement in their child's hobbies and interests (six items). A sample item for *interest development - extracurricular activities* is "Encouraging your child to read for pleasure". Each item was rated on a five-point Likert-type scale (1 = very unsuitable, 2 = unsuitable, 3 = neither unsuitable nor suitable, 4 = suitable, and 5 = very suitable).

The *anxiety and overprotection* subscale was removed because factor loading for the anxiety and overprotection subscale (below 0.1) was too low. Furthermore, in the Chinese context, items in this subscale were not closely related to parental involvement. Furthermore, this subscale overlapped the Pandemic Stress Scale to some extent. The modified scale, shown in Figure 3, contains four factors and twenty-four items. The scale's reliability and validity meet the requirements of psychometric indicators, with good reliability and validity. The Cronbach's alpha value for the modified scale was 0.90, and the Cronbach's alpha values for the four subscales were 0.81, 0.76, 0.85, and 0.85, indicating the internal consistency levels of the whole survey instrument and the four subscales were good. CFA (using AMOS 28.0) and a chi-squared test were used to compare the fit indices of the seven models (CMIN/DF, RMSEA, GFI, AGFI, CFI, IFI, and TLI). The results showed that CMIN/DF was 3.19, RMSEA was 0.06, GFI was 0.92, CFI was 0.93, AGFI was 0.90, IFI was 0.93, and TLI was 0.92; all indices met the criteria for a good model fit. The scale was adjusted based on Georgiou and Tourva (67) to provide better data for each indicator.

Data analysis

Data cleaning was carried out before data analysis. No variables had missing data. The outliers were processed by IBM SPSS 27.0, and 52 samples with standard scores less than or greater than 3 were removed, leaving a final sample of 709. An examination of correlations revealed that no independent variables were highly correlated ($r > 0.80$). The multi-collinearity statistics including Tolerance and VIF (variance inflation factor) were within acceptable limits.

SPSS 27.0 was used to test the three scales' reliability. SEM was used to conduct CFA on the modified Family Quality of Life Scale and Parental Involvement Scale. EFA was conducted for the Pandemic Stress Scale.

SPSS 27.0 was used to describe each FQOL subscale to answer the first research question. Then, one-sample *t*-tests were conducted to assess the mean difference between participants' perceptions of these variables and the hypothesized midpoint score (i.e., critical value = 3).

Structural equation modeling (SEM) was applied to test the hypothetical model to answer the second question (see Figure 1). SEM is a series of multivariate statistical models used to estimate the effects and relationships between multiple

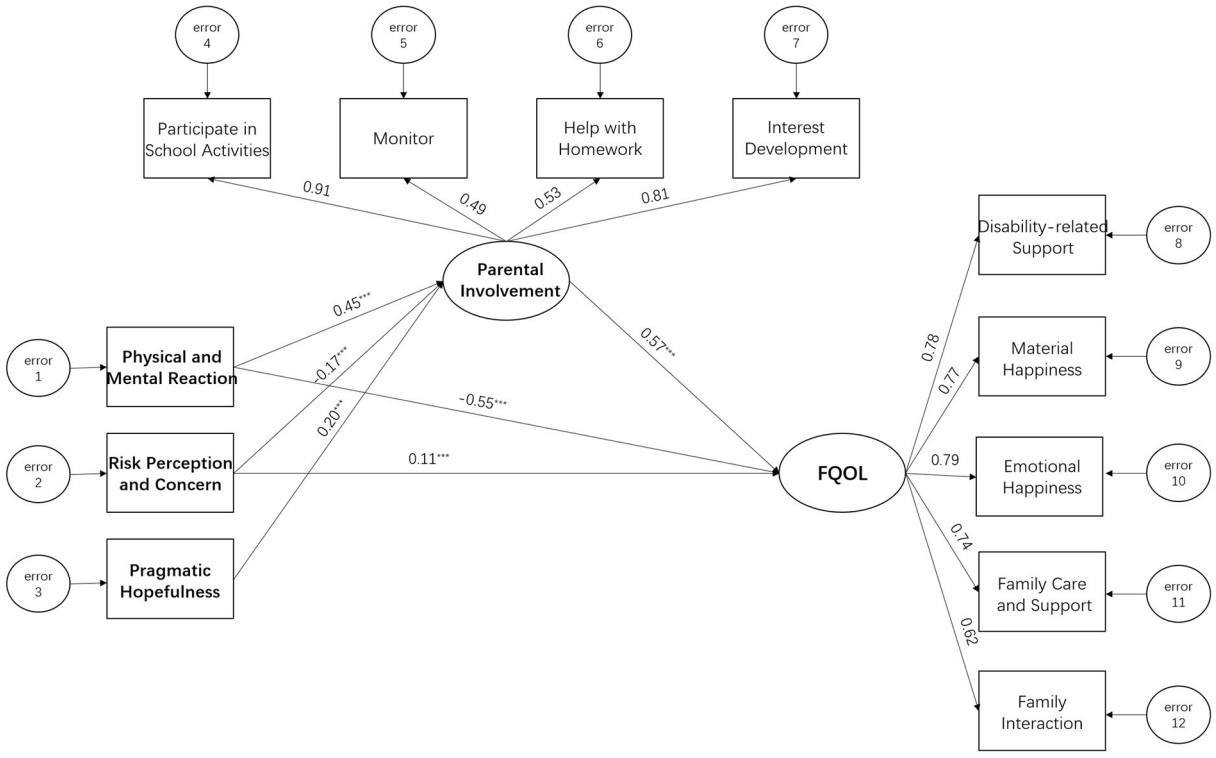

FIGURE 4
Structural equation model path diagram of the interrelations between stress, involvement, and FQOL. FQOL, family quality of life. ***$p < 0.001$.

variables representing a hypothetical, theoretical model (68). In the present research, the three variables were the sum of the items from each scale. Due to the *risk perception and concern* and *physical and mental reaction* subscales' low loading coefficients for pandemic stress and the non-significant direct effect between pandemic stress and FQOL in the hypothetical model, a new model was reconstructed, within which the three factors of pandemic stress were used as observed independent variables (see Figure 4).

Results

Descriptive results

The first research question addressed the current status of pandemic stress, parental involvement, and FQOL among families of children with autism in China. As shown in Table 2, the FQOL for children with autism in China is significantly higher than the expected average (score 3). *Emotional happiness* was the lowest [M = 3.12, SD = 0.81, $t_{(708)}$ =3.92, $p < 0.001$], followed by *disability-related support* [M = 3.26, SD = 0.83, $t_{(708)}$ = 8.33, $p < 0.001$]; the highest was *family interaction* [M = 3.91, SD = 0.77, $t_{(708)}$ = 31.35, $p < 0.001$], followed by *family care and support* [M = 3.80, SD = 0.70, $t_{(708)}$ = 30.55, $p < 0.001$].

Parents' involvement with their children with autism was above our expected average (score 3). I*nterest development* was highest [M = 4.03, SD = 0.63, $t_{(708)}$ = 43.67, $p < 0.001$], followed by *help with homework* (M = 3.89, SD = 0.68, $t_{(708)}$ = 34.88, $p < 0.001$).

Of the three dimensions of pandemic stress, *risk perception and concern* [M = 2.51, SD = 0.90, $t_{(708)} = -14.60$, $p < 0.001$] and *physical and mental reaction* [M = 2.83, SD = 0.83, $t_{(708)} = -5.45$, $p < 0.001$] were lower than the expected mean, while *pragmatic hopefulness* was higher [M = 3.91, SD = 0.66, $t_{(708)}$ = 37.02, $p < 0.001$].

SEM results

The second research question concerned the relationship between pandemic stress, parental involvement, and FQOL. The final SEM (see Figure 4) was determined and the model fit index indicated it was feasible, where X^2/df = 13.40, RMSEA = 0.13, GFI = 0.86, AGFI = 0.80, CFI = 0.78, IFI = 0.78, and TLI = 0.72.

TABLE 2 Descriptive statistics for family quality of life, parental involvement, and stress.

	n	*m*	sd	df	*T*	*p*
F1	709	3.91	0.77	708	31.35	<0.001
F2	709	3.80	0.70	708	30.55	<0.001
F3	709	3.12	0.81	708	3.92	<0.001
F4	709	3.42	0.89	708	12.61	<0.001
F5	709	3.26	0.83	708	8.33	<0.001
PS	709	3.79	0.67	708	30.97	<0.001
PM	709	3.69	0.65	708	28.37	<0.001
PH	709	3.89	0.68	708	34.88	<0.001
PI	709	4.03	0.63	708	43.67	<0.001
EW	709	2.51	0.90	708	−14.60	<0.001
EE	709	2.83	0.83	708	−5.45	<0.001
EP	709	3.91	0.66	708	37.02	<0.001

F1, family interaction; F2, family care and support; F3, emotional happiness; F4, material happiness; F5, disability related support; PS, participate in school activities; PM, monitor; PH, help with homework; PI, interest development; EE, physical and mental reaction; EW, risk perception and concern; EP, pragmatic hopefulness.

TABLE 3 Results of structural equation model analysis.

Model	EE	EW	EP	Involvement
Direct effects				
FQOL	−0.55***	0.11***		0.57***
Indirect effects				
Involvement	0.45***	−0.17***	0.20***	
FQOL	0.257***	−0.097***	0.114***	
Total				
FQOL	−0.293***	0.013***	0.114***	

EE, physical and mental reaction; EW, risk perception and concern; EP, pragmatic hopefulness; FQOL, family quality of life. ***$p < 0.001$.

The modification indices function was used to see if Amos could propose further improvements to the model. After the modification, the SEM has a better model fit index, $X^2/df = 5.323$, RMSEA = 0.08, GFI = 0.95, AGFI = 0.91, CFI = 0.94, IFI = 0.94, TLI = 0.90. In addition, by conducting exploratory model exploration with Amos, the output suggested deleting the direct covariate path between *pragmatic hopefulness* and FQOL; the current model was the preferred SEM for revealing these data and describing the correlation effects between pandemic stress, parental involvement, and FQOL.

The range of standardized loadings for each latent variable and the observed scales and standardized path coefficient is shown in Figure 4. FQOL ranged from 0.62 to 0.79 and parental involvement ranged from 0.49 to 0.91, with all loading indices >0.40 and statistically significant ($p < 0.001$), indicating that the dimensions of the factors adequately measured and explained the latent variables.

The direct effect of *pragmatic hopefulness* on FQOL was not significant and had a positive effect on FQOL through the mediation of parental involvement as shown in Table 3, a full mediation effect with an effect size of 0.20*0.57 = 0.114. *Risk perception and concern* had a direct positive effect on FQOL with a size of 0.11 and a negative effect on FQOL through the mediation of parental involvement with a size of −0.17*0.57 = −0.097. The total effect of *risk perception and concern* on FQOL is positive, size 0.11–0.17*0.57 = 0.013; *physical and mental reaction* had a direct negative effect on FQOL, size −0.55, a positive effect on FQOL mediated through parental involvement, size 0.45*0.57 = 0.257, a negative total effect on FQOL with a size of −0.55 + 0.45*0.57 = −0.293.

To summarize, the model results largely supported the two hypotheses. Consistent with the first hypothesis, there was a significant direct correlation between pandemic stress and FQOL. The direct predictive effect of pandemic stress on FQOL was supported by two dimensions, *physical and mental reaction* and *risk perception and concern*, where *physical and mental reaction* was negatively related to FQOL and *risk perception and concern* was positively related to FQOL. Consistent with the second hypothesis, there was a significant indirect correlation between pandemic stress and FQOL, mediated by parental involvement. The three dimensions of *physical and mental reaction*, *risk perception and concern*, and *pragmatic hopefulness*

supported the indirect predictive role of pandemic stress on FQOL, where *physical and mental reaction* was positively related to FQOL, *risk perception and concern* was negatively related to FQOL, and *pragmatic hopefulness* was positively related to FQOL.

Discussion

This study aims to describe the current status of pandemic stress, parental involvement, and family quality of life for children with ASD, and explore the relationships among the three variables. Results responded well to the research questions, and the research hypotheses were largely supported.

The current status of pandemic stress, parental involvement, and FQOL

Families of children with ASD had relatively higher satisfaction with *family interaction* and relatively lower satisfaction with their e*motional wellbeing*, which is consistent with previous research (69). On the one hand, this may be due to the fact that many people in China consider ASD as a stigma (70), and social labeling and self-labeling reduce their self-identity and emotional level needs. On the other hand, studies have showed that family quality of life for children with ASD decreases under the psychological stress [e.g., (5)]. Family quality of life for children with ASD was significantly influenced by the pandemic. For parents of children with ASD, their interaction with the surrounding environment was reduced, and consequently social inclusion was hindered as well as emotional needs were unmet.

During the COVID-19, parents of children with special needs spent more time and energy caring for their children because of the limitations of pandemic prevention regulations such as isolation (34–36). In China, parents of children with ASD are often involved in all aspects of their children's learning and life due to their children's medical condition. Results showed that parents were sufficiently involved in all four areas, with the highest involvement being in "interest development-extracurricular activities", which is consistent with previous studies (67, 71). Meanwhile, the lowest level of involvement was "monitoring", which is consistent with several studies on parental involvement in cerebral palsy, surgical hospitalization, and mobile children (72–74).

The relationships among pandemic stress, parental involvement and FQOL

Previous studies have confirmed the positive predictive effect of parental involvement behaviors on FQOL (12, 50, 58), and promoting parental involvement in the learning, living, and rehabilitation interventions of children with ASD is beneficial not only for the development of children with ASD, but also for their family life situation.

For *physical and mental reaction,* the SEM results show a direct negative effect of *physical and mental reaction* on family quality of life and a positive effect on family quality of life mediated by parental involvement, with a negative overall effect of *physical and mental reaction* on family quality of life. Higher *physical and mental reaction* means parents of children with ASD experience more physical and mental suffering in pandemic, such as insomnia, and have more need for counseling caused by high level anxiety. Family quality of life is a multidimensional concept that involves people's emotional wellbeing, and the *physical and mental reaction* to the pandemic reduce people's emotional wellbeing, which in turn reduces the quality of family life.

Risk perception and concern had a direct positive effect on family quality of life and a negative effect on family quality of life mediated through parental involvement, with a small positive total effect on family quality of life. This is also inconsistent with previous results regarding the negative effect of stress on family quality of life (7, 8, 24, 25). Considering the pandemic, the more severe the perception of the pandemic, the stronger the desire to reduce the impact of the pandemic on children with ASD in various ways, and the increased family care, material wellbeing and disability-related support, which would improve their quality of life; at the same time, *risk perception and concern* of the pandemic may discourage parents from participating in their children's lives and thus reduce their participation behavior, but overall, *risk perception and concern* during the pandemic enhance family quality of life to some extent.

Although *pragmatic hopefulness* has no direct effect on FQOL, it has positive indirect effect on FQOL through parental involvement. The higher level of *pragmatic hopefulness* results in higher parental involvement, and the higher level of parental involvement results in higher level of FQOL. This means the increase of *pragmatic hopefulness* can improve FQOL for children with ASD. The continued spread of pandemic and the associated home isolation requires pragmatic hope so that families of children with autism could mobilize their own resources for a more active life. Providing social support to families of children with autism to help them develop an objective and positive intellectual orientation to the outbreak is critical (56), and the public health sector should provide families of children with autism with timely and correct knowledge and

guidance about the impact of the outbreak on their personal health as well as on their child's growth and development (4, 21).

It is worth exploring that as a dimension of pandemic stress, *physical and mental reaction* elevate parental involvement, which is contrary to findings of previous research (55, 56). This may be related to the context of the pandemic. Parents reacted strongly both physically and mentally during the pandemic and were more concerned about their children, minimizing the impact on their children by over-caring for them. At the same time, the policy of home isolation in pandemic situations requires greater parental control of children in the home, and school rules for online teaching make parents more participating in their children' schooling actively or passively.

Limitations

The current study has five limitations. First, pandemic stress was initially constructed as a second-order latent variable, but it is not so fit in original SEM model, and to reconstruct the model, three factors of pandemic stress was used as observed variables, respectively. The relationships abovementioned need verification in the future study. Second, the model did not incorporate covariates, such as gender, household income status, and other demographic contexts. Most participants were mothers, but the influence of fathers was equally important and needed to be considered and discussed. There may be subgroup differences in family quality of life for families with different income levels. In addition, 73 participants aged from 18 to 22 (only 10%) were included in the present research, which may have influenced the present study's results.Third, the study attempted to obtain a diverse sample in mainland China, but the representativeness of the sample needs further verification as it currently lacks the support of a national census. Fourth, the data collected in this questionnaire are cross-sectional in nature. A longitudinal design may be conducted in the future, which can better argue the cause-effect of pandemic pressure on parental involvement and FQOL. Fifth, this study adopted online survey, which might have inadvertently excluded some parents such as low-income, resource-constrained single-parent groups, and those without smartphones/laptops/tablets.

Significance and implication

The present study makes three important contributions. First, this is the pioneer study to investigate the impact of COVID-19 pandemic on parenting children with ASD in mainland China which has a large number of children with ASD and is highly impacted during COVID-19 pandemic in terms of life and schooling. Second, the study explored the pandemic stress among parents of children with ASD during COVID-19, which enriched the research field of pandemic stress. Furthermore, the study verified the mediating role of parental involvement and enriched the research related to the relationship between parental involvement and family quality of life (FQOL). Finally, this study enriched the databank regarding the psychometric properties of the three scales and tested the Pandemic Stress Scale, the Parental Involvement Scale, and the FQOL Scale. Notably, this is the pioneer study using EFA to explore pandemic stress among children with ASD in a Chinese context.

Reference can be made to the findings of this study to pay attention to parents' *risk perception and concern*, *physical and mental reaction*, and *pragmatic hopefulness* during COVID-19 to better promote parental involvement in the life, learning, and rehabilitation of children with ASD and to enhance family quality of life for children with ASD. Three detailed practical implications may be proposed. First, a systematic psychological intervention services may be provided for family of children with ASD to reduce their physical and mental response to the pandemic, and thus to enhance the overall FQOL. For instance, rational emotive behavior therapy could help parents reduce their psychological stress. Specifically, the ABC model encourages parents to look at the "activating event" (e.g., their goals and difficulties) and "emotional disturbance" (their own largely negative "beliefs" or interpretations of these events) they have experienced. Afterwards, attention is directed to the "beliefs" and inferences that powerfully influence emotional disturbance. It is possible to teach this model effectively and quickly, and most parents can grasp it, apart from those who are seriously ill or confused. Parents are encouraged to learn relaxation procedures, yoga or meditation, as well as how to dispute problem-causing irrational beliefs.

Second, parent-to-parent groups have played important roles in promoting parental adaptation (75), so family support groups to reduce the pandemic stress are also one of the most important ways to improve the family quality of life. In addition, ASD caregivers need more support during the pandemic. Caregivers of children with ASD can learn behavioral strategies and interventions through telehealth training programs to help reduce their stress and improve their wellbeing during the COVID-19 pandemic (76).

Third, interventions with families of children with ASD have had a positive effect in improving family quality of life of caregivers' families, but these strategies are still in their infancy and need to be further explored, especially given the complexity of the pandemic (76, 77). At the policy level, during the COVID-19 and similar pandemic, taking effective actions to maintain and enhance the pragmatic confidence of people who are involved in is very important to encourage parental involvement, and thus to maintain and improve their family quality of life. For instance, university/school administrators could offer resources and inform parents of various involvement strategies, or compare data on university/school-level parental involvement across districts; if university/school-level parental involvement is low, counselors could work with administrators

and parent-teacher associations to create more welcoming and inviting environments and provide more opportunities for parents to engage in university/school activities—e.g., by arranging flexible times for working parents to attend parent-teacher meetings and other events inside and outside the classroom or providing child care or refreshments at evening events (78).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Shandong University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

ShC supervised the whole manuscript. SaC was responsible for conceptionalization and finalize the manuscript. SL analyzed the data. YL drafted the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Does the eight-factor "power to live" in disaster exist since childhood?

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Background: Studies on the survivors of the 2011 Great East Japan earthquake and tsunami have revealed eight factors, called power to live, which are closely related to resilience and effective coping after intense and prolonged stress. However, whether the eight factors, which were examined in adults, are applicable to children is unclear. The purpose of this study is to evaluate whether the eight-factor structure of power to live was present since late childhood.

Method: A 34-item power to live questionnaire was filled by middle- to upper-grade elementary ($n = 378$) and junior high school students ($n = 456$). Moreover, because elementary school students may lack introspective ability, their power to live was evaluated through a parental assessment ($n = 358$). Additionally, we examined the relationship between each power to live factor and questions regarding disaster prevention awareness among 25 elementary school students.

Results: The results from confirmatory factor analysis for factor structure revealed generally acceptable fit indices. The reports from elementary school students and their parents significantly positively correlated with each power to live factor. Although reliability indices for factors such as stubbornness, etiquette, self-transcendence, and active well-being were not good for elementary school students, the reliability indices for all factors, excluding stubbornness, increased in junior high school students. Moreover, we identified a correlation between problem-solving, altruism, and emotional regulation and questionnaire items regarding awareness of disaster prevention in elementary school students.

Conclusion: Our results suggest that although factors common to adults, such as leadership, problem-solving, altruism, and emotional regulation, were identified at the elementary school stage, some factors, such as stubbornness, are in the process of being formed. Future studies should examine the developmental changes assumed to underlie these factors and their relationship to experience and neurodevelopmental basis.

KEYWORDS

children, personality, disaster prevention education, emotion regulation, leadership, problem-solving, factor structure

Introduction

Resilience is defined as the capacity of a dynamic system to withstand or recover from significant challenges that threaten its stability, viability, and development (1, 2). Resilience from a catastrophic disaster involves the diverse and long-term process of evacuation, shelter-living, and rebuilding lives. Examining the factors that play a protective role in these processes is necessary when considering disaster prevention and promoting resilience (3).

From the studies on survivors of the 2011 Great East Japan earthquake and tsunami, which killed nearly 19,000 people and caused extensive damage to the coastal areas of eastern Japan, eight factors called "power to live" were extracted that are closely related to resilience and effective coping using a bottom-up approach (4, 5). Sato et al. (4) interviewed survivors of the 2011 Great East Japan earthquake and tsunami about their experiences of avoiding crises and solving problems in various disaster contexts, such as evacuation, living in shelters, and rebuilding lives, as well as the psychological and behavioral characteristics that worked to their advantage. Based on that survey, Sugiura et al. (5) conducted a questionnaire survey of 1,412 disaster survivors and constructed an 8-factor, 34-item power to live questionnaire using exploratory factor analysis and examined the relationship between each factor and behavior during the 2011 Great East Japan earthquake and tsunami.

The power to live questionnaire is an eight-factor questionnaire that evaluates a wide-range of individual characteristics related to post-disaster resilience. The eight factors include: Factor 1 (leadership) represents the attitude and habit of gathering and organizing people; Factor 2 (problem-solving) is associated attitudes and practices that strategically address problems; Factor 3 (altruism) is a personality trait that leads to concern for and assistance of others; Factor 4 (stubbornness) is the attitude or habit of sticking to one's wishes or beliefs; Factor 5 (etiquette) is the attitude or habit of following social conventions in one's daily behavior; Factor 6 (emotional regulation) is the attitude or habit of attempting to calm down in a difficult environment; Factor 7 (self-transcendence) is associated with consciousness and making sense of life from a spiritual perspective; and Factor 8 (active well-being) is related to the daily practice of maintaining and improving physical, mental, and intellectual health (5).

Each factor in the power to live questionnaire was examined in relation to the survivors' condition at the time of the 2011 Great East Japan earthquake and afterwards. Promptness during evacuation positively correlated with leadership, problem-solving, and emotional regulation (5, 6). Positive correlations have been observed in other indicators such as problem-solving in shelters (problem-solving, altruism, emotional regulation, and self-transcendence) or subjective sense of recovery (problem-solving and active wellbeing) (5). Leadership, emotional regulation, problem-solving, etiquette, and self-transcendence correlated with rebuilding of houses (7). Relationships were also found between post-disaster problem-solving styles (e. g., self-resolution, resolution through request, resolution through acquaintances, etc.) and various factors in the power to live questionnaire (8).

Studies have evaluated the neurocognitive basis of each factor in the power to live questionnaire (9, 10). In a study in which an MRI task was used to simulate easy or difficult problems in the operation of powerplants, a relationship was found between brain activity involved in coping with difficult problems and problem-solving (11). In another study, an inverse correlation was reported between neural activation during constructive thinking and stubbornness (12).

However, whether the eight factors related to the power to live examined in adult survivors from the 2011 Great East Japan earthquake and tsunami are applicable to children is unclear. In disaster prevention education, knowledge acquisition is often the main goal, and focusing on nurturing the characteristics required to overcome a disaster is challenging (13–15). Evaluating the similarities and differences between power to live factors in adults and children can help identify traits formed at an early age, which can then be applied to disaster-prevention education. Although protective factors, such as cognitive skills (16, 17) and family relationships (18) have been related to resilience in children, children differ from adults in many traits related to resilience, including nurturing of family, community factors, and intrapersonal factors, such as immature personality and cognitive functioning (19). There is a possibility of prematurity in each power to live factor between elementary and junior high school students.

Thus, the purpose of this study is to confirm whether the eight-factor structure of the power to live, which was reported for the adult survivors of the 2011 Great East Japan earthquake and tsunami, is present since late childhood. For this purpose, we examined the factor structure and homogeneity of the power to live in elementary and junior high school students. Because the questionnaire may be unsuitable for students, especially for elementary school students given their ability of introspection, elementary school students were assessed by using a combination of the self- and parent-rated power to live questionnaires. Moreover, the items were paraphrased to match the vocabulary of elementary school students to not detract from the original meaning. In addition to the original 34-item version, the model was examined using a 16-item version created by extracting two items that showed higher correlation with each factor score (20). Scores on the 16-item version were shown to have a very high positive correlation with the 34-item version, and its relevance to behavior during the 2011 Great East Japan earthquake and tsunami was also examined (20). Moreover, we explored the relationship between disaster prevention awareness

TABLE 1 Power to live questionnaire and factor loading in elementary and junior high school students (34-item factor structure).

Item	Elementary school student	Junior high school student
Factor 1. Leadership		
1. To resolve problems, I gather together everyone involve to discuss the matter	0.71	0.70
2. In everyday life, I often take the initiative to gather people together	0.79	0.82
3. I take the initiative in taking to other people	0.62	0.79
4. Sophisticated words that move people's hearts come out of my mouth	0.70	0.55
5. In everyday life, I make sure to keep in contact with friends and acquaintances	0.52	0.81
Factor 2. Problem-solving		
6. When I am fretting about what I should do, I compare several alternative actions	0.66	0.59
7. Before taking action, I think of a plan and the order of priority	0.69	0.83
8. When talking to someone, I think about that person's personality, wishes, and abilities and choose an appropriate attitude and words accordingly	0.58	0.66
9. The more agitated the people around me become, the calmer I somehow become	0.32	0.71
10. To resolve a problem, I first of all initiate action	0.65	0.63
Factor 3. Altruism		
11. I like it when other people rely on me and are grateful to me	0.82	0.79
12. When I see someone having trouble, I have to help them	0.65	0.52
13. When someone asks me to do something for them, I cannot refuse	0.35	0.85
14. Other people's good fortune makes me happy so I like to help others	0.87	0.67
15. I am meddlesome and I like to do things for others	0.61	0.45
Factor 4. Stubbornness		
16. I am stubborn and always get my own way	0.54	0.56
17. I unhesitatingly say whatever it is I want to say	0.50	0.69
18. I clearly distinguish between black and white: what's good is good, and what's bad is bad	0.50	0.50
19. I hate losing	0.65	0.54
20. I am highly motivated with regard to things that I like or want to d.	0.59	0.44
Factor 5. Etiquette		
21. On a daily basis, I take the initiative in greeting family members and people living in the neighborhood	0.67	0.71
22. In everyday life, I take care of myself as much as possible	0.59	0.70
23. When someone has helped me or been kind to me, I clearly convey my feelings of gratitude	0.63	0.61
Factor 6. Emotional regulation		
24. During difficult times, I endeavor not to brood	0.71	0.74
25. During difficult times, I endeavor to think positively, telling myself that this experience will benefit me in the future	0.72	0.67
26. During difficult times, I compare my circumstances with the situation around me and in society, and I think that matters cannot be helped	0.58	0.39
27. When something happens, I try to stay calm and not panic	0.71	0.76
Factor 7. Self-transcendence		
28. I am aware that I am alive, and have a sense of responsibility in living	0.56	0.80
29. I am aware of the path and teachings I should follow as a person	0.61	0.64
30. I am aware of the role I should play in society	0.60	0.62
31. I think that my actions toward others will go around and eventually come back to me	0.56	0.77
Factor 8. Active well-being		
32. In everyday life, I have habitual practices that are essential for relieving stress of giving me a change of pace	0.53	0.60
33. In everyday life, I have habitual practices that are essential for maintaining my physical health	0.55	0.78
34. In everyday life, I endeavor to find opportunities to acquire new knowledge, skills, and attitudes	0.61	0.76

and the power to live among elementary school students to apply them on disaster prevention education.

Methods

Participants

In the Tohoku region of Japan, envelopes containing questionnaires were distributed and collected on a voluntary basis from elementary and junior high schools. The envelopes contained a written explanation of the questionnaire and a statement that the return of the envelope constituted consent. The elementary schools distributed questionnaires to families with children in grades 3 and above. The questionnaires were collected from 455 families at the elementary school. Of these, 378 (191 boys and 187 girls, 9–12 years old, mean age = 10.71 years, standard deviation = 0.84), without missing responses from the children, were included in the data analysis for the elementary school students themselves. In addition, data from 358 parent–child pairs, who also had no missing responses, were used for analyzing the relationship between their own ratings and those of their parents. Questionnaires filled out by the junior high school students themselves were distributed at 4 schools and collected from 513 students. The 456 students whose answers were not missing were included in data analysis (237 boys and 219 girls, 12–16 years old, mean age = 13.58 years, standard deviation = 0.99). The participants of the questionnaire-based survey on disaster prevention awareness were obtained from 28 sixth graders, 25 of whom had no missing responses on both power to live questionnaires, and the relationship between the two scales was examined (9 boys and 16 girls, aged 11–12 years; mean age = 11.92 years, standard deviation = 0.28). The procedures for this study were approved by the Institutional Review Board of the International Research Institute of Disaster Science, Tohoku University, Japan.

Questionnaires

Power to live questionnaire

The power to live questionnaire (5) was used for the survey. The questionnaire contained 34 items (Table 1), asking for responses on a 6-point scale ranging from "0 = not at all" to "5 = very much." From the responses, individual scores are calculated for eight factors related to the power to live. As noted earlier, the eight factors were leadership, problem solving, altruism, stubbornness, etiquette, emotional regulation, self-transcendence, and active well-being. Only each factor was considered, and no higher-order factors were assumed. Cronbach's alpha for each factor ranges from 0.71 to 0.80.

Original wording was used for junior high school students. The questionnaire items for the elementary school students were rephrased to fit their vocabulary and comprehension, and all items were drafted by all authors based on the 34-item version of the questionnaire. Then, we interviewed several third-grade elementary school students—the lower limit of the surveyed grade level—to evaluate their understanding of the words used in the items and determined the wording of the final questionnaire. Original wording was used for the parent of the elementary school student, with instructions to answer and respond to the question "How much does this apply to your child?"

Disaster prevention awareness

Questionnaire items were selected from those used in studies on disaster prevention education (21–23). Table 2 shows the eight questions asked of the children. The children were asked to self-evaluate their evacuation behavior and sense of fear as relevant factors, as well as their proactive involvement in disaster prevention and self-evaluation of communication with family members involved in disaster prevention. Each question was answered on a 5-point scale ranging from "1 = Strongly Disagree" to "5 = Strongly Agree."

Statistical analyses

Confirmatory factor analysis (CFA) was conducted on three data sets (elementary school students, parents of elementary school students, and junior high school students). CFA verifies the validity of the factor structure from the goodness-of-fit indices of the model. Two models were examined: a 34-item version (5) and a 16-item version (20). The maximum likelihood method was used to estimate factor loadings. This study reports on the comparative fit index (CFI), Tucker–Lewis index (TLI), root-mean-square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR). In a study, goodness-of-fit was considered good if CFI > 0.95, TLI > 0.95, RMSEA < 0.06, and SRMR < 0.06 (24).

The similarity of the factor structure between elementary and junior high school students was tested by employing multigroup CFA. Goodness-of-fit indices were calculated and compared across models for factor structure (configural model), factor loading (weak invariance model), and when factor loading and intercept (strong configural) were constrained to be equal. Additionally, correlational analyses (Pearson's r) were conducted to explore the relationship between each factor on the power to live questionnaire and responses to questions on disaster prevention awareness. Software (ver. 4. 2. 1) was used for statistical analysis. Confirmatory factor analysis was performed using the lavaan package (ver. 0. 6–12).

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TABLE 2 Correlation coefficients between disaster prevention awareness and power to live factors (34-item version).

Item	Leader-ship	Problem-solving	Altruism	Stubborn-ness	Etiquette	Emotional regulation	Self-Transcen-dence	Active well-being
Q1. Do you think you could evacuate safely if an earthquake, tsunami, typhoons, heavy rain, or volcanic eruption were to occur?	0.30	0.22	0.48*	−0.14	0.32	0.29	0.32	−0.13
Q2. Do you think your family could evacuate safely if an earthquake, tsunami, typhoons, heavy rain, or volcanic eruption were to occur?	−0.04	0.10	0.41*	−0.14	0.00	−0.04	0.26	−0.11
Q3. Are you scared of natural disasters, like earthquakes, tsunamis, typhoons, heavy rain, and volcanic eruptions?	−0.15	−0.10	−0.27	−0.07	−0.11	−0.42*	−0.21	−0.30
Q4. Do you think you may get injured if a natural disaster were to occur?	0.04	0.03	0.10	−0.20	0.27	−0.09	0.08	0.03
Q5. Do you think natural disasters will occur in your area?	0.30	0.46*	0.31	−0.25	0.41*	0.33	0.23	0.26
Q6. Do you think you need to talk with your family to decide what to do in the event of a natural disaster?	0.09	−0.11	0.17	0.22	0.11	−0.01	0.41*	0.13
Q7. Do you think your family would become safer if you talked and made promises to improve preparedness?	0.17	0.26	0.26	−0.18	0.47*	0.03	0.45*	0.05

*$p < 0.05$.

TABLE 3 Descriptive statics and Cronbach's alpha of the power to live questionnaire (34-item factor structure).

	Elementary school students			Junior high school students		
	M	SD	α	*M*	SD	α
1. Leadership	14.22	4.94	0.80	15.86	5.63	0.85
2. Problem-solving	14.22	4.57	0.70	17.64	4.66	0.82
3. Altruism	15.85	4.98	0.79	16.82	4.53	0.79
4. Stubbornness	15.30	4.55	0.68	15.88	4.12	0.67
5. Etiquette	10.96	2.82	0.66	12.44	2.46	0.72
6. Emotional regulation	10.70	3.84	0.76	13.55	3.83	0.73
7. Self-transcendence	13.66	3.57	0.67	13.64	4.10	0.81
8. Active well-being	8.97	3.26	0.58	10.20	3.25	0.76

Results

Descriptive statistics, reliability in the 34-item version power to live questionnaire

The means and standard deviations for each factor of the 34-item version of the power to live questionnaire and values of Cronbach's alpha are shown in Table 3. Cronbach's alpha for each factor in elementary school students ranged from 0.58 to 0.80. Reliability coefficients were slightly lower for stubbornness (0.68), etiquette (0.66), self-transcendence (0.67), and active wellbeing (0.58). By contrast, reliability coefficients were acceptable (≥0.70) for leadership, problem-solving, altruism, and emotional regulation. For junior high school students, although slightly below the customary criterion for stubbornness (0.67), the other factors of power to live showed acceptable reliability (from 0.72 to 0.85).

Confirmatory factor analysis and factor loading in the 34-item version of the power to live questionnaire

CFA results are summarized in Table 4. For elementary school students, the goodness of fit indices were CFI = 0.84, TLI = 0.82, RMSEA = 0.06, and SRMR = 0.07. The trend in the goodness-of-fit index was the same for junior high school students (CFI = 0.88, TLI = 0.87, RMSEA = 0.06, and SRMR = 0.07). Regarding standardized factor loading on each item, junior high school students generally exceeded the conventional criterion (>0.40); however, only item 26 was slightly below customary standards (0.39). Although two items were slightly below the standard for elementary students (items 9 and 13), other items were acceptable (Table 1).

Descriptive statistics and reliability in the 16-item version of the power to live questionnaire

Means, standard deviations, and Cronbach's alpha for each factor of the 16-item version of the power to live questionnaire are shown in Table 5. For elementary school students, a certain degree of reliability was found for leadership (0.72); however, other factors showed a generally low reliability (from 0.47 to 0.62). By contrast, junior high school students had a low value of Cronbach's alpha for stubbornness (0.55) and altruism (0.63); however, generally acceptable reliability coefficients were obtained for other factors (from 0.70 to 80).

Confirmatory factor analysis and factor loading in the 16-item version of the power to live questionnaire

The lower part of Table 4 shows the results of CFA in the 16-item version factor structure. For both elementary and junior high school students, all items exceeded conventional factor loading criteria (>0.40; Supplementary Table 1). Adequate goodness-of-fit indices were observed in elementary school students (CFI = 0.97, TLI = 0.95, RMSEA = 0.04, and SRMR = 0.04). Correlation coefficients (Spearman's ρ) between the two items measuring each factor were ρ = 0.56, 0.45, 0.48, 0.33, 0.39, 0.46, 0.37, and 0.31, respectively, for factors 1 to 8. The correlation coefficients between the 34- and 16-item

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TABLE 4 Goodness-of-fit indices of CFI for the power to live questionnaire.

Factor structure	Subjects	χ^2	CFI	TLI	RMSEA	RMSEA 90% CI	SRMR
34-item version	Elementary school students	1197.55***	0.84	0.82	0.06	[0.06, 0.07]	0.07
	Junior high school students	1409.03***	0.88	0.87	0.06	[0.06, 0.07]	0.07
	Elementary school students' parent	1365.43***	0.82	0.80	0.07	[0.07,0.07]	0.08
16-item version	Elementary school students	122.92**	0.97	0.95	0.04	[0.03, 0.05]	0.04
	Junior high school students	152.51***	0.98	0.96	0.05	[0.04, 0.06]	0.03
	Elementary school students' parent	185.21***	0.94	0.90	0.06	[0.05, 0.08]	0.05

CFI, comparative fit index; RMSEA, root-mean-square error of approximation; SRMR, standardized root-mean-square residual; TLI, Tucker–Lewis index.
***$p < 0.001$.

TABLE 5 Descriptive statistics and Cronbach's alpha of the power to live questionnaire (16-item factor structure).

	Elementary school students			Junior-high school students		
	M	SD	α	*M*	SD	α
1. Leadership	4.85	2.49	0.72	5.88	2.69	0.78
2. Problem-solving	5.82	2.24	0.61	6.99	2.07	0.70
3. Altruism	6.76	2.22	0.64	7.36	2.08	0.66
4. Stubbornness	5.35	2.26	0.50	5.20	2.12	0.55
5. Etiquette	7.42	2.00	0.56	8.55	1.80	0.70
6. Emotional regulation	5.52	2.19	0.63	6.80	2.40	0.70
7. Self-transcendence	7.40	1.97	0.53	7.12	2.19	0.73
8. Active wellbeing	5.92	2.33	0.47	6.65	2.36	0.80

versions were $r = 0.90$, 0.83, 0.89, 0.81, 0.92, 0.91, 0.48, and 0.90, respectively, for factors 1 to 8 (>0.80 for all, except factor 7).

Regarding CFA for junior high school students, the trends for goodness-of-fit indices were similar to those for elementary school students (CFI = 0.98, TLI = 0.96, RMSEA = 0.05, and SRMR = 0.03). The correlation coefficients (Spearman's ρ) between the two items measuring each factor were 0.62, 0.52, 0.45, 0.37, 0.48, 0.57, 0.55, and 0.52, respectively, for factors 1 to 8. The correlation coefficients between the 34- and 16-item versions were $r = 0.93$, 0.90, 0.91, 0.86, 0.93, 0.91, 0.90, and 0.95. The results of CFA analysis for the 16-item version of the power to live questionnaire for elementary and junior high school students are shown in Supplementary Table 1.

Relationship between parental report and child report of the power to live questionnaire

The results of CFA for parental rating of the power to live questionnaire (Table 4) revealed that based on the 34-item version, the goodness-of-fit indices were CFI = 0.82, TLI = 0.80, RMSEA = 0.07, and SRMR = 0.08). For the 16-item version, acceptable levels of fitness of good indices were obtained (CFI = 0.94, TLI = 0.90, RMSEA = 0.06, and SRMR = 0.05). The correlation coefficients for parental and self-ratings of the corresponding factors were all small to moderately positive in the 34-item version ($r = 0.46$, 0.29, 0.47, 0.46, 0.39, 0.30, 0.20, and 0.26, respectively, for factors 1–8; all $p < 0.001$). The 16-item version also showed small to moderate positive correlations (factors 1–8; $r = 0.48$, 0.25, 0.40, 0.41, 0.41, 0.26, 0.18, and 0.16, respectively; all $p < 0.001$).

Homogeneity of power to live factor structure across schools

Multigroup CFA were conducted combining datasets from elementary school and junior high school students. The results are summarized in Table 6. The results regarding the goodness-of-fit indices and differences in chi square values between models indicate that the configural invariance model was supported for both the 34- and 16-item versions of the structure, suggesting that the factor loading for each power to live factor varied between elementary and junior high schools.

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To explore age and gender differences among power to live factors, we conducted multiple regression analyses, where each power to live factor was the objective variable and age, gender, and age-by-gender interaction terms were subjective variables (Supplementary Table 2). Gender was coded 0 for females and 1 for males. The results revealed a statistically significant positive effect of age on leadership, problem-solving, stubbornness, etiquette, emotional regulation, active wellbeing. For altruism, by contrast, the negative partial regression coefficient for gender was significant; however, the effects of age and age-by-gender interaction effects were not significant. None of the explanatory variables were significant for self-transcendence.

Relationship between awareness of disaster prevention and power to live in elementary school students

Because of the low reliability of each factor of the 16-item version of the power to live questionnaire, we only report the relationships between the 34-item version power to live factors and awareness of disaster prevention. Results for the 16-item version are shown in Supplementary Table 3. Table 2 shows the relationship between elementary school students' awareness of disaster prevention and each power to live factor. Significant positive correlations were found between Q1 and Q2 regarding self-evaluation of one's own or family members' ability to evacuate safely in the event of a disaster and altruism. In addition, we observed a significant negative correlation between Q3, which is regarding fear of disasters, and emotional regulation. Q5, which is on proactiveness, showed a positive relationship with etiquette and problem-solving. Q6 and Q7, which are related to communication with family members about disaster prevention, were positively correlated with self-transcendence. Q8 was positively correlated with etiquette. No significant correlation coefficients were found for leadership, stubbornness, and active well-being.

Discussions

In this study, we examined the validity of the factor structure and its reliability in elementary and junior high school students regarding the power to live in overcoming sustained challenges, such as natural disasters. In addition, the relationship between awareness of disaster prevention and power to live was explored with the intention of adapting the results to disaster prevention education. The results of CFA for the 34-item and 16-item versions of power to live questionnaires were acceptable for both elementary and junior high school students. In elementary school students, the results were confirmed by parental ratings. These results support the structural validity of the power to live in elementary and junior-high school

TABLE 6 Results of multigroup CFA for the power to live questionnaire.

Factor structure	Model	χ^2	df	$\Delta\chi^2$	df	*p*	CFI	TLI	AIC	BIC	RMSEA	RMSEA 90%CI	SRMR
34-item version	Configural invariance	2606.58	998				0.87	0.85	84769.24	85998.06	0.06	[0.06, 0.07]	0.07
	Weak invariance	2681.13	1024	74.54	26	<0.000	0.86	0.85	84791.78	85897.72	0.06	[0.06, 0.07]	0.07
	Strong invariance	3146.37	1050	465.25	26	<0.000	0.83	0.81	85205.03	86188.08	0.07	[0.07, 0.07]	0.08
16-item version	Configural invariance	275.43	152				0.97	0.96	40186.46	40904.85	0.04	[0.04,0.05]	0.03
	Weak invariance	289.66	160	14.23	8	0.08	0.97	0.96	40184.69	40865.27	0.04	[0.04, 0.05]	0.04
	Strong invariance	350.12	168	60.46	8	<0.000	0.96	0.94	40229.15	40871.92	0.05	[0.05,0.06]	0.04

AIC, Akaike information criterion; BIC, Bayesian information criterion; CI, confidence interval, CFA, confirmatory factor analysis, CFI, comparative fit index, RMSEA, root-mean-square error of approximation, SRMR: standardized root-mean-square residual; TLI, Tucker–Lewis index.

students. However, in terms of reliability, the results suggest that some factors are not stable, especially for elementary school students. Among junior high school students, many reliability coefficients increased, but stubbornness remained insufficiently reliable. Leadership, problem-solving, altruism, and emotional regulation are suggested to be relatively stable at the elementary school age. When these factors were examined in relation to disaster prevention awareness, correlations were found between these factors and items such as fear of disasters and preparedness in cooperation with family members. Based on these results, this study partially clarified the formation process of the power to live extracted from the survivors of the 2011 Great East Japan earthquake and tsunami. In addition, we were able to identify factors closely related to early disaster prevention awareness.

Factor structure and reliability of the power to live in elementary and junior high school students

As mentioned, the power to live in elementary and junior high school students was supported in terms of factorial validity; however, some factors were found to be unreliable. In the self-report, stubbornness was consistently unreliable regardless of school type or scale type (34-item or 16-item version). In elementary school students, the 34-item version was not sufficiently reliable for etiquette, self-transcendence, and active well-being. More factors were unstable in the 16-item version, but this is due in large part to the nature of Cronbach's alpha that the number of items is affected (25). The results from multigroup CFA, which suggested the configural invariance model, indicated that some power to live factors, such as stubbornness, etiquette, self-transcendence, and active wellbeing, vary across school types.

The following possibilities exist for the lack of stability in both elementary and junior high school students for stubbornness. First, their beliefs or desires, which are a core part of stubbornness, were in the process of formation. Stubbornness is the tendency to stick to one's beliefs and desires and is assumed to be related to persistence in difficult situations. Elementary and junior high school students may have been in the process of self-formation (26, 27), and thus, had lower reliability coefficients for stubbornness. Second, cognitive immaturity of students may be confounded by low alpha values. This reason might also be involved in problem-solving, which had marginal reliability in elementary school students.

Etiquette and active well-being had lower reliability among elementary school students and relatively higher reliability among junior high school students. These results may be related to differences in age and parental involvement between elementary and junior high school students (28, 29). Elementary school students need adult help to maintain their own health and learn etiquette. An increased risk of physical and mental health problems was reported in children required to care for themselves more from an early age (30). Conversely, learning customary manners and developing habits for one's well-being during elementary and junior high school years may underpin an aspect of the power to live.

In a study on self-transcendence in elementary school students, a lower reliability coefficient was reported than that in adults (31). In self-transcendence, which concerns the perception of the self in the world and society in terms of spiritual significance, a long process of experience-dependent development from early childhood is assumed (10, 32). Knowledge of social conventions and a certain degree of self-establishment are considered to be the primordial stages of self-transcendence (33). Moreover, it has been suggested that the changes of self-transcendence are complex even after adolescence (34). This may be a reason for the low reliability of self-transcendence in elementary school children.

Relationship between power to live and disaster prevention awareness in elementary school students

We explored how the power to live is related to the awareness of disaster prevention, which will be fostered through disaster prevention education, in elementary school students. We found a relationship between disaster awareness questions and the factors of the power to live questionnaire.

Regarding the fear of disasters, a reasonable correlation was found between lower fear of disaster (Q3) and higher score in emotional regulation. A positive correlation was found between self-assessment of ability to evacuate themselves (Q1) and their families (Q2) during a disaster and altruism. This result is consistent with studies that show that evacuation from disasters involves a variety of social support and that altruism is related to it (6, 35). Awareness of the possibility of disaster (Q5) was related to problem-solving, and etiquette. Learning about possible disasters in the community and how to protect oneself and preparing for disasters with family are the basics of disaster prevention (36). Our results suggested that several factors of power to live were related to awareness for disaster prevention efforts.

Finally, leadership showed a weak positive correlation with items such as awareness of one's own evacuation (Q1) and proactive attitude toward disaster prevention (Q5 and Q6), but it was not statistically significant, despite consistently adequate reliability in all CFA models. The relationship between leadership and resilience was identified as a characteristic that contributes to facilitating the resolution of long-term difficulties (37). Even elementary school students have been observed successfully leading groups (38, 39). Leadership was relatively

stable as a factor, but may have been less likely to be associated with awareness of disaster prevention in elementary school students who were influenced by family members or other adults in leadership roles (40).

Limitation

It is necessary to verify concurrent validity with other psychological scales and cross-validity in a different sample set. In particular, leadership should be validated in relation to indicators such as role in the class (e.g., whether the student is a member of the class council). In addition, the number of participants in this study, which examined the relationship between each power to live factor and awareness toward disaster prevention, was small. Further validation with a larger number of participants is needed.

For methodological reasons, we did not evaluate first- and second-grade elementary school students. Research on how the eight factors extracted from adult data are formed, including studies using different factor structures and methodologies, must clarify the formation process of the power to live. In relation to disaster education, it will be useful to examine the relationship between the power to live in disasters and the acquisition of knowledge through disaster education and compare scores before and after the implementation of disaster education.

In elementary school students, stubbornness, etiquette, self-transcendence, and active well-being were qualitatively different from those in adults and may have led to low reliability. Future studies must clarify the neurocognitive bases of factors that are formed empirically among power to live factors as well as the environmental factors involved in their formation. Studies are being conducted to examine the cognitive basis of self-transcendence (9, 10). By contrast, leadership, problem-solving, altruism, and emotional regulation were found to be reliable, even among elementary school students. Factors such as executive function (41, 42) and altruism (43), which are believed to be stable from relatively early developmental stages, may related to these factors.

Conclusion

We examined the psychological traits, termed power to live, that enabled survivors to overcome the challenges in the immediate aftermath of the 2011 Great East Japan earthquake and tsunami and rebuild their lives in elementary and junior high school students. The results of CFA and reliability coefficients indicated that leadership, problem-solving, altruism, and emotional regulation were stable and related to disaster awareness even in the middle and upper grades of elementary school. In junior high school students, all factors (excluding stubbornness), such as etiquette and active wellbeing, were stable. Factors related to cognitive skills, such as problem-solving and altruism, that facilitate building relationships with others, including adults, and emotional regulation, which helps tolerate disaster anxiety and fear, were consistent with factors identified in other studies on disaster prevention. Therefore, the power to live questionnaire has the potential to contribute to disaster education for children and foster resilience. Future research should focus on improving the power to live questionnaire to test the relationship between the questionnaire and disaster prevention education or actual behavior in emergency. In addition, as the subjects were exclusively Japanese, it is necessary to examine whether the structure of the power to live is replicated in other cultures in order to make this questionnaire a useful tool. It would be also useful to examine the aspects of each factor of the power to live that can be cultivated as well as educational programs for this purpose. These considerations could make this scale a useful tool in clarifying the neurocognitive basis and experiential factors involved in long-term resilience, such as disaster recovery.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of the International Research Institute of Disaster Science, Tohoku University, Japan. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

Conceptualization, methodology, writing, review, and editing: MS, TA, AH, AT-I, MY, RI, and YM. Formal analysis and writing original draft preparation: YM. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Negative interpretation of ambiguous bodily symptoms among illness-anxious individuals: Exploring the role of developmental and maintenance constructs

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Background: Cognitive factors play an essential role in the development and maintenance of anxiety problems. Among individuals with illness anxiety problems, their interpretation of bodily symptoms is a crucial factor in the determination of their ability to regulate their emotions. The catastrophic interpretation of ambiguous bodily symptoms and changes, known as interpretation bias, in line with the failure to reappraise the symptoms in safer ways, is supposed to increase the levels of anxiety in illness-anxious individuals.

Methods: This study aimed to address the statistical limitations of the direct (self-report) measure of interpretation bias, using an indirect (online interpretation bias task) measure for assessing biased interpretations of bodily symptoms. In addition, we examined the contribution of self-report anxiety sensitivity (AS), intolerance of uncertainty (IU), interpretation bias, and reappraisal to illness anxiety problems in a subclinical population and compared it with controls with low levels of illness anxiety.

Findings: Illness-anxious individuals made more negative interpretations of ambiguous, potentially health-threatening information. They used less reappraisal to regulate their emotion. Among the measures, the physical subscale of AS and the reaction time to the safe resolution of ambiguous information were the best factors that could contribute to the differentiation between the illness-anxious individuals and non-anxious individuals.

Conclusion: Our findings provided further support for the biased processing of information related to physical symptoms among individuals with illness anxiety. AS-physical and safe resolutions for ambiguous situations could differentiate the illness-anxious and the control groups better than other

factors. These findings suggest that a change of interpretation of ambiguous bodily symptoms among individuals suffering from chronic conditions can be a possible intervention to target anxiety and improve patients' lives.

KEYWORDS

illness anxiety, interpretation bias, reappraisal, intolerance of uncertainty, anxiety sensitivity, bodily symptoms, COVID-19

Introduction

Illness anxiety disorder, formerly known as hypochondria, is characterized as dysfunctional worry about serious illnesses (1). In addition, illness anxiety can be experienced as a symptom in people suffering from other disorders, such as GAD, specific phobia, and OCD (2, 3). The experience of illness anxiety has increased since the emergence of the COVID-19 (SARS-CoV-2) pandemic in December 2019, as it has caused notable physical and psychological distress as well as high mortality and morbidity rates (4). Studies showed that during the pandemic, people had concerns about COVID-19 and a considerable portion of them reported that their level of anxiety and psychological stress increased during the pandemic (5). Anxiety and fear of COVID-19 were also reported to worsen preexisting mental health problems and lead to post-traumatic stress disorder (PTSD) and even suicidal thoughts and attempts (6–8).

Some studies propose a developmental perspective to explain susceptibility or resilience to mental problems (9). Furthermore, studies suggest that long-term exposure to stress can result in changes in physiological functioning, which can lead to long-lasting effects and the development of long-term consequences (10, 11). According to the cognitive behavioral approach to illness anxiety (12), the core feature of illness anxiety is the catastrophic interpretation of ambiguous bodily symptoms and changes, known as interpretation bias. Biased interpretations may increase hypervigilance of the internal sensations (i.e., body sensations) (13–15). These perceived sensations, in turn, can be interpreted as signs of a serious disease and consequently increase the primary dysfunctional catastrophic interpretations (12, 16). These catastrophic interpretations, then, might be maintained as individuals may make less effortful reappraisal strategies to replace these negative interpretations with safer ones. Thus, they might experience more dysfunctional anxiety in response to the maintained negative interpretations. Reappraisal is one of the emotion regulation strategies that refer to altering the meaning of a stimulus or a situation to reduce negative emotions (17, 18). A negative relationship between reappraisal strategy and interpretation bias for health-threatening information has been established by several studies (19–21). Therefore, the biased interpretation of health-related information and deficit in further reappraisal regulatory strategy might be two maintaining factors contributing to the maintenance of illness anxiety disorder.

Anxiety sensitivity (AS) and intolerance of uncertainty (IU) are suggested as two psychological constructs that may make people vulnerable to illness anxiety disorder and the experience of interpretation bias when facing physical sensations. AS is defined as the experience of fear or worry over the symptoms that are associated with anxiety (22). Sensitivity to arousal-related sensations makes individuals misinterpret harmless bodily sensations and symptoms of a medical problem, which may lead to illness anxiety (23). The experienced anxiety, in turn, might increase the severity of perceived anxiety-related symptoms convincing the individual that a health problem exists. The somatosensory amplification model of hypochondriasis supports the role of AS in illness anxiety, stating that people with illness anxiety are more sensitive to normal sensations and interpret them as signs of a serious disease (24).

A low threshold for tolerating the unknown nature and consequences of bodily signs may contribute to IU. People with IU believe that uncertainty and ambiguity are negative and attempt to put an end to this ambiguity by considering the most catastrophic consequences (25). As such, individuals with illness anxiety may consider ambiguous bodily sensations as indicators of a serious medical disease since they are less tolerant of ambiguity (23).

Despite the growing body of evidence about the relationship between catastrophic interpretations and negative emotions such as anxiety, few studies have compared the relationship between anxiety and interpretation bias among people with and without illness anxiety symptoms. Such a comparison can highlight the role of negative interpretation bias in illness anxiety. In addition, the studies about illness anxiety and catastrophic interpretations mostly relied on direct self-report measures of interpretation bias. These measurement methods are reported to be subject to respondent bias (13). Therefore, indirect measures would be more appropriate for assessing these biased interpretations.

It is important to consider that illness anxiety is a common disorder, with estimates ranging up to 13% in the general adult population (26). Furthermore, the emergence of new

diseases (for example, COVID-19 and monkeypox) in recent years and their uncertain health outcomes have triggered higher levels of illness anxiety. With regard to the prevalence of illness anxiety and the importance of comprehending the cognitive factors that are involved in its development and maintenance, the current study was designed to examine the role of cognitive factors in the development and maintenance of illness anxiety by comparing individuals with and without illness anxiety symptoms. Unlike previous studies, we aimed to measure interpretation bias for ambiguous bodily symptoms using an indirect online interpretation bias task (27). We believe that the application of this novel method would assist us in understanding the role of biased interpretations in differences among people with and without illness anxiety symptoms. We hypothesized that individuals with illness anxiety symptoms show more catastrophic interpretations of ambiguous health-related situations. We also investigated the levels of reappraisal, AS, and IU in individuals with illness anxiety symptoms and compared them with those without these symptoms. We hypothesized that the illness-anxious participants would report higher levels of AS, IU, and interpretation bias but less reappraisal in comparison to the individuals without illness anxiety symptoms. More importantly, we aimed to examine which factor among interpretation bias, appraisal, AS, and IU had the most power in differentiating the illness-anxious group from the control group.

Method

Participants

A power analysis, based on previously published and unpublished pilot studies, investigated the interpretation bias among individuals with high and low levels of illness anxiety (28) and suggested 29 participants in each group to explore the between-subject differences. Participants were 60 students of Shahid Beheshti University [two groups: illness-anxious and control (30 in each)]. First, the participants for the illness-anxious group were recruited *via* ads in public places of the university that called for individuals with illness anxiety symptoms specified in the ad. A semi-structured interview was used to confirm the presence of illness anxiety symptoms. Then, the matched participants for the control group were recruited using an announcement inviting individuals without illness anxiety symptoms.

Illness-anxious group

The illness-anxious sample included 30 (15 female) students of Shahid Beheshti University selected through an announcement calling for individuals with illness anxiety symptoms. In this announcement, illness anxiety symptoms, including experiencing worries about health, checking body status, avoidance of health-related information or searching for health-related information, and being sensitive to bodily changes, were listed. Volunteer students were supposed to inform the experimenter using email or SMS. To clarify the presence of illness anxiety symptoms, a semi-structured interview assessing illness anxiety symptoms was conducted by one of the authors (M.E.) who holds a master's degree in clinical psychology. Participants who are suffering from a serious medical condition, are under medical or psychiatric medication, have a history of surgery in the last 12 months, have a strong belief in already suffering from a disease that cannot be diagnosed by physicians, and suffering from psychotic disorders were excluded. Regarding the illness anxiety symptoms as well as exclusion criteria, 30 students (15 female) were selected among 47 volunteer students. Other 17 participants were excluded due to not meeting the criteria for illness anxiety symptoms (6), suffering from a medical disease (3), having a history or suffering from another psychiatric disorder (4), using psychiatric medications (2), and being under psychotherapy (2).

Control group

The control group consisted of 30 students at Shahid Beheshti University selected through an announcement requesting individuals without illness anxiety symptoms. Volunteer students were supposed to inform the experimenter using email or SMS. Volunteers whose gender and age range matched the illness-anxious individuals were invited to the interview session. To clarify the absence of illness anxiety symptoms, a semi-structured interview assessing illness anxiety symptoms was conducted. Suffering from a serious medical condition, being under medical or psychiatric medication, having a history of surgery during recent 12 months, and suffering from psychotic disorders were the exclusion criteria. A total of 30 students (15 female) among 38 volunteers were determined as eligible to be studied as the control group. Notably, eight volunteers were excluded due to suffering from a medical disease (2), a history of suffering from another psychiatric disorder (3), using psychiatric medications (2), and a recent history of surgery (1). However, one of the volunteers could not attend the measurement session due to an unexpected medical problem, and the sample size was reduced to 29 participants.

Measures

The structured clinical interview for DSM-5, clinician version (SCID-5-CV)

The SCID-5-CV (29) is a semi-structured interview guide to make the DSM-5 diagnoses. In this study, however, it was used to check illness anxiety symptoms, including (1) preoccupation with illness in the absence of somatic symptoms,

(2) experiencing anxiety regarding illness-related issues, and (3) avoidance or safety behaviors. The experience of all these three symptoms during the last 6 months was our criteria for inclusion in the illness-anxious group. It was administered by the author (M.E.) who holds a certified degree in clinical psychology. The purpose of using this tool was not to diagnose participants with IAD or determine the severity but to check the existence and absence of the aforementioned symptoms, respectively, in the illness-anxious and control groups.

Interpretation task

The interpretation task was specifically designed for the study and was modeled after the online interpretation paradigm as described by Vancleef et al. (27). The task assesses interpretation bias for ambiguous health-related information. It consisted of 32 scenarios with a length of four lines, of which the final sentence of each description is incomplete and lacks a word. The task incorporates 16 ambiguous (AMB) scenarios that can have both an unsafe (health-threatening) or a safe resolution. Furthermore, it includes 16 forced inference scenarios, of which 8 are health-threatening (HR) such that only the unsafe resolution makes sense for that scenario (endorsing safe resolutions are considered as errors) while the other 8 are non-health-related (NHR) such that only the safe resolutions make sense (endorsing unsafe resolutions are considered as errors). A total of eight ambiguous scenarios are matched to eight health-related scenarios (the HR resolution of the ambiguous is the same as the correct resolution of the forced), while eight ambiguous scenarios are matched to eight non-health-related scenarios (the NHR resolution of the ambiguous is the same as the correct resolution of the forced). The forced inference scenarios are used as control scenarios. Each task trial started with a fixation point presented on the screen for 500 ms. Then, the first line of a scenario was shown on the screen for 2,000 ms, and after that, the second to the fourth lines (each for 1,500 ms) were consecutively added. The fourth line contained a missing word. In the ambiguous descriptions, the missing word maintained the ambiguity of the scenario. Next, at 7,000 ms, one unsafe and one safe word were simultaneously presented on screen for a total of 3,000 ms while the scenarios were still on the screen. The participant was instructed to start reading the scenario line by line as soon as it appeared on the screen. When the two words were presented, the participant's task was to choose the word that completed the story in the way they thought. They were instructed to make this choice as soon as possible. As soon as the subject pressed the key, the next trial started with the presentation of a fixation point. Although we had a control group to control any confounding variables, such as the speed of reading the scenarios and resolutions, the readability of both resolutions, that is, their length, was similar.

Interpretation bias was indexed by valence and reaction time scores. A negative interpretation bias-valence refers to the smaller number of safe resolutions and the greater number of unsafe resolutions for ambiguous scenarios. A negative interpretation is also expected to result in faster reaction times when the subject has chosen the unsafe resolutions of ambiguous scenarios than the safe ones.

The current task was the modified and summarized version of the original Dutch version of the online interpretation task developed by Vancleef et al. (27). The mean of latency for safe resolutions (ambiguous safe and forced safe conditions) was less than the latency for health-threatening resolutions (ambiguous health-threatening and forced health-threatening conditions) (27). Lower levels of latency (i.e., faster reaction time) can reflect that the scenarios can validly differentiate health-threatening interpretations from safe ones. The scenarios were translated into Farsi and adapted based on the cultural context. The accuracy of the translation was assessed by a person holding a degree in Farsi literature as well as two clinical psychologists holding a PhD degree in clinical psychology. Then, 10 students from other majors than psychology read and informed us if the scenarios were understandable. They also evaluated if sentences were correctly categorized in each of the AMB, HR, and NHR trials. In addition, these students were asked to perform the computerized task to see if reading and comprehension of the scenarios are possible in different periods (5,000, 6,500, and 8,000 ms). A total presentation time of 6,500 ms was selected as appropriate, providing enough time to read the scenarios fully while not allowing additional time to (re)think about them. The task was developed using the Affect 4.0 program (30). The task also had a training phase consisting of 10 non-health-related scenarios that were different from the main scenarios. The training phase was performed to get participants acquainted with the response procedure. Refer to Appendix A for some examples of the scenarios translated into English.

Anxiety sensitivity index (ASI)

The Anxiety Sensitivity Index (31) is a 16-item questionnaire that assesses the fear of somatic and cognitive symptoms of anxiety. ASI has three subscales, including physical concerns, mental incapacitation concerns, and social concerns (32). Each item is rated on a five-point Likert scale (0 = very little; 4 = very much). The psychometric properties and predictive validity have been well-approved (32). The internal consistency of the Farsi version of this questionnaire, calculated by Cronbach's alpha, was 0.90 in the current study.

Intolerance of uncertainty scale (IUS)

The Intolerance of Uncertainty Scale (33) is a 27-item questionnaire that measures the inability to tolerate uncertain situations. Participants are asked to rate items on

a five-point Likert scale (1 = "not at all characteristic of me" to 5 = "entirely characteristic of me"). It has two sub-factors, including uncertainty having negative behavioral and self-referent implications (factor 1; 15 items) and uncertainty being unfair and spoiling everything (factor 2; 12 items). The total scale has excellent internal consistency and good test–retest reliability (34). The internal consistency of the Farsi version of this questionnaire, calculated by Cronbach's alpha, was 0.96 in the current study.

Emotion regulation questionnaire (ERQ)

The Emotion Regulation Questionnaire (35) is a 10-item scale designed to measure cognitive reappraisal and expressive suppression. Participants rate their answers on a seven-point Likert Scale (1 = strongly disagree, 4 = neutral, and 7 = strongly agree). The original internal consistency of the questionnaire was reported as appropriate (35). We used the reappraisal subscale in the current study. The internal consistency of the Farsi version of the reappraisal subscale of this questionnaire, calculated by Cronbach's alpha, was 0.84 in the current study.

Cognitions about body and health questionnaire (CABAH)

The Cognitions about Body and Health Questionnaire (36) is a 31-item questionnaire assessing five subscales of catastrophizing interpretation of bodily complaints, autonomic sensations, bodily weakness, intolerance of bodily complaints, and health habits. Items are rated on a four-point Likert Scale (0 = completely wrong, 3 = completely right). The internal consistencies of this questionnaire in the clinical and normal samples were reported as 0.90 and 0.80, respectively (36). The internal consistency of the Farsi version of this questionnaire, calculated by Cronbach's alpha, was 0.93 in the current study. In the current study, we only used the catastrophizing interpretation of the bodily complaints subscale (CABAH-Cat) as the index of self-report (and direct measure of) interpretation bias toward health-related information.

Procedure

The study was approved by the Ethical Committee of the Department of Psychology at Shahid Beheshti University (Ref Number: 30514). The ads for recruiting the illness-anxious participants were put in public places in the university. Upon the expression of interest and our favored gender ratio (15 female and 15 male), volunteers were individually invited to an interview session held at the laboratory in the Department of Psychology. Participants who met inclusion criteria but not exclusion criteria were informed by the interviewer (M.E.) that they were selected for further examinations. The interviewer also informed the participants briefly that the current study consisted of completing questionnaires and one computerized task. Then, participants were asked to read the consent form describing research aims and procedures, as well as possible advantages and risks of the study, and sign it in case they agreed with the provided information. After obtaining informed consent, the participant and experimenter (M.E.) scheduled a date for the test appointment.

The test appointment session started in the psychology laboratory where participants completed the questionnaires. After completing the questionnaire battery, participants were taken to the test laboratory equipped with desktop computers (19 inches, Core i5, RAM: 4GB, CPU: 3.20 GHS) to perform the computerized online interpretation task. After reading the task instructions, participants performed the training phase of the interpretation task to make sure that participants learned how to respond. The results of the training phase were not included in the analysis. Next, participants completed the main phase of the interpretation task. Upon completion of the task, participants were debriefed, and the session was terminated. After testing all subjects in the illness-anxious group, recruitment of the control group was started. The procedures for selecting participants without illness-anxiety symptoms and collecting data were the same as the procedures for the illness-anxious group.

Results

Data preparation for the online interpretation task

The frequency of chosen safe and unsafe word resolutions for ambiguous, health-related, and non-health-related scenarios, as well as the mean reaction time to each scenario type, was extracted using MATLAB R2017a. The frequencies of correct and incorrect (error) answers for forced health-related and non-health-related trials were calculated as well. For the calculation of RTs in the forced scenarios, trials with incorrect responses were excluded.

Data analysis

Before the main statistical analysis, the data from one participant (in the health-anxious group) were removed due to a high number of missing data. The two groups were age-matched (the health-anxious group: M = 23.20 y.o., SD = ±2.35; and the control group: M = 23.86 y.o., SD = ± 2.57).

We first aimed to evaluate the between-group differences in self-reported measures. Therefore, we used multivariate analysis of variance (MANOVA), while AS subscales (physical, mental, and social), IU subscales (Factor 1 and Factor 2), CABAH-Cat, and reappraisal were considered as the dependent variables, the group (illness-anxious vs. control group) was considered as

TABLE 1 Results of descriptive statistics and MANOVA for between-group differences in self-report variables: AS-physical, AS-mental, AS-social, IU-Factor 1, IU-Factor 2, reappraisal, and CABAH-Cat.

	Group						
	Illness-anxious ($n = 29$)		Control ($n = 29$)				
	M	SD	M	SD	SS	MS	F
AS-Physical	16.44	5.71	6.68	4.45	1,380.84	1,380.84	52.55***
AS-Mental	7.24	30.80	2.58	2.14	314.22	314.22	32.93***
AS-Social	9.20	2.92	7.62	2.70	36.48	36.48	4.60*
IU-Factor 1	48.20	12.81	36.31	8.00	2,052.15	2,052.15	17.99***
IU-Factor 2	40.10	9.81	30.65	6.06	1,294.41	1,294.41	19.45***
Reappraisal	23.51	5.01	27.55	5.11	236.01	236.01	9.20**
CABAH-Cat	22.68	6.66	12.75	4.53	1,430.06	14,30.06	44.01***

***$p < 0.001$, **$p < 0.01$, **$p < 0.05$; SS, Sum of Squares; MS, Mean of Squares.
AS, Anxiety Sensitivity; IU, Intolerance of Uncertainty; CABAH-Cat, Catastrophic cognition subscale of Cognitions about body and health questionnaire.

TABLE 2 Results of descriptive statistics and MANOVA for between-group differences in task-related variables: AMB-Safe, AMB-Unsafe, HR-Unsafe, and NHR-Safe.

	Group						
	Illness-anxious ($n = 29$)		Control ($n = 29$)				
	M	SD	M	SD	SS	MS	F
AMB-Safe	4.51	2.38	7.37	2.94	118.77	118.77	16.54***
AMB-Unsafe	10.37	2.55	8	3.02	82.08	82.08	10.47**
HR- Unsafe	7.58	0.73	7.51	0.68	0.06	0.06	0.137
NHR-Safe	7.48	0.78	7.68	0.6	0.62	0.62	1.266

***$p < 0.001$, **$p < 0.01$, **$p < 0.05$; SS, Sum of Squares; MS, Mean of Squares.
AMB, ambiguous; HR, health-related; NHR, non-health-related.

the fixed factor. The result of Box's M-test was not significant ($p = 0.86$), and the MANOVA assumption of homogeneity of covariance was approved. The Pillai's trace test was significant [V = 0.57, F (7, 37) = 9.59, $p = 0.001$, $\eta_p^2 = 0.57$], revealing that the between-group difference was meaningful at least in one variable. According to the MANOVA results, the illness-anxious group, in comparison to the control group, significantly reported higher levels of AS-physical [F (1, 56) = 52.55, $p = 0.001$, η_p^2 =0.48], AS-mental [F (1, 56) = 32.93, $p = 0.001$, $\eta_p^2 = 0.37$], AS-social [F (1, 56) = 4.60, $p = 0.03$, $\eta_p^2 = 0.07$], IU-factor 1 [F (1, 56) = 17.99, $p = 0.001$, $\eta_p^2 = 0.24$], IU-Factor 2 [F (1, 56) = 19.45, $p = 0.001$, $\eta_p^2 = 0.25$], and CABAH-Cat [F (1, 56) = 44.01, $p = 0.001$, $\eta_p^2 = 0.44$], as well as lower levels of reappraisal [F (1, 56) = 9.20, $p = 0.004$, $\eta_p^2 = 0.14$]. The results are presented in Table 1.

Then, we used MANOVA to test our second hypothesis on the between-group differences in the valence of resolutions in the online interpretation task, including safe resolution for ambiguous scenarios (AMB-safe), unsafe resolution for ambiguous scenarios (AMB-unsafe), threatening resolution for health-related scenarios (Forced: HR-unsafe), and safe resolution for non-health-related scenarios (forced: NHR-safe). The valences were the dependent variables, while the group was the fixed factor. MANOVA assumption of homogeneity of covariance was approved ($p = 0.18$). The Pillai's trace test was significant [V = 0.26, F (4, 53) = 4.75, $p = 0.002$, $\eta_p^2 = 0.26$], revealing that the between-group difference was meaningful at least in one variable. MANOVA results are reported in Table 2. Results demonstrated that individuals with illness anxiety significantly selected less safe [F (1, 56) = 16.54, $p = 0.001$, $\eta_p^2 = 0.22$] and more unsafe, that is, health-threatening [F (1, 56) = 10.47, $p = 0.002$, $\eta_p^2 = 0.15$] resolutions for ambiguous scenarios in comparison to the control individuals. There was no significant between-group difference in the valence of resolution of forced health-related and non-health-related scenarios. Between-group differences on the error variables in the forced inference descriptions were not significant for either the safe resolution for the health-related scenario [F (1, 56) = 0.95, $p = 0.33$, $\eta_p^2 = 0.01$] or the unsafe resolution for the non-health-related scenario [F (1, 56) = 1.23, $p = 0.27$, $\eta_p^2 = 0.2$].

TABLE 3 Results of pairwise comparisons for reaction time to interpretation bias task trials for all participants ($n = 58$).

(I) Trial	(J) Trial	Mean Difference (I-J)	Std. Error	Sig.
AMB	HR	253.09	34.06	0.001
	NHR	284.46	25.74	0.001
HR	AMB	−253.09	34.06	0.001
	NHR	31.36	32.25	0.33
NHR	AMB	−284.46	25.74	0.001
	HR	−31.36	32.25	0.33

AMB, ambiguous; HR, health-related; NHR, non-health-related.

To test the between-group differences in the reaction time (RT) to each scenario type, a 2 (Group) × 3 (Scenario-types-RT) MANOVA was applied while the group was specified as the between-subject factor and mean reaction times to scenario types (AMB, HR, and NHR) as the within-subject variables. Box's M ($p = 0.98$) and Mauchly's test of sphericity ($p = 0.58$) were both nonsignificant, approving the homogeneity of covariance and within-subject covariance equality, respectively. Results revealed that there was a significant effect of scenario-type-RT [F (2, 112) = 50.96, $p = 0.001$, $\eta_p^2 = 0.47$] and its interaction with the group [F (2, 112) = 3.61, $p = 0.03$, $\eta_p^2 = 0.06$]. *Post-hoc* tests demonstrated that all participants significantly reacted slower to ambiguous scenarios compared with HR and NHR scenarios (Table 3).

To identify the scenario types that the groups reacted to with different speeds, we used MANOVA after analyzing the homogeneity of covariance ($p = 0.98$) and the Pillai's trace [V = 0.13, F (3, 37) = 2.67, $p = 0.057$, $\eta_p^2 = 0.13$]. Scenario-types-RT was the dependent variable while the group was the fixed factor. Results showed that the illness-anxious individuals significantly had a higher reaction time (slower) to non-health-related (NHR) scenarios compared with the control participants. The two groups' reaction times to ambiguous and health-related scenarios were not significantly different. A summary of these findings is presented in Table 4.

In the next step, we evaluated if the illness-anxious and the control group had different reaction times when they selected resolutions with safe and unsafe valences for ambiguous scenarios. One of the individuals in the illness-anxious group had no safe resolution and one of the participants in the control group had no unsafe resolution for ambiguous scenarios. Therefore, these two reaction times were considered missing data before the analysis. We did a 2 (Group) × 2 (Ambiguous-resolution-RT) MANOVA while the group was specified as the between-subject factor and reaction time to safe and unsafe resolutions of ambiguous scenarios as the within-subject variables. Box's M ($p = 0.70$) was non-significant approving homogeneity of covariance. Results demonstrated that there was a significant effect of ambiguous-resolution-RT [F (1, 54) = 9.22, $p = 0.004$, $\eta_p^2 = 0.14$] but not its interaction with the group [F (1, 54) = 0.49, $p = 0.48$, $\eta_p^2 = 0.009$]. Participants in both groups significantly reacted faster to unsafe resolutions [M = 1,559.55, SD = ± 351.33] than safe resolutions [M = 1,672.45, SD = ± 379.20]. The mean reaction time for the illness-anxious group was [Unsafe: M = 1,613.30, SD = ± 367.93; Safe: M = 1,752.32, SD = ± 407.44] and for the control group was [Unsafe: M = 1,505.80, SD = ± 331.78; Safe: M = 1,592.59, SD = ±337.16].

After revealing the between-group differences in the developmental and maintenance factors, we aimed to explore our research question about the identification of the variables that could appropriately discriminate between individuals in the illness-anxious and control groups. Therefore, a discriminant analysis was performed on self-report and IB task-related variables separately.

The discriminant analysis was first performed on the self-report variables of AS-physical, AS-mental, AS-social, IU-factor1, IU-factor2, CABAH-Cat, and reappraisal. The results of the equality of group means, assessed by the MANOVA option of discriminant analysis, were the same as in Table 1. Wilks' Lambda (0.42) was significant ($p = 0.001$), showing that the groups were different according to their means in the mentioned questionnaires. The canonical correlation (0.75) revealed that the correlation between the discriminant scores and the dependent variable was high. The Chi-square and Eigenvalues were 44.70 and 1.34, respectively, for this canonical correlation. The absolute size correlation for each variable has been presented in Table 5. These discriminant variables could correctly classify 89.7% of the subjects ($n = 29$) in the illness-anxious group and 89.7% of the subjects ($n = 29$) in the control group.

Then, we performed the discriminant analysis for two IB task-related variables that were found to differ significantly between the two groups, that is, the numbers of safe and unsafe resolutions (valence) for ambiguous scenarios (AMB-safe and AMB-unsafe). The results of the equality of group means, assessed by the MANOVA option of discriminant analysis, were the same as in Table 2. Wilks' Lambda (0.74) was significant ($p = 0.001$), showing that the groups were different according to their means in these task-related indices. The canonical correlation (0.50) revealed that the correlation between the discriminant scores and the dependent variable was moderate. The Chi-square and Eigenvalues were 16.26 and 0.34, respectively, for this canonical correlation. The absolute size of the correlation for each variable is presented in Table 6. These discriminant variables could correctly classify 72.4% of the subjects ($n = 29$) in the illness-anxious group and 69% of the subjects ($n = 29$) in the control group.

TABLE 4 Results of descriptive statistics and MANOVA for between-group differences in Reaction Time to AMB, HR, and NHR scenarios.

	Group						
	Illness-anxious ($n = 29$)		Control ($n = 29$)				
	M	SD	M	SD	SS	MS	F
AMB-RT	1,650.93	356.93	1,541.69	299.28	173,015.67	173,015.67	1.59
HR-RT	1,349.22	337.24	1,337.20	324.09	2,097.86	2,097.86	0.01
NHR-RT	1,400.56	373.37	1,223.13	247.18	456,466.68	456,466.68	4.55*

*$p < 0.05$.
AMB, ambiguous; HR, health-related; NHR, non-health-related.

TABLE 5 Within-groups correlations between self-report discriminating variables and standardized canonical discriminant functions.

	Function 1
AS-Physical	0.83
CABAH-ICat	0.76
AS-Mental	0.66
IU-Factor 2	0.50
IU-Factor 1	0.48
Reappraisal	−0.35
AS-Social	0.24

AS, Anxiety Sensitivity; IU, Intolerance of Uncertainty; CABAH-INT cat, Catastrophic Cognition subscale of Cognitions about body and health questionnaire.

TABLE 6 Within-groups correlations between discriminating variables and standardized canonical discriminant functions.

	Function 1
AMB-Safe	0.92
AMB-Unsafe	−0.73
AMB: Ambiguous	

Discussion

The current study aimed to study the role of cognitive factors in the development and maintenance of illness anxiety symptoms by going beyond mono-method assessment and using indirect measures of interpretation bias to bodily symptoms. We evaluated the contribution of developmental factors (AS and IU) and maintaining factors (interpretation bias and reappraisal) to illness anxiety disorder. The illness-anxious group reported higher levels of AS and IU and interpreted ambiguous health-related situations more catastrophically compared with the control group. Both self-report catastrophic interpretation and the online interpretation task, which is an indirect measure of biased interpretation, supported this finding. Illness-anxious participants used less reappraisal to regulate their emotions than participants in the control group. Interestingly, the illness-anxious individuals processed non-health-related situations longer than the control group, reflected in their higher reaction time to these scenarios. We also aimed to go beyond evaluating the relationship between illness and cognitive factors by assessing which factors might contribute more to the difference between people with and without illness anxiety symptoms. The results indicated that the physical subscale of AS and individuals' reaction to the safe resolution of the ambiguous scenario were among the best factors that could differentiate individuals with illness anxiety from others.

Our findings are in line with the findings and suggestions of several previous studies. Fergus and Bardeen (38) studied the incremental specificity of AS and IU with health anxiety using a large sample of adults and endorsed that both AS and IU incrementally contribute to the prediction of health anxiety. However, they demonstrated that only physical AS and inhibitory IU (corresponding to factor 1 in IUS-27) had a unique relation with health anxiety. The unique relationship between illness anxiety and AS-physical has been supported in different studies, suggesting that the role of the physical domain of AS might be more prominent in illness anxiety than the other domains (38–42). Although in our research, AS-physical had a higher correlation with discriminant function (group), all other sub-factors of AS and two factors of IU were significantly different between the illness-anxious and control groups. Our results supported the idea that AS is a fundamental fear and people with different emotional problems can experience AS as a whole construct regardless of its domains (31, 43, 44). Our results about the significant contribution of AS and IU to illness anxiety also questioned the claim raised by Fergus and Bardeen (38) that the importance of AS and IU in illness anxiety might have been overestimated.

Sensitivity to uncertain bodily sensations might be related to the vulnerability to biased processing of health-related information and an increment of anxiety over somatic sensations (45). Supporting the presence of interpretation bias in the illness-anxious individuals, our results indicated

that participants with illness anxiety interpreted ambiguous health-related information as more threatening than individuals without illness anxiety. These results were observed both in the self-report and the task-related indices of interpretation bias. Although our study did not aim to study reflective and automatic processes, self-report and task-related misinterpretation in illness anxiety might support the idea that individuals with illness anxiety show reflective and automatic interpretation biases for health-related information. It is believed that the amount of effort that someone allocates to information processing distinguishes the processes of interpretation at automatic and reflective levels (46). Self-report measurements assess explicit/reflective processes, while fast-paced tasks evaluate more spontaneous and automatic interpretative processing (47). In our study, we used both a self-report questionnaire and a fast-paced online task to measure interpretation bias. As mentioned earlier, our research was not designed to evaluate reflective vs. automatic processes, and further studies are required to investigate this topic appropriately designed for.

In the online interpretation bias task, the illness-anxious individuals showed higher unsafe and lower safe interpretations of ambiguous health-related information than the control individuals. Consistent with our findings, a positive correlation between health-threatening resolution of the online ambiguous health-related information and fear of pain was reported (27). Furthermore, a systematic review by Leonidou and Panayiotou (48) supported the association between interpretation bias for health-threatening information and illness anxiety. Miles et al. (49) reported that individuals with high fear of cancer considered more negative interpretations of ambiguous cancer-related scenarios in comparison with those having lower levels of fear of cancer. However, between-group differences in Miles et al.'s study (49) were not significant for positive interpretations. The between-group difference, however, was not significant regarding the other indices of interpretation bias (i.e., faster reaction time in choosing the unsafe resolution of ambiguous scenarios than safe resolutions). Both groups reacted slower to the ambiguous scenarios when compared with the forced scenarios, while there were no between-group differences in reaction time to ambiguous scenarios. However, the study showed that the illness-anxious individuals processed NHR-forced scenarios significantly slower than the control group. It might be speculated that people with illness anxiety are inclined to look for health-related resolutions even in evident non-health-related situations and take more processing time to make sure that no threatening interpretation is possible. This finding has not been reported previously and the present results on within-subject differences provide relative support for the aforementioned explanation. Consistent with Vancleef et al.'s (27) study, our results demonstrated that both the illness-anxious and control groups reacted slower to ambiguous scenarios in comparison with HR and NHR ones.

Our results demonstrated that both groups selected unsafe resolutions faster than safe resolutions for ambiguity. Consistent with this finding, Vancleef et al. (27) reported that all participants reacted faster to the threatening resolutions of ambiguous health-related situations than the safe resolutions. An automatic threat evaluation system (TES) makes people vigilant to potentially threatening information (50). Even though our task encompassed control over non-health-related scenarios, the ambiguous and forced health-related scenarios might have acted as unintentional primes for the activation of these mechanisms and resulted in faster responses to unsafe resolutions in all participants, irrespective of the level of illness anxiety (27).

Our findings also suggest that illness-anxious individuals may have problems with reappraisal strategies to replace unsafe interpretations with safer ones. These findings are also congruent with the theories that argue the negative interpretation of health-related information is associated with reappraisal abilities (19, 20). Bardeen and Fergus (51) demonstrated that less application of reappraisal strategy was associated with higher levels of concerns about health and preoccupation with bodily sensations. Therefore, individuals with illness anxiety not only experience misinterpretation of health-related information but also lack functional reappraisal to lessen the negative emotional consequences of such misinterpretations.

Discriminant analyses showed that all the aforementioned variables could discriminate illness-anxious individuals from non-anxious individuals. AS-physical and safe resolutions for ambiguous scenarios were the best self-report and task-related discriminators, respectively, among other measures. The discriminative ability of self-report questionnaires was higher than that of task-related indices. This difference might be due to the overlap between illness anxiety symptoms and the items of the questionnaires used for the assessment of AS, IU, and self-report interpretation bias. For example, Taylor (37) argued that ASI assesses the same construct that health anxiety targets. Furthermore, the difference between self-report and task-related indices in distinguishing the individuals might be considered as the different roles of systematic and automatic cognitive processes, respectively, in illness anxiety. In other words, it might be hypothesized that individuals might attribute negative interpretations to ambiguous situations automatically regardless of their illness anxiety level. However, it seems that their levels of AS, IU, and regulatory strategies might be involved in the development of illness anxiety. This assumption is speculative and needs further investigation. Moreover, when we entered the scores of the health anxiety inventory into the analysis, the correctness of group allocation increased from 89 to 96%. It indicates that there might be other factors contributing to illness anxiety rather than AS, IU, reappraisal, and interpretation bias.

The findings of the present study should be interpreted in light of the following limitations. Participants' personal

experiences of health-related issues were not controlled for. Therefore, it is not clear if their resolutions for a situation are an interpretation bias or an association of their personal experiences. Both illness-anxious and control groups were university students and caution is warranted in generalizing the findings to the clinical and general population. Furthermore, the sample was recruited through a volunteer catchment at the university rather than selecting more diverse clients who are seeking help in clinics. Therefore, the level of dysfunctionality reported by our sample might be less than the clinical population. This may increase the chance of type-II error in our analyses, which has to be considered when we interpret the results. The other limitation of the current study was the small sample size. Regarding the number of statistical comparisons, having a bigger sample size would reduce the chance of type-II error. Item overlap across some of our measures, such as ASI and CABAH, might be another statistical issue. However, CABAH items mostly measure "beliefs" about somatic sensations and health while ASI evaluates the "fear" of these sensations. In addition, regarding the number of comparisons we included in our study, having a larger sample size would be more beneficial in estimating more precise effect sizes.

Despite these limitations, the current study is one of the few works that used multi-method assessment to highlight the role of different developmental and maintenance constructs in the psychopathology of illness anxiety. Considering that direct measures of interpretation bias in previous studies were prone to response bias, we evaluated the interpretation bias as an indirect process using an online reading task. The study investigated if interpretation bias, reappraisal, AS, and IU could differentiate the illness-anxious and control individuals. Based on the results, AS and IU might moderate the attention to and perception of ambiguous bodily sensations or somatosensory amplification. The efforts of the individual to resolve this ambiguity, in turn, may prone the person to more negative interpretation bias for this ambiguous sensation and increase anxiety. Deficits in the reappraisal strategy of emotion regulation, then, prevent the individual from replacing these unsafe interpretations with safe ones to reduce anxiety levels. They might try to gain certainty or decrease the levels of anxiety by dysfunctional strategies such as safety-seeking behaviors or avoidance that will lead to illness anxiety disorder in the long term. The methods and findings of the current study can be addressed in future studies for a more comprehensive understanding of illness anxiety and the application of its treatment. For instance, in the current study, there were no between-group differences in reaction time to ambiguous situations. Further studies can investigate if the reaction time might be different in the clinical sample who probably experience the symptoms more severely. Our results showed that people with illness anxiety symptoms are generally interpreting ambiguous situations in negative ways. However, it can be examined if illness-anxious individuals may interpret some ambiguous health-related situations as more catastrophic than other ambiguous health-related situations. The results will reveal the within-individual differences in catastrophic interpretations of ambiguous health-related situations, leading to identifying more specific factors that are involved in illness anxiety. Regarding the role of interpretation bias in illness anxiety, cognitive behavioral therapy (CBT) protocols target these biases by asking patients to evaluate the meaning of bodily sensations and adopt less-threatening interpretations (52). Considering that CBT strategies require higher levels of cognitive resources for introspection and awareness, they may not be as effective as more automatic and habitual level strategies in more stressful situations with high cognitive loads. Accordingly, there is a need for developing indirect and online techniques that address the interpretation biases more subtly and without requiring effortful introspection.

Conclusion

The current study highlighted the role of cognition in the development and maintenance of illness anxiety symptoms. Our results revealed that the illness-anxious group associated ambiguous health-related situations with more catastrophic consequences than the control group. Compared with the control group, the illness-anxious individuals also tended to be more sensitive to physical and cognitive symptoms of anxiety and showed less tolerance to general ambiguous situations. Sensitivity to the physical symptoms of anxiety and less safe interpretations for ambiguous health-related situations were among the best factors that could differentiate individuals with illness anxiety from others. These findings provide important suggestions for future interventions aiming to reduce anxiety and improve the quality of life among those patients suffering from conditions that raise the possibility of health anxiety. Changing the health-threatening interpretation of ambiguous bodily symptoms to more neutral interpretations might be a possible way to reduce health-related anxiety and improve patients' quality of life.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Department of Psychology, Shahid Behesht University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

ME was involved in the design, conducting study, analysis, and writing. MD was involved in design, supervision, and writing. MH was involved in design, analysis, and writing. LV was involved in material development and writing. AK was involved in design, material development, supervision, analysis, and writing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2022.985125/full#supplementary-material

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Social media use as a coping mechanism during the COVID-19 pandemic: A multidimensional perspective on adolescents' well-being

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Introduction: Social media use was previously characterized as both a maladaptive coping mechanism, and a source of engagement with peers, suggesting an ambivalent effect. The present study explored how adolescents might use social media as a coping mechanism during the COVID-19 pandemic, using a multidimensional perspective on well-being.

Methods: Our sample consisted of 259 Romanian teenagers aged 11–16 ($M = 13.38$, $SD = 0.93$, 57% males). We investigated the potential indirect effect of social media use, i.e., its cognitive, affective, and behavioral dimensions on the relationship between depressive symptoms and adolescents' well-being.

Results: Across all mediation analyses, our results suggested that social media use positively predicted adolescents' well-being. Given the multidimensional approach to both social media use and well-being, our findings suggested that adolescents' well-being was predicted not only by actual social media use behaviors but also by cognitions related to the expectation of receiving gratification on social media and the intense affective states related to the desire to use social media. Also, our data suggested that adolescents with high levels of depressive symptoms might be more likely to capitalize on social media use and have expectations related to receiving approval from others in the context of social media use.

Discussion: Depressive symptoms might be more relevant when explaining the cognitive and affective involvement during social media use. However, their ability to predict the actual social media use behaviors may be limited. Furthermore, adolescents that present depressive symptoms might be more prone to use social media, in order to improve their well-being.

KEYWORDS

adolescents, social media, engagement, emotions, well-being, depression

Introduction

Adolescence is a fascinating and challenging period of self-discovery. From a biological point of view, the beginning of puberty can signal the beginning of adolescence (1). Socially, however, adolescence is generally characterized by growing independence from parents, the increased influence of the peer group, and other aspects such as frequent mood swings, the impact of people from the same age group, the need to build an identity, and the fear of social rejection, which all play an essential role in

determining behaviors, emotional reactions, and the formation of coping strategies (1, 2). In addition, a more systemic perspective also underlines the significant role of individual and cultural variability (i.e., more significant than age-related norms) that might influence the developmental tasks achieved during this stage [e.g., (2)].

Among the challenges of adolescence, the development of a secure and stable sense of identity is critical since it can contribute to the shaping of sexuality (both in terms of identity and orientation) (3), the development of intimacy in various types of relations, strengthening the autonomy and different achievements, particularly associated with the educational path (4). Moreover, the COVID-19 pandemic has brought substantial challenges to people of all ages, youngsters included, imposing unprecedented, unpredictable changes.

In this context, previous studies highlighted the hardship experienced by adolescents and their caregivers (5), with a particular increase in experienced difficulties due to the COVID-19 pandemic (6, 7). At the same time, a growing body of research also emphasized teenagers' variety of coping resources and personal strengths (8), with technology playing a significant role in this regard (9). Building on this perspective, the present study aimed to explore how social media might be used as a coping mechanism during the COVID-19 pandemic, using a multidimensional perspective on adolescents' well-being.

Adolescents' well-being: The EPOCH model

Positive psychology devoted increased attention in the last decades to happiness, well-being, or life satisfaction, all of them describing a common feature, i.e., the constant and long-lasting presence of positive feelings, emotions, and outcomes for a person (10). Some positive psychologists reject hedonistic theories in favor of Aristotelian or eudaemonic views of well-being (11). For the conceptualization of well-being in the present study, we used the EPOCH paradigm, which understands well-being as a variable structured on five dimensions: *engagement* in activities, *perseverance*, *optimism*, *connection* with the people around us, and *happiness* (12).

Engagement

The EPOCH model's engagement dimension refers to adolescents' active and voluntary participation in activities in different areas of life (social, professional, and educational) (13). Engagement implies a strong motivation for adolescents to pursue their goals and passions and to take the initiative to start enjoyable or exciting activities. In other words, engagement refers to adolescents' ability to become absorbed in what they do (with its most intense form referring to a sense of flow), a state of complete absorption with the loss of a sense of time and self (14). Recent studies (15) suggested a significant link between engagement and educational mastery goals.

Perseverance

Within the EPOCH model, perseverance is conceptualized as an adolescent's ability to accomplish personal goals despite encountering obstacles (12). Previous studies suggested significant associations of persistence in educational contexts with the establishment of harmonious relationships. For example, in the study by Tian et al. (16), which involved 1,476 adolescents, social support in the educational context, both from teachers and colleagues, had significant associations with the participants' subjective well-being. Also, some studies have suggested a bidirectional relationship between persistence and the other dimensions of well-being and adolescent school performance (17).

Optimism

The EPOCH model's optimism dimension refers to adolescents' orientation toward self-confidence, hope, adopting positive attitudes related to the future, and anticipating positive long-term results (12). Furthermore, Zeng et al. (18) suggested that optimism is a central feature of adolescent well-being, and similar results were reported in subsequent studies. For example, Zou et al. (19) suggested that optimism seems to be a significant predictor of life satisfaction among adolescents.

Social connectedness

Within the EPOCH model, social connectedness refers to establishing and maintaining harmonious social relationships with family members and relevant others. Furthermore, these relationships are bidirectional, with adolescents' perceptions of their relationship with other people and those people's perceptions of adolescents being important in establishing social connections. Previous studies suggested social connectedness as a central dimension in determining adolescent well-being and that the feelings of belonging and integration in the school social environment mediated the relationship between students' academic and social skills and dimensions of social connection, happiness, and optimism within well-being (20, 21). Furthermore, other studies [e.g., (22)] suggested that adolescents' low social connectedness within middle school social groups is positively associated with depressive and anxiety symptoms.

Happiness

Of the five dimensions of the EPOCH approach, happiness is a particularly controversial one, as the scientific community is divided between adherents of positivist psychology, which positions happiness as a central concept in the assessment of well-being, and those who oppose this approach, considering happiness as a subjective construct and difficult to measure and assess (23). However, the EPOCH approach integrates the concept of happiness alongside other dimensions into the central idea of well-being. The results presented by Lukoševičiute et al. (24), in which 133 studies on the subjective happiness of adolescents were included, suggested that most studies [i.e., 64] used a single item to measure subjective happiness, and only 18 of them had validation procedures. However, adolescent happiness seems to be positively associated with social connectedness and optimism (21), highlighting its relevance for the optimal development of adolescents' well-being.

Adolescents' social media use

Addressing any issue concerning adolescence today without considering social media and its presence would mean ignoring a significant factor. The "digital natives" concept refers to the generations that have had access to digital technologies (e.g., computers, smartphones) since childhood (25, 26). The growing literature concerning the features of the digital natives has also highlighted the existence of the Z generation (children born between 1995 and 2010) (27) and the alfa generation (born 2010+) (28).

Digital natives might be different from children and teenagers of other generations due to their early and continuous exposure to a much faster and broader flow of information, studying, writing, and interacting with each other in ways that are very different from previous generations (29). As such, the rise of new social interaction methods (such as social media networks) is also strongly connected with the characteristics and behaviors of digital natives (30).

The Internet makes available, both to teenagers and people of other age groups, a series of tools that simplify various social and cognitive processes (31) and tasks that would require, in its absence, an increased effort. Although early digitally exposed teenagers (as the ones in the present study) have access to vast sources of information, new methods of socialization and entertainment from a very young age, the potential positive or negative effects of this factor are still a debated subject in the scientific community (32). Among adolescents' negative aspects of Internet access, disrupting the circadian rhythm and reducing sleep hours are expected consequences of excessive Internet use (33). Furthermore, Internet, smartphones, and video game addictions are also highly prevalent among teenagers, with higher rates among male adolescents (34). More importantly, a variety of studies suggested a significant association between social media use and adolescents' psychological distress, such as depressive and anxiety symptoms (35) and the time spent on social media (36–39).

Social media use refers to engaging in communication, information and data sharing, and entertainment activities on online community-building sites that typically include acquaintances and strangers (40). While some of the approaches to social media described the aspects related to the use of social media networks or the frequency of social media use (41), Dessart et al. (42) conceptualized the use of social media through three dimensions, i.e., cognitive, affective, and behavioral. The *cognitive* dimension of social media use refers to the presence of attitudes, beliefs, and states associated with the behaviors of using social networks, displayed in the long term (42). Often, adolescents with a high level of cognitive involvement in social media use express solid beliefs about the importance of social media in their personal lives, constantly thinking about social media use (43). The *affective* dimension of social media use refers to the emotions and feelings people feel using social networks, both when they are using them and when they are not (42). For example, while using social media, individuals may feel satisfaction, happiness, or other emotions associated with social media features (44). However, in the absence of social media use, individuals may feel anxious and impatient, anticipating further use (45). Finally, the *behavioral* dimension of social media use refers to the actual behaviors of using social media, such as communicating with others, sharing news, information, images, and videos, and obtaining information about other people or important events through ads, advertisements, news, and social media posts (42).

Building on this multidimensional approach to the use of social media, Ni et al. (46) defined social media engagement as an individual attitude toward the relationship with social media use. Their approach suggested that social media engagement might replace measures such as the time spent on social media or the frequency with which users access social media better to understand the underlying mechanisms of adolescents' related behaviors. In addition, the authors also validated a scale in this regard, i.e., the Social Media Engagement Scale for Adolescents, SMES-A (2020), which we used for the current investigation.

Adolescents and social media use effects

However, the impact of social media's use on adolescents' well-being has yet to be made clear since previous studies suggested ambivalent results regarding the valence of the impact of social media on adolescent well-being. For example, Beyens et al. (47) suggested that 44% of the adolescents in their investigated sample did not present significant changes in their

well-being following the use of social media. Also, 10% of participants had significantly worse well-being, while 46% had significantly increased well-being. A subsequent longitudinal study (48) observed a similar pattern (although the positive impact of social media use was lower).

Among the reasons for using social media and its benefits, adolescents usually report the need to communicate with friends and other people in their social circle, share images and obtain information related to the activities of people they know (49). Swirsky et al. (50) also reported positive and significant associations between the frequency of social media use and prosocial support. However, more recent studies highlighted that social media presence is not critical for the self's construction, but for the feedback received for the content adolescents post (51).

Excessive social media use seems to be associated with depressive symptoms and low self-esteem [e.g., (52)], and depressive symptoms were identified as positive predictors of social media use and increased frequency of social media use in both early and late adolescence (53). In the study coordinated by Sampasa-Kanyinga and Lewis (54), social media use among adolescents was associated with higher levels of psychological distress and suicidal ideation. Also, adolescents who reported low psychological support levels spent more time on social media networks. Furthermore, Haand and Shuwang (55) reported that depressive symptoms significantly and positively predicted participants' social media addiction. However, it is important to note that such studies have an associative nature, which makes it difficult to establish causal relationships between the investigated variables. For example, depressive symptoms can be interpreted as both a cause and an effect of social media use. On the one hand, it can be assumed that the frequent use of social media networks can contribute to the emergence of depressive symptoms. On the other hand, teenagers might use the Internet as a coping mechanism, with already existing depressive symptoms causing them to use social media networks more frequently.

Sela et al. (56) suggested depressive symptoms as a predictor of excessive Internet use and time spent online through the mediating variable of fear of missing social opportunities (i.e., fear of missing out). Furthermore, the meta-analysis conducted by McCrae et al. (57) suggested significant associations between depressive symptoms and social media use. Finally, in the meta-analysis of Huang (58), excessive social media was negatively associated with participants' well-being and self-esteem and positively related to loneliness and depressive symptoms, regardless of participants' age.

The bright side of social media use

A limited number of previous studies suggested the positive role of social media in coping with negative psychological states. For example, Cauberghe et al. (59) suggested that teenagers were more likely to use social media platforms to adapt to the changes brought by the COVID-19 pandemic rather than for communication purposes. Furthermore, the authors reported results suggested that coping through social media use may diminish the negative impact of anxiety on participants' happiness. Again, Ostic et al. (60) suggested that social capital (i.e., aspects of human social interactions, including communication networks, that allow individuals to collaborate to pursue objectives) might mediate the positive relationship between social media use and psychological well-being.

Also, a limited number of studies investigated the potential gender differences in social media use. For example, Luijten et al. (61) suggested that a higher level of social media use was reported among girls. It was also observed that girls who used social media more frequently had a lower state of well-being, which was not observed in the case of boys. Additionally, Li and Ni (62) suggested that boys and girls might express different patterns in the cognitive, affective, and behavioral use of social media networks, meaning that personality factors would explain to a greater extent the use of social media by boys (i.e., as they grow, they might gain an increased interest in forming social interactions and bonds through social media).

Depressive symptoms

Depressive symptoms, both in their moderate forms and in situations where they can lead to the diagnosis of depressive disorders, have a considerable prevalence among the world population, including adolescents (63). For example, Shorey et al. (64) reported a global prevalence of ∼34% of depressive symptoms among adolescents, 12% meeting the criteria for diagnosing depressive disorders. Their results also suggested that the prevalence of depressive symptoms and disorders seems higher among females, a pattern also found in other previous studies [e.g., (65)].

Recent studies suggested positive associations between pathologic use of the Internet and its features and depressive symptoms. In a meta-analysis, Lozano-Blasco and Cortés-Pascual (66) reported a moderate and positive relationship between pathologic internet use and depression. This effect was stronger among male participants and did not differ across cultures. Similarly, in a recent literature review, Vidal et al. (67) reported that higher frequencies of social media use were associated with higher levels of depression and suicidal ideation. The authors also highlighted the possibility of a dual relationship between depression and social media use. For example, the authors suggested that adolescents with depressive symptoms might predict higher levels of social media use in the long term and actively engage in social media use through posts and image sharing. Previous studies suggested potential reasons for these results. For example, Elmquist and McLaughlin (68) postulated that social media, despite its potentially harmful effects, can offer opportunities for coping with mental health issues (e.g.,

seeking advice or support from other individuals, sentiments of belonging to a group, or the possibility to access mental health resources while remaining anonymous).

Depressive disorders during adolescence are associated with later depressive episodes in adulthood, school dropout, unemployment during adulthood, and subsequent difficulties in social and professional adaptation and integration (69). Also, some previous studies suggest weak or moderate associations between adolescent depressive symptoms and social media use. For example, in a meta-analysis by Ivie et al. (36), which included 11 studies that recruited participants between the ages of 11 and 18, social media use had weak, positive, and significant associations with depressive symptoms.

The present study

Studies to date have provided divergent results regarding the impact of social media on adolescent mental health and well-being. For example, some studies suggested a positive effect associated with higher well-being and life satisfaction. In contrast, others showed a negative effect, associated with a higher level of anxiety and depressive symptoms, insomnia, and difficulties in social integration (40). Also, some studies [e.g., (47)] have reported ambivalent effects of social media use, suggesting that a considerable number of adolescents are not significantly affected by social media use, while two groups at the extremes are affected positively or negatively. Therefore, further studies, such as the present one, are needed to understand the impact of social media use on adolescent mental health.

At the same time, our study also aimed to understand better the relationships between mental health issues and adolescents' use of social media networks. For example, previous studies suggested that social media use could contribute to depressive symptoms through exposure to adverse factors, or well-being, through engaging in enjoyable socializing and entertainment activities (49). Alternatively, depressive symptoms may lead adolescents to use social media more as a coping mechanism to cope with the adverse effects of depression by seeking social support and approval from others.

Furthermore, the results of the previous literature documenting depressive symptoms and social media use nuance in the perspective according to which the well-being of adolescents does not represent a simple absence of depressive symptoms or other mental disorders, being instead the actual presence of positive aspects, such as optimism, the formation of social connections, commitment in activities, perseverance, and happiness of teenagers (12). Furthermore, these aspects seem also to be associated with positive consequences for adolescents, such as higher school performance, better integration into the educational and social environment and reduced depressive and anxious symptoms (12, 70). However, all these studies highlight the need for further research to provide a more comprehensive view of these links, and our study answers this call.

Also, although the negative relationship between well-being and depressive symptoms is robust and intuitive, it is important to understand the potential effect of other variables, which might influence various aspects of the two factors differently. For example, some previous studies (48) suggested that external factors, such as the use of social networks, could have ambivalent effects on the well-being of adolescents. Also, in addition to some weak direct associations, social media use can significantly impact adolescent sleep quality. Consequently, lack of sleep was associated with a significantly higher presence of depressive symptoms among adolescents (71).

Given all these previous findings, the present study aims to add to the current literature regarding the relationships between these variables, especially accounting for the divergent results describing the effects of different magnitudes of the use of social media on the well-being of adolescents and young people in general. More importantly, our study addresses these issues in a highly challenging context, i.e., the COVID-19 pandemic, when Romania was heading to the peak of the deadliest COVID-19 pandemic wave.

Our study was built on two primary objectives: (1) To explore the potential associations between the use of social media at cognitive, affective, and behavioral levels and depressive symptoms and the well-being of adolescents during the COVID-19 pandemic; (2) To investigate the potential indirect effect of social media use on the relationship between depressive symptoms and adolescent well-being, during the COVID-19 pandemic.

Considering previous studies suggesting depressive symptoms as a potential predictor of social media use (53) and social media use as a potential predictor of well-being, we assumed that (*H1*) Social media use (i.e., the cognitive, affective, and behavioral dimensions) would mediate the relationship between depressive symptoms and participants' well-being. A higher level of depressive symptoms would be associated with a higher level of social media use, which would be related to a higher level of well-being. Also, considering the possible gender differences in the use of social media (61), we assumed *(H2)* that there would be significant differences between male and female adolescents regarding their social media use, with female participants scoring higher than male participants.

Method

Participants and procedure

Our convenient research sample was formed of 258 adolescents aged 11–16 years ($M = 13.38$, $SD = 0.93$), out of which 147 were males (57%). The participants were recruited from three educational institutions in a northeastern town in

Romania. The data were collected between September 23, 2021, and October 7, 2021, as a part of a project aiming to explore adolescents' well-being. During that period, the schools were reopened, and the scales were filled in person (paper and pencil procedure). However, not all schools were open. Even in the schools where our participants were students, online teaching was alternated with offline classes in a cyclical system to avoid spreading the virus. Thus, we collected our data during the time when the students were physically present in schools.

The research was conducted following the Helsinki Declaration's ethical criteria and the ethical research requirements approved by the institutional board of the authors' institution. Permission was also received from the schools' principals, as well as the parents of the participants, who were informed of the study's goal and methodology. After receiving these approvals, we began the data collection process. Participants who agreed to participate voluntarily were told of the contents of the research, the tasks they were required to do (i.e., to answer the scales' items), the possibility to withdraw from the study at any time, and the confidentiality and anonymity of their answers, which would only be used solely for the present research. The participants gave informed consent to take part in this research. Furthermore, the participants were informed that none of their answers or participation would impact their academic performance or other academic-related variables. The average completion time was ∼15 min.

Measures

Before using the instruments, we followed the cross-cultural adaptation methods indicated by the International Test Commission (72) and related recommendations [e.g., (73, 74)]. Using the experience of two independent translators, we first translated the original instrument into the target language, i.e., from English to Romanian. Using the input of a third independent translator, we compared the two translated versions and evaluated the potential ambiguities and discrepancies of words, sentences, and meanings. There were no acknowledged significant inconsistencies, and the consensus reached permitted the tentative initial version of the translated scales. We next conducted a blind back-translation of the initial preliminary translation of the instruments, followed by a comparison of the two back-translated scales., which resulted in the final versions of the instruments.

Social media use

We used the Social Media Engagement Scale for Adolescents (46) to measure adolescents' social media use. The scale consists of 11 items, each item presenting a statement regarding certain aspects of the use of social media networks. Participants provided their answers on a Likert scale ranging from 1 ("not true at all") to 5 ("very true"). The scale comprises three dimensions. The first dimension, the *behavioral* use of social media networks, includes four items (e.g., "Using social media is my daily habit"), with a Cronbach's alpha of 0.79. The second dimension, the *cognitive* use of social media networks, includes three items related to participants' cognitions related to the use of social networks (e.g., "Support and encouragement of others on social media are very important for me"), with a Cronbach's alpha of 0.84. The third dimension, the *affective* use of social media networks, includes four items related to possible emotional reactions related to social media use (e.g., "I feel anxious when I can't use social media"), Cronbach's alpha of 0.84. High scores indicated a higher level of social media usage at that level.

Well-being

We used the 20-item EPOCH Measure of Adolescent Well-Being scale (12). Each item presents a statement regarding various aspects related to the proper functioning and well-being of the participants. Participants indicated to what extent they agreed with each statement on a Likert scale ranging from 1 ("not true at all") to 5 ("very true"). The scale comprises five dimensions, i.e., *Engagement* (e.g., "When I do an activity, I enjoy it so much that I lose track of time."), *perseverance* (e.g., "I finish whatever I start"), *Optimism* (e.g., "I think good things are going to happen to me."), *Connection* (e.g., "When I have a problem, I have someone who will be there for me."), and *happiness* (e.g., "I have a lot of fun."). High scores indicated a higher level of well-being. Cronbach's alpha for the overall scale was 0.91.

Depression

We used the 11-item Adolescent Depression Rating Scale (75) to measure participants' depressive symptoms. Participants provided their answers on a Likert scale ranging from 1 ("not true at all") to 5 ("very true"), and higher scores indicated higher symptoms. Example items include "I feel overwhelmed by sadness and listlessness" and "I feel downhearted and discouraged". Cronbach's alpha was 0.90.

Finally, a demographic scale assessed participants' gender and age.

Overview of the statistical analysis

We conducted preliminary analyses (using the IBM SPSS 26 statistical software) to assess whether participants' age relates to the primary variables of interest. Also, zero-order correlations

TABLE 1 Descriptive statistics for the primary variables ($N = 258$).

	M	SD	Min	Max	Skewness (SD)	Kurtosis (SD)	α
Well-being	18.75	3.31	5	25	0.01 (0.15)	−0.23 (0.30)	0.91
Social media use (overall)	34.52	9.80	11	55	−0.29 (0.15)	−0.02 (0.30)	0.90
Affective (social media use)	14.63	4.12	4	20	−0.58 (0.15)	−0.24 (0.30)	0.84
Behavioral (social media use)	9.02	3.10	3	15	−0.10 (0.15)	−0.37 (0.30)	0.84
Cognitive (social media use)	10.86	4.22	4	20	0.21 (0.15)	−0.53 (0.30)	0.79
Depressive symptoms	23.77	9.10	10	50	0.56 (0.15)	−0.22 (0.30)	0.90

TABLE 2 Zero-order correlations between the main variables ($N = 258$).

	M	SD	1	2	3	4	5	6
1. Well-being	18.75	3.31	–					
2. Social media use (overall)	34.52	9.80	0.22**	–				
3. Affective (social media use)	10.86	4.22	0.11	0.87**	–			
4. Behavioral (social media use)	9.02	3.10	0.34**	0.85**	0.69**	–		
5. Cognitive (social media use	14.63	4.12	0.16**	0.83**	0.53**	0.57**	–	
6. Depressive symptoms	23.77	9.10	−0.32**	0.28**	0.34**	0.12	0.24**	–
7. Age	13.38	0.93	−0.21**	0.15*	0.08	0.03	0.25**	0.12*

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

among the main study variables were computed. Finally, we investigated the mediating effect of each social media use dimension on the relationship between depressive symptoms and adolescents' well-being.

Results

Descriptive statistics of the study variables (mean, standard deviation, minimum and maximum values, Skewness and Kurtosis coefficients, Alpha Cronbach's coefficients) are reported in Table 1.

Associations between the variables

The results of Pearson correlations are reported in Table 2. Adolescents' well-being was positively associated with overall social media use and the behavioral and affective dimensions. At the same time, adolescents' well-being was negatively correlated with depressive symptoms and age: older participants reported a lower level of well-being. The behavioral and affective dimensions of social media use were also positively associated with depressive symptoms, while the affective dimension of social media use and depressive symptoms were positively correlated with participants' age.

Gender differences

Next, to observe potential differences between male and female participants on study variables, we applied independent samples *t*-tests (see Table 3). Results of independent sample *t*-tests suggest no significant differences between male and female participants on well-being, overall social media use score, behavioral or cognitive dimensions of social media use, or depressive symptoms. The only significant differences were observed in the affective dimension of social media use. More specifically, female participants reported significantly higher levels of social media use on the affective dimension than male participants.

Mediation analyses

Based on these findings, we further performed three mediation analyzes, using depressive symptoms as an independent variable, well-being as a dependent variable, and each dimension (cognitive, behavioral, and affective) of social media use as mediating variables. We used Hayes' (76) macro Process (Model 4; 95% confidence interval (CI); 5000 bootstrapped samples).

a. The mediating role of the cognitive dimension of social media use on the relationship between depressive symptoms and participants' well-being.

TABLE 3 Independent T-test results ($N = 258$).

	Self-reported gender		
	Male (N=147)	Female (N=111)	t
	M (SD)	*M (SD)*	
Well-being	18.72 (3.26)	18.80 (3.39)	−0.196
Social media use (overall)	33.54 (10.06)	35.82 (9.33)	−1.864
Affective (social media use)	13.90 (4.07)	15.60 (3.99)	−3.342***
Behavioral (social media use)	8.93 (3.19)	9.14 (2.98)	−0.519
Cognitive (social media use	10.69 (4.25)	11.08 (4.19)	−0.723
Depressive symptoms	22.99 (8.71)	24.80 (9.53)	−1.583

***$p < 0.001$.

The total effect of depressive symptoms on participants' well-being was significant ($B = -0.11$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.15; −0.07]), a higher level of depressive symptoms being associated with a lower level of well-being. The direct effect of depressive symptoms on well-being was significant as well ($B = -0.15$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.19; −0.10]). The effect of depressive symptoms on the cognitive dimension was significant as well ($B = 0.15$, $SE = 0.02$, $p < 0.001$, 95% CI [0.10; 0.21]). The effect of cognitive dimension on well-being was significant ($B = 0.21$, $SE = 0.04$, $p < 0.001$, 95% CI [0.11; 0.30]). The indirect effect of depressive symptoms on well-being through the cognitive dimension of social media use was significant ($B = 0.03$, $SE = 0.01$, 95% CI [0.01; 0.05]), with higher depressive symptoms being associated with a higher level of cognitive involvement in social media use. At the same time, a higher level of social media use was associated with a higher level of well-being. The results indicated a partial mediating effect of the cognitive dimension of social media use on the relationship between depressive symptoms and well-being (see Figure 1).

b. The mediating role of the behavioral dimension of social media use on the relationship between depressive symptoms and participants' well-being.

The results of the second mediation model are presented in Figure 2. They indicate that the total effect of depressive symptoms on well-being was significant ($B = -0.11$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.15; −0.07]), a higher level of depressive symptoms being associated with a lower level of well-being. The direct effect of depressive symptoms on well-being was significant as well ($B = -0.13$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.17; −0.09]). The effect of depressive symptoms on the behavioral dimension of social media use was not significant ($B = 0.04$, $SE = 0.02$, $p > 0.05$, 95% CI [0.00; 0.08]). The effect of the behavioral dimension of social media use on well-being was significant ($B = 0.41$, $SE = 0.05$, $p < 0.001$, 95% CI [0.29; 0.52]), with a higher level of behavioral involvement being associated with a higher level of well-being. The indirect effect of depressive symptoms on well-being, through the cognitive dimension, was not significant ($B = 0.01$, $SE = 0.01$, 95% CI [−0.00; 0.03]). Thus, the results indicate a non-significant mediating effect of the behavioral dimension of social media use on the relationship between depressive symptoms and well-being.

c. The mediating role of the affective dimension of social media use on the relationship between depressive symptoms and participants' well-being.

The results of the third mediation model are presented in Figure 3. These indicate that the total effect of depressive symptoms on well-being was significant ($B = -0.11$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.15; −0.07]), a higher level of depressive symptoms being associated with a lower level of well-being. The direct effect of depressive symptoms on well-being was significant ($B = -0.14$, $SE = 0.02$, $p < 0.001$, 95% CI [−0.18; −0.09]). The effect of depressive symptoms on the affective dimension of social media use was significant ($B = 0.10$, $SE = 0.02$, $p < 0.001$, 95% CI [0.05; 0.16]). The effect of the affective dimension of social media use on well-being was significant ($B = 0.21$, $SE = 0.04$, $p < 0.001$, 95% CI [0.12; 0.31]). The indirect effect of depressive symptoms on well-being through the affective dimension of social media use was significant ($B = 0.02$, $SE = 0.00$, 95% CI [0.009; 0.04]). A higher level of depressive symptoms was associated with a higher level of the affective dimension of social media use, which in turn was associated with a higher level of well-being. The results indicate a partial mediating effect of the affective dimension of social media use on the relationship between depressive symptoms and well-being. When gender was introduced as a covariate, we observed a partial mediating effect (direct effect: $B = -0.14$, 95% CI [−18; −0.09], indirect effect: $B = 0.02$, 95% CI [0.007; 0.04]).

Discussion

Across all mediation analyses, our results suggested that social media use positively predicted adolescents' well-being. These results aligned with previous studies (48), suggesting the ambivalent effects of social media use on well-being, with the present study providing results in favor of the positive impact

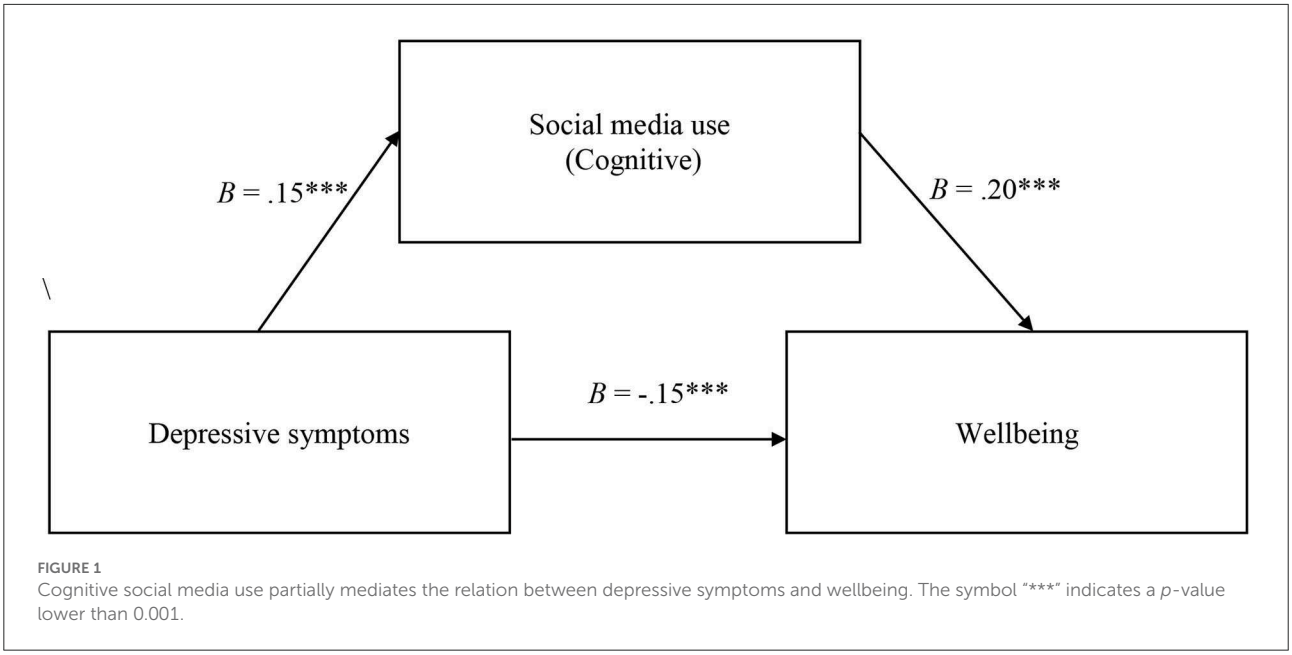

FIGURE 1
Cognitive social media use partially mediates the relation between depressive symptoms and wellbeing. The symbol "***" indicates a *p*-value lower than 0.001.

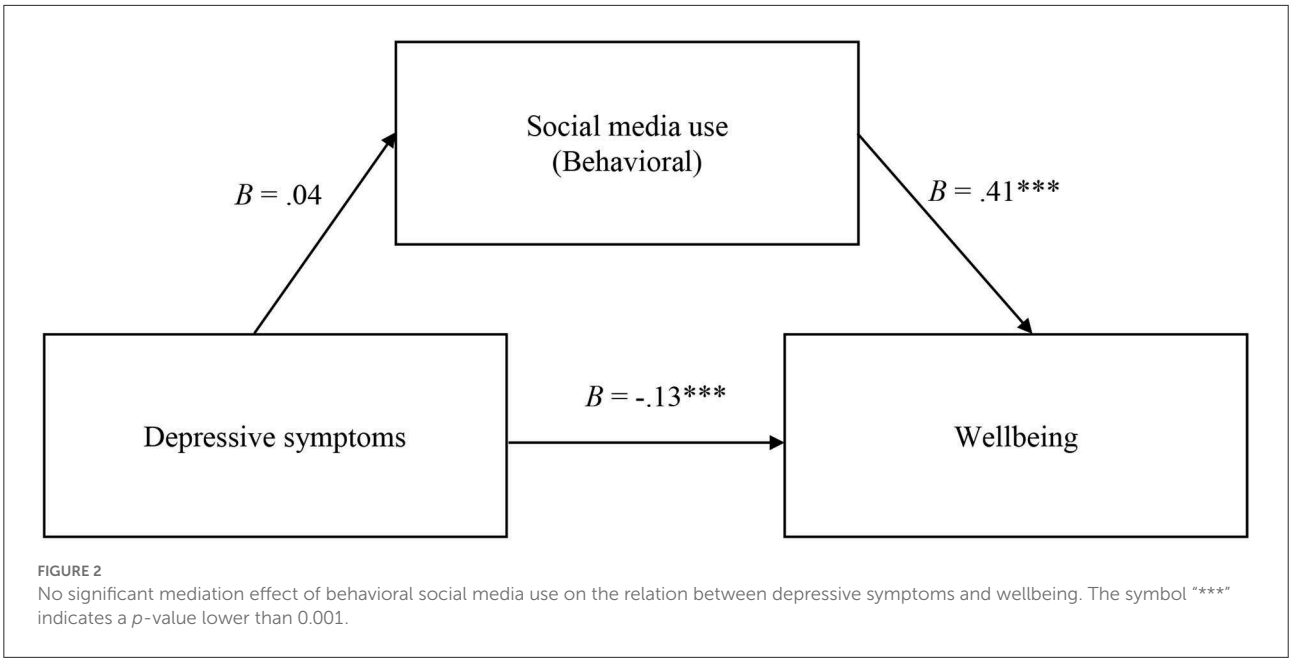

FIGURE 2
No significant mediation effect of behavioral social media use on the relation between depressive symptoms and wellbeing. The symbol "***" indicates a *p*-value lower than 0.001.

of social media use. Taking into account the particularities of the instrument used to measure social media use, adolescent well-being was predicted not only by actual social media use behaviors but also by cognitions related to the expectation of receiving gratification on social media and by the intense affective states related to the desire to use social media.

Consequently, the relationship between these variables (especially in the COVID-19 pandemic context) might be interpreted in a positive key, improving the well-being of adolescents by using the facilities offered by social media (communication with close people, building and maintaining social relationships, sharing and retrieving information and data), but as well in a less positive key, using maladaptive coping mechanisms, participants associated the use of social media with pleasant feelings, high expectations of receiving gratification and distraction from problems. Previous findings support this interpretation. For example, Matthes et al. (77) suggested that using social media sites such as YouTube, WhatsApp and Snapchat might contribute to perceptions of information overload, leading to more depressive symptoms. On the other hand, Cauberghe et al. (59) suggested that active coping through social media use mediated the relationship between anxiety and

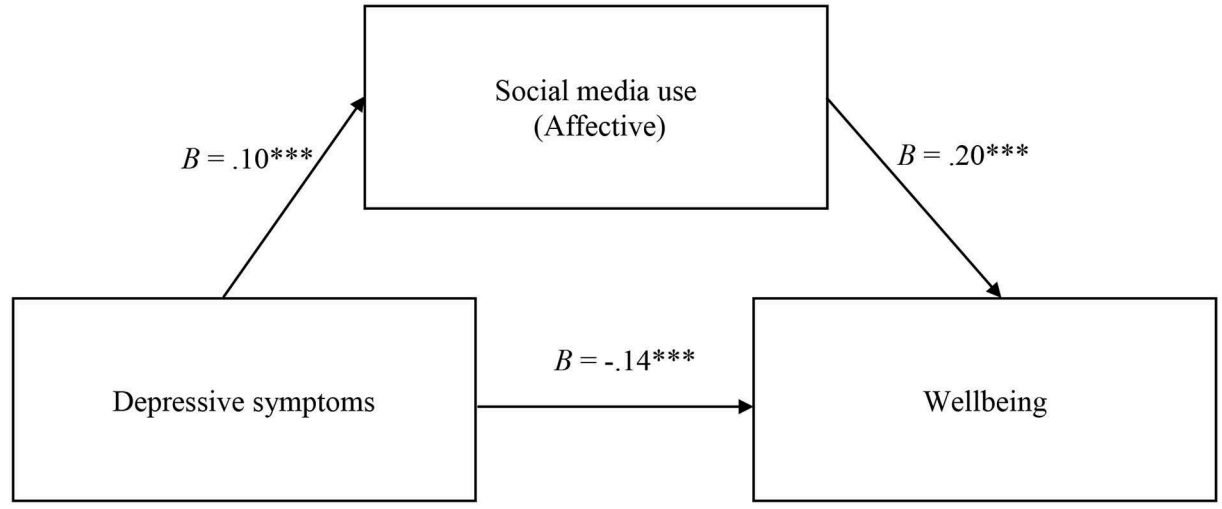

FIGURE 3
Affective social media use partially mediates the relation between depressive symptoms and wellbeing. The symbol "***" indicates a *p*-value lower than 0.001.

happiness, with higher levels of anxiety being associated with higher levels of active coping through social media use, which in turn led to higher levels of happiness.

The cognitive dimension of social media use partially mediated the relationship between depressive symptoms and well-being. Depression had a direct negative effect on well-being, but it positively affected the cognitive dimension of social media use, which positively impacted well-being. These specific results suggested that adolescents with high levels of depressive symptoms are more likely to capitalize on social media use and to have expectations related to receiving approval from others in the context of social media use. Consequently, building this social media image is associated with a higher level of well-being. In addition, these findings also suggested that adolescents may use cognitive engagement in social media use as a coping mechanism.

In line with other similar studies [e.g., (78)], our results might sustain the idea that in the case of youth who presented depressive symptoms before the pandemic, COVID-19 might have had even a more substantial impact on their well-being due to isolation, less direct peer interaction and overall predictability. In such a context, relying on the digital universe might have been enforced both as a solution to continue education and as the sole means to keep in contact with others. Thus, our results might signal a potential path to the positive role of social media capital in building their identity if facing depressive symptoms that hinder their direct participation, also after the pandemic.

On the other hand, the behavioral dimension of social media use did not mediate the relationship between depressive symptoms and well-being. Thus, depressive symptoms did not significantly impact adolescents' actual use of different social media functions, as defined by Ni et al. (46). However, the behavioral dimension of social media use positively predicted adolescent well-being, having the most substantial effect on the dependent variable among all mediating variables. These results suggested that actual use of social media may improve adolescent well-being, but depressive symptoms do not cause them to change their frequency of use or time spent on social media. Alternatively, these results could be explained by depressive symptoms, with adolescents high in depressive symptoms being apathetic, thus having little interest in engaging in activities that would ordinarily interest them, be it that we refer to direct or virtual activities. A secondary line of explanation can be linked to the period of the data collection (fall of 2021, returning to school after a significant period of online schooling); at this point of the pandemic, we can talk of a potential decrease in the use of social media as a consequence of boardroom, fatigue associated to being only online and an overall reduction of interest in social media, as direct exposure to peers was again possible [similar results reported by Longest and Kang (79)]. At the same time, the lack of significant correlations between depressive symptoms and the behavioral dimension of social media use may suggest that the association between the two variables could be weak, making it difficult to establish a causal relationship between them. In this regard, previous studies have suggested weak or moderate associations of depression with social media use, with many identifying only a small effect in the relationship between the two variables (58).

Next, the affective dimension of social media use partially mediated the relationship between depressive symptoms and well-being. Depression had a negative effect on well-being, but it had a positive effect on the affective dimension of social

media use, which positively impacted adolescent well-being. These results suggest that depressive symptoms may lead adolescents to compare physical and online social interactions and conclude that social media interactions are more enjoyable than traditional ones. Consequently, these attitudes could lead adolescents to spend more time on social networks, contributing to increased well-being. Similar to the pattern observed in the relationship between depression, the cognitive dimension of social media use, and well-being, these results could suggest that adolescents use social networks as a maladaptive coping mechanism to deal with depressive symptoms.

The present results indicated significant gender differences only at the affective dimension of social media use level, only partially confirming the second hypothesis. The results suggest that female participants show a higher level of affective involvement in the use of social media than boys. Furthermore, these results suggested a greater preference for teenage girls to socialize online over traditional socializing. Given the lack of significant differences between the two groups on all other study variables, these differences cannot be adequately explained by variance in variables such as the prevalence of depressive symptoms or different dimensions of social media use. Also, although the results related to gender differences in social media use are in line with previous studies, these results are contradictory to some previous studies where girls reported a higher level of social media use, which was associated with a lower level of well-being (61), in this study no gender differences in well-being were observed. To explain these divergences, it is important to note that social media use refers to socializing through sites built primarily to serve this purpose (such as Facebook, Twitter, and Instagram). However, virtual socializing can also occur in the context of multiplayer or online-only video games, with previous research suggesting a much higher prevalence of video game socializing among boys, with girls preferring to socialize through social media networks (80). Therefore, in further studies, it would be necessary to adopt a broader conceptualization of socialization in the online context, which includes more modalities in addition to using social networks.

The results of this study suggested the potential role of social media use by adolescents as a coping mechanism to deal with depressive symptoms and improve their well-being. At the same time, the study's results suggested that different dimensions of social media use may play varied roles in the relationship between depressive symptoms and well-being, the behavioral dimension of social media use not being influenced in the same way as the cognitive or affective dimension.

Several limitations of the present study need further attention. First, we used a convenience sample, limiting the possibility of generalizing these results to the adolescent population. Further studies consider using larger and more representative samples. A second limitation is related to the self-reported scales that we used, which may have led participants to provide socially desirable responses. At the same time, they require introspection and subjective evaluations. Therefore, further studies could use more objective methods, such as experimental approaches to observe the relationship between the investigated variables.

Further studies may consider the introduction of new variables relevant to the investigation of adolescent well-being and depressive symptoms, such as fear of missing out (56), and may use instruments alternatives to gain a better understanding of the relationship between social media use and adolescent depressive symptoms and well-being. Also, for a better understanding of the impact of online socialization on adolescents' well-being and depressive symptoms, it would be recommended to use more comprehensive conceptualizations that include, in addition to social media networks, other platforms that facilitate online socializing, such as video games, blogs, problem-solving sites. Also, the EPOCH approach presents specific limits [e.g., the cultural impact for each research setting (81)], which future studies might address. Finally, we did not specifically assess the impact of the COVID-19 pandemic nor the related experiences, which might have accounted for some variations in our results.

Conclusion

Previous studies examining the impact of the actual use of social media networks on depression and the well-being of adolescents paid little attention to other factors associated with using social networks (such as cognitive and affective involvement), especially during the COVID-19 pandemic. The present study nuanced the perspective on these variables, suggesting that depressive symptoms may not be directly associated with actual behaviors of regularly using social media but rather with some maladaptive cognitive and affective processes related to social media use. Also, this study contributes to the understanding of gender differences in social media use, suggesting a tendency for teenage girls to show maladaptive affective reactions related to social media use at a significantly higher level than male teenagers. However, further studies are needed to test the relevance of these conclusions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary files, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by FPSE Iasi. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

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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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Cross-cultural adaptation and psychometric evaluation of the Portuguese version of the family resilience questionnaire – short form (FaRE-SF-P) in women with breast cancer

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Background: A diagnosis of cancer, and the resulting treatment process, can be perceived as a life-threatening event, affecting not only patients but also their social network and, more specifically, their relatives. While the ability to cope and adjust to difficult health situations may be challenging, family resilience may optimize a positive adaptation to adversity and contribute to enhance the patient's quality of life. The Family Resilience Questionnaire (FaRE) is a self-report measure of family resilience that assesses this construct systematically. We aimed to validate the Portuguese version of a short form of the FaRE (FaRE-SF-P) in a sample of women with breast cancer.

Methods: 147 women recently diagnosed with early breast cancer were recruited at the Champalimaud Clinical Centre in Lisbon. Participants completed psychometric assessment including the Portuguese version of the FaRE-SF-P, composed by two subscales of the original version – the FaRE Perceived Family Coping (FaRE-PFC) and the FaRE Communication and Cohesion (FaRE-CC). Confirmatory factor analysis (CFA) was performed to assess the factor structure of the FaRE-SF-P. Construct validity was assessed using the Hospital Anxiety and Depression Scale (HADS) for divergent validity, and the Modified Medical Outcomes Study Social Support Survey (mMOS-SS) as well as the social functioning subscale from the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30 (EORTC QLQ-C30) for convergent validity.

Results: The CFA results confirmed a correlated two-factor structure model consistent with the Perceived Family Coping and the Communication and Cohesion subscales. Internal consistency reliability indicated good values both for Perceived Family Coping and Communication and Cohesion subscales. The results for construct validity showed acceptable convergent and divergent validity.

Discussion: The FaRE-SF-P showed good psychometric properties demonstrating to be a valid and reliable family resilience measure to use in Portuguese women diagnosed with breast cancer. Since FaRE-SF-P is a short instrument it may be a useful screening tool in an oncological clinical practice routine.

KEYWORDS

family resilience, breast cancer, psychological distress, assessment, coping, validation

Introduction

Resilience is a multidimensional construct, which can be defined as one's ability to mobilize coping resources to adapt and properly function after a perceived significant adverse event (Southwick et al., 2014). From the several dimensions that may compose the construct of resilience, family resilience is of considerable relevance and can be defined as the ability of a functional system to withstand and adapt to adversity (Walsh, 2021). The importance of this dimension stems from the notion that perceived adverse events occurring to one member impact the whole family, and, in turn, that the dynamic interpersonal processes within the family mediate possible adaptation for the individual members, their relationships, and, finally, the whole system (Walsh, 2021).

Cancer diagnosis and the respective treatment process are normally perceived as life-threatening events (Seiler and Jenewein, 2019), leading to significant levels of distress and, possibly even the development of major depression and other neuropsychiatric disorder (Mitchell et al., 2011; Smith, 2015). Such events affect not only patients but also impact their social network and, more specifically, their relatives (Edwards and Clarke, 2004). In the presence of a life-threatening event such as a cancer diagnosis, both patients and their relatives will need to adapt not only individually but also in terms of their family dynamics (Faccio et al., 2018). Cancer diagnosis and treatment impose to the whole family, as a unit, the need to face new challenges in the different stages of the disease. These challenges can range from adaptation to managing resources between work and added home responsibilities, to changing family roles, or even the need to balance and adapt to the needs of the whole family (Northouse, 1992). Relatives of patients with cancer are also at high risk of developing affective symptoms, with prevalence rates of anxiety and depression in this population ranging from 20 to 40% (Friðriksdóttir et al., 2011).

In that sense, it becomes fundamental to understand which psychosocial factors may play a role in the prevention of these conditions and its burdensome consequences. Resilience, perceived social support (Zhao et al., 2020; Tamura, 2021), perceived family support (Su et al., 2017) and family communication skills (Park et al., 2022) have been reported in the literature as important protective factors for symptoms of depression and for the adaptation to this life-threatening event. To optimize the prevention of these neuropsychiatric disorders, clinicians and researchers need to be attentive, screen and monitor affective symptoms in patients with cancer (Walker et al., 2014) and, additionally, understand and bolster the psychosocial resources available both for patients and their relatives (Seiler and Jenewein, 2019).

For resilience and, specifically, family resilience, Walsh's conceptual framework has been used in the oncological setting, providing insights on the relevance of such construct for patients and their relatives (Walsh, 2021). Walsh's *Family Resilience Framework* provides multilevel systems orientation associated with a positive adaptation in the presence of perceived adverse events. Under this framework, three key processes are proposed to underlie functional adaptation of the whole family system to the perceived adversity. First, the family's belief system, composed of making meaning of adversity, a positive outlook and transcendence and spirituality (Walsh, 2016). The second key process concerns the familial organizational processes, comprised of flexibility, connectedness, and resource mobilization between family members (Walsh, 2016). Finally, the third key process is communication and problem-solving skills, where clarity, open emotional sharing and a collaborative problem-solving approach should be present to optimize a positive adaptation to adversity (Walsh, 2016).

Albeit being a useful theoretical model to guide the understanding of family resilience to adversity, a quantification of this construct is needed, and to do so, adequate psychometric instruments are required. Four psychometric instruments have been developed and submitted to a formal validation process for this purpose, in diverse contexts. The *Family Resilience Assessment Scale* (*FRAS*; Sixbey, 2005) was implemented in the general American population without considering the presence of a significant perceived adverse event, leading to a significant limitation in the process of its validation. The second example is the *Family Resilience Assessment (FRA)*, with its authors suggesting that, throughout the validation process, the items were not all fitting the construct which they were trying to measure, leading to important constraints in the assessment of the family resilience construct (Duncan Lane et al., 2017). The third psychometric instrument, *The Walsh Family Resilience Questionnaire* (*WFRQ*; Walsh, 2016) was designed by the developer of the family resilience construct framework considered above. However, validation of this psychometric instrument was not conducted in an oncological setting, with one study conducted with Iranian families selected from a military center and the other with patients with chronic diseases and their relatives (Rocchi et al., 2017; Dadashi Haji et al., 2018).

Finally, the *Family Resilience (FaRE) Questionnaire* attempted to bridge all the gaps in the quantification of the family resilience construct in the oncological setting (Faccio et al., 2019). *FaRE* was validated for a population of patients with breast and prostate cancer and respective caregivers, in Italy, and presented acceptable psychometric properties. In the validation process, an initial 60-item version was refined into a 24 item questionnaire, which can be aggregated in four different factors: communication and cohesion, perceived social support, perceived family coping, and religiousness and spirituality (Faccio et al., 2019). In Portugal, breast cancer is the most frequent cancer diagnosis and the most frequent cause of cancer mortality, with incidence rates gradually increasing throughout the past decades (Forjaz de Lacerda et al., 2018). To the best of our knowledge, in this clinical population data regarding family resilience is scarce, and family resilience instruments lack proper psychometric evaluation. In that sense, here we propose to adapt and validate a short form of the European Portuguese version of the *FaRe* (FaRE-SF-P) for a sample of patients with breast cancer and their relatives, to better characterize family resilience in this context and to compare its psychometric properties with the original FaRE scale. We hypothesize that a Portuguese translation of the FaRE-SF will conserve the reliability and construct validity of the original version.

Materials and methods

Participants

Participants were recruited within the scope of the BOUNCE multicenter clinical study (Predicting Effective Adaptation to Breast

Cancer to Help Women to BOUNCE Back) between April 2019 and January 2021 (Pettini et al., 2022). The study was conducted at the Champalimaud Clinical Centre and followed the same approach as the Portuguese Validation study of the Perceived Ability to Cope with Trauma (PACT; Lemos et al., 2022). Eligibility criteria included: female patients, 18–70 years of age at the time of diagnosis, histologically confirmed invasive early or locally advanced operable Breast Cancer (BC), tumor stages I – III, surgery included as part of the local treatment, receipt of any type of systemic treatment regardless of treatment type, and of adjuvant radiation therapy if indicated as part of local treatment. Criteria for exclusion were: presence of distant metastases, history of another malignancy or contralateral invasive BC within the last 5 years except cured basal cell carcinoma of skin or carcinoma *in situ* of uterine cervix, history of early onset (i.e., <40 years of age) mental disorder (i.e., schizophrenia, psychosis, bipolar disorder, major depression) or of severe neurologic disorder (i.e., neurodegenerative disorder), other serious concomitant diseases such as clinically significant (i.e., active) cardiac disease (e.g., congestive heart failure, symptomatic coronary artery disease or cardiac arrhythmia not well controlled with medication), myocardial infarction within the last 12 months, and/or major surgery for a severe disease or trauma which could affect patient's psychosocial wellbeing (e.g., major heart or abdominal surgery) within 4 weeks prior to study entry, or lack of complete recovery from the effects of surgery.

For this validation study, conducted only with participants in Portugal, all participants were submitted to the same experimental research protocol, which included a baseline assessment for patients that started oncological systemic treatment approximately 3 months before. Longitudinal assessments were performed across 12 months, with two additional time points at 6 months (M6) and 12 months (M12). Since this study was performed with data collected in the BOUNCE Project, sample size calculation was dependent on the global aims of the main study, rather than performed to address the objectives of this sub-study. However, the minimum sample size recommended to perform this psychometric analysis, when considering the number of items and factors of the scale (Nunnally, 1978; Mundfrom et al., 2005), is less than the sample sized that was analyzed here.

Measures

Sociodemographic and lifestyle questionnaire and medical data

This form includes questions on patients' sociodemographic and lifestyle variables (age, educational level, marital status and employment status) and the characteristics of the disease and treatment (cancer staging and treatment type).

Family resilience questionnaire – short form

The FaRE-SF is a brief 12-item self-report questionnaire derived from two of the original FaRE subscales (Faccio et al., 2019): Perceived family coping (FaRE-PFC; 4 items –2, 5, 8 and 11), and Communication and cohesion (FaRE-CC; 8 items –1, 3, 4, 6, 7, 9, 10, 12). Answers are given in a Likert-type scale that ranges from 1 ("Totally disagree") to 7 ("Totally agree"). The Perceived family coping scale refers to the ability to recover from a stressful life event by activating and mobilizing coping strategies to deal with the illness. Higher values means higher levels of perceived family coping (maximum value of 28). On the other hand, the Communication and cohesion scale measures the capacity of a family to be open to communicate about the illness, the associated feelings, their impact on daily life as well as their ability to think about ways to solve problems, conflicts and to share decision-making processes. Higher values in this scale means higher levels of family cohesion and communication, with a maximum value score of 56. While the FaRE-SF is not yet formally validated, in the original validation study of the full FaRE, good convergent validity values were found for both 'Communication and Cohesion' ($rho = 0.56$; $p < 0.0001$) and 'Perceived Family Coping' ($rho = 0.30$; $p < 0.0001$) scales when correlated with the Resilience Scale for Adults (RSA; Friborg et al., 2003).

Modified medical outcomes study social support survey – mMOS-SS

To assess convergent validity, we used the mMOS-SS (Moser et al., 2012) as a measure of Social Support. The mMOS-SS is a brief self-report Likert-type (1 = 'never' to 5 = 'always') scale with 8 items organized in two dimensions: emotional and instrumental social support (4 items each). This instrument presented very good psychometric properties, similar to those of the original 19-item from which it derived (Moser et al., 2012). The mMOS-SS validation study was conducted with three geriatric samples (two samples of women with breast cancer and one sample comprised by patients with chronic diseases) showing excellent reliability ($0.88 < \alpha < 0.93$), a two-factor structure (instrumental and emotional social support) and a good convergent validity with the mMOSSS total scale (Hays et al., 1994). In this study we used the brief mMOS-SS scale based on the Portuguese version of the total scale by Alonso Fachado et al. (2007) to assess convergent validity, where Cronbach's alpha values of 0.92 and 0.88 were obtained for the emotional support and instrumental support subscales, respectively.

Hospital anxiety and depression scale

The HADS is a 14-item measure of psychological distress divided in two scales with 7 items each: HADS-Depression, assessing symptoms of depression, and HADS-Anxiety, measuring symptoms of anxiety (Zigmond and Snaith, 1983). Higher score indicates higher levels of symptoms. In the oncological setting, the HADS is a widely used questionnaire, with several validation studies showing good psychometric properties (Mitchell et al., 2010). The Portuguese version was validated by Pais-Ribeiro et al. (2007) in a study including patients with cancer, with Cronbach's alphas of 0.76 and 0.81 obtained for the Anxiety and the Depression subscales, respectively. In this study HADS was used to assess divergent validity.

European Organization for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30

The EORTC QLQ-C30 is a measure of quality of life specifically developed and validated for the oncological setting. It includes 30 items divided in 15 dimensions: 5 functional scales (physical, role, cognitive, social and emotional functioning), 3 symptoms scales (fatigue, nausea and pain), a global quality of life scale and some single items to assess other symptoms, such as dyspnea, insomnia, appetite loss, constipation, diarrhea as well as the presence of financial difficulties due to oncological treatments. We used the Portuguese version of the EORTC QLQ-C30 in our study, validated by Pais-Ribeiro et al. (2008), in which the Cronbach's alpha for the global quality of life scale was 0.88. Here we will focus more on the EORTC social functioning subscale that had a Cronbach's alpha of 0.78 in the Portuguese validation study, to assess convergent validity.

Procedures

Permissions to translate the FaRE-SF scale were obtained from the original authors by the BOUNCE consortium. We then followed the International Test Commission Guidelines for Translating and Adapting Tests ["ITC Guidelines for Translating and Adapting Tests (Second Edition)," Bartram et al., 2018]. The Portuguese version of the FaRE-SF was thus developed using a forward-backward translation process both from and to English and European Portuguese, as follows. (i) A forward translation was completed by two bilingual experts in Psychology of Portuguese dominant language, resulting in two translated versions of the FaRE-SF (FaRE-SF-1 and FaRE-SF-2). (ii) A translation panel composed of psychology and oncology specialists who had not been involved in any of the forward translations compared FaRE-SF-1 and FaRE-SF-2, and discrepancies were reconciled through discussion among the translators. (iii) The reconciled Portuguese translation of the FaRE-SF (FaRE-SF-3) was then back-translated into English by two bilingual official translators, of English dominant language, that were independent of each other, not involved in the original translations, and not familiar with the original scale, resulting in two independent back-translations (FaRE-SF-4 and FaRE-SF-5). (iv) The original translation team compared FaRE-4 and FaRE-5, resulting in a consensus back-translation version (FaRE-SF-6). (v) FaRE-SF-6 was then compared against the original FaRE-SF by the initial translation team, to identify any major differences between the two, resulting in a final review of the reconciled Portuguese translation (FaRE-SF-3), with adjustments leading to a synchronized version (FaRE-SF-7) (vi) In a cognitive debriefing session, FaRE-SF-7 was tested among a small group of patients, intended to represent the target population and language group (Portuguese Patients with Breast Cancer, $n=6$) to assess if the respondents correctly understood the questions being asked, if the questions were clearly stated and if there were words or phrases that were not familiar. Minor suggestions were made by these patients essentially reflecting replacement of some words for synonyms with higher frequency in European Portuguese, so it could facilitate understanding. For example, "*pensamos*" (Portuguese word for "think") was replaced by "*refletimos*" (Portuguese word for reflect), as the verb "to reflect" includes a sense of serious thought or consideration. Considering the input from these patients, the translation was reviewed and proof-reading was conducted to ensure that minor errors were corrected, resulting in the definition of the FaRE-SF final Portuguese version (FaRE-SF-P).

Study procedures and protocol were reviewed and approved by the Ethics Committee of the Champalimaud Foundation. All participants provided written informed consent, and the study was conducted in accordance with the tenets of the Declaration of Helsinki.

Data analysis

Statistical analyses were performed using JASP version 0.14.1 (built on the R-package lavaan). Descriptive statistics were used for sample characterization. To assess dimensionality, a Confirmatory Factor Analysis (CFA) was conducted to compare a proposed solution based on two subscales from the original scale (Factor 1 – FaRE Perceived Family Coping; Factor 2 – FaRE Communication and Cohesion). To evaluate the goodness of fit of the tested factorial structure, we considered the following indices: non-significant $\chi 2$, CFI (comparative fit index), TLI (Tucker–Lewis index), and RMSEA (root mean square error of approximation), according to the suggestion of Schermelleh-Engel et al. (2003). The cut-off criteria proposed by the same authors were considered as indicative of goodness of fit, as follows: CFI and TLI good fit ~0.97, acceptable fit >0.95; RMSEA: good fit ≤0.05, adequate fit 0.05–0.08. Item local adjustment was assessed through the factor loadings (λ), which reflect the strength of correlation between the latent variable and the observed variable. We considered factor loadings above 0.40 as good indicators of the quality of the items (Gana and Broc, 2018). Reliability was assessed by internal consistency using Cronbach's alpha and McDonald's omega, with coefficients above 0.70 indicating good reliability (Hair, 2010). Corrected item-total correlation was also used, with values above 0.30 considered to be good (Cristobal et al., 2007). Pearson's correlation coefficients were calculated between FaRE-SF-P subscales and mMOS – Emotional Support, mMOS – Instrumental Support and EORTC – Social Functioning scores for convergent validity; and with HADS total score, HADS-Depression and HADS-Anxiety for divergent validity. Finally, comparisons of the FaRE subscales scores between groups of treatment across study endpoints of assessment were analyzed by fitting a mixed model, with Geisser–Greenhouse correction, as implemented in GraphPad Prism 8.0.1, due to the presence of missing data. This model uses a compound symmetry covariance matrix, and is fitted using Restricted Maximum Likelihood (REML). In the presence of missing values, this method gives the same p values and multiple comparisons tests as repeated measures ANOVA, so the results can be interpreted likewise. Results with $p<0.05$ were considered statistically significant.

Results

Descriptive statistics

Among the 163 patients who accepted to participate in the study, 147 completed all the questionnaires (Table 1). The majority of the participants included were middle age women (41 to 50 years old), with an overall mean age of 51.3 (SD = 9.1). More than a half of the participants had a graduate degree (73.5%), full or part-time employment (76.2%), and was married (74.1%). Regarding the ongoing treatment, at the moment of the assessment, 55.1% of the patients were under chemotherapy (CT) and 44.9% were undergoing endocrine therapy (ET).

Descriptive statistics of individual FaRE-SF-P items are presented in Table 2, including mean, standard deviation, kurtosis and skewness. The same table provides the percentage of endorsement, showing a tendency for higher agreement responses (7 – "totally agree," and 6 – "moderately agree," respectively).

Dimensionality

A CFA was performed to test the two-factor structure of the FaRE-SF-P consisting of Perceived Family Coping (Factor 1) and Communication and Cohesion (Factor 2) subscales. Goodness-of-fit indices of the general model have demonstrated good values and adequate fit for the study sample date, representing a two-factor structure: $\chi^2 = 12.6$; df = 53, $p = 1.00$; CFI = 1.00; TLI = 1.00; and RMSEA = 0.000. Furthermore, as presented in Figure 1, the two factors proved to be significantly positively correlated ($r = 0.97$, $p < 0.001$). Globally, in both factors, all items presented good local adjustment. In

TABLE 1 Demographic and clinical characteristics of the sample.

Demographic and clinical characteristics (*n*=147)	*n*	%
Age, mean (SD)	51.3	9.1
Age group		
≤40 y	16	10.9
41–50 y	59	40.1
51–60 y	47	32.0
>60 y	25	17.0
Missing data	2	1.2
Education		
Primary	4	2.7
Lower secondary	7	4.8
Higher secondary	25	17.0
Post-secondary non graduate	3	2.0
Graduate degree	108	73.5
Marital status		
Single/Engaged	17	11.6
Married	109	74.1
Divorced/widowed	21	14.3
Employment status		
Employed	112	76.2
Unemployed/housewife	19	12.9
Retired	16	10.9
Treatment		
Chemotherapy (CT)	79	53.7
Endocrine Therapy (ET)	68	46.3

Factor 1 – FaRE-PFC loadings ranged from λ = 0.76 (item 2 – "*We believe that we can manage the illness*") to λ = 0.91 (item 5 – "*We can work out the significant difficulties in our life such as this illness*"), while in Factor 2 – FaRE-CC loadings ranged from λ = 0.44 (item 7 – "*Everyone in the family feels free to express their own opinion regarding the illness*") to λ = 0.88 (item 3 – "*In our family we feel that we can talk about how to communicate between us*"). In fact, only item 7 had a loading near to the recommended minimum value of 0.40. However, we decided not to remove it, as our tested model presented an overall good fit to the data, that did not improve with exclusion of item 7 (data not shown).

Reliability

To assess internal consistency, we used the McDonald's omega and the Cronbach's alpha. Perceived Family Coping (Factor 1) showed an excellent reliability (ω = 0.92, 95% CI = 0.90–0.94; α = 0.89, 95% CI: 0.85–0.91). Corrected item-total correlations ranged from 0.77 to 0.87 and the internal consistency values decreased with removal of any item (Table 2). Communication and Cohesion (Factor 2) also presented excellent values of reliability (ω = 0.92, 95% CI = 0.90–0.94; α = 0.91 95% CI: 0.89–0.93). As depicted in Table 2, corrected item-total correlation coefficient values ranged between 0.68 and 0.85, with internal consistency remaining stable or decreasing with removal of any item.

Construct validity

Analysis of the Pearson's correlation coefficient (*r*) of the FaRE-PFC and the FaRE-CC with other constructs, to test convergent and divergent validity, are described in Table 3. Regarding convergent validity, both FaRE-PFC and FaRE-CC had weak but significant positive correlations with the MOS-Emotional Support (FaRE-PFC: $r = 0.37$, $p < 0.001$; FaRE-CC: $r = 0.35$, $p < 0.001$), the MOS-Instrumental Support (FaRE-PFC: $r = 0.32$, $p < 0.001$; FaRE-CC: $r = 0.35$, $p < 0.001$) and the Social Functioning scale from the EORTC QLQ-C30 (FaRE-PFC: $r = 0.25$, $p < 0.01$; FaRE-CC: $r = 0.28$, $p < 0.001$). For divergent validity, weak but significant negative correlations were found between FaRE subscales and the HADS-Total score (FaRE-PFC: $r = -0.37$, $p < 0.001$; FaRE-CC: $r = -0.31$, $p < 0.001$), HADS – Depression (FaRE-PFC: $r = -0.37$, $p < 0.001$; FaRE-CC: $r = -0.31$, $p < 0.001$), and HADS – Anxiety (FaRE-PFC: $r = -0.29$, $p < 0.001$; FaRE-CC: $r = -0.26$, $p < 0.001$).

Perceived family coping and communication and cohesion in different groups of treatments across time

Mean scores of the FaRE – PFC and the FaRE – CC in our global sample are presented in Table 4.

Mixed-models analysis were performed to assess the effect of type of treatment (CT or ET) and study time points (baseline, M6 and M12) on FaRE – PFC and FaRE – CC scores. Statistically significant effects were not found in FaRE – PFC for oncological treatment ($F_{(1,78)} = 0.98$, $p = 0.33$), time point of assessment ($F_{(2,\ 156)} = 0.30$, $p = 0.74$), nor the interaction between the two factors ($F_{(2,66)} = 1.88$, $p = 0.16$), suggesting that patient's perceived family coping does not vary depending on the treatment nor on time (Figure 2). Similar results were found for the FaRE – CC scores: no significant differences depending on treatment ($F_{(1,78)} = 3.05$, $p = 0.08$), time point of assessment ($F_{(2,156)} = 0.86$, $p = 0.43$), nor the interaction between the two ($F_{(2,64)} = 1.15$, $p = 0.32$). These results suggest that family communication and cohesion seems to be relatively stable over time and similar between types of treatment, as illustrated in Figure 3.

Discussion

The purpose of this study was to translate and culturally adapt and validate the Portuguese version of the FaRE-SF (FaRE-SF-P) for patients with early breast cancer. To the best of our knowledge, this is the first study validating the short version of the FaRE (Faccio et al., 2019). We demonstrate that the FaRE-SF-P is a valid measure to assess family resilience in this population, with good reliability and construct validity, and a two-factor structure reflecting Communication and Cohesion, and Perceived Family Coping subscales. Furthermore, we found that FaRE-SF-P subscales scores are stable over 1 year and did not differ between patients who underwent different types of systemic oncological treatment (CT and ET).

Our study assessed the psychometric properties of the FaRE-SF-P scale in a sample comprised by women with breast cancer, with an equivalent patient population also included in the validation study of the original FaRE scale (Faccio et al., 2019). Compared with the original full version of FaRE (Faccio et al., 2019), the FaRE-SF maintains the 'perceived family coping' and the 'communication and

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TABLE 2 Individual FaRE item summaries and reliability parameters.

Item	Statistics			Percentage of endorsement								Reliability		
	M (SD)	Sk	Ku	1	2	3	4	5	6	7	Total	Item-total correlation	α if item deleted	ω if item deleted
1	6.15 (1.35)	−2.17	4.58	2.0	2.0	2.7	4.1	4.8	29.9	54.4	100	0.76	0.90	0.91
2	6.32 (1.05)	−2.13	5.19	0.0	2.0	0.7	4.1	6.8	29.3	57.1	100	0.77	0.85	0.91
3	6.25 (1.20)	−2.45	7.09	2.0	0.7	1.4	2.7	8.8	28.6	55.8	100	0.85	0.89	0.90
4	6.48 (1.04)	−3.14	12.02	1.4	0.7	0.0	3.4	3.4	23.1	68.0	100	0.80	0.90	0.91
5	6.45 (1.08)	−3.27	12.76	2.1	0.0	0.7	2.7	2.1	27.4	65.1	100	0.82	0.87	0.87
6	6.06 (1.40)	−2.16	4.54	2.7	2.7	2.0	2.0	8.2	33.3	49.0	100	0.77	0.90	0.91
7	6.60 (0.89)	−3.09	12.50	0.7	0.0	0.7	2.0	6.8	13.6	76.2	100	0.57	0.91	0.92
8	6.42 (0.88)	−2.48	10.03	0.7	0.0	0.0	3.4	5.4	33.3	57.1	100	0.80	0.86	0.90
9	6.46 (0.89)	−2.18	5.81	0.0	0.7	0.7	3.4	5.4	27.2	62.6	100	0.70	0.91	0.92
10	6.23 (1.19)	−1.88	3.59	0.7	1.4	0.7	9.5	5.4	23.8	58.5	100	0.68	0.91	0.92
11	6.50 (0.85)	−2.65	10.04	0.0	1.4	0.0	2.0	3.4	33.3	59.9	100	0.81	0.85	0.90
12	6.63 (0.72)	−2.05	3.68	0.0	0.0	0.0	2.7	6.1	17.0	74.2	100	0.73	0.91	0.91

For each item of the FaRE scale, the mean (M), standard deviation (SD), and the percentage of endorsement for each possible item score (range 1–7) is presented. Sk = Skewness; Ku = Kurtosis; α if item deleted = Cronbach's α if item deleted; ω if item deleted = McDonald's ω if item deleted.

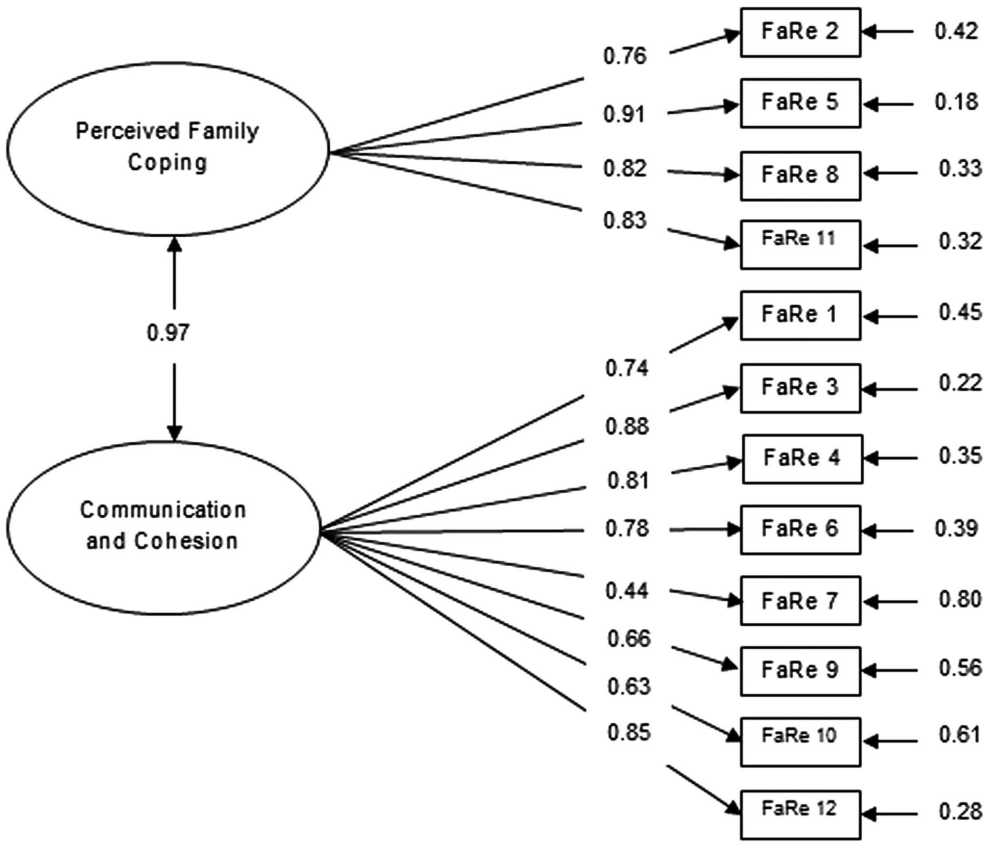

FIGURE 1
Confirmatory factor analysis of the FaRE two-factor model (Faccio et al., 2019) with standardized parameter estimates and measurement errors, in a sample of Portuguese women with breast cancer.

cohesion' subscales, excluding the 'perceived social support' and the 'religiousness and spirituality' subscales. The purpose of using a short form of the FaRE scale was to have a brief tool focusing mainly on the involvement of the family in problem solving and decision-making, as well as in the ability to rebound from a stressful life event, while keeping good psychometric properties. The excluded subscales focused more on family instrumental support and on the spiritual component of resilience, with the latter obtaining the lower percentage

of variance on the FaRE total scale in the initial validation study (Faccio et al., 2019).

In our study, the CFA presented good evidence to support factorial validity, with a two-factor structure consisting of 'Perceived Family Coping' and 'Communication and Cohesion' providing excellent goodness-of-fit indices values, slightly better than the ones obtained in the FaRE original development and validation study with the four-factor structure (Faccio et al., 2019). In both subscales, no items with severe misfit were found. In terms of structural weights of the items, all had higher loadings than the recommended value of 0.40, with only item 7 from the FaRE – CC subscale ("*Everyone in the family feels free to express their own opinion regarding the illness*") having a borderline loading value. Analyzing its content, item 7 is more related with the expression of personal opinions in a family context. The linguistic formulation of the remaining items seems to be more focused on a collective response or action (e.g., item 6 "*We think about the illness-related problems until we find a shared solution*"), which can explain this result. However, we decided to retain item 7 since it achieves the minimum recommended value for inclusion, the internal consistency of the scale did not improve with its removal and, furthermore, our model showed an overall very good fit. Regarding reliability, Cronbach's α coefficient and McDonald's ω were all above 0.89 in both FaRE – PFC and FaRE – CC subscales, which indicates high internal consistencies. Both subscales confirmed a good reliability which is aligned with the original FaRE version, where FaRE – PFC obtained a Cronbach's α of 0.82 and FaRE – CC had a Cronbach's α of 0.88 (Faccio et al., 2019).

Likewise, the construct validity of the FaRE-SF-P was supported in our sample of women with breast cancer. Indeed, both the FaRE-PFC and the FaRE-CC correlated significantly and positively with emotional and instrumental support (mMOS), as well as with social functioning (EORTC), thus supporting convergent validity. Moreover, they correlated significantly and negatively with distress, depression and anxiety measurements (HADS), therefore supporting divergent validity. Although these correlations were weak, they were statistically significant and had the expected directionality. There is no previous evidence of divergent validity of this scale. However, regarding convergent validity, the original FaRE authors tested the association between the total scale with another measure of resilience – the Resilience Scale for Adults (RSA; Bonfiglio et al., 2016) in their validation study (Faccio et al., 2019), confirming significant positive correlation (rho = 0.43, $p < 0.0001$). Specifically, the FaRE – PFC showed a significant positive weak correlation with RSA perceived family coping subscale (rho = 0.30, $p < 0.0001$), and the FaRE – CC demonstrated a significant positive moderate correlation with family cohesion from the RSA (rho = 0.56, $p < 0.0001$) (Faccio et al., 2019). As convergent validity of the FaRE subscales was already proved with a measure of resilience (RSA), in our study, we decided to use measures related to family resilience, but not necessarily measuring the same construct. As expected, patients with higher levels of perceived family coping, capable of communicating among them, and with a sense of family cohesion, have more emotional and instrumental social support and better social function. On the other hand, our findings are consistent with previous research that demonstrated that higher levels of resilience, even not specifically related to the family context, were associated with lower levels of depression and anxiety in patients with cancer (Min et al., 2013).

To summarize, in comparison with the original version of the scale (Faccio et al., 2019), the FaRE-SF-P conserved good psychometric properties, namely regarding reliability and the construct validity. Despite not having the same factor structure, which is expected since the FaRE-SF-P is a short version of the original scale, the two-factor structure comprising 'Perceived Family Coping' and 'Communication and Cohesion' subscales have slightly better goodness-of-fit indices values than the four-factor structure of the original FaRE scale (Faccio et al., 2019). Furthermore, these two subscales had good reliability both in the FaRE-SF-P and the original scale (Faccio et al., 2019), reflected, respectively, by a Cronbach's α of 0.82 and 0.89 for the Perceived Family Coping subscale, and a Cronbach's α of 0.88 and 0.91 for the

TABLE 3 Correlations between FaRE-SF-P subscales and other psychometric measures to assess construct validity.

	FaRE – perceived family coping	FaRE – communication and cohesion
mMOS – EMOTIONAL support	0.37**	0.35**
mMOS – Instrumental support	0.32**	0.35**
EORTC – Social Functioning	0.25*	0.28**
HADS – Total Score	−0.37**	−0.31**
HADS – Depression	−0.37**	−0.31**
HADS – Anxiety	−0.29**	−0.26*

Pearson's product moment correlation coefficient used as correlation measure.
FaRE-SF-P = family resilience questionnaire – short form; mMOS = modified medical outcomes study social support survey; EORTC = European Organization for Research and Treatment of Cancer Core Quality of Life Questionnaire; HADS = Hospital Anxiety and Depression Scale.
**$p < 0.001$; *$p < 0.01$.

TABLE 4 FaRE subscale scores at different time of assessments in the global sample and in both the chemotherapy and endocrine therapy treatment groups.

	Global sample			Chemotherapy sample			Endocrine therapy sample		
	N	Range	M (SD)	*N*	Range	M (SD)	*N*	Range	M (SD)
FaRE – PFC									
Baseline	146	9–28	25.8 (3.1)	78	13–28	25.8 (3.0)	68	9–28	25.7 (3.3)
6 Months from baseline	122	7–28	25.7 (3.2)	65	7–28	25.1 (3.7)	57	18–28	26.4 (2.4)
12 Months from baseline	116	7–28	25.5 (3.4)	62	15–28	25.2 (3.4)	54	7–28	25.8 (3.5)
FaRE – CC									
Baseline	147	15–56	50.9 (7.0)	79	15–56	50.4 (7.5)	79	21–56	51.4 (6.4)
6 Months from baseline	120	14–56	50.8 (6.4)	65	14–56	49.3 (7.7)	55	40–56	52.5 (3.8)
12 Months from baseline	115	20–56	50.3 (7.3)	62	23–56	49.3 (8.1)	53	20–56	51.4 (6.2)

FaRE – PFC = family resilience questionnaire, perceived family coping subscale; FaRE – CC = family resilience questionnaire, communication, and cohesion subscale.

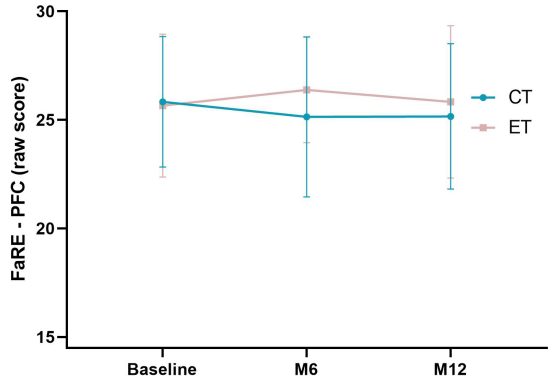

FIGURE 2
Mixed-models of the FaRE – PFC scores in both chemotherapy (CT; blue line) and endocrine therapy (ET; pink-gray line) in the three time points of the study (baseline, M6 and M12). Error bars represent the standard deviation.

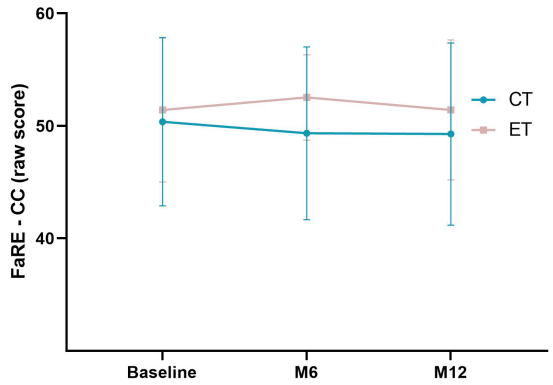

FIGURE 3
Mixed-models of the FaRE – CC scores in both chemotherapy (CT; blue line) and endocrine therapy (ET; pink-gray line) in the three time points of the study (baseline, M6 and M12). Error bars represent the standard deviation.

Communication and Cohesion subscale. Convergent validity was assessed with different measures and both FaRE-SF-P and FaRE (Faccio et al., 2019) subscales had significant, yet weak, correlations with measures related to the construct of interest.

Furthermore, we found that perceived family coping and family communication and cohesion are stable over time and are similar between the two different systemic treatment groups (CT or ET). Family resilience was assessed in women with breast cancer starting approximately 3 months after initiating systemic treatment. As treatment phases can be characterized by distinct levels of uncertainty, differences across time in family resilience could be hypothesized. However, these results suggest that some of the family resilience processes that facilitate adaptation to cancer care (Faccio et al., 2018), such as the ability to activate coping strategies to deal with an illness within the family, or the family's openness in communicating about this stressful event, are stable in time and do not differ between the different systemic treatment groups. In fact, the levels of resilience found shortly after diagnosis seem to remain stable across time, suggesting that family resilience may support the dynamic process in which patients and their families adapt coping strategies towards the ongoing challenges and uncertainty of cancer diagnosis and treatment. Therefore, the FaRE-SF-P proved to be a temporally reliable measure, applicable to patients with breast cancer independently of the type of systemic treatment or the phase of diagnosis and treatment. Importantly, as recommended by the original authors (Faccio et al., 2019), after testing the responsiveness of FaRE-SF-P to changes over 1 year, we can support its use as a psychoemotional tool in the course of cancer diagnosis and treatment.

Considering the aspects mentioned above, the FaRE-SF-P seems to have several benefits worth noting, that confirm its usefulness as a practical assessment tool of family resilience in the oncological setting. First, in the adaptation process, we followed a methodology based on international test commission guidelines ["ITC Guidelines for Translating and Adapting Tests (Second Edition)," Bartram et al., 2018], as well as the suggested quality criteria of health status questionnaires (Terwee et al., 2007), and of assessment tools in oncological settings (Tian et al., 2019). Second, the FaRE-SF-P has the advantage of being a short measure composed by 12 items with similar or better psychometric properties than other construct-related measures, such as the FRAS with 54 items (Sixbey, 2005), the FRA with 29 items (Duncan Lane et al., 2017), the WFRQ with 32 items (Walsh, 2016), and even the original FaRE (Faccio et al., 2019). The availability of a valid brief family resilience measure presents an opportunity to reduce patient burden in the oncological setting. Importantly, the FaRE-SF-P maintains the overall Walsh's family resilience conceptual framework for functional adaptation of the whole family system to perceived adversity, with the exception of the spirituality component (Walsh, 2021). Previous evidence confirmed that family resilience has direct and indirect effects on quality of life and caregiver burden in patients with breast cancer (Li et al., 2019). Thus, the use of a reliable and valid measure of family resilience developed specifically for patients with cancer such as the FaRE-SF-P could help to develop prevention and intervention strategies, as has been highlighted by some authors (Hawley, 2000; Walsh, 2021). It is plausible that family resilience assessed by FaRE-SF-P might enable the prediction of affective symptoms, which could guide early referral to psychological and psychiatric consultations. This is emphasized by previous research indicating that families who struggle to activate resilience processes in face of a diagnosis of cancer tend to have increased levels of distress and higher risk of developing psychosocial problems (Weihs and Reiss, 1996; Kazantzaki et al., 2018). On the other hand, if there are difficulties in shared communication, problem-solving, emotional expression and mobilization of coping strategies, clinicians could develop specific interventions, supporting the patient and their family to develop their own meaning of the illness and integrating it in the family narrative.

Nevertheless, this study is not free from limitations. One is that we based our comparisons with results obtained in the validation study of the FaRE total scale. Even though FaRE and FaRE-SF-P share two subscales, comparisons should be cautious as different scales were applied to different populations of two distinct countries (Italy and Portugal). However, since there are no validation studies of the FaRE-SF-P, we believe it is important to have an overview of the differences and similarities between the psychometric properties of these two scales. Second, our sample size could be considered insufficient to power performance of a CFA. Even though we achieved the minimum necessary sample size condition for variables-to-factor ratio (Mundfrom et al., 2005), multigroup comparisons between oncological treatment types was not possible. Moreover, it was not possible to do a sample size calculation before the data collection once this study was performed under another multicenter study with a different aim. On the other hand, as FaRE-SF-P measures family resilience, it could be interesting to include a group of family members of patients with cancer to compare not only the psychometric properties between samples but also to assess

the level of agreement between members regarding their resilience level, in line with the work developed by the original authors of the FaRE (Faccio et al., 2019). Finally, here we validated the FaRE-SF-P in a very specific population comprised by patients with early breast cancer. Despite the lack of significant differences between patients with breast cancer and patients with prostate cancer in the FaRE total scale validation reported by Faccio et al. (2019), it could be important to assess FaRE-SF-P psychometric properties in samples of patients with other tumor types and stages. Future studies should address this question by further validating the short form of the FaRE to different countries and to other clinical samples so healthcare professionals can properly assess family resilience and integrate this information in their specific oncological clinical practice.

In conclusion, we have demonstrated that the Portuguese version of the FaRE-SF is a reliable and valid measure of family resilience in patients with breast cancer, with a two-factor structure reflecting perceived family coping and family communication and cohesion. This study offers significant implications for both researchers and clinicians. The availability of a culturally validated instrument of family resilience, with good psychometric properties, will allow a better understanding of the importance of this construct in patients with cancer, as well as its impact on symptom burden, which should be addressed by further research. On the other hand, due to its brevity, the FaRE-SF-P can easily be included in oncological clinical practice without being significantly time consuming neither for the patient nor for the clinician.

Data availability statement

The datasets presented in this article are not readily available because they belong to the BOUNCE Project Consortium. Requests to access the datasets should be directed to AO-M, albino.maia@neuro.fchampalimaud.org.

Ethics statement

Study procedures and protocol were reviewed and approved by the Ethics Committee of the Champalimaud Foundation. Patients provided written informed consent to participate in this study.

Author contributions

SA, RL, BS, and AO-M conceived and designed the work. RL and DF were responsible for the translation process of the FaRE scale. DF, BC, and BS acquired the data, including assessment of eligibility criteria of patients participating in the study. SA, RL, and AO-M analyzed and interpreted data. SA and BS extracted clinical and demographic data with input from RL, and AO-M. JG, TM, and AO-M supervised and validated the work. SA, DR, and AO-M drafted the manuscript, which was critically revised by the remaining authors for important intellectual content. AO-M supervised the research and acts as corresponding author. All authors contributed to the article and approved the submitted version.

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Conflict of interest

AO-M was national coordinator for Portugal of a non-interventional study (EDMS-ERI-143085581, 4.0) to characterize a Treatment-Resistant Depression Cohort in Europe, sponsored by Janssen-Cilag, Ltd. (2019–2020), and of trials of psilocybin therapy for treatment-resistant depression, sponsored by Compass Pathways, Ltd. (EudraCT number 2017-003288-36) and of esketamine for treatment-resistant depression, sponsored by Janssen-Cilag, Ltd. (EudraCT NUMBER: 2019-002992-33). He is also recipient of a grant from Schuhfried GmBH for norming and validation of cognitive tests.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Exosomes may be the carrier of acupuncture treatment for major depressive disorder

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The incidence of major depressive disorder (MDD) is increasing all over the world. There is a great need for complementary or alternative therapies with high safety, few side effects, and precise efficacy to care for MDD. In China, acupuncture has significant laboratory data and clinical trials to demonstrate its antidepressant efficacy. However, there is no clear answer as to how it works. Exosomes are membranous vesicles that rely on cellular multivesicular bodies (MVBs) fused to the cell membrane for release into the extracellular matrix. Almost all cell types are capable of producing and releasing exosomes. As a result, exosomes contain complex RNAs and proteins from their relatives (Cells that secretes exosomes). They can cross biological barriers and participate in biological activities, such as cell migration, angiogenesis, and immune regulation. These properties have made them a popular research topic. Some experts have suggested that exosomes may serve as delivery vehicles for acupuncture to work. This presents both an opportunity and a new challenge for improving the protocols of acupuncture as a treatment for MDD. To better define the relationship between MDD, exosomes, and acupuncture, we reviewed the literature from the last few years. Inclusion criteria included randomized controlled trials and basic trials evaluating acupuncture in the treatment or prevention of MDD, the role of exosomes in the development and progression of MDD, and the role of exosomes in acupuncture. We believe that acupuncture may affect the distribution of exosomes *in vivo*, and exosomes may be a new carrier for acupuncture treatment of MDD in the future.

KEYWORDS

acupuncture, exosomes, major depressive disorder, Traditional Chinese Medicine (TCM), alternative therapies, opportunity, mechanism, antidepressant

1. Introduction

Major depressive disorder is an affective disorder mainly characterized by depressive mood (Malhi and Mann, 2018). It is also a heterogeneous condition with different clinical presentations, severity, and longitudinal course (Herrman et al., 2022), such as depressed mood, slowed thinking, and reduced volitional behavior (Tandon, 2014). Its pathogenesis is influenced by multiple factors, such as genetic (Feurer et al., 2022), environmental (van den Bosch and Meyer-Lindenberg, 2019), and psychological (Fu et al., 2021). As neuronal activity is governed by synaptic inputs from excitatory or inhibitory neural circuits, the impairment of neural circuits involved in emotion, cognition (Price and Drevets, 2012), and synaptic plasticity (Duman et al., 2016) is often considered as the "main culprit"

for the development of MDD. For example, some studies have found that MDD patients have overactivation of the amygdala and the prefrontal cortex, which are involved in the processing of negative emotions. This results in poor cognitive regulation of emotions and a tendency to process negative information related to the self (Seo and Oemisch, 2020; Asede et al., 2022; Rolls et al., 2023). The hippocampus, the most central region responsible for learning, emotion, and cognitive functions, has decreased density, reduced dendrites, and neuronal necrosis. Atrophy of the hippocampal region directly corresponds to memory loss, cognitive decline, and depressed mood states (Sheline et al., 2019; Du et al., 2021). In contrast, hippocampal synaptic remodeling is mainly dependent on rapid mitochondrial bursting and fission processes (Divakaruni et al., 2018). As well as it requires continuous mitochondrial production of ATP and Ca^{2+} (Cardanho-Ramos and Morais, 2021)and high sensitivity to mitochondrial transport damage (Tseng et al., 2015; Course et al., 2017). This mechanism of occurrence may be the result of the activation of several signaling cascades. Among them, adenosine monophosphate-activated protein kinase (AMPK) is an important protein kinase for the sensory energy state of the cell and is the master switch for cellular energy metabolism. AMPK activity is susceptible to stress (Hardie et al., 2012; Grahame Hardie, 2014). It has been clearly shown that AMPK activity reduction is involved in the control of depressive behavior (Odaira et al., 2019; Nakagawasai et al., 2020). Moreover, the aging process of organisms is often accompanied by a downregulation of AMPK activity, which tends to be higher in young animals than in older ones (Burkewitz et al., 2014). This explains to some extent why menopausal populations are more likely to suffer from MDD. Mitochondrial damage may be a common theme of research in other psychiatric disorders. In addition, MDD patients also have abnormalities in the neuro-endocrine-immune network system, particularly activation of the neuroinflammatory response and hyperactivity of the hypothalamic-pituitary-adrenal (HPA) axis, with crosstalk between them (Zunszain et al., 2011; Kim et al., 2016). Immune cells, such as monocytes, macrophages, lymphocytes, and dendritic cells, can secrete a series of pro-inflammatory cytokines interleukin-6 (IL-6), IL-1β, and tumor necrosis factor-α (TNF-α), which affects the neural circuitry of emotion and cognition. These cytokines are involved in the initiation, recurrence, and progression of MDD (Young et al., 2014; Adzic et al., 2018). Besides, many other pathogenic hypotheses have been proposed, such as impaired neurogenesis (Du Preez et al., 2022), decreased neurotrophic factors (Lee et al., 2022), oxidative stress (Bhatt et al., 2020), brain-gut axis disorders (Gheorghe et al., 2022), and decreased monoaminergic neurotransmitters (Joca et al., 2015); triggering one of these may cause a cascade of responses affecting the cerebral cortex (**Figure 1**).

However, suitable and satisfactory cures for these cascade problems have not been found in clinical practice. Not only that, but the rate of relapse and comorbidity of MDD is increasing. In 2008, the World Health Organization (WHO) listed MDD as the third most burdensome disease in the world and estimated that it will rank first by 2030 (Walton et al., 2006). Plus, with the spread of the COVID-19 pandemic, the likelihood of suffering from MDD has increased significantly in different occupational groups (Lokman and Bockting, 2022; Steen et al., 2022), such as COVID-19 survivors (Mazza et al., 2022), healthcare workers (Aoun et al., 2021; Moro et al., 2022), and self-quarantined people (Nantaayi et al., 2022) around the world. Besides, MDD occurs not only as a primary disease alone, but also merges with other underlying diseases, including perimenopause (Rudzinskas et al., 2021), puerperium (Zeng et al., 2022), stroke (Zhou et al., 2022), diabetes (Bakker et al., 2022), Parkinson's disease (Xie et al., 2022), epilepsy (Aimaier et al., 2022), hepatitis (Gupta et al., 2020), gastritis (Eustis et al., 2022), and brain cancer (Nazli and Sevindik, 2022), as well as promotes the pathological development of the above diseases in turn. Thus, its occult pathogenesis features can easily lead to misdiagnosis (Kostaras et al., 2017). There are also adverse reactions to antidepressants (Uher et al., 2009), low patient compliance (Khalifeh and Hamdan-Mansour, 2021), withdrawal symptoms (Kendrick, 2021), drug resistance (Touloumis, 2021), and many other issues, which force us to find supplementary or alternative therapies with high safety, few side effects, and accurate curative effects.

Acupuncture has good efficacy and few side effects in the treatment of MDD (Armour et al., 2019; Yang et al., 2022). This can be strongly evidenced by the regulation of neurotransmitters, intestinal flora (Li P. et al., 2021), neuroplasticity (Li X. et al., 2020), inflammation (Kwon et al., 2012), and other molecular mechanisms, all of which explain its antidepressant effect. Acupuncture has a history of thousands of years. Its operating principle is to correct the imbalance of yin and yang in the body by piercing fine needles into specific acupoints according to the theory of the "eight-principles" and the concepts of "Zang-fu" and "meridians and collaterals" syndrome differentiation. However, many principles are based on traditional Chinese anatomy and philosophy, rather than Western neurophysiology and anatomy, so it is difficult to integrate Chinese and Western medicine and limit the transformation of basic research on acupuncture into modern medicine (Smith et al., 2018). In recent years, exosomes have received much more attention, and current modern biological studies have begun to analyze their ability to assess the effectiveness of acupuncture for several diseases, such as emphysema (Zou et al., 2021), ischemic stroke (Zhang et al., 2020), and kidney disease (Klein and Wang, 2018). At the same time, this knowledge may inspire acupuncture to explore the mechanism of prevention and treatment of MDD by using exosomes as an application carrier. Thus, we summarize the relationship between MDD, exosomes, and acupuncture to provide some enlightenment for the development and innovation of acupuncture to treat MDD.

2. The background of exosomes and MDD

As a type of extracellular vesicle (EV), exosomes were first discovered in the supernatant of sheep erythrocytes cultured *in vitro* in the 1980s and can be secreted by various cells. However, exosomes have been often overlooked in the past because they are a superfluous membrane protein that is released to regulate membrane function during cell maturation or they act as an organelle that scavenges cell debris and knocks out cell surface molecules. After extensive research, in the mid-1990s, exosome-borne cargo was found to be involved in important physiological and pathological links, such as cell migration and

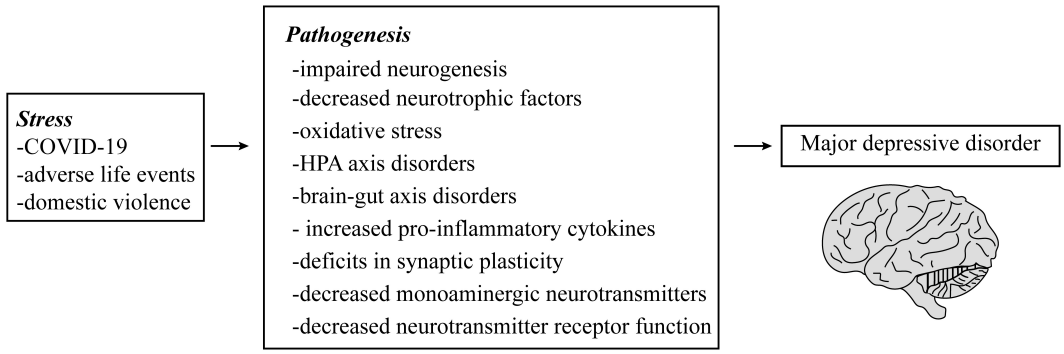

FIGURE 1
The possible pathogenesis of major depressive disorder (MDD).

differentiation, promotion of angiogenesis, modulation of the immune reactions, remission of the inflammatory response, and antitumor invasion. These are closely related to reproductive development, immune regulation, cardiovascular diseases, and neurological diseases, which have attracted the attention of many researchers (Mashouri et al., 2019; Nabariya et al., 2020). Exosomes measure approximately 40–150 nm in diameter, are released into the extracellular milieu by almost all mammalian cells in normal/abnormal stages, and are found in body fluids, such as tears, nasal secretions, saliva, blood, cerebrospinal fluid, amniotic fluid, and urine. Initially, the plasma membrane undergoes invagination and fusion to form early endosomes (ESEs), and then ESEs continue to develop into mature late endosomes (LSEs) and produce multivesicular bodies (MVBs). MVBs are intraluminal vesicles (ILVs) formed by the reinvagination of multiple LSEs, whose components come from endocytic and secretory (endoplasmic reticulum/Golgi) pathways into the lumen. Subsequently, a fraction of MVBs is transported to autophagosomes or lysosomes for degradation. The fusion of the remaining MVBs with the plasma membrane relies on exocytosis to release ILVs, which are then called exosomes (Kalluri and LeBleu, 2020; **Figure 2**). Furthermore, exosomes are heterogeneous and targeted, and their rate, size, and composition are highly dependent on the parental cell (Zhang et al., 2019). In particular, the composition has specific proteins, lipids, mRNA, and microRNAs (miRNAs), all of which are associated with the parental cell. Thus, exosomes are considered a mini-version of the parental cells. These substances are wrapped in exosomes and rely on circulatory pathways to reach neighboring cells and distant target cells, making them important players in intercellular signaling. At the same time, they are not only a biomarker for diagnosing pathology and prognosis, but also an important carrier for gene and drug delivery. Exosomes have great potential for clinical application and the development of innovative treatments (Zhang et al., 2015; Meldolesi, 2018). Moreover, some studies have demonstrated that the heterogeneity and targeting of exosomes can reflect the characteristics of acupuncture and meridian induction (Chen et al., 2015; Li N. C. et al., 2021), which also provides great support for this paper.

3. The role of exosomes in the development, diagnosis, and treatment of MDD

Recently, several studies showed that exosomes are involved in pathological processes, such as neurogenesis (Wei et al., 2020), neuroinflammation (Brites and Fernandes, 2015), and other pathological processes. They can be used as a source of depression-specific markers for the diagnosis and treatment of MDD. Due to the prominent ability of exosomes to modulate intercellular communication and transport across the blood-brain barrier (BBB) to help cellular transmission, neurogenesis, and synaptic plasticity in the central nervous system (CNS), scholars' interest in studying the relationship between exosomes and MDD has gradually increased.

3.1. Exosomes in the development of depression: Initiation and invasion in the brain

The bioactive proteins and microRNAs contained in exosomes can create a microenvironment that is conducive to the progression of MDD, thereby supporting the spread of other diseases. For example, insulin resistance not only leads to hyperglycemia but also promotes neuroinflammation, mitochondrial dysfunction, and neurogenesis, which are associated with human depression (Watson et al., 2021). Nasca et al. (2021) isolated brain-derived exosomes from the plasma of MDD patients by labeling L1 cell adhesion molecule^{+} (L1CAM^{+}) and then found that brain-derived L1CAM^{+} exosomes contained more insulin receptor substrate 1 (IRS-1). Moreover, elevated levels of IRS-1 were associated with suicide and anhedonia. The reason could be the impaired transport of insulin across the BBB, leading to the inhibition of the neuronal insulin signaling pathway and the accumulation of IRS-1 in exosomes. It is believed that insulin resistance (IR) in the brain may not only be the result of the development of mood disorders, but also the starting point of the development of mood disorders. Kuwano et al. (2018) suggested that some proteins related to neuroinflammation and synaptic function can travel from brain neurons to the peripheral blood with the help

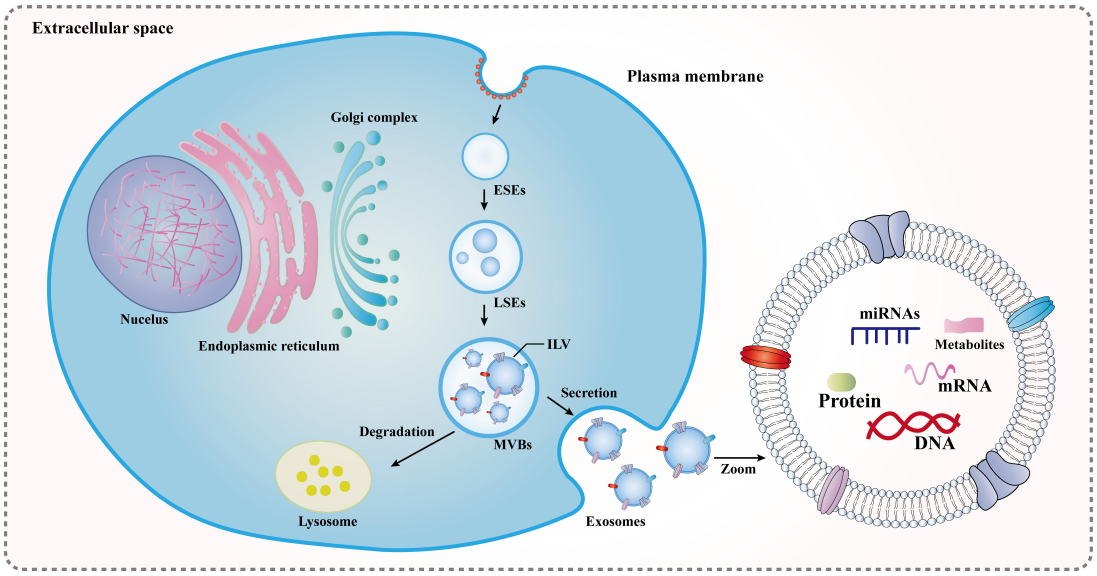

FIGURE 2
Formation mechanisms of exosomes: ESEs, early endosomes; LSEs, late endosomes; ILVs, intraluminal vesicles; and MVBs, multivesicular bodies. The plasma membrane undergoes invagination and fusion to form ESEs, and then ESEs continue to develop into mature LSEs and produce MVBs. MVBs are ILVs formed by the reinvagination of multiple LSEs, whose components come from endocytic and secretory (endoplasmic reticulum/Golgi) pathways into the lumen. Subsequently, a fraction of MVBs is transported to autophagosomes or lysosomes for degradation. The fusion of the remaining MVBs with the plasma membrane relies on exocytosis to release ILVs, which are then called exosomes.

of exosomes, which was experimentally demonstrated. The results showed that peripheral blood CD81 (neuron-derived exosomes) of MDD patients were indeed positively correlated with neuron-related blood biomarkers synaptophysin (SYP), tumor necrosis factor receptor (TNFR1), and interleukin 34 (IL-34), thus helping to objectively assess the severity of clinical depressive symptoms. Exosomes-derived proteins may play a role in initiation and invasion in the development of MDD.

In addition to specific proteins, microRNAs can also be packaged into exosomes to facilitate communication between neurons (Brites and Fernandes, 2015). Xian et al. (2022) found that the exosomes-derived miR-9-5p could transmit from neurons to microglia, resulting in microglial M1 polarization and neuronal reinjury. It also increased the release of proinflammatory cytokines, including IL-1β, IL-6, and tumor necrosis factor-alpha (TNF-α), thus exacerbating depressive symptoms in MDD mice. Fan et al. (2022) found that miR-146a-5p-containing exosomes derived from microglia could be a key factor in regulating hippocampal dentate gyrus (DG) neurogenesis *via* the krüppel-like factor 4/cyclin-dependent kinase like 5 (KLF 4/CDKL 5) pathway, and inhibited the proliferation and differentiation of NSCs during the pathogenesis of MDD. It can be considered a new crosstalk channel between glial cells and neurons. Luarte et al. (2017) also showed that astrocyte-derived miRNA-containing exosomes have potential regulatory effects on neurogenesis under stress conditions. Moreover, previous studies also demonstrated that the miRNA profiles of MDD rats were altered, when the expression levels of brain-derived neurotrophic factor (BDNF), tropomyosin receptor kinase B (TrkB), and synaptophysin 1 in serum exosomes were reduced in the serum exosomes of MDD rats. These differential expressions were related to the Mitogen-activated protein kinases (MAPK) pathway, Wnt pathway, and mammalian target of rapamycin (mTOR) pathway (Fang et al., 2020). It can be seen that the cargo carried by exosomes has the potential to initiate and slowly invade the emotional cognition field of the brain, thereby achieving the purpose of promoting the occurrence and development of MDD. Previously, Sakamoto et al. (2021) proposed a similar idea that alterations in circulating EVs might underlie social stress-induced behavior in mice. Chronic stress induces peripheral and intracerebral immune changes and inflammation, leading to neuropathies associated with psychiatric disorders such as MDD. Overall, although the above studies still require further exploration and validation, it is sufficient to indicate that exosomes carrying specific proteins and miRNAs are likely to be potential biomarkers to initiate and invade the emotional and cognitive domains of the brain. Ultimately, they can exacerbate the development of MDD.

3.2. Exosomes in the diagnosis and treatment of MDD: Enemies become friends

Despite various clinical interventions, including exercise, psychology, medication, etc., relapse of MDD remains very common. It was reported that MDD is more likely to recur after drug treatment is discontinued (Ebell, 2022). Moreover, MDD often accompanies various stages of other diseases. These diseases are latent and undiagnosed until the occurrence of some sort of physical injury leads to mortality or disability. Therefore, there is an urgent need for robust biomarkers that can accurately identify high-risk individuals or predict relapse, thereby helping to effectively guide diagnosis and treatment. However, it is important that exosomes are secreted from the early stage of MDD, and

the secreted cargo can eventually produce different effects due to different sources, opening up a new way for the diagnosis and treatment of MDD.

Being a negative agent, or an "enemy," is a promising diagnostic marker to inform the occurrence of MDD. Li L. D. et al. (2021) found that plasma exosomal has-miR-335-5p was significantly upregulated and plasma exosomal has-miR-1292-3p was significantly downregulated in patients with treatment-resistant depression (TRD). Go and KEGG analyses indicated that these changes were associated with postsynaptic density, axon formation, and cell growth signaling pathways. Liang et al. (2020) showed that serum exosome-derived miR-139-5p in patients with MDD could be used as a potential diagnostic biomarker.

As a positive agent, or a "friend," the exosome-derived content provides a direction for therapy. Clinical trials and animal experiments by Wei et al. (2020) also found the specific overexpression of hsa-miR-139-5p in the blood exosomes of MDD patients. When exosome-derived miR-139-5p from the blood of MDD patients was injected into normal mice, it caused depression-like behaviors and hippocampal neurogenesis impairment. However, when exosomes from blood that was taken from healthy people who do not suffer from MDD and intranasal treatment of miR-139-5p antagomir was injected into CUMS mice, it rescued depressive-like behaviors, inhibited neural stem cell (NSC) proliferation, and neuronal differentiation. This demonstrates that miR-139-5p, a negative regulator of NSC proliferation and neuronal differentiation, plays a role in MDD neurogenesis. A study by Wang et al. (2021) showed that injection of plasma exosomes from MDD patients could significantly improve the depression-like behavior of LPS-induced depression in mice. The mechanism may be to transmit sigma-1 receptors (Sig-1R) to the CNS, thereby improving the inflammatory response in microglia. Li P. et al. (2021) found that natural killer (NK) cell-derived exosomes carrying miR-207 targeted the leucine-rich repeat (Tril) interactor of toll-like receptor 4 (TLR4), inhibited nuclear factor-kappa B (NF-κB) signaling in astrocytes, and reduced the release of pro-inflammatory cytokines (IL-1β, IL-6, and TNF-α), to attenuate depression-like symptoms in CMS mice. Guo et al. (2020) showed that there was a minor expression of miR-26a in MDD, but exosomes derived from bone marrow mesenchymal stem cells (BMSCs) could increase the expression of miR-26a in corticosterone-induced depressed rats. Besides, superoxide dismutase (SOD) levels were increased, and malondialdehyde (MDA), lactate dehydrogenase (LDH), TNF-α, and IL-1β levels were reduced. Exosomes also promoted the proliferation of hippocampal neurons and inhibited apoptosis, thereby improving the damage of hippocampal neurons in depressed rats. Pusic et al. (2019) demonstrated that during environmental enrichment, progressively increasing interferon-gamma stimulation of dendritic cell-produced exosomes (IFNγ-DC-Exos) significantly improved myelination and reduced oxidative stress and susceptibility to diffuse depression disorder *in vivo* and *in vitro*. Gelle et al. (2021) found that serum exosomes from MDD patients taking antidepressants could help BDNF pass the BBB, resulting in increased BDNF levels, decreased pro-BDNF levels, and improved neuronal plasticity in the CNS. These exosome-wrapped cargoes are both enemies and friends, which can not only become promising diagnostic markers but also provide certain information and direction for treatment (reference **Table 1**).

4. Background role of acupuncture in MDD

Acupuncture is an integral part of Traditional Chinese Medicine (TCM). A significant number of clinical and basic research data have verified the safety and efficacy of acupuncture in the treatment of MDD and acupuncture has been recognized and widely applied in many countries. It can be used alone or in combination with drugs, especially when combined with antidepressants, not only to improve primary and secondary depressive symptoms but also to reduce the side effects of drug treatment (Xu M. M. et al., 2022). We have summarized the past decade of research on the possible mechanisms of acupuncture therapy (reference **Table 2**).

4.1. Regulating neuroplasticity

Chronic stress and depression-like behaviors have been implicated in impaired neuroplasticity, such as neuronal atrophy and synaptic loss in the medial prefrontal cortex (PFC) and hippocampus. However, Fan et al. (2016) found that electroacupuncture (EA) stimulation at Hegu (LI4), and Taichong (LR3) had the same effect as riluzole in improving neuroplasticity of chronic unpredictable stress (CUS) rats, including sucrose consumption, horizontal and vertical movement. Moreover, the level of glutamate and the synaptic soluble N-ethylmaleimide-sensitive factor attachment receptor (SNARE) complex-associated proteins and genes were all reduced [SNAP25, syntaxin1, vesicle-associated membrane protein 1 (VAMP1), VAMP2, and VAMP7]. Using the same acupoints, Luo et al. (2017) found that the antidepressant effect of EA may increase the level of glutamate transporter EAAT2 in glial cells. Jiang also found that LI4 and LR3 attenuated depression-like behaviors and protected the neuroplasticity of chronic unpredictable mild stress (CUMS) rats by upregulating the expression of α-amino-3-hydroxy-5-methyl-4-isoxazole-propionic AMPA receptor-related mRNA and proteins in the hippocampus, including GluR1, GluR2, Stargazin, Pick1, SYP, PSD-95, and GAP-43 (Jiang et al., 2020). Gao et al. (2021) observed that physostigmine could exacerbate depression-like symptoms in rats induced by CUMS. Instead, depression-like symptoms with body weight, latency feeding time, sucrose preference rate, horizontal and vertical activity frequency, and grooming frequency could be reversed thanks to EA stimulation at Baihui (GV20 or DU20), Yintang (GV29 or EX-HN3), LI4, and LR3 points. Furthermore, acetylcholine (ACh), acetylcholinesterase (AChE), spine density, and synaptic proteins [glutamate receptor 2 (GluR2), postsynaptic density protein 95 (PSD95), synapsin I] in the PFC were also reversed, resulting in an antidepressant effect.

4.2. Inhibiting stress-induced neuroinflammation

Neuroinflammation is an important factor in the development of depression. For example, repeated social stress activates

TABLE 1 The role of exosomes-derived cargoes in major depressive disorder (MDD).

Cargoes	Sample source	Expression	The effect of exosomes-derived cargoes change	References
L1CAM^{+}, IRS-1	DD patients' plasma exosomes	↑, ↑	These are associated with suicide and anhedonia.	Nasca et al., 2021
SYP, TNFR1, IL34	MDD patients' peripheral blood exosomes	↑	These are important blood biomarkers for patients with MDD	Kuwano et al., 2018
miR-9-5p	MDD patients' serum exosomes	↑	Promoted M1 polarization in microglia and enhanced the release of proinflammatory cytokines (IL-1β, IL-6, and TNF-α), and reactivated SOCS2-JAK/STAT3 pathways.	Xian et al., 2022
miR-146a-5p	CUMS rats' serum exosomes	↑	Regulated hippocampal DG neurogenesis *via* the KLF4/CDKL5 pathway and inhibited the proliferation and differentiation of NSCs	Fan et al., 2022
Synaptotagmin 1, BDNF, TrkB,	CUMS rats' serum exosomes	↓, ↓, ↓	By regulating the MAPK pathway, Wnt pathway, and mTOR pathway	Luarte et al., 2017
miR-335-5, miR-1292-3p	TRD patients' plasma exosomes	↑, ↓	By regulating postsynaptic density, axon formation, and cell growth signaling pathways	Li L. D. et al., 2021
miR-139-5p	MDD patients' serum exosomes	↑	Use as a potential diagnostic biomarker	Liang et al., 2020
miR-139-5p	MDD patients' blood exosomes	↑	Tail vein injection in normal mice induced depressive-like behavior and hippocampal neurogenesis impairment.	Wei et al., 2020
	Healthy volunteers' blood exosomes	–	Tail vein injection into CUMS mice (+ miR-139-5p antagomir) rescued depressive-like behaviors, inhibited NSC proliferation, and neuronal differentiation	
Sig-1R	MDD patients' plasma exosomes	↑	Transmit Sig-1R to the CNS, and improve the inflammatory response in microglia.	Wang et al., 2021
miR-207	NK cells-produced exosomes	↑	miR-207 targets TLR4 interactor with leucine-rich repeats (Tril), inhibits NF-κB signaling in astrocytes, decreases the release of pro-inflammatory cytokines in CMS mice	Li X. et al., 2020
miR-26a	BMSCs-produced exosomes	↑	miR-26a-BMSCs-Exos promotes the corticosterone-induced depressed rats' proliferation of hippocampal neurons and inhibits apoptosis, ↑SOD levels, ↓MDA, LDH, TNF-α, and IL-1β levels,	Guo et al., 2020
IFNγ	Dendritic cell-produced exosomes	↑	IFNγ-DC-Exos improves myelination and reduces oxidative stress and susceptibility to diffuse depression disorder *in vivo* and *in vitro*.	Pusic et al., 2019
–	MDD patients' serum exosomes	–	Helps BDNF pass the BBB, ↑BDNF levels, ↓pro-BDNF levels, and improves neuronal plasticity in the CNS.	Gelle et al., 2021

microglia in the medial PFC *via* the innate immune receptor TLR2/4. This triggers the expression of the inflammation-associated cytokine IL-1 and the tumor necrosis factor TNF, leading to neuronal atrophy and impaired responses in the medial PFC (Nie et al., 2018). Acupuncture of GV20 and GV29 ameliorated neuroinflammation in chronic restraint stress (CRS)-induced rats. The reason was the reversal of the high expression of ionized calcium-binding adaptor 1 (Iba1), TNF-α, and mobility group B1 (HMGB1) in the hippocampus (Chen et al., 2022). Another study showed that acupuncture at GV20 and Neiguan (PC6) significantly reduced nitric oxide (NO), inducible nitric oxide synthase (iNOS), prostaglandin E2 (PGE2), and epocloidase 2 (COX-2) levels, and also inhibited activation of NF-κB activity in CUMS-induced rats. It was suggested that the antidepressant-like effect of acupuncture therapy may happen through the regulation of NF-κB in the brain region to inhibit the secretion of inflammatory mediators (Lu et al., 2017).

4.3. Regulating neurotrophic factors

Neurotrophic factors affect the morphology and physiological function of neurons, especially the reduction of BDNF can inhibit the growth of neurons, and hinder the formation and stability of neuronal synapses and long-term potentiation in the brain (Castren and Monteggia, 2021). A study by Li et al. (2017) found that EA of GV20 and GV29 prevented hippocampal apoptosis, reversed the decline in Bcl-2 and growth-associated protein (GAP-43)

TABLE 2 The possible mechanism of the antidepressant effect of acupuncture.

Acupuncture points	Model	Species	Possible antidepressant mechanisms of acupuncture	References
LI4 and LR3	CUS	Male SD rats	↑Sucrose consumption, ↑horizontal and vertical movement, ↓glutamate, and ↓SNARE complex-related mRNA and proteins (VAMP1, VAMP2, VAMP7, SNAP25, and Syntaxin1)	Fan et al., 2016
LI4 and LR3	CUMS	Male SD rats	↑Sucrose consumption, ↑food intake, ↓latency, and ↑glial glutamate transporter EAAT2 in the hippocampus and PFC	Luo et al., 2017
LI4 and LR3	CUMS	Male SD rats	↑AMPA receptor-related mRNA and proteins (GluR1, GluR2, Stargazin, Pick1, SYP, PSD-95, and GAP-43)	Jiang et al., 2020
GV20, GV29, LI4, LR3+ Physostigmine	CUMS	Male SD rats	↑Body weight, ↑latency feeding time, ↑sucrose preference rate, ↑horizontal and vertical activity frequency, ↑grooming frequency, ↓ACh in the serum and prefrontal cortex, ↑AChE in the serum and prefrontal cortex, and ↑spine density and synaptic proteins in the PFC (BDNF, GluR2, PSD95, and synapsin I)	Gao et al., 2021
GV20 and GV29	CRS	Male SD rats	↓HMGB1 and Iba-1 in the hippocampus and ↓serum TNF-α	Chen et al., 2022
GV20 and PC6	CUMS	Male SD rats	↓NO, iNOS, COX-2, and PGE_2 NF-κB expression in the hippocampus and prefrontal cortex.	Lu et al., 2017
GV20 and GV29	CUMS	Male SD rats	↑Bcl-2, GAP-43, p-ERK/ERK, and BDNF in the hippocampus and prefrontal cortex	Li et al., 2017
DU20, EX-HN3, BL23, BL20, BL18, BL15, Ren4	SI	Male SD rats	↓Plasmatic CORT, ↑plasmatic T and E_2, and ↑hippocampal BDNF	Davila-Hernandez et al., 2021
DU23 and PC7	CUMS	Male SD rats	↓NO and cGMP pathway in the hippocampus and plasma (cGMP, NO, NR1, nNOS, iNOS, NR2A, and NR2B)	Huang et al., 2019
A: DU20; B: PC6, HT7; C: ST36, SP6, LR3	DD	Patients	↑GDNF in the serum	Sun et al., 2013
GV20, BL23, and SP6	PDD	KM female mice	↑T and E_2 in serum, ↓FSH and LH in serum, ↑5-HT, DA, and NE in the brain, ↑hypothalamic nerve cells, ↓the patina, synapses of the nerve in the hypothalamus	Guo et al., 2019
KI10, LR8, LU8, and LR4	CRS	Male C57BL/6 mice	Induced hippocampus, cingulate cortex, motor cortex, and thalamus activity, ↑5-HT1A receptor expression in the hippocampus, cingulate cortex, motor cortex, and thalamus, and ↑5-HT1B receptor expression in the cingulate cortex, motor cortex, and the thalamus.	Lee et al., 2019
GV20	MDD	Patients	Altered amygdala resting-state functional connectivity	Duan et al., 2020
RN12, RN10, RN6, RN4, KL17, ST24, and Qipang	MDD	Patients	Modulated resting-state functional connectivity of the amygdala by rs-fMRI	Wang et al., 2016
RN12, RN10, RN6, RN4, KL17, ST24, and Qipang	MDD	Patients	Modulated corticostriatal reward/motivation circuits by rs-fMRI	Wang et al., 2017c
GV20	MDD	Patients	↑The activation level of left PFC by fNIR, and ↑the correlation between activation of left dorsolateral PFC and acupuncture during executive function	Zhang et al., 2021
GV20 and EX-HN3	CRS	Male SD rats	It is related to inflammatory pathways, amino acid metabolism, and, especially TNF signaling pathway, NF-κB signaling pathway, and Toll-like receptor signaling pathway.	Wang et al., 2017a
GV20 and EX-HN3	CRS	Male SD rats	Inhibited the innate immune response and inflammatory response.	Wang et al., 2017b

expression, activated downstream targets of neurotrophin signal-regulated kinase (ERK) phosphorylation in the hippocampus and PFC, and increased ERK phosphorylation/ERK and BDNF expression. This suggested that chronic stress depression is regulated by the ERK signaling pathway and is ameliorated by EA. Davila-Hernandez et al. (2021) indicated that acupuncture at Du20,

Yintang (EX-HN3), Shenshu (BL23), Pishu (BL20), Ganshu (BL18), Xinshu (BL15), and Guanyuan (Ren4) exerted antidepressant-like effects by decreasing the express of corticosterone (CORT), increasing the level of testosterone (T) and estradiol (E_2) in plasma, and enhancing the level of hippocampal BDNF in socially isolated male rats. Huang et al. (2019) found that acupuncture at Shangxing (DU23) and Daling (PC7) exerted antidepressant effects by mediating nitric oxide (NO) and cyclic guanosine monophosphate (cGMP) signaling pathways in the CUMS rat model. A clinical study by Sun et al. (2013) found that EA at DU20 and Zusanli (ST36) group and Taichong (LR3), Sanyinjiao (SP6), Neiguan (PC6), and Shenmen (HT7) group were as effective in treating MDD as the fluoxetine group, and that EA was more advantageous in regulating the production of glial cell-derived neurotrophic factor (GDNF).

4.4. Regulating monoamine transmitters

Some studies have shown that persistent stress or brain dysfunction can lead to MDD by reducing the concentration and activity of monoamine neurotransmitters, including dopamine, norepinephrine, epinephrine, serotonin, and histamine. Drugs that increase the activity of monoamine neurotransmitters in the CNS or the concentration of intersynaptic gaps have the effect of improving mood and treating MDD. EA also had this effect. Guo et al. (2019) showed that EA at GV20, BL23, and SP6 could improve the activity and memory of PDD mice, improve sex hormone disorders in serum (elevated T and E2, FSH and LH decreased), increase the levels of monoamine transmitters (5-HT, NE, DA) in brain tissue, and improve the morphological changes of the hypothalamus. Lee et al. (2019) found that acupuncture at KI10, LR8, LU8, and LR4 alleviated depressive-like behaviors in CRS mice by regulating the hippocampus, cingulate cortex, motor cortex, and thalamus activity (considered as the specific area where acupuncture works). Furthermore, the level of serotonin receptors (5-HT1A and 5-HT1B) was also increased in the above brain areas. It is believed that the acupuncture-induced brain nerve activity and the selected acupoints determine the signaling pathways in the MDD brain region.

Additionally, we were able to analyze the relationship between acupuncture and MDD through brain imaging and high-throughput sequencing techniques. Through resting-state functional magnetic resonance imaging (rs-fMRI), Duan et al. (2020) found that the abnormal amygdala network in MDD patients could be improved by EA stimulation of GV20. Through rs-fMR, Wang also found that acupuncture at Zhongwan (RN12), Xiawan (RN10), Qihai (RN6), Guanyuan (RN4), Shangqu (KL17), Huaroumen (ST24), and Qipang (extra-point) not only modulated resting-state functional connectivity of the amygdala in MDD patients by rs-fMRI (Wang et al., 2016), but also therapeutically modulated corticostriatal reward/motivation circuits (Wang et al., 2017c). Using functional near-infrared spectroscopy (fNIR), Zhang et al. (2021) found that acupuncture at GV20 tended to enhance the activation of the PFC in patients with severe depression symptoms. Moreover, there was a correlation between the activation of the left dorsolateral PFC and acupuncture during the execution of acupuncture. Wang et al. (2017a),b explored the transcriptomic study of acupuncture GV20 and EX-HN3 on the frontal cortex and hippocampus of CRS rats by RNase sequencing (RNA-seq) technology. The results indicated that the antidepressant mechanism is related to regulating the frontal cortex, amino acid metabolism, and inflammatory pathways, especially toll-like receptor signaling, TNF, and NF-B signaling. These are all associated with the suppression of hippocampal stress-induced activation of innate immune responses and inflammatory responses. The above illustrated the effectiveness of acupuncture in regulating MDD, which has great clinical development value.

5. The development of acupuncture in exosomes: Whether the cause can be cured

Acupuncture has an incredible appeal: it is simple, convenient, inexpensive, clinically useful, and brings immediate effects. These features make acupuncture widely recognized and used worldwide. MDD is one of the specific diseases that can be treated by acupuncture. This form of treatment can be used alone or in

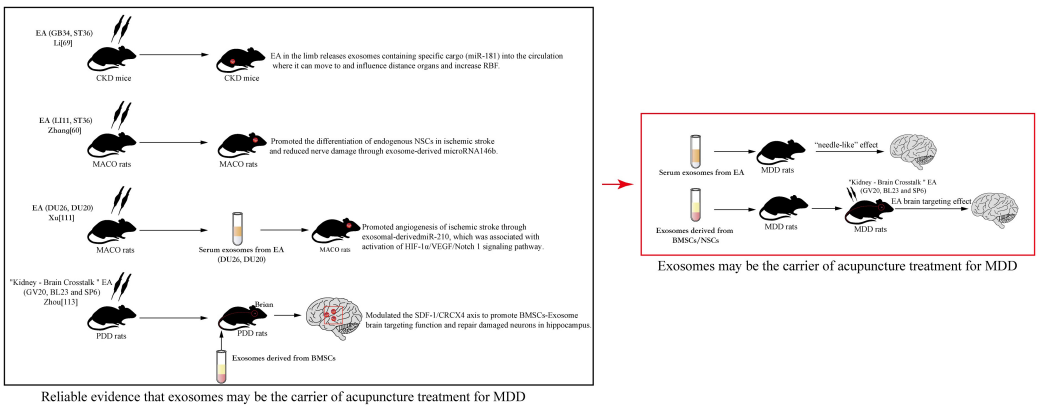

FIGURE 3
Reliable evidence that exosomes may be the carrier of acupuncture treatment for major depressive disorder (MDD).

combination with TCM and Western medicine to alleviate MDD (Li et al., 2019). However, acupuncture is a form of physiotherapy that is so limited in terms of innovative development that it is less advanced in terms of basic research and clinical practice when compared, for example, to natural drugs. Currently, with the increased interest in exosomes and the emergence of the latest medical evidence, scholars have noted that exosomes can serve as modern biological carriers for the transformation of acupuncture effects. Li N. C. et al. (2021) proposed that serum exosomes are expected to develop into "acupuncture network drugs." The reason being that acupuncture has its own network biology, and injecting exosomes that have been intervened by acupuncture into the body would have a "needle-like" effect. It was shown that exosomes derived from live cells after acupuncture intervention had low immunogenicity and could carry various active ingredients, so there is a possibility of exosomes being developed as "acupuncture network drugs." It was also reported that exosomes derived from mast cells at stimulated acupoints activated neuroimmunomodulation and participated in local network activity caused by acupoint stimulation (Chen et al., 2015, 2017). To the best of our knowledge, there are no studies that explore MDD treated by acupuncture from an exosomes perspective, but we can draw insight from a few other studies. Klein and Wang (2018) found that acupuncture with low-frequency electrical stimulation at GB34 and ST36 stimulation increased miR-181 levels of serum exosomes derived from mice with chronic kidney disease (CKD) and targeted suppression of angiotensinogen to raise renal blood flow (RBF). Other studies identified that EA (LI11 and ST36) could not only promote the differentiation of endogenous NSCs in ischemic stroke, but also reduced nerve damage through exosome-derived microRNA146b, providing essential new insights into the ability of acupuncture to exert neuromechanical regulation through brain-derived exosomes (Zhang et al., 2020). Similar studies also showed that EA at Renzhong (DU26) and DU20 treatment could promote angiogenesis of ischemic stroke through exosomal-derived miR-210, which was associated with activation of the HIF-1α/VEGF/Notch 1 signaling pathway (Xu S. Y. et al., 2022). In addition, exosomes have the potential for non-invasive therapy, such as acting as drug carriers, or stem cell delivery carriers (Peng et al., 2020). This suggests that, in the future, we can explore the modern mysteries of acupuncture from the perspective of exosomes to better serve clinical care and society. Our group has also made some scientific speculations based on the following: the proliferation and differentiation of BMSCs and NSCs may be a modern manifestation of the process of "kidney essence entering the marrow and brain" in Chinese medicine. The group obtained preliminary data from animal and cellular experiments. Zhou's experiments showed that the improvement of depressive behavior in rats with perimenopausal depression disorder (PDD) model by "Kidney–Brain Crosstalk" EA (GV20, BL23, and SP6) may be due to the modulation of the SDF-1/CRCX4 axis to promote BMSCs-Exosomes brain targeting function and repair damaged neurons in the hippocampus (Zhou, 2020). Analysis of the above literature, especially Chen et al. (2015, 2017), Klein and Wang (2018), Zhang et al. (2020), Zhou (2020), Li N. C. et al. (2021), and Xu S. Y. et al. (2022) provided us with viable ideas that acupuncture can facilitate exosomes to a designated location to exert their healing effects. Exosomes may be one of the carriers of the therapeutic effect of acupuncture, exerting similar effects to acupuncture (**Figure 3**).

The experiments of Li and Zhong suggested that acupuncture therapy in the treatment of MDD may also alleviate depression by affecting the content and concentration of endogenous exosomes. It is further suggested by Xu's experiments that serum exosomes collected by acupuncture in MDD patients or animals may also have a similar effect to acupuncture when reinfused into the body. Through Zhou's experiments, it was suggested that MDD patients or animals can target exogenous NSCs-Exosomes to reach brain sites and amplify the effect of acupuncture. This provided the basis for the main theme of this article "Exosomes may be the carrier of acupuncture treatment for MDD."

6. Limitations and future directions

Inevitably, there is a limitation to this paper. There are few papers on the current physiopathological role of exosomes in MDD and the regulation of exosomes by acupuncture to improve depressive behaviors, which fails to fully reveal the specific mechanism and application potential of acupuncture in the field of regulating exosomes in depression. On the other hand, there are also some limitations in the field. Exosomes samples are not suitable for clinical settings due to the lack of standardized methods for collecting and isolating exosomes, and their low recovery rate and purity. Therefore, the biggest challenge for researchers to overcome is still how to obtain high-quality exosomes and their inclusions, and how to efficiently translate them to clinical care. In addition, acupuncture research faces many difficulties. For example, how to further improve the objectivity of animal experiments, how to scientifically explain the physiological effects of acupuncture points, and how acupuncture facilitates the targeted transport of substances by exosomes. The levels of serum exosomes collected after acupuncture at specific acupuncture points are uncertain, and none of the specific mechanisms have been more thoroughly elucidated. Examples include mitochondrial function, AMPK mechanisms, and the role of NSC-derived exosomes in MDD. These may become the main areas of focus in the future.

7. Conclusion

In summary, exosomes act as both friends (diagnostic targets, drug carriers) and enemies (delivery of pathogenic factors) in the pathogenesis of MDD. On the other hand, we know that acupuncture is effective in improving MDD. It is also known that the relationship between exosomes and acupuncture is that exosomes may carry information about the effects of acupuncture points. The structure and content of exosomes reflect the concept of "Deqi" in the principles of acupuncture. At the same time, the heterogeneity and targeting of exosomes also reflect some characteristics of acupuncture, such as the identification of acupuncture points and meridian transmission. It is proposed that exosomes may be the vehicle for acupuncture treatment of MDD. Their contents may not only carry therapeutic targets, but also reveal the differences in tonicity and variety of acupuncture techniques, and the selection and combination of

specific acupuncture points. The emergence of exosomes seems to provide a feasible way to fully simulate the therapeutic effects of acupuncture, assuming that exosomes can become not only the transmitters during acupuncture treatment, but also carriers of needle-like effects at the end of an acupuncture intervention. Therefore, exosomes are very interesting and promising research components.

Author contributions

QL: responsible for writing and making. XZ and H-YC: responsible for making. L-QS and ML: responsible for searching relevant literature. X-DM: responsible for providing advice. LR: responsible for providing advice and funding. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Automatic adaptive emotion regulation is associated with lower emotion-related activation in the frontoparietal cortex and other cortical regions with multi-componential organization

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Although some researchers consider automatic adaptive emotion regulation to be an automatized strategy whereas others consider it to be implicit disengagement of deliberative process, to date, its neural correlates have been poorly investigated. In addition, the valence specificity of automatic adaptive emotion regulation and levels of activation relative to the neutral condition are controversial; the former is relevant to the attribution of resilient emotion regulation to positivity bias or emotional stability, and the latter to determining whether regulation is based on emotion-specific or emotion-non-specific processes. In this functional magnetic resonance imaging (fMRI) study, we presented positive and negative emotional pictures to healthy young participants and investigated the neural correlates of automatic adaptive emotion regulation in spontaneous emotional response. A significant negative trait effect (i.e., regression coefficient) on activation was identified both for positive and negative emotional responses in various cortical regions. A cluster analysis identified three clusters among these regions based on the valence specificity of the trait effect and level of activation relative to neutral stimuli. Cluster 1 included regions in the sensorimotor cortex characterized by negative emotion-specific decreases in activation relative to neutral stimuli in adaptive individuals. Cluster 2 included several cortical regions including the bilateral dorsal executive network, anterior cingulate, and inferior frontal gyrus, which were characterized by valence-independent decreases in activation in adaptive individuals. Cluster 3 included the bilateral ventrolateral and dorsomedial prefrontal cortices, right insula, and other posterior regions, which were characterized by increased activation for negative stimuli in non-adaptive individuals. These findings

support the assumption that automatic adaptive emotion regulation involves the implicit disengagement of deliberative process and suggest the relevance of different cortical networks to the potential emotion- and valence-specificity of adaptive regulation.

KEYWORDS

emotion regulation, reappraisal, acceptance, mindfulness, fMRI, prefrontal cortex, spontaneous, implicit

1. Introduction

Emotionally stressful situations are inevitable in daily life and may be particularly frequent under adverse circumstances such as disease or disaster. Although people may try to cope with such situations by solving the underlying problem (problem-focused coping), if this appears impossible, they must endure the situation by regulating their emotion to reduce the magnitude of its adverse impacts (emotion-focused coping) (Folkman and Lazarus, 1980; Carver et al., 1989; Garnefski et al., 2001). Early research explored the adaptive emotion regulation strategy and typically identified reappraisal of a situation using benign or positive interpretation as the most adaptive, by showing the relationship between the more capacity or frequency of its daily use and the less psychopathology (Gross, 1998; Garnefski et al., 2001; Aldao et al., 2010). The successful coping was typically discussed in the context of explicit or instructed choice and implementation of such adaptive regulation strategies, in part motivated by its application in cognitive behavioral therapy (Smits et al., 2012).

Adaptive emotion regulation also occurs automatically, which explains successful emotion-focused coping in stressful situations in daily life (Bargh and Williams, 2007; Fiori, 2009; Koole et al., 2015b); this type of emotion regulation may be much more common than instructed use or strategic choice. There are two distinct views on the processes underlying automatic adaptive emotion regulation. Some researchers consider it to consist of automatized recruitment of the emotion regulation strategy, i.e., spontaneous and potentially implicit use of the same adaptive emotion regulation strategy (e.g., reappraisal) used in explicit emotional regulation (Bargh and Williams, 2007; Koole et al., 2015b). Such automatic emotion regulation is assumed to develop over frequent use. Other researchers consider the automatic adaptive emotion regulation process to be independent of explicit regulation (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020), in an implicit disengagement of deliberative process that has been shown to occur in the early subliminal phase (Moon and Lord, 2006) and is characterized by acceptance of a situation without judgment or evaluation (Wenzel et al., 2020).

Exploration of the neural correlates of automatic adaptive emotion regulation remains in its infancy. Many studies have investigated the processes underlying explicit adaptive emotion regulation, mainly by examining activation during instructed reappraisal of negative emotional stimuli (Buhle et al., 2014; Frank et al., 2014; Kohn et al., 2014; Morawetz et al., 2017b). Automatic adaptive emotion regulation is associated with activation in wide range of frontoparietal cortices, including the dorsal executive network, emotion processing areas such as the ventrolateral and medial prefrontal cortices, and insula; it also accompanies deactivation of the limbic emotion response system (e.g., the amygdala). A few studies have investigated automatic adaptive emotion regulation by examining individual differences in activation (i.e., related to successful regulation) during the passive presentation of emotional stimuli, i.e., without explicit instruction of emotion regulation or conscious monitoring. One study passively presented pictures of negative facial expressions (e.g., anger or fear) and demonstrated higher and lower neural responses in the prefrontal cortex and amygdala, respectively, in individuals with high reappraisal scores on the Emotion Regulation Questionnaire (ERQ; Gross and John, 2003); this pattern suggested that automatic emotion regulation was driven by automatized strategic regulation (Drabant et al., 2009). Two studies compared neural responses to negative emotional stimuli between controls and experienced meditation practitioners who were considered to have a high automatic emotion regulation capacity. One used noxious heat stimuli and Zen meditators (Grant et al., 2011) and the other used negative emotional pictures and yoga meditators (Froeliger et al., 2012). In both studies, the experienced meditators had lower prefrontal cortex neural responses than control groups, suggesting that automatic emotion regulation consists of implicit disengagement of deliberative processes. However, these studies had reservations about a possible association between individual differences and automatic emotion regulation capacity. The ERQ is a theoretically constructed measure of the capacity for reappraisal, mainly in the context of conscious attempts. Meditation has been documented to affect emotion regulation as well as various physical and psychological measures (e.g., anxiety, depression, life satisfaction; Lomas et al., 2017; Creswell et al., 2019); long-term commitment to meditation has also been associated with pre-existing brain functional differences (Mascaro et al., 2013).

The recently developed Power to Live questionnaire includes an adaptive automatic emotion regulation trait measure (Sugiura et al., 2015), which may be a promising tool for investigating the mechanisms of adaptive automatic emotion regulation. The Power to Live questionnaire measures eight major psychobehavioral characteristics relevant to survival, which were identified through interviews with 1,400 survivors of the 2011 Great East Japan Earthquake and Tsunami disaster, followed by factor analysis (Sugiura et al., 2015). The emotion regulation factor is composed of four items: "During difficult times, I endeavor not to brood," "During difficult times, I endeavor to think positively, telling myself that this experience will benefit me in the future," "During difficult times, I compare my circumstances with the situation around me

and in society, and I think that matters cannot be helped," and "When something happens, I try to stay calm and not panic." These items largely correspond to four of the nine strategies that are considered to be used by people who have experienced negative life events (Cognitive Emotion Regulation Questionnaire, CERQ; Garnefski et al., 2001): specifically, rumination (reversed), positive reappraisal, putting into perspective, and acceptance. The four emotion regulation items were well correlated (Cronbach's $\alpha = 0.77$) and the construct was validated through confirmatory factor analyses using data from normative populations (Ishibashi et al., 2019; Matsuzaki et al., 2022). The adaptability of the factor was demonstrated by its positive contribution to survival in various phases of disaster: immediate tsunami evacuation in the initial phase, refugee-related problem solving (Sugiura et al., 2015) and positive perception of public support (Sugiura et al., 2021) in the emergency response phase, and housing recovery and wellbeing in the recovery phase (Sugiura et al., 2015; Sato et al., 2021). This factor has a conceptual advantage as a summary measure of adaptive automatic emotion regulation in that it was empirically and primarily identified as an independent adaptive factor among other adaptive traits, in contrast to the other measures such as ERQ and CERQ scores, which were theoretically constructed as multidimensional models for different emotion regulation strategies and *post hoc* tests of adaptability in each dimension. For example, one CERQ factor (refocus on planning) largely corresponds to the problem solving Power to Live factor.

In exploring the neural correlates of the automatic adaptive emotion regulation using the Power to Live emotion regulation trait measure, two issues are worth further consideration: valence specificity and levels of activation relative to neutral stimuli. Valence specificity is relevant to adaptive emotion regulation in the context of resilience; some researchers have focused on positive appraisal of negative stimuli (i.e., positivity bias) as the key mechanism protecting against the detrimental effects of stress (Kalisch et al., 2015), whereas others have suggested the importance of counter-regulating both negative and positive emotions for psychological adaptation by maintaining a steady emotional balance (Koole et al., 2015a). However, because relevant fMRI studies have examined activation only for negative stimuli (Drabant et al., 2009; Grant et al., 2011; Froeliger et al., 2012), the same trait effect on activation should also be examined for positive stimuli. Previous studies have also assumed a higher level of activation for negative than for neutral stimuli, generally testing how a trait affects increases in activation levels in emotion-specific processes. This assumption largely depends on the process model of emotion (Gross, 1998), in which regulation processes are triggered by an early valuation of emotion and reduce the negative effect of emotional response at a late valuation process. By contrast, some studies appear to suggest that activation levels are lower for negative stimuli than for neutral stimuli (Grant et al., 2011), in which case the basic tenets of emotion regulation must be reconsidered.

In this functional magnetic resonance imaging (fMRI) study, we investigated the neural correlates of automatic adaptive emotion regulation in the spontaneous response to emotional stimuli. We presented positive and negative emotional pictures to healthy young participants and measured their neural responses. We explored the correlation of these responses with adaptive emotion regulation according to the emotion regulation factor of the Power to Live questionnaire (Sugiura et al., 2015). To address the mechanism underlying spontaneous emotion regulation, we avoided providing any explicit instructions or prohibiting emotion regulation or self-evaluation of emotional state. We were interested in whether the effects of adaptive emotion regulation (as reflected in regression coefficients) on activation of the neural correlates of explicit emotion regulation are positive or negative, i.e., whether the frontoparietal cortices would show higher or lower activation in adaptive individuals. Positive and negative effects were predicted under the assumptions of automatized strategic regulation (Bargh and Williams, 2007; Koole et al., 2015b) and implicit disengagement of deliberative processes (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020), respectively. To further characterize the functions of the identified regions, we examined the valence specificity of the trait effect on activation and level of activation relative to that for neutral stimuli. Emotion regulation was predicted to be influenced primarily by negative emotions, under the assumption that positivity bias is adaptive (Kalisch et al., 2015), and to be common for both emotional valances, under the assumption that the maintenance of steady emotional balance is adaptive (Koole et al., 2015a). Previous studies have generally predict higher activation levels for emotional stimuli than for neutral stimuli; however, one study predicted the opposite response (Grant et al., 2011). We also performed a cluster analysis of the identified regions based on valence specificity of the trait effect and activation levels relative to neutral stimuli to identify functional networks comprising subsets of regions with similar functional characteristics. This approach complements the separate tests for each characteristic in each region by allowing the identification of networks that integrate both characteristics without spurious dichotomization using a specific statistical threshold (Chen, 2022).

2. Materials and methods

2.1. Participants

We enrolled 47 healthy, right-handed, young adult students *via* advertisements placed around Tohoku University. All participants were native Japanese speakers and had no history of neurological or psychiatric illnesses. Data from 40 participants (19 females, 21 males; mean age ± standard deviation [SD] = 21.9 ± 1.8) were analyzed. Seven participants were excluded because of deficient MRI data ($n = 5$) or excessive head movement during MRI (> 3 mm; $n = 2$). The study was approved by the Institutional Review Board of the Graduate School of Medicine of Tohoku University, Japan, and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

2.2. Trait measure of adaptive automatic emotion regulation

As a trait measure of adaptive automatic emotion regulation, we used the emotion regulation factor of the Power to Live questionnaire (Sugiura et al., 2015), which measures eight survival-related psychological and behavioral factors: leadership, problem solving, altruism, stubbornness, etiquette, self-transcendence, active wellbeing, and emotion regulation. The questionnaire

includes 34 items related to ways of thinking, daily attitudes, and habits; some are related to stressful situations in general, whereas others appear to be unrelated. Respondents rate the self-applicability of each item on a six-point scale (0: not at all; 5: very much). Each factor consists of three to five items; item scores are averaged and converted to% maximum values to generate a factor score. Although we focused on emotion regulation in this study, the mean score of the eight factors was calculated as a covariate or to standardize emotion regulation scores to adjust for general tendencies in trait questionnaire responses among participants; i.e., some participants show an overall preference for high or low scores, irrespective of the question.

2.3. Experimental tasks

We presented each participant with 18 negative (codes: 2691, 3500, 6213, 6260, 6300, 6312, 6821, 6834, 6838, 8485, 9007, 9280, 9342, 9424, 9471, 9830, 9910, and 9925), 18 positive (codes: 1440, 1441, 1710, 2091, 2260, 2311, 2331, 2332, 2340, 2345, 2387, 2530, 4614, 4626, 5201, 5833, 7325, and 8185), and 18 neutral (i.e., control) (codes: 2840, 2980, 5390, 5471, 5534, 7000, 7004, 7009, 7020, 7050, 7052, 7130, 7150, 7161, 7187, 7211, 7705, and 7950) pictures from the International Affective Picture System (IAPS) (Lang et al., 2008). Each session had a block design (**Figure 1**) with each 20-s block composed of showing three pictures with the same valence category (each 6-s presentation separated by a 1-s eye-fixated rest). The triad of three blocks with different valences, with their order counterbalanced across participants, was repeated six times with a 12-s eye-fixated rest being inserted between consecutive blocks and at the beginning and end of the session, resulting in a total session duration of 588 s.

Each participant was placed in a supine position on the MRI scanner bed; the head was immobilized using a band and elastic blocks. Visual stimuli were presented on a translucent screen from an LCD projector. The participants viewed the stimuli using a mirror attached to the head coil. They were instructed to press the button of a fiber optic response pad (Current Designs Inc., Philadelphia, PA, USA) with their right index finger after they had sufficiently appreciated each picture to ensure their wakefulness. Stimulus presentation and response collection were controlled using the Presentation software (Neurobehavioral Systems, Inc., Berkeley, CA, USA).

2.4. fMRI data acquisition and pre-processing

The fMRI time-series dataset of whole-brain T2*-weighted gradient echo-echo planar imaging (EPI) scans was acquired using a 3-Tesla Philips Achieva scanner (Philips Medical Systems, Best, Netherlands). The entire cerebrum was covered in 33 transaxial images (echo time = 30 ms, flip angle = 70°, slice thickness = 3.0 mm, slice gap = 0.0 mm, field of view = 192 mm, matrix = 64 × 64, voxel size = 3 mm × 3 mm × 3 mm) at a repetition time of 2,000 ms. The time-series dataset for each participant consisted of 294 scans obtained during the 588-s session.

Statistical Parametric Mapping (SPM12; Wellcome Department of Imaging Neuroscience, London, UK) was used for data preprocessing and analyses. The preprocessing procedure included correction for head motion, adjustment of acquisition timing across slices, spatial normalization using an EPI template of the Montreal Neurological Institute (MNI), and smoothing using an isotropic Gaussian kernel with an 8-mm full-width at half-maximum.

2.5. fMRI data analysis

A conventional two-level approach for a multi-subject time-series dataset was adopted. At the first (within-subject) level, the condition-specific neural activation of each participant was estimated using a voxel-by-voxel multiple regression analysis of the time course. A general linear model including a regressor for each valence (i.e., negative, positive, and control) was constructed by assuming a 20 s neural activation during each block and using the conventional hemodynamic response function. Six head-motion parameters (three for translation and three for rotation) estimated during the head-motion-correction process were included as covariates. A high-pass filter with a cutoff frequency of 1/128 Hz was applied for detrending. Activation images for negative and positive emotional responses were generated using the contrast estimate (beta) of negative–control and positive–control, respectively.

At the second (between subjects) level, the neural correlates of the automatic adaptive emotion regulation trait were explored using separate voxel-by-voxel multiple regression analyses of activation images for negative and positive emotional responses. The emotion regulation score was included as an independent variable of interest (i.e., a measure of adaptive automatic emotion regulation trait). Age, sex, and the mean Power to Live score (i.e., to adjust for general tendencies in trait questionnaire responses) were included as covariates. Both positive and negative effects of emotion regulation were explored in terms of regression coefficients of the trait score. Activation clusters of significant effects were initially identified using a threshold of $p < 0.001$ (uncorrected) and then at a cluster-level extent threshold ($p < 0.05$) based on random field theory was applied to control for family wise error, assuming the entire cerebrum as the search volume (Friston et al., 1994).

To further characterize the functions of the identified regions, we examined the valence specificity of trait effects and activation levels relative to neutral stimuli at each peak voxel. To examine valence specificity, the trait effect was also tested for the opposite valence, and the results were compared. To examine activation levels relative to neutral stimuli, we performed separate one-sample *t*-tests on the average activation for negative and positive emotional responses (i.e., negative vs. control and positive vs. control, respectively) across participants. The threshold for statistical significance was $p < 0.05$, uncorrected for multiple comparisons (because we were interested in two characteristics of the activation pattern at each voxel).

To identify regional subsets with similar functional characteristics (i.e., valence specificity and activation levels relative to neutral stimuli), we applied a hierarchical cluster analysis to all identified regions in the four voxel-wise analyses (i.e., positive and negative trait effects on activation for negative

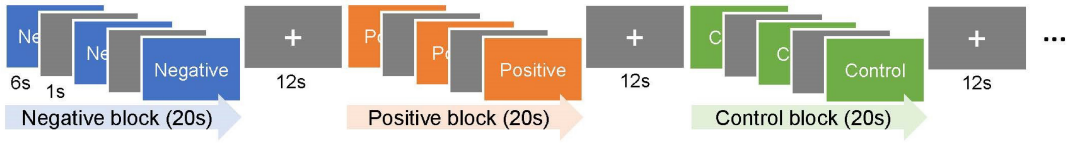

FIGURE 1
Experimental design. Each block consisted of a serial presentation of three emotional pictures with the same valence, i.e., negative, positive, or neutral (control), from the International Affective Picture System. The triad of three blocks with different valences, with the order counterbalanced across participants, was repeated six times. The participants pressed the button after they had sufficiently appreciated each picture to ensure their wakefulness.

and positive emotional responses). As a dissimilarity measure across regions, we determined Euclidian distances using the set of four *t*-values (i.e., trait effect and average activation for emotional responses in two valences) at each peak voxel. Ward's method, which minimizes the total within-cluster variance, was used for clustering (Ferreira and Hitchcock, 2009). Principal component analysis was applied to the same dataset to visualize the distribution of regions.

3. Results

3.1. Emotion regulation score

The emotion regulation factor scores (% maximum; mean ± SD) were 60.1 ± 18.5 and Cronbach's α was 0.74 for the analyzed participants ($n = 40$).

3.2. Neural correlates of the automatic adaptive emotion regulation trait

On activation for the negative emotional response (i.e., negative vs. control), a significant positive effect of the emotion regulation score was not detected. A significant negative effect of the score was detected in the bilateral sensorimotor cortex, including the central sulcus, pre-central and paracentral gyri, and supplementary motor area, as well as the bilateral temporal cortices, including multiple regions in the superior and middle temporal gyri along the posterior–anterior axes (**Table 1** and **Figure 2A**). The finding supports the assumption that automatic adaptive emotion regulation involves the implicit disengagement of deliberative processes (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020).

We also did not detect a significant positive effect of the emotion regulation score on activation for the positive emotional response (i.e., positive vs. control). A significant negative effect of the score was identified in multiple prefrontal regions, including the bilateral superior frontal sulci (dorsolateral prefrontal cortex; dlPFC), inferior frontal gyri (ventrolateral prefrontal cortex; vlPFC), and dorsomedial prefrontal cortex (dmPFC). Furthermore, significant negative effects were observed in several regions in the bilateral anterior cingulate cortex (ACC), right insula, intraparietal gyrus, occipito-temporal and occipito-temporo-parietal junctions, and the left superior temporal gyrus (**Table 2** and **Figure 2B**). This result also supports the assumption of implicit disengagement of deliberative processes.

3.3. Functional characterization of the identified regions

For regions that showed a significant trait effect on activation for the negative emotional response, functional characteristics including valence specificity of the trait effect and activation levels relative to neutral stimuli are summarized in **Table 1**. Regarding the valence specificity of the trait effect, the negative trait effect was significantly larger for negative than positive emotional responses in most identified regions of the bilateral sensorimotor cortex, supporting the assumption that positivity bias is adaptive (Kalisch et al., 2015). By contrast, in all identified regions of the bilateral temporal cortices, the negative trait effect was significant for both negative and positive emotional responses, with no significant between-valence difference, supporting the assumption that maintenance of steady emotional balance is adaptive (Koole et al., 2015a). Average activation was significantly lower for negative stimuli than for neutral stimuli in all identified regions except the bilateral middle temporal gyri, and the pattern was similar in the average activation for positive stimuli in the identified temporal cortical regions. This result contradicts current views about the regulation of activation for emotional response.

The functional characteristics of regions that showed a significant trait effect on activation for positive emotional response are summarized in **Table 2**. Regarding the valence specificity of the trait effect, the negative trait effect was significant for both positive and negative emotional responses, with no significant between-valence differences in most regions, supporting the assumption that maintenance of steady emotional balance is adaptive. In the bilateral dmPFC and right occipito-temporo-parietal junction, the trait effect was not significant for negative emotional response, and the trait effect for positive emotional response was significantly larger than for negative emotional response in the right dmPFC. Average activation was significantly lower for positive stimuli than for neutral stimuli in most identified regions, and the pattern was similar in the average activation for negative stimuli, except in the right occipito-temporo-parietal junction.

3.4. Cluster analysis

The results of hierarchical cluster analysis for all 34 identified regions (i.e., pooled data for identified regions with a trait effect for emotional response in both valences) based on their functional characteristics (i.e., *t*-values for trait effect and average activation for emotional response in both valences) are shown

TABLE 1 Neural correlates of the automatic adaptive emotion regulation trait for negative emotional response.

Structure		Coordinate			Trait effect			Average	Positive–Control		Trait	Cluster	
		x	y	z	*t*	k	*p*	*t*	Trait	Average	N–P	/Label	
Central sulcus	L	−30	−24	64	−5.15a			−2.92*	−2.26*	1.14	−1.84*	1	LCS
	R	34	−30	64	−5.61a	5134	<0.001	−4.02*	−3.01*	−0.24	−1.85*	1	RCS
Pre-central gyrus	R	22	−20	72	−5.55a			−3.39*	−2.50*	0.88	−2.73*	1	RPreCG
	R	52	−2	34	−4.83	734	0.001	−2.63*	−1.88*	−0.37	−2.13*	1	RPreCS
Paracentral gyrus (posterior)	L	−8	−28	66	−4.39a			−2.07*	−0.43	1.36	−2.38*	1	LpParaCG
Paracentral gyrus (anterior)	R	8	−18	74	−5.11a			−1.93*	−2.24*	0.52	−2.84*	1	RaParaCG
Paracentral gyrus (posterior)	R	12	−28	60	−4.77a			−2.55*	−1.62	0.39	−1.64	1	RpParaCG
Supplementary motor area	L	−6	−10	74	−4.91a			−2.16*	−0.96	−0.68	−2.57*	1	LSMA
	R	8	−4	62	−5.46a			−3.27*	−2.10*	−0.99	−2.04*	1	RSMA
Superior temporal gyrus (posterior)	L	−38	−32	14	−4.91c	979	<0.001	−3.57*	−3.21*	−2.56*	−0.47	2	LpSTG
	R	40	−36	10	−5.48b	1041	< 0.001	−5.84*	−2.19*	−2.39*	−1.65	2	RpSTG
Superior temporal gyrus (middle)	L	−62	−26	6	−3.97c			−3.91*	−2.75*	−3.75*	−1.57	2	LmSTG
	R	62	−18	2	−4.38b			−6.37*	−2.35*	−3.56*	−0.82	2	RmSTG
Superior temporal gyrus (anterior)	L	−56	−4	−8	−4.76c			−2.19*	3.41*	−1.69*	−0.65	2	LaSTGn
	R	54	−6	−10	−3.91b			−2.26*	−2.94*	−1.41	−0.77	2	RaSTG
Middle temporal gyrus (middle)	R	56	−30	−12	−4.34b			2.5*	−2.71*	0.88	−1.13	3	RmMTG
Middle temporal gyrus (anterior)	R	62	−10	−18	−4.59b			4.48*	−1.93*	1.19	−1.23	3	RaMTG

For each peak voxel, laterality (L, left; R, right), MNI coordinate, *t*-value for the trait effect, and the associated cluster are given. The number of voxels (k) and *p*-value are given at the highest peak voxel. Letters that are the same indicate belonging to the same cluster. To further characterize each peak voxel, the *t*-value for average activation (i.e., one-sample *t*-test) for the negative emotional response, for the trait effect and average activation for the positive emotional response, and for a difference in the trait effect between the negative and positive emotional responses (negative–positive) are given (*$p < 0.05$, uncorrected). The rightmost column shows the cluster number and abbreviation for anatomical name used in Figure 3.

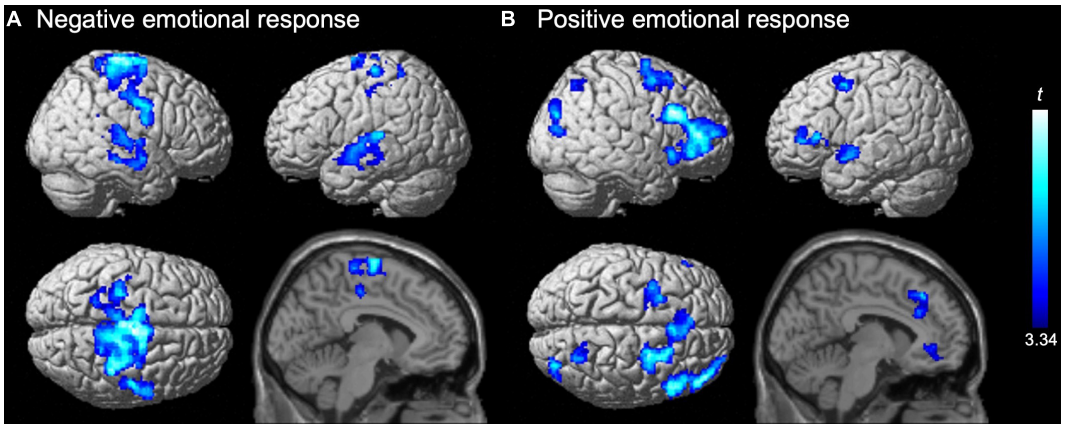

FIGURE 2
Negative effects of the emotion regulation trait on activation for **(A)** negative and **(B)** positive emotional responses. Significant effects (*t*-values) of the emotion regulation score (power to live questionnaire) in the second-level multiple regression model are represented by a blue-cyan scale, rendered on the surface and overlaid on the parasagittal section ($x = -6$) of an SPM12 standard structural brain image. Statistical significance was determined at a cluster-forming threshold of uncorrected $p < 0.001$ and then corrected to $p < 0.05$ (family wise error) for the cluster size. No positive trait effect was detected.

TABLE 2 Neural correlates of the automatic adaptive emotion regulation trait for positive emotional response.

Structure		Coordinate			Trait effect			Average	Negative–Control		Trait	Cluster	
		x	y	z	*t*	k	*p*	*t*	Trait	Average	N–P	/Label	
Inferior frontal gyrus (orbitalis)	R	34	36	−4	−5.49a			−4.08*	−2.15*	−1.95*	1.19	2	RIFGob
Superior frontal sulcus	L	−24	6	50	−5.45	436	0.003	−3.51*	−3.49*	−1.65	0.4	2	LSFS
	R	22	14	50	−5.05b	1719	0	−3.88*	−2.54*	−2.48*	0.69	2	RSFS
Anterior cingulate cortex (rostral)	L	−14	40	2	−4.94	291	0.021	−0.73	−2.63*	−1.11	0.49	2	LrACC
Anterior cingulate cortex (dorsal)	L	−8	28	28	−4.24b			−1.97*	−1.94*	−1.87*	0.82	2	LdACC
	R	8	40	24	−3.93b			−4.03*	−1.78*	−2.44*	0.55	2	RdACC
Anterior cingulate cortex (caudal)	R	8	16	36	−4.32b			−1.41	−3.59*	−1.63	0.03	2	RcACC
Intraparietal sulcus	R	28	−62	50	−5.19	266	0.029	−5.86*	−2.12*	−3.20*	1.15	2	RIPS
Superior temporal gyrus (anterior)	L	−50	−6	−8	−4.23	234	0.045	−3.47*	−3.18*	−3.14*	0.17	2	LaSTGp
Inferior frontal gyrus (opercularis)	R	50	20	30	−6.37a	2366	0	0.27	−2.45*	3.7*	0.78	3	RIFGop
Inferior frontal gyrus (triangularis)	L	−50	30	6	−4.23	282	0.023	−1.91*	−3.48*	2.74*	0.73	3	LIFGtr
	R	40	32	20	−5.17a			−1.69*	−2.23*	0.84	0.79	3	RIFGtr
Insula	R	44	20	−10	−4.28a			−2.71*	−2.24*	1.16	0.61	3	Rins
Dorsomedial prefrontal cortex	L	−6	32	44	−4.57b			−3.66*	−1.04	−0.01	1.65	3	LdMPFC
	R	6	28	48	−5.03b			−4.68*	−0.69	0.69	1.84*	3	RdMPFC
Occipitotemporal junction	R	38	−82	14	−4.57c	312	0.016	−6.54*	−2.07*	1.12	1.65	3	ROTJ
Occipito temporo parietal junction	R	34	−82	30	−4.11c			−5.12*	−1.32	2.45*	1.65	3	ROTPJ

To further characterize each peak voxel, *t*-values for the trait effect and average activation for the negative emotional response are given. Other details are the same as for Table 1.

as a dendrogram in Figure 3A. The degrees of similarity in functional characteristics among regions were visualized as two-dimensional plots of the loadings for the first and second principal components, which explained 41 and 36% of the total variance, respectively (Figure 3B). We chose a three-cluster solution based on a threshold of 13.96 for between-cluster distances, where cluster 1 was dissociated from cluster 2 (Figure 3A). Further lowering the threshold divided cluster 3, which seemed inappropriate based on the visual inspection of its distribution (Figure 3B). The anatomical distribution of the regions (i.e., peaks) of each cluster is represented by symbols on the brain surface and section in Figure 3C. To visualize the functional characteristics of each cluster, the average activation for emotional responses in the two valences are shown separately for adaptive (n = 20) and non-adaptive (n = 20) groups in the representative region (Figures 3D–F). The groups were determined based on the median emotion regulation score (standardized using the mean Power to Live score), which resulted in average ± SD scores of 1.12 ± 0.17 and 0.77 ± 0.15, respectively. There were no significant differences between groups in age (22.0 ± 1.9 and 21.9 ± 1.7 years, respectively; p = 0.930) or sex (male/female: 12/8 and 9/11, respectively; χ^2 = 0.902, df = 1, p = 0.342).

Cluster 1 included all nine regions identified in the sensorimotor cortex. In these regions, the trait effect was largely specific to negative emotional response and average activation was significantly lower for negative stimuli than for neutral stimuli (Table 1). These two characteristics appear to correspond with a negative emotion-specific decrease in activation relative to neutral stimuli in adaptive individuals (Figure 3D).

Cluster 2 was composed of the dorsal executive network (i.e., dlPFC and intraparietal sulcus), multiple regions in the bilateral ACC and superior temporal gyri, and the orbital part of the right inferior frontal gyrus. In these regions, the trait effect was largely significant for both negative and positive valences, with no significant between-valence difference, and average activation was significantly lower for both emotional stimuli than for neutral stimuli (Tables 1, 2). These two characteristics appear to correspond with a valence-independent decrease in activation relative to neutral stimuli in adaptive individuals (Figure 3E).

Cluster 3 was composed of the bilateral vlPFC and dmPFC, right insula, middle temporal gyrus, and posterior occipitoparietal regions. In these regions, the trait effect was largely significant for both negative and positive valences, with no significant between-valence difference, and average activation tended to be higher for negative stimuli and lower for positive stimuli than for

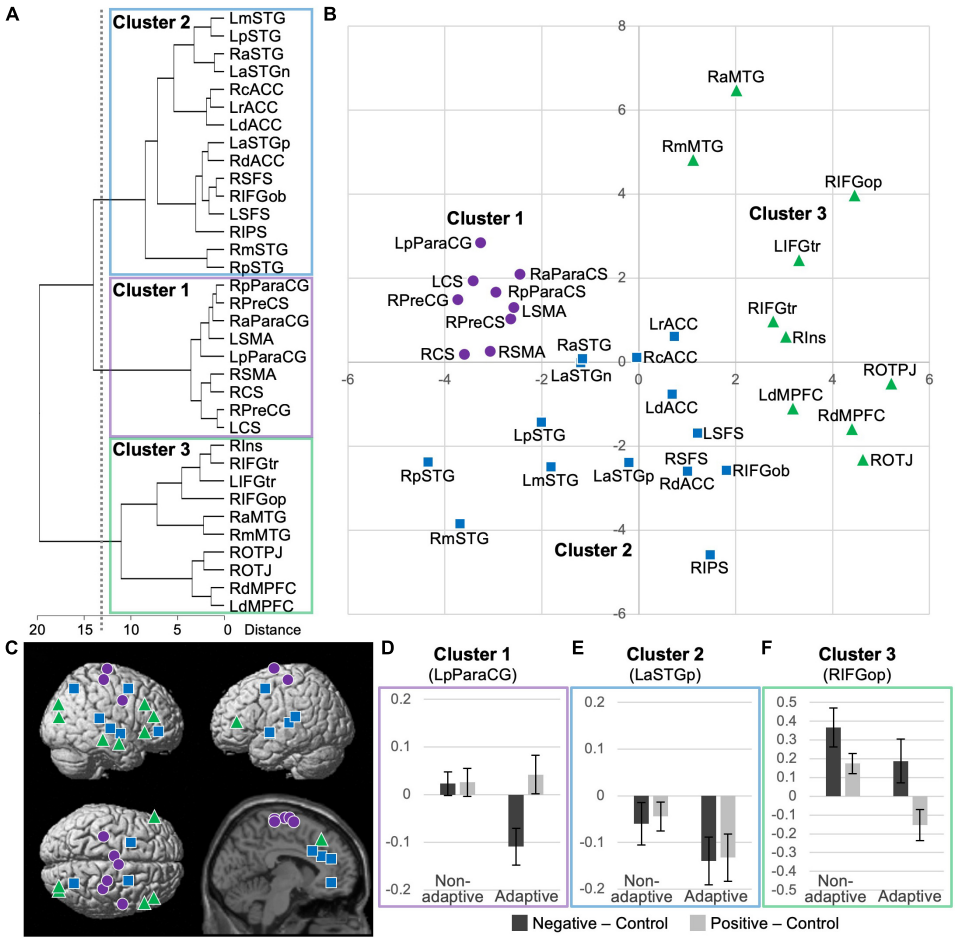

FIGURE 3
Results of cluster analysis of 34 identified regions with significant trait effects based on *t*-values for trait effect and average activation for emotional responses in two valences. **(A)** Dendrogram of the hierarchical cluster analysis; a threshold of 13.96 for between-cluster distances (dotted line) resulted in a three-cluster solution. **(B)** Two-dimensional plots of principal components. See **Tables 1**, **2** for anatomical labels. **(C)** Anatomical locations of the peaks, indicated by cluster-specific symbols. **(D–F)** Activation profiles of the representative regions of clusters 1–3 (i.e., the posterior left paracentral gyrus, the anterior left superior temporal gyrus, and opercular part of the right inferior frontal gyrus, respectively). Average emotional responses for two valences are shown separately for non-adaptive (n = 20) and adaptive (n = 20) groups, based on a median-split of low and high emotion regulation scores, respectively.

neutral stimuli (**Tables 1**, **2**). These two characteristics appear to correspond to a complicated activation pattern in the opercular part of the right inferior frontal gyrus. Compared to that for neutral stimuli, activation for negative stimuli showed a greater increase in non-adaptive than in adaptive individuals, whereas that for positive stimuli appeared to increase in non-adaptive and decrease in adaptive individuals (**Figure 3F**). This pattern is consistent with the regulation of activation for emotional response.

4. Discussion

We explored the neural correlates of automatic adaptive emotion regulation in spontaneous responses to emotional stimuli; we also characterized the functions of these regions in terms of the valence specificity of the trait effect on activation and activation levels relative to neutral stimuli. A significant positive effect of the trait score on activation was not detected for either negative or positive emotional response. A significant negative effect of the score on activation was identified in the bilateral sensorimotor and temporal cortices for negative emotional response and in the bilateral prefrontal cortices, ACC, right insula, intraparietal, and other posterior areas for positive emotional response. This finding supports the assumption that automatic adaptive emotion regulation is the implicit disengagement of deliberative processes (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020). Regarding the valence specificity of the trait effect, the effect was predominant for negative emotional response in the bilateral sensorimotor cortex, supporting the assumption that positivity bias is adaptive (Kalisch et al., 2015), whereas the effect was equally significant for negative and positive emotional responses in other regions, supporting the assumption that maintenance of steady emotional balance is adaptive (Koole et al., 2015a). Significantly higher average activation levels for emotional stimuli, which are predicted by the regulation of activation for emotional response, were identified only in a few regions, such as the bilateral middle temporal gyri and the right occipito-temporo-parietal junction. In most other regions, average activation was significantly lower for emotional stimuli

than for neutral stimuli. The cluster analysis results suggested three clusters among the identified regions. Cluster 1 included regions in the sensorimotor cortex characterized by negative emotion-specific decreases in activation relative to neutral stimuli in adaptive individuals. Cluster 2 included several cortical regions including the bilateral dorsal executive network, ACC, superior temporal gyri, and the orbital part of the right inferior frontal gyrus, which are characterized by valence-independent decreases in activation in adaptive individuals. Cluster 3 included the bilateral vlPFC and dmPFC, right insula, middle temporal gyrus, and posterior occipitoparietal regions, which are characterized by a complicated activation pattern. For negative stimuli, activation increases relative to neutral stimuli were higher in non-adaptive than in adaptive individuals, consistent with the regulation of activation for emotional response; however, for positive stimuli, activation increased in non-adaptive and decreased in adaptive individuals.

Although recent studies have supported implicit disengagement of deliberative processes as the mechanism underlying automatic adaptive emotion regulation (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020), previous neural evidence obtained from studying experts in Zen (Grant et al., 2011) and yoga meditators (Froeliger et al., 2012) have had methodological issues in that meditation affects not only emotion regulation but also various physical and psychological measures (Lomas et al., 2017; Creswell et al., 2019) and is associated with preexisting functional differences in the brain (Mascaro et al., 2013). In this study, we overcame this limitation by enrolling healthy individuals and adopting a parametric approach using a trait measure for automatic adaptive emotion regulation, and obtained more robust evidence for the predominantly negative effect of automatic adaptive emotion regulation on activation of emotional responses. The meditation studies by Grant et al. (2011) and Froeliger et al. (2012) enrolled relatively few participants (13 and 14, respectively), whereas we enrolled a larger sample ($n = 40$), which may also have contributed to our ability to identify trait effects in more extensive regions than these previous studies.

In addition to the role of the frontoparietal cortices, the involvement of the amygdala is another difference between the two potential mechanisms of automatic adaptive emotion regulation. Suppression of the amygdala response by prefrontal functioning is a key feature of explicit reappraisal (Buhle et al., 2014; Frank et al., 2014; Kohn et al., 2014). Previous studies of individual differences have reported mixed results. One study demonstrated association of higher reappraisal scores in ERQ and lower neural responses in the amygdala (Drabant et al., 2009) and another study on Zen meditators reported greater amygdala deactivation in experts than in controls (Grant et al., 2011). On the other hand, the study on yoga meditators showed an absence of the dlPFC–amygdala correlation (Froeliger et al., 2012). In line with the latter, we did not detect a trait effect in the amygdala, despite our liberal statistical threshold (uncorrected $p < 0.05$), which supports the implicit disengagement of deliberative processes.

Although acceptance appears to be conceptually closer to automatic adaptive emotion regulation, our findings suggest that these are at least in part distinct concepts. Acceptance of the reality of a stressor together with an absence of an active coping strategy is an adaptive emotion regulation strategy distinct from reappraisal (Aldao et al., 2010). Some researchers regard it as a subtype of reappraisal strategy (McRae et al., 2012a), while others consider it an essential aspect of mindfulness and related therapy (Bishop et al., 2004; Hayes et al., 2006) and thus a form of automatic adaptive emotion regulation (Wenzel et al., 2020). Although a limited number of studies have examined the neural basis of acceptance, a recent meta-analysis identified decreased brain activity in the posterior cingulate cortex or precuneus as a common finding (Messina et al., 2021). Although the association of regulation with decreased activation is consistent with the implicit disengagement of deliberative processes (Moon and Lord, 2006; Fiori, 2009; Wenzel et al., 2020), the identified regions did not overlap with our current finding on the automatic adaptive emotion regulation trait.

The current finding on the valence specificity of the trait effect appears to reconcile the discussion on the nature of adaptive emotion regulation in the context of resilience; that is, different cortical networks showed activation patterns supporting distinct mechanisms. Regions in the sensorimotor cortex (cluster 1) showed negative emotion-specific trait effects, supporting the assumption of positivity bias adaptiveness, where positive appraisal of negative stimuli (i.e., positivity bias) is a key mechanism protecting against the detrimental effects of stress (Kalisch et al., 2015). Deactivation or suppression of the sensorimotor cortex has not been detected in meta-analyses of reappraisal (Buhle et al., 2014; Frank et al., 2014; Kohn et al., 2014; Morawetz et al., 2017b) or acceptance (Messina et al., 2021). However, it has been reported in some studies as reduced activation during explicit reappraisal compared to the natural viewing of negative pictures (McRae et al., 2012b; Morawetz et al., 2017a). In patients with borderline personality disorder, which is characterized by poor emotion regulation, increased activation of the sensorimotor cortex is observed for negative but not positive images (Koenigsberg et al., 2009). It may be possible to link deactivation of the sensorimotor cortex with suppression of the emotional response in the physiological domain, given the association between sensorimotor activation and physiological emotional markers during the viewing of negative (vs. positive) images (Anders et al., 2004). However, the remaining regions identified as having a trait effect in this study (clusters 2 and 3) showed valence-independent trait effects for emotional responses, supporting the assumption of adaptiveness in the maintenance of steady emotional balance by counter-regulating both negative and positive emotions (Koole et al., 2015a).

Our findings on activation levels relative to neutral stimuli also support and contradict parts of the proposed mechanisms for the regulation of emotion-specific processes. An activation increase for negative stimuli relative to neutral stimuli, with a higher degree in non-adaptive individuals, was observed in regions of cluster 3. In the framework of the classical process model of emotion (Gross, 1998), such a trait effect on activation may reflect inefficient top-down regulation triggered by the early valuation of emotion or unsuppressed emotional responses in the late valuation with adverse psychological impacts. The involvement of various saliency detection systems, such as the insula (Menon and Uddin, 2010) and vlPFC (Vossel et al., 2014), and regions implicated in the elaborative process for socioemotional conflict, such as the middle temporal gyrus, dmPFC, and posterior occipitoparietal region (Wakusawa et al., 2009; Sekiguchi et al., 2013; Oba et al., 2020), in this cluster appears to be consistent with this interpretation. However, a contradictory finding to mechanisms based on the

conventional process model was identified in regions of clusters 1 and 2. Significantly lower average activation for emotional stimuli than for neutral stimuli, with a larger degree in adaptive individuals, identified in these regions may suggest the involvement of emotion-non-specific processes as a target of regulation. Thus, adaptive regulation may involve the suppression of emotion-non-specific processes for task execution (e.g., general picture appreciation). The involvement of top-down attention or executive systems including the dlPFC, ACC, intraparietal sulcus (Banich, 2009; Vossel et al., 2014), and regions sensitive to semantic processing loads including the superior temporal gyrus and orbital part of the inferior frontal gyrus (Peyrin et al., 2010; Davis et al., 2011) in cluster 2 is consistent with this idea.

The current findings have important basic and clinical implications regarding the role of the prefrontal control system in emotion regulation. The identified association between high prefrontal activation and low automatic adaptive emotional regulation is congruent with the view that prefrontal activation can index emotional reaction, as demonstrated by the causal effect of visceral stimulation on prefrontal activation (Hamaguchi et al., 2004), and with the general tendency of high prefrontal activation in response to negative emotional stimuli in patients with poor emotion regulation, such as those with borderline personality disorder (Koenigsberg et al., 2009), anorexia nervosa (Seidel et al., 2018), and attention-deficit/hyperactivity disorder (Materna et al., 2019). However, we do not intend to generalize this simple relationship between lower prefrontal activation and better emotional regulation across all contexts or situations. During conscious emotion regulation, reduced prefrontal activation is associated with poor emotion regulation (Picó-Pérez et al., 2017; Wang et al., 2018). Both excitatory and suppressive effects of the prefrontal cortex on the visceral response to emotional stimuli have been demonstrated in recent brain stimulation studies (e.g., Aizawa et al., 2021). The prefrontal control and emotion systems have bidirectional relationships that vary contextually.

In summary, we report a predominantly negative effect of automatic adaptive emotion regulation on activation for emotional responses, supporting a mechanism of implicit disengagement of deliberative processes, rather than automatized strategic regulation. These regions were divided into three subsets/clusters based on functional characterization of the valence specificity of the trait effect on activation and activation levels relative to neutral stimuli. Cluster 1 included regions in the sensorimotor cortex characterized by negative emotion-specific decreases in activation relative to neutral stimuli in adaptive individuals. Cluster 2 included several cortical regions including the bilateral dorsal executive network, ACC, superior temporal gyri, and the orbital part of the right inferior frontal gyrus, which were characterized by valence-independent decreases in activation in adaptive individuals. Cluster 3 included the bilateral vlPFC and dmPFC, right insula, middle temporal gyrus, and posterior occipitoparietal regions, which were characterized by activation increases for negative relative to neutral stimuli in non-adaptive individuals. The identified negative emotion-specific trait effect in cluster 1 and valence-independent trait effect in clusters 2 and 3 support different mechanisms for adaptive emotion regulation in the context of resilience; i.e., adaptiveness in positivity bias and maintenance of steady emotional balance, respectively. The higher activation levels in cluster 3 and lower levels in clusters 1 and 2 relative to neutral stimuli also had different functional implications, with the former supporting existing theories based on the regulation of emotion-specific processes and the latter suggesting the involvement of emotion-non-specific general processes for task execution as a target of regulation. These findings have important basic and clinical implications in understanding of the functional organization of automatic adaptive emotion regulation, which appear to be underpinned by at least three distinct functional networks.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Tohoku University Graduate School of Medicine, Sendai, Japan. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MSu, YK, RK, and SF contributed to the study conception and design. YK, TM, MSh, SH, KN, and DT prepared the experimental stimuli and conducted the MRI experiment. MSu performed the statistical analysis and wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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SARS-CoV-2 pandemic as a catalyst? Development of emotional problems of preschool children of mothers with childhood maltreatment experiences in the course of the pandemic–a longitudinal analysis

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Background: SARS-CoV-2 pandemic have posed great challenges for all families and children. Health risks and fears associated with SARS-CoV-2 negatively affect the parental mental health and perceived stress, which in turn influence parental coping and thereby impairs the mental health and well-being of their children. Additional risk factors within the parents, such as maternal childhood maltreatment (CM) experiences, may increase the risk of children to develop emotional problems during the pandemic.
Objective: The purpose of this longitudinal study is to determine whether preschool children of mothers with CM are at higher risk of developing emotional problems during the pandemic than preschool children of mothers without CM.
Method: 74 mothers from a birth cohort examining pathways to resilience or vulnerability in the transgenerational transmission of CM, provided information on emotional problems of their children (aged 3–7 years) at two measurement time points (t1: May 2020, t2: March 2021) as part of an online "SARS-CoV-2 pandemic" survey. In addition, parents were asked for a retrospective assessment of their children's emotional problems before the pandemic at time t1. Children's emotional problems were assessed using the "emotional problems" scale of the German version of the Strengths and Difficulties Questionnaire (SDQ) and linked to previously collected data on mothers' childhood maltreatment experiences, which were collected using the German short version of the Trauma in Childhood Questionnaire (CTQ).
Results: Our analyses showed that children's emotional problems increased significantly over the SARS-CoV-2 pandemic [$F(1.86, 116.88) = 3.72$, $p = 0.030$ $\eta^2 = 0.06$] and were rated significantly higher in the group of children of mothers with CM, than in the group of mothers without CM [$F(1, 63) = 126.06$, $p < 0.001$ $\eta^2 = 0.67$]. Furthermore children's emotional problems of mothers with CM increased significantly more and reached a clinically significant value during the pandemic than for children of mothers without CM [$F(1.86, 116.88) = 8.89$, $p < 0.001$, $\eta^2 = 0.12$].

Abbreviations
SARS-CoV-2, severe acute respiratory syndrome coronavirus type 2; SDQ, Strengths and Difficulties Questionnaire; CTQ, German short version of the Childhood Trauma Questionnaire; CM+, maternal childhood maltreatment experiences; CM−, none maternal childhood maltreatment experiences

Conclusions: Children of mothers with CM appear to be at increased risk of developing emotional problems during the pandemic. CM therefore needs to be considered as an additional risk factor in the impact of the pandemic on children.

KEYWORDS

children's emotional problems, SARS-CoV-2 pandemic, maternal childhood maltreatment (CM), risk factors, parental mental health

Introduction

Restriction in the context of SARS-CoV-2 pandemic and the loss of support by institutional social systems and other family members have posed great challenges for all families and children (1, 2). Within a few days, the lives of 13 million children and their families in Germany had changed abruptly. Schools and daycare centers were closed, playgrounds were off-limits, contact with friends and relatives was restricted, and the children and young people could no longer pursue their usual leisure activities (3), which led to a loss of daily routines and important developmental aspects (4).

Such epidemiologically required restrictions appear to be particularly stressful for families. Brooks and colleagues (5) point out that they endure a plethora of psychological distress, multiple neuropsychiatric manifestations, and psychosocial stigma (5).

Initial studies showed that the quality of life of children and adolescents in Germany declined during the pandemic due to changes and restrictions in their social life (6). Isolation, fear for grandparents, and lack of contact with friends have immediate and lasting psychological effects on children, as their lifestyle, physical activity levels, and mental activities change drastically (7, 8). Thus, current epidemiological restrictions have a demonstrable impact on the emotional and social development of children and adolescents.

Current research is investigating the effect of the ongoing pandemic on the mental health of children and adolescents. The longitudinal COPSY study (COrona and PSYche) of the University Medical Center Hamburg-Eppendorf (UKE) showed that emotional problems among children and adolescents increased from 16% to 24% during the pandemic. In addition, psychosomatic complaints in both children and adolescents increased significantly during the pandemic (e.g., abdominal pain from 21% before the pandemic to 36% during the second lockdown, dejection from 23% to 43%, headache from 28% to 46%, irritability from 40% to 57% and difficulty falling asleep from 39% to 47%) (3). Particularly children between 3 and 6 years old seem more likely to be affected by stress symptoms in their emotional and social development due to the pandemic (9). Findings at the beginning of the pandemic also indicate increased psychological distress for preschool-aged children (3–6 years) and a significant increase of behavioral problems and hyperactivity (4, 10). This finding is consistent with the study by Maldei-Göhring et al. (11), in which more than one-third of preschoolers also had psychological distress by the end of the second lockdown.

Preschool years have an important role in growth and adaption of a child's future. From the perspective of developmental psychology, preschool children go through a variety of developmental steps that require them to be able to experience and try out new situations and social interaction on a daily basis (12). As a developmentally vulnerable population, they need a stable and secure family environment, nurturing relationships, and emotional safety to cope with strains in times of stress and uncertainty, currently triggered primarily by the SARS-CoV-2 pandemic (13). Mentally healthy parents can be seen as an essential aspect here, who serve as a strong and protective factor in children's daily life (13).

Diverse studies found evidence that the health risks and fears associated with SARS-CoV-2 also negatively affect the parental mental health and perceived stress, which in turn influence parental coping and thereby impairs the mental health and well-being of their children (14–19). In particular parents of younger children showed a decrease in mental health since spring 2020 (20).

Several studies have already shown a strong association between parental and children's mental health under pre-pandemic normal conditions [e.g., (21–24)] and the role of caregiver well-being in supporting healthy parenting practices and positive material is also well established (25, 26). For example, Daud et al. (27) found an association between parents' traumatic history and their children's mental health: children of traumatized parents exhibited significantly more symptoms of anxiety, depression, posttraumatic stress, attention deficits, as well as conduct disorders (27). These findings are consistent with the recent research of Prime et al. (28) that also declared an association between preexisting vulnerabilities within the family, such as a parental history of psychological distress, and increased vulnerability to psychological distress in children. A recent meta-analysis of the intergenerational effects of maternal adverse childhood experiences (ACEs)—child abuse, neglect, and household dysfunction—found out that maternal childhood maltreatment had a significant impact on the offspring's depression and internalizing behaviors (29). By the age of 7 children of maltreated mothers were at an increased risk of clinically significant emotional and behavioral problems (30).

The very limited data available suggested a positive association between a history of maternal maltreatment in childhood and offspring mental health problems, including aggression, impulsivity, mood and anxiety disorders, posttraumatic stress disorder (PTSD), suicide attempts, and general emotional and behavioral problems, as well as poorer development of emotional adjustment over time (31–36). A link is hypothesized between maternal childhood maltreatment experiences and emotional problems in children, likely due to adverse parenting outcomes, for example parenting hostility, maternal emotional unavailability, and decreased maternal sensitivity (37, 38). Heleniak et al. (39)

suggested a connection between childhood maltreatment experiences and increased emotional reactivity as a maladaptive response to stress, resulting in mothers with maltreatment childhood experiences experiencing more stress and less social support (39).

Thus, maternal experiences of childhood maltreatment could potentially act as a catalysator that significantly influences the impact of SARS-CoV-2 pandemic restrictions on children's mental health. As a developmentally vulnerable population that is particularly depending on family resources and regular social interactions for social-emotional development, this study hypothesizes that preschool children of mothers with childhood maltreatment experiences will be at higher risk for developing emotional problems during the pandemic than preschool children of mothers without childhood maltreatment experience.

Methods

Study design

The study TransGen was conducted through a cooperative interdisciplinary project with a prospective study design to investigate protective and risk factors concerning biological, psychological, and social components of the transgenerational transmission of maternal abuse. The joint project incorporates sub-projects, which consist of four clinical projects as well as an animal model and was financed by the Federal Ministry of Education and Research from October 2013 till March 2017. The Ethics Committee of Ulm University permitted the research project which got realized in concordance with requirements and policies.

The recruitment of mother-child-dyads took place during the first year after birth at the located maternity unit of the Ulm University. Using the German version of the Childhood Trauma Questionnaire (CTQ), maternal experiences of childhood maltreatment (CM) got assessed one to three days after the women gave birth (40, 41). This was supplemented by three follow-up measurements three months, twelve months, and three years postpartum. The data on maternal childhood maltreatment experiences used in the present study are from this first longitudinal study.

To measure the current stress level of the mothers as well as the children's emotional problems due to the pandemic two online "SARS-CoV-2 pandemic surveys" in two different time frames were offered. First, from May 18th–July 31st, 2020 after the first lockdown (t1), the second from March 1st–May 31st, 2021 after the second lockdown (t2). At the first survey time point (t1), parents were additionally asked for a retrospective assessment of their children's emotional problems before the pandemic (bp). To assess the emotional problems of preschool children the scale "emotional problems" of the German version of the Strengths and Difficulties Questionnaire [SDQ; (42)], a behavioral screening questionnaire which is filled in by a parent, was used.

The following results relate to the emotional problems of children over the time course of the pandemic.

Participants

From October 2013 to December 2015 533 mother-child-dyads could be recruited for the study. Inclusion criteria for women compromised age ≥18 years, adequate use as well as understanding of the German language and, in addition, the health status of both mother and child. A woman's illness (e.g., AIDS disease, hepatitis, etc.), present/prior drug or alcohol abuse, acute mental health problems, severe birth complications, a premature birth with less than 37 weeks of pregnancy or a child with a vastly low weight of birth under 1,500 g depicted an exclusion criterion. For the first follow-up, including laboratory as well as home visits, collectively 240 mothers gave written informed consent, and were then asked to take part in the survey three months postpartum. The next measurement was realized about 12 months postpartum and included an additional laboratory and home visit with a total of 158 mother-child-dyads, followed by a third survey at the child´s age of three. All 158 mother-child-dyads were contacted again per mail and asked to participate in the additional online questionnaire "SARS-CoV-2 pandemic survey" concerning the effect of the pandemic on families on two independent measuring points (t1: May 18th–July 31st, 2020, t2: March 1st–May 31st, 2021). $N = 91$ of the contacted mothers were willing to edit the survey at t1 and $N = 74$ at t2. There were different reasons for not participating in measurement t1 and t2 like a lack of time, no willingness to take part in a particular survey concerning the SARS-CoV-2 pandemic or merely not reaching the families. Analysis was just executed for complete data sets on emotional problems of mother-child-dyads at both waves of data collection, resulting in $N = 74$ sets. Of the $N = 17$ participants from the first survey t1, no data on emotional problems were available at the second measurement point t2 for the reasons stated above and were therefore excluded.

Measures

Consequences of SARS-CoV-2

In the "SARS-CoV-2-pandemic survey" numerous socio-demographic data of the mothers and their family were assessed. These included age, educational level and monthly income of the mother as well as number, age and gender of the children living in the household. Furthermore, changes in income and quantity of work due to the pandemic were surveyed and it was asked, whether they were currently working in a systemically relevant area (professional groups, which contribute to maintaining the economy, health system or basic services). Additional assessments of the online survey are not further explained because of its irrelevance for the present study.

Emotional problems of children

The children's emotional problems were assessed using the German version of the Strengths and Difficulties Questionnaire [SDQ; (42)], a behavioral screening questionnaire for children between 2 and 17 years old, which is filled in by a parent. With $r =$ 0.7 the measurement exhibits an adequate Cronbach´s alpha (43).

This instrument consists of five scales (emotional problems, externalizing behavioral problems, hyperactivity/attention problems, problems with peers and prosocial behavior) addressing positive and negative behavioral attributes of the children. Each scale contains 5 items and is rated on a 3-point Likert scale (0 = not applicable, 1 = partially applicable, 2 = clearly applicable). A total value can be calculated for all items as well as for each of the 5 scales, which provides information about the extent to which the behavior displayed is within the normal, borderline or conspicuous range.

For this study, only the scale "emotional problems" (Cronbach's alpha = 0.66) (44) at the measurement times t1 (May 18th–July 31st, 2020) and t2 (March 1st–May 31st, 2021) as well as the retrospective date assessed at t1 (bp) were analyzed.

For the emotional problems scale all five items were included: "frequently complains of headache, stomachache or nausea", "has a lot of worries, often appears depressed", "Often unhappy or depressed; often cries", "nervous or clinging in new situations; easily loses self-confidence" and "has many fears; is easily afraid". Sum values between 0 and 3 are in the normal range, the sum value of 4 marks the borderline range, and values between 5 and 10 are in the conspicuous range.

Maternal experiences of childhood maltreatment (CM)

Maternal childhood maltreatment experiences were assessed in a previous survey using the German short version of the Childhood Trauma Questionnaire (CTQ) (40, 41). The CTQ is a screening, retrospective self-report questionnaire for the assessment of child maltreatment. The CTQ contains five subscales each assessed by 5 items on a 5-point Likert scale, including emotional, physical and sexual abuse as well as physical and emotional neglect. Additionally, three items assess whether participants tend to trivialize problematic experiences. The psychometric properties of the German version of the CTQ have been demonstrated by Klinitzke and colleagues (45). The internal consistency range between 0.62 and 0.96 for the subscales. Severity scores for each subscale as well as a total score including all five subscales can be calculated, range from "none maltreatment experiences" (CM–) over "minimal" to "extreme" maltreatment load (CM+) (46). Mothers with a total score ≥6 were declared as CM+.

Statistical analysis

Data were analyzed using the Statistic Software R (Version 4.1.3). Statistical significance was set at $p < 0.05$ (two-tailed). Descriptive statistics were calculated to examine the variables' distributions and characteristics. χ^2 tests were calculated to test the distribution of categorical variables in the sample.

We reviewed the bivariate association between potential control and key study variables ahead of our main analyses by calculating Pearson correlations, one-way-ANOVAS and two-sample-*t*-tests.

Inferential analyses were conducted as follows: a mixed analysis of variance (mixed ANOVA) with children's emotional problems (EP) as the dependent variable, time as the within-subject-factor, parental childhood maltreatment (CM) as the between-subject-factor and mother's education and children's sex as covariates were calculated. The requirements normality and homogeneity of variances for a mixed ANOVA were not met. In addition, the data set contained $n = 20$ extreme outliers on the variable emotional problems. Therefore, an additional robust ANOVA with 20% trimmed means was calculates in R using the "WRS2"-package.

Results

Descriptive analysis

Complete data of all measurements could be collected for $N = 74$ children (39 boys and 35 girls) and $N = 74$ mothers. 28 (38%) of the 74 mothers reported CM and were classified as CM+.

During the collection of the "SARS-CoV-2-pandemic-survey" the mother's age ranged from 32-to-50 years ($M = 40.00$, SD = 3.87), children's age ranged from 3-to-6 years before the pandemic (retrospective assessed at t1) ($M = 4.45$, SD = 0.62), 4-to-6 years at t1 ($M = 5.12$, SD = 0.70) and 5-to-7 years at t2 ($M = 5.89$, SD = 0.69). Boys and girls were almost equally represented with a slight overhang of boys (53%). Most women occupy a higher level of education with 54% having a university degree, 7% completed 13 years and 16% 10 years of school education (secondary school degree). Just 4% of the mothers attended 9 years or less at school. Concerning the COVID-19-pandemic 4% of the participants reported a reduction in income and another 8% a reduction of working hours. Descriptive data and results of χ^2-tests are illustrated in **Table 1**.

The mean score of children's emotional problems (EP) rated by their parents was $M = 1.50$ (SD = 1.58) before the pandemic (retrospective assessed at t1), $M = 2.66$ (SD = 1.67) at t1 and $M = 3.27$ (SD = 2.00) at t2 (**Table 2**). Descriptive data and results of χ^2-tests are illustrated in **Table 1**.

Correlation analysis

The calculation of Pearson correlations showed a high intra-individual stability of emotional problems over all three measuring points (bp and t0: $r = 0.77$, $p < 0.001$, bp and t1: $r = 0.63$, $p < 0.001$, t0 and t1: $r = 0.85$, $p < 0.001$).

Mother's age, children's age, mother's highest education and children's sex were tested as covariates. Pearson correlations revealed no significance between mother's age and children's age with emotional problems at every measuring point (**Table 2**) and were therefore not included as covariates. Mother's highest education (retrospective (bp): $F(3, 63) = 3.81$, $p = 0.014$); t1: $F(3, 63) = 5.97$, $p = 0.001$) and children's sex [t1: $t(67.97) = -1.09$, $p = 0.003$]; t2: $t(72) = -3.43$, $p = 0.001$) had a significant effect on children's emotional problems at more than one measuring point and were therefore included as covariates.

Emotional problems in children and maternal CM during the pandemic

A mixed ANOVA with children's sex and mother's highest education as covariates was calculated. Note, that

TABLE 1 Descriptive data and results of χ^2-tests.

	M	SD	Median	Min	Max
Mother's age	40.00	3.87	40	32	50
Children's age bp	4.45	0.62	4	3	6
Children's age at t1	5.12	0.70	5	4	6
Children's age at t2	5.89	0.69	6	5	7
	N	**%**	χ^2	**Df**	***P***
CM					
Yes	28	38	4.38	1	.036
No	46	62			
Children's sex			0.22	1	.642
Male	39	53			
Female	35	47			
Education			82.63	4	<.001
University	42	57			
13 years	6	8			
10 years	13	18			
≤9 years	6	8			
Monthly income			32.38	6	<.001
>4,000 €	22	30			
3,500–4,000 €	13	18			
3,000–3,500 €	26	22			
2,500–3,000 €	11	15			
2,000–2,500 €	8	11			
1,500–2,000 €	1	1			
<1,500 €	2	3			
Diminish in income			49.60	1	<.001
Yes	3	4			
No	58	78			
Reduction working hours			32.67	1	<.001
Yes	6	8			
No	48	65			

Percentages do not add up to 100% due to missing data in some variables. bp, before pandemic (retrospective assessed at t1).

homoscedasticity was not fulfilled for this analysis, results could therefore be distorted and should be interpreted with caution. The analysis showed, that both main effects, as well as the interaction effect were significant. Children's emotional problems increased significantly over time [$F(1.86, 116.88) = 3.72$, $p = 0.030$, $\eta^2 = 0.06$] and were rated significantly higher in the group with CM+ mothers, than in the group with CM− mothers [$F(1, 63) = 126.06$, $p < 0.001$, $\eta^2 = 0.67$]. Furthermore, the analysis showed, that children's emotional problems of children with CM+ mothers increased significantly more, than for children of CM− mothers [$F(1.86, 116.88) = 8.89$, $p < 0.001$, $\eta^2 = 0.12$].

Due to unmet preconditions and limited interpretability, a second analysis without covariates was calculated using a robust ANOVA with 20% trimmed means. The analysis showed, that both main effects, as well as the interaction effect were significant. Children's emotional problems increased significantly over time [$F(2, 44.02) = 46.94$, $p < 0.001$, $\eta^2 = 0.12$] and were rated significantly higher in the group with CM+ mothers, than in the group with CM− mothers [$F(1, 42.02) = 126,06$, $p < 0.001$, $\eta^2 = 0.75$]. Furthermore, the analysis showed, that children's emotional problems of mothers with CM increased significantly more, than for children with CM− mothers [$F(2, 44.02) = 6.95$, $p = 0.002$, $\eta^2 = 0.24$].

More importantly, the measured scores in the SDQ scale "emotional problems" of children with CM+ mothers reached at t1 a value in the borderline range: 4.39 (sum value of 4) and at t2 a value in the conspicuous range to clinically significant psychological distress: 5.54 (sum values ≥5) (see **Table 3**). Descriptive data of children's emotional problems at every measuring point with CM+ and CM− mothers is illustrated in **Table 3** and **Figure 1**.

Discussion

The aim of this study was to investigate if preschool children of mothers with childhood maltreatment experiences are at higher risk to develop emotional problems during the SARS-CoV-2 pandemic than preschool children of mothers without childhood maltreatment experiences.

First, we could demonstrate that emotional problems of all preschool children in the sample increased significantly over the course of the pandemic (see **Table 3**, **Figure 1**). This finding is

TABLE 3 Descriptive data M(SD) of children's emotional problems at every measuring point with CM+ and CM− mothers.

	CM−	CM+
Bp	0.78 (0.96)	2.68 (1.70)
t1	1.61 (0.91)	4.39 (1.07)
t2	1.89 (0.88)	5.54 (1.00)

bp, before pandemic (retrospective assessed at t1).

TABLE 2 Descriptive data and correlations between all relevant variables.

Variable	M	SD	1	2	3	4	5	6	7
1 EP bp	1.50	1.58							
2 EP at t1	2.66	1.67	.77***						
3 EP at t2	3.27	2.00	.63***	.85***					
4 Mother's age	40.00	3.87	.10	.08	.01				
5 children's age bp	4.45	0.62	.13	.08	.10	.25*			
6 children's age t1	5.12	0.70	−0.01	−0.05	.00	.29*	.75***		
7 children's age t2	5.89	0.69	.00	−0.08	−0.06	.26*	.72***	.82***	

bp, before pandemic (retrospective assessed at t1).
*$p < 0.05$.
***$p < 0.001$.

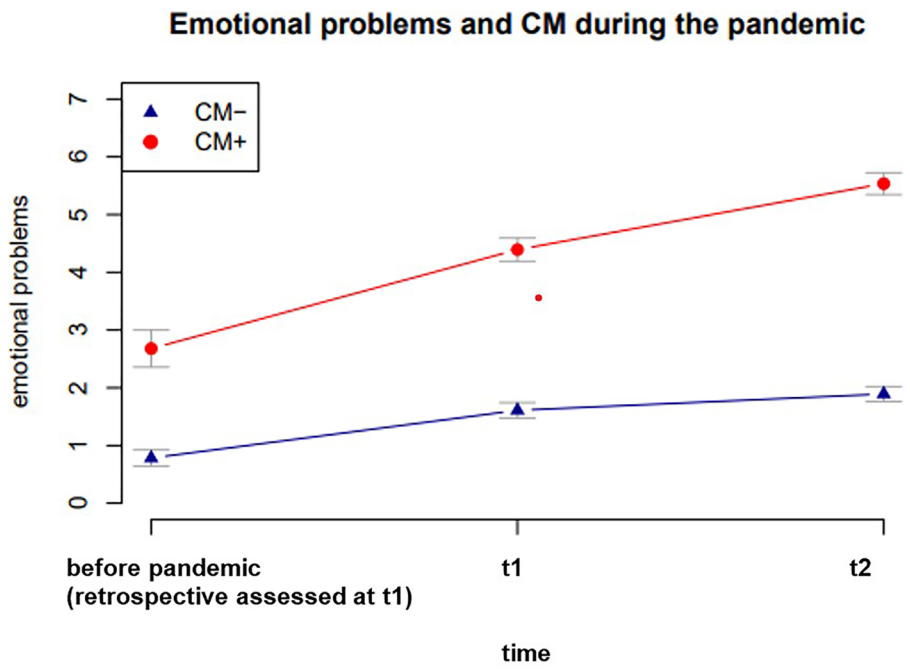

FIGURE 1
Means of children's emotional problems as a function of CM and the SARS-CoV-2-pandemic with standard errors.

consistent with current studies (2–4, 9–11). Our analyses showed that emotional problems of children of CM+ mothers were assessed significantly higher than in the group of children with CM− mothers and that emotional problems of children with CM + mothers increased significantly more and reached a clinically significant value during the pandemic than those of children with CM− mothers. A high intra-individual stability of emotional problems over all three time points could be observed (see **Table 3**, **Figure 1**).

Several studies can be used to explain this effect. Children's developmental risk is related to caregivers' current mental and physical health status through multiple social and biological pathways, including epigenetic changes related to early adversity such as childhood maltreatment experiences (47–49). Numerous strands of research suggested that the experience of childhood maltreatment leads to permanent disruption of stress regulation abilities, negatively affecting both structures and functions of brain areas involved in mental health and the ability to regulate emotion and behaviour (50–60). Several research findings suggested that the impact of a maternal history of childhood maltreatment on one's children is dependent on the child's developmental status as well as ecosystem-level risk factors, i.e., environmental elements that have been shown to influence quality of care, including maternal exposure to stress/negative life events and access to social support (59). For example, the risk for poor care and/or child maltreatment among mothers with childhood maltreatment experiences may increase during the preschool years when the child is struggling for autonomy, testing limits, and having frequent and intense emotional outbursts (51). Maltreated mothers may respond inappropriately to these demands due to their own impaired self-regulatory abilities (51).

Disruption of stress regulation abilities can also impact the caregiving and interactional context in which it negatively affects maternal mental health and quality of care, and directly exposes the child to adverse growth conditions (36, 52). Several studies have demonstrated associations between a maternal childhood maltreatment history and insensitive caregiving behaviors, including hostility, harsh discipline, intrusiveness, inconsistency, lower involvement, and rejection (32, 34, 36, 53, 54). Exposure to such caregiving behaviors increases the risk for child's mental health problems (60). A few studies suggested that disrupted maternal caregiving partially mediates the association between maternal childhood maltreatment history and offspring mental health [e.g., (32, 36)], whereas other studies have found no such evidence (34).

Very limited data suggested that children of maltreated mothers experience greater psychosocial adversity and negative life events (32, 34). For example, Collishaw et al. (2007) (32) found out that children of mothers with childhood maltreatment experiences were not only exposed to a wide range of stressful life experiences in early childhood, but were also faced with an increasing number of different stressors between the ages of four and seven (32), and that these stressors partially mediate the association between maternal childhood maltreatment experiences and child's mental health problems (32, 34).

Because only few studies to date have examined the factors that influence the impact of maternal childhood maltreatment experiences on children's mental health, again, only hypotheses can be made about the individual mechanisms by which

maternal childhood maltreatment experiences affect preschool children's mental health during the SARS-CoV-2 pandemic. The pandemic can be seen as a critical and stressful life event for both children and adults, which poses special challenges to both children and adults and demands a high level of stress regulation skills. If parents are limited in their stress regulation abilities as well as parenting skills due to their own childhood experiences, it can be assumed that mothers with CM+ will not be able to meet the needs of their children to the required extent in times of the pandemic and emotional problems in these children may increase or intensify during the pandemic, as our results showed.

However, the results do not allow to draw any conclusions about the individual mechanisms how maternal childhood maltreatment experiences acts on the mental health of preschool children in the context of the pandemic. It is unclear, for example, whether the children's emotional problems can be attributed solely to the parents' inability to regulate stress and meet the children's special needs during the pandemic, or whether these children are already limited in their own ability to regulate stress through transgenerational transmission or because they have already been exposed to increased stressors in their life history. Further research is needed to specify the link between maternal childhood maltreatment experiences and children's mental health in the context of the pandemic.

Limitations

Considering the present study, we have to contemplate some limitations.

First, the collected data sets and online survey consist of a restricted sample of mother-child dyads of one mother birth cohort. Willingness to talk openly about their children's mental health could influence their consent to participate in the survey. In addition, it has to be taken into account that social desirability might impact the motheŕs evaluation of such questions. In addition, there may have been recall bias or underestimation by self-report, since children' s emotional problems before the pandemic, which was used as a baseline in this study, were recalled retrospectively by the mothers.

Due to the small sample size and the short survey duration during an early stage of the pandemic, future studies need to focus on the validation of our results and support our hypothesis with a representative sample size.

Secondly, our study was conducted at the end of the 1st and 2nd lockdown in Germany. Preliminary findings suggest that the burden in the population has decreased again since then (62). Therefore, to assess the long-term impact of the COVID-19 pandemic on children's mental health, a longitudinal analysis is needed. In this, additional protective and risk factors, such as parental mental health (63) as well as parental coping and parenting (64, 65) should be assessed to uncover critical evidence of mechanisms for child well-being and provide an empirical basis for implementing pandemic prevention programs.

Third, it has to be considered that a great number of our participants had a high standard of education, a partnership and did not suffer from reduction of income as a consequence of the pandemic. Thus it is difficult to generalize our results to all families or the general population. According to Meng et al., (66) psychological well-being and life satisfaction are influenced by education and socioeconomic status with an increase resulting in greater well-being and life satisfaction. Thus, it must be assumed that the emotional problems of children from families with low socioeconomic status could be even higher than in our present sample.

It should also be noted that the internal consistency of the emotional problems scale of the SDQ is low, with a value of Cronbach's alpha = 0.66 (44). Comparisons with existing studies on the development of emotional problems in preschool children during the pandemic, which were not conducted with the same measurement instrument (emotional problem scale of SDQ), should be made with caution.

Finally, there are some limitations regarding statistical analyses. A mixed ANOVA with children's sex and mother's highest education as covariates was calculated. Note, that Homoscedasticity was not fulfilled for this analysis, results could therefore be distorted and should be interpreted with caution. Due to unmet preconditions and limited interpretability, a second analysis without covariates was calculated using a robust ANOVA with 20% trimmed means. Both analyses showed, that both main effects, as well as the interaction effect were significant, so it can be assumed, that the results are statistically significant.

Conclusion

Our study demonstrated that preschool children of mothers with childhood maltreatment experiences are at significantly higher risk of developing clinically significant emotional problems over the course of the pandemic.

Several studies have already addressed variables or family risk factors that influence children's mental health or led to psychological distress in the context of SARS-Cov-2- pandemic restrictions (e.g., low socioeconomic status (4, 6, 66), tight housing, preexisting mental illness, immigrant background, parents with a low level of education or who suffer from mental illness (3, 4, 67–71), age of the child, reduce income, dissatisfaction with shared childcare as consequences of the pandemic (64)).

Our findings show that maternal childhood experiences (CM+) also represent a risk factor for preschoolers' mental health that is amplified by pandemic conditions. CM+ therefore needs to be considered as an additional risk factor, that influences children's emotional well-being during the pandemic. Thus, the study makes an important contribution to the analysis of family risk factors affecting children's mental health during the pandemic and joins the research strand on risk factors.

Our findings suggest that pandemic disasters and subsequent containment efforts create a condition that can negatively affect the emotional health of young children and their mothers. Because of the increased dependence of children on their parents for stress regulation and the influence of parental stress on children's mental health, special response strategies are needed to

address the emotional health needs of young children and their families. Pandemic mitigation measures must take these needs into account. Because pandemic disasters are unique and there are no held-forward interventions for prolonged support and recovery our findings reinforce existing calls [e.g., (3, 67, 69)] to expand preventive services to promote and maintain stress coping skills for both children and parents in order to maintain children's mental health in times of crisis.

Data availability statement

The original contributions presented in the study are includes in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The study involving human participants were reviewed and approved by the Ethics Committee of Ulm University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MD, FK and KR analyzed and interpreted the data regarding measures in the context of the SARS-CoV-2-pandemic on the emotional health of preschool children. KR and FK prepared the Figure 1 and Tables 1–3. MD drafted the main manuscript text. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Motivational decline and proactive response under thermal environmental stress are related to emotion- and problem-focused coping, respectively: Questionnaire construction and fMRI study

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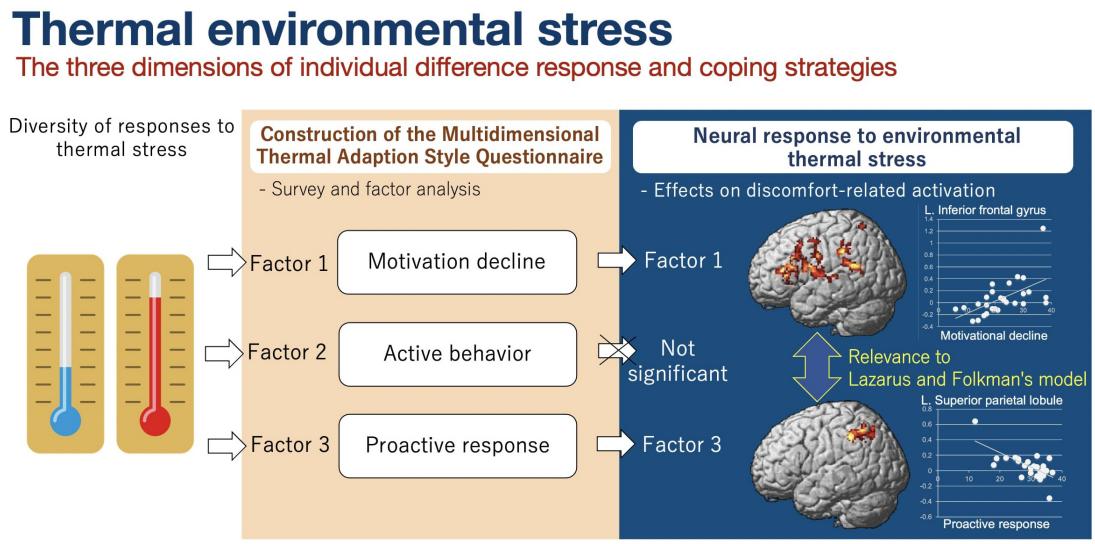
Despite the diversity of human behavioral and psychological responses to environmental thermal stress, the major dimensions of these responses have not been formulated. Accordingly, the relevance of these responses to a framework of coping with stress (i.e., emotion- and problem-focused) and the neural correlates are unexplored. In this study, we first developed a multidimensional inventory for such responses using social surveys and a factor analysis, and then examined the neural correlates of each dimension using a functional magnetic resonance imaging; we manipulated the ambient temperature between uncomfortably hot and cold, and the correlations between the inventory factor scores and discomfort-related neural responses were examined. We identified three factors to construct the inventory: motivational decline, proactive response, and an active behavior, which appeared to reflect inefficient emotion-focused coping, efficient problem-focused coping, and positive appreciation of extreme environmental temperatures, respectively, under environmental thermal stress. Motivational decline score was positively associated with common neural response to thermal stress in the frontal and temporoparietal regions, implicated in emotion regulation, while proactive response score negatively with the neural responses related to subjective discomfort in the medial and lateral parietal cortices, implicated in problem-solving. We thus demonstrated that two of three major dimensions of individual variation in response to and coping with environmental

thermal stress conform to an influential two-dimensional framework of stress coping. The current three-dimensional model may expand the frontiers of meteorological human science in both basic and application domains.

KEYWORDS

coping, stress, thermal, fMRI, discomfort, emotion regulation, thermal stress, psychological responses



GRAPHICAL ABSTRACT

1. Introduction

Humans live in diverse thermal environments on earth (Jendritzky and Tinz, 2009). Rarely are temperatures within the range of human comfort, and all people cope with thermal environmental stress through technical, behavioral, or psychological methods (Gao et al., 2018; Coudevylle et al., 2019). Interestingly, a great deal of individual variation exists in how people respond and prefer to cope with thermal stress (Foster et al., 2020). That is, the individual difference in such responses or coping strategies may have multiple dimensions: for example, the difference can have an aspect of vulnerability or tolerance to temperature changes (Shi et al., 2016), that of the level of preparedness to the change (Tochihara et al., 2022), and that of the degree how one enjoys the change (Nikolopoulou et al., 2001).

Understanding such multiple dimensions in the diversity of responses and coping strategies to thermal environmental stress and their psycho-behavioral or neural underpinning may provide more effective ways to cope with thermal environmental stress (Salomons et al., 2007; Coudevylle et al., 2019). This is an issue of wellbeing (Tham, 2004; Li et al., 2021), due to the decreased physical condition (Coudevylle et al., 2019) and cognitive performance (Laurent et al., 2018), as well as increased mortality (Huynen et al., 2001), related to thermal environmental stress. In addition, this is significant in terms of the growing importance of reducing energy for air conditioning and sustainability (Fukusaka and Matsubara, 2014). On the other hand, it may also contribute to an anthropological understanding of why humans can adapt to a wide range of thermal environments and have become distributed more ubiquitously across the globe than other animal species (Hanna and Brown, 1983; Tochihara et al., 2022).

An influential conceptual framework for multiple dimensions in stress-coping in general is the Lazarus and Folkman's model (Folkman and Lazarus, 1980, 1985), which categorizes stress coping strategies into emotion-focused coping and problem-focused coping strategies. Emotion-focused coping strategies (also referred to as antecedent-focused) involve regulating the emotional reaction that the stressor elicited; these occur in two forms of adaptive emotion regulation strategies, such as restructuring and reinterpreting a negative situation (reappraisal), or accepting negative situations more easily (acceptance) (Wolters et al., 2010; Aldao and Nolen-Hoeksema, 2012; Shin et al., 2014). Emotion-regulation failure of this adaptive strategy is thought to be responsible for some psychopathology, such as mood-related disorders (e.g., depression and anxiety), externalizing disorders (e.g., substance use and eating disorders) (Aldao et al., 2010), and anti-social attitudes (i.e., as a consequence of regulatory failure) (Koenigsberg et al., 2009). In contrast, the adaptive emotion regulatory strategy related to the problem-focused coping strategy (also referred to as proactive coping) (Aldao et al., 2010) attempts to focus directly on the problem and to solve the existing problem (i.e., stress) (Diponegoro et al., 2020). Individuals plan the next step or incorporate information to mobilize actions to change the situation (Lazarus, 1991; Van Zomeren et al., 2010).

These two dimensions of stress-coping strategies may be relevant to neural processes at different stages of emotion processing. A successful emotion-focused coping strategy (i.e.,

reappraisal or acceptance) is assumed to tap into the early stage detection process, or the first-level valuation of emotion in an influential process model of emotion (Gross, 1998b) as well as the acceptance of mindfulness (Ho et al., 2015). Individuals who efficiently use this type of strategy prevent this first-level valuation developing into second-level valuation, which encompasses emotional responses in various domains (i.e., consciousness, physiology, and behavior) linked to emotional stress (Öner, 2018). Neuroimaging studies have explored neural correlates of such a capacity using correlational analysis and trait measures of emotion-regulation capacity scores. They compared groups with different levels of neural activation capacity during manipulation of emotional stress caused by various stressors (Salomons et al., 2007; Preis et al., 2015; Kober et al., 2019; Messina et al., 2021), such as unpleasant scenes, thermal pain, negative autobiographical memories, one-sentence stressful scenarios, worry statements, and negative self-belief statements. Most of these studies demonstrated that adaptive individuals present with less activation of the brain regions involved in the emotional control response and modulation of emotion-generating processes, such as limbic (e.g., amygdala, insula) and semantic (e.g., superior temporal gyrus; STG) related brain structures, respectively, under potential emotional stress (Preis et al., 2015; Kober et al., 2019; Messina et al., 2021). However, the role of the executive function system remains controversial (e.g., dorsolateral prefrontal cortex; DLPFC, ventrolateral prefrontal cortex; VLPFC), which is used with various emotion regulation strategies (Salomons et al., 2007; Kober et al., 2019; Messina et al., 2021). Some studies have suggested that adaptive individuals show greater activation, reflecting the appropriate use of these strategies (Salomons et al., 2007) while others have suggested the opposite (Kober et al., 2019; Messina et al., 2021), arguing that involvement reflects the emotional response itself, inefficient use of the strategy, or dependence on the type of instruction (i.e., natural reaction or focus on emotion).

On the other hand, it is theoretically expected that the capacity to problem-focus cope is reflected in the late stage of emotion processing, that is, when one is aware of the emotional stress and the problem behind the stress is worth solving. Neuroimaging studies have suggested the involvement of lateral and medial parietal cortices in such creative problem-solving (Bartley et al., 2018) and future thinking (Stawarczyk and D'Argembeau, 2015; Schacter et al., 2017), but the view remains mixed regarding how spontaneous engagement of such problem-solving systems is related to individual problem-solving capacity. Some studies have suggested more engagement of the system in higher-capacity individuals. For example, high problem-solving performance is associated with greater activation of the medial parietal region during the performance of an unrelated task before explicit problem-solving (Kageyama et al., 2019) and young adults rich in social experience reveal high activity in the lateral parietal cortex during judgment of the appropriateness of the use of honorific expressions (Cui et al., 2022). Other studies have suggested the opposite; high problem-solving performance is associated with minimal activation of the lateral parietal during the management of unexpected trouble in a realistic plant-control simulator (Miura et al., 2020) and high decision-making speed with low temporoparietal activation during realistic social-problem solving (recommending clothing in a difficult social context) (Oba et al., 2020).

Regarding the thermal environmental stress, however, dimensions in the responses and coping strategies has been yet to be formulated and accordingly their psycho-behavioral or neural underpinning are yet to be explored. Previous relevant meteorological studies relied on a unidimensional vulnerability/tolerance construct to investigated individual factors (e.g., age, sex, emotional state) that affect thermal environmental stress and the cognitive processes (Wang et al., 2018; Zhang et al., 2019). Cognitive neuroscience of environmental thermal perception remains its infancy (Oi et al., 2017) and individual difference in the responses or coping strategies has not been explored.

In this study, we aimed at formulating major dimensions of the individual difference in responses or coping strategies to thermal environmental stress and understand the neural correlates of each dimension. To this end, we first created a multidimensional inventory (Multidimensional Thermal Adaption Style Questionnaire; MTASQ) by collecting a wide range of people's daily responses or coping strategies to thermal environmental stress and then identifying their major dimensions using a factor analysis (Comrey, 1988). We also explored the correlation between each MTASQ dimension score and various demographic, physiological, and psycho-behavioral variables to validate and characterize each dimension; we were interested in if the identified dimensions conform to Lazarus and Folkman's model and how they are related to adaptability based on anthropological interest. For psycho-behavioral variables, we used two questionnaires: one known as the eight factors of the "Power to Live," which was advantageous for survival in various disaster contexts (Sugiura et al., 2015), and another known as the Big Five General Personality Traits (Gosling et al., 2003; Oshio et al., 2012). The former was included based primarily on anthropological interest because the eight factors are relevant to different survival-relevant processes in various physical (Sugiura et al., 2019; Sato et al., 2021), social (Sugiura et al., 2020, 2021), and developmental (Matsuzaki et al., 2022; Sugiura, 2022) contexts. The latter, together with demographic and physiological variables, were used to compare their correlation pattern between the MTASQ dimensions and two types of stress-coping strategy (i.e., emotion- and problem-focused) in Lazarus and Folkman's model, for which knowledge on such correlation patters are available (Chen et al., 2018; Agbaria and Mokh, 2022). We expected that some of the MTASQ dimensions would be conformal to emotion-focused or problem-focused strategy.

We then investigated the neural correlates of each MTASQ dimension during uncomfortable thermal environmental stress using fMRI. We manipulated the ambient temperature in the gantry of the scanner between uncomfortably hot and cold ranges and obtained the time-series data of brain activation and rating of subjective level of discomfort. For the analyses, we adopted two neural-activation models to extract different types of thermal discomfort-related neural response relevant to different stages of emotion processing (Gross, 1998a). The first model was created to capture the detection process of thermal discomfort at an early stage, which was the first level of valuation before the second-level valuation or the emotional responses. Assuming that the process was unaffected by individual emotion-focused coping and

largely the same across participants, the model was created by averaging the time-series data of the discomfort rating across all the participants (average model). The second model was created to capture responses related to subjective perception of thermal discomfort associated with a late stage, second-level valuation, or an emotional response. The model was individually tailored using a subjective rating for each participant (individual model). We expected that the scores of the emotion-focused MTASQ dimension would be correlated with activation in emotion-regulation-related brain regions in the average model, and that those of the problem-focused MTASQ dimension would be correlated with the parietal cortices in the individual model.

2. Materials and methods

The research was composed two components. First, we created a multidimensional inventory (i.e., MTASQ) for individual difference in the responses or coping strategies to thermal environmental stress, and explored the correlation between each dimension score and various demographic, physiological, and psycho-behavioral variables to validate and characterize each dimension (2.1). Second, we investigated the neural correlates of each MTASQ dimension during uncomfortable thermal environmental stress using fMRI (2.2).

2.1. Construction of the MTASQ

A qualitative survey was initially performed to prepare the candidate inventory items, and then a quantitative survey was conducted to perform a factor analysis of these candidate items. The latter survey also included variables to assess the criterion-related validity of the identified factors. The survey protocols were reviewed and approved by the Ethics Committee for Surveys and Experiments at the International Research Institute of Disaster Sciences, Tohoku University (2016-013).

2.1.1. Participants

The two surveys were conducted by a crowd-sourcing company (Cross Marketing Inc., Tokyo, Japan). The respondents were recruited from the company's registered panel in Japan and participated in exchange for an online voucher/shopping points. The participants were stratified into five age classes (20s, 30s, 40s, 50s, and 60s) and two sexes (male or female) for each survey. We intended to have 20 and 120 respondents for each class after data pre-screening (excluding straight-line responders) in the qualitative and quantitative surveys, respectively. As a result, we obtained 20–22 (n = 203 in total) and 114–145 (n = 1,327 in total), respectively. See **Supplementary Table 1** for the detailed statistics of the responders. The recruitment of the responders for the two surveys was conducted separately, but the potential overlap of the responders between the two surveys could not be assessed due to the anonymous nature of the surveys.

2.1.2. Qualitative survey

Responders were asked to provide ten first-person-perspective descriptions for "what they think, do, or want to do" when "the temperature gets hotter" and when "the temperature gets colder". They were also asked to provide five third-person-perspective descriptions of a person who is tolerant of heat, a person who is sensitive to heat, a person who is sensitive to cold, and a person who is tolerant of cold, regarding their "characteristics and what they are likely to think or do".

All of the descriptions were pooled and sorted by their meaning and context. Through extensive discussions with the authors, the descriptions were summarized and formatted into phrases for a self-applicability rating, resulting in 70 candidate items for the hot environment and 70 for the cold environment. There were many common or similar items between the hot and cold environments.

2.1.3. Quantitative survey

Respondents were presented with 70 candidate questionnaire items for the hot environment ("When it's hot,") and 70 for the cold ("When it's cold,") and were asked for a self-applicability rating on a 7-point scale (1: *not at all applicable*; 7: *very much applicable*).

The participants responded to another 54 items to generate 22 variables to assess the criterion-related validity of the factors. Demographic variables included sex and age. Physiological or psychological variables related to thermal perception included body mass index (BMI = weight/height^2), subjective levels of tolerance/intolerance to hot/cold environment ($2 \times 2 = 4$ variables; "I think I am a hot/cold tolerant/sensitive person,") on a 7-point scale (1: *not at all applicable*; 7: *very much applicable*), and the tolerable range of ambient temperatures (in °C). The "Power to Live" scale was comprised of 34 items on a 6-point scale (0: *not at all*; 5: *very much*), with eight factors: leadership, problem-solving, altruism, stubbornness, etiquette, emotion regulation, self-transcendence, and active wellbeing. The internal consistency and concurrent validity of the questionnaire have been demonstrated (Sugiura et al., 2015; Ishibashi et al., 2019). We used the Japanese version of the Ten-Item Personality Inventory for the Big Five Personality Scale (Gosling et al., 2003; Oshio et al., 2012), which includes one positive item and one reverse-scored item on a 6-point scale (0: *not at all*; 5: *very much*) for each of the five factors, including extraversion, agreeableness, conscientiousness, neuroticism, and openness. We adopted this very short version of the Big Five Inventory to minimize fatigue or frustration, which could decrease the rate and quality of the responses. The validity of this short version of the Big Five Inventory has been established in terms of convergent and discriminant validity, coverage of sub-dimensions, test–retest reliability, and patterns of external correlates. The sum of the scores for each factor or dimension (the scores of reverse items were reverse coded) was converted to a ratio against the maximum score.

2.1.4. Analysis

A factor analysis was performed on the ratings of the 140 candidate items using a maximum likelihood method to determine the major factors associated with the individual differences in the responses to environmental thermal stress. The number of factors to include was determined using a scree plot. The Promax rotation method was applied.

We expected to identify factors related to the responses to general environmental thermal stress rather than those specific to a hot or cold environment. As a result, similar psychological or

behavioral responses to hot and cold environments were largely clustered in the factor analysis (see section "3. Results"). Therefore, we decided to include similar hotness-related and coldness-related responses as a pair and select the three pairs with the highest average factor loadings. This resulted in a list of three typical responses to the uncomfortable thermal environment for each factor without specific responses to the hot or cold environment. By limiting the pairs to three, the questionnaire was kept concise enough to be easily used. The internal reliability of each factor (i.e., six items) was evaluated using Cronbach's α.

Criterion-related validity of each factor was assessed using associations between the factor score (i.e., the total score of six items) and the demographic, physiological, and psycho-behavioral variables. Because a hypothesis of normal distribution was rejected ($p < 0.05$, Shapiro-Wilk test) in all the three factors, non-parametric tests were used. The effect of sex was assessed using a Mann-Whitney *U*-test (Mann and Whitney, 1947) and the effects of the other variables were tested using Spearman's correlation analysis (Spearman, 1961). We also examined the cross-correlation among MTASQ factors. We report *p*-statistics at an uncorrected $p < 0.05$ and a Bonferroni's corrected *p* (*total number of tested associations across all variables and factors) <0.05 level. However, we selected the significant associations based on the effect-size criteria given too much statistical sensitivity due to a large sample size (Cohen, 1992): large, medium, and small size effects for Vargha and Delaney's A >0.71, 0.64, and 0.56, or <0.29, 0.34, and 0.44 (Vargha and Delaney, 2000), and Spearman's $\rho > 0.5$, 0.3, and 0.1 (Ellis, 2010), respectively. The analyses were performed with free R (version 4.2.2) statistical software by using the *stats*, *psych*, and *effsize* packages.

2.2. fMRI

2.2.1. Participants

Forty-six healthy right-handed adults (mean age = 21.2 years, *SD* = 1.6, age range = 18.0–25.0 years, 15 females) were recruited from Tohoku University, Sendai, Japan. The experiment was performed during July–September. Written informed consent was obtained from each participant. The experiment was conducted following the Declaration of Helsinki, and all procedures were approved by the Institutional Review Board of the Tohoku University, Graduate School of Medicine, and the Nissan Motor Ethics Committee.

2.2.2. Experimental equipment and procedures

The participants adjusted their clothes until they felt comfortable in the ambient temperature of the scanner room (approximately 22°C). Strict control over clothing was avoided to match more closely the study environment with that of the participant's daily life experience. Each participant lay on the MRI scanner bed with a temperature transducer attached to the scanner bed, close to the MRI head coil, and the participant's head was fixed to the head coil using a band and foam blocks. The participants were covered with a large plastic canopy fit to the size of the MRI gantry, and hot or cold air produced using an air conditioner located outside the scanner room was blown into the canopy through a duct (Oi et al., 2017). During the fMRI measurement, 10 min heating and 10 min cooling phases were alternated twice; the session began with the heating phase for half of the participants and with the cooling phase for the other half. All participants were asked to rate independently their subjective levels of thermal sensation and discomfort/comfort every 30 s. The temperature change was intended to range between uncomfortably hot or cold with a comfortable range in between (mean = 23.1°C, mean range = 19.3–26.2°C, *SD* = 1.3), which would cause the frequency of the time-series changes in thermal uncomfortable ratings to be double those of the thermal sensation ratings; thus, the two ratings were independent. After the fMRI scanning and tasks were completed, each participant was removed from the scanner and completed the MTASQ rating.

2.2.3. fMRI task

The ratings of subjective levels of thermal sensation and discomfort/comfort were alternately instructed separated by 15 s interval. A 4-button MRI-compatible pad was held in each hand. One pad was used for the four-point scale to indicate thermal sensation (1: *cold*, 2: *cool*, 3: *warm*, and 4: *hot*), while the other pad was used for the four-point scale to indicate thermal comfort (1: *discomfort*, 2: *slight discomfort*, 3: *slightly comfortable*, and 4: *comfortable*). The button arrangements were counterbalanced across all participants. The task instructions were presented *via* MRI-compatible goggles. In each trial, an instruction for the button assignment was visually presented for 5 s, during which the participant was required to respond, followed by presentation of a fixation cross for 10 s. In total 80 sensation and 80 comfort trials were performed over 40 min. The task was controlled by PsychoPy v1.83.03, which presented the stimuli and recorded the participants' ratings for later analysis.

2.2.4. fMRI data acquisition and pre-processing

All fMRI data were acquired with a 3T Philips Achieva scanner (Philips Healthcare, Best, Netherlands) using an echo-planar sequence sensitive to the blood oxygenation level-dependent contrast with the following parameters: 64 × 64 matrix, repetition time (TR) = 2,500 ms, TE = 30 ms, flip angle = 85°, FOV = 192 mm^2, 39 slices, slice thickness = 3.0 mm and gap = 0.5 mm. A total of 960 volumes were acquired during the session.

The following preprocessing procedures were performed using Statistical Parametric Mapping (SPM12) software (Wellcome Department of Imaging Neuroscience, London, UK) and MATLAB (Mathworks, Natick, MA, USA): acquisition timing across slices was adjusted and head motion was corrected and normalized to the Montreal Neurological Institute (MNI) reference space using the EPI template and smoothed with an isotropic Gaussian kernel with 5 mm full-width at half-maximum. The choice of the smoothing-kernel size was based on our previous study (Oi et al., 2017).

2.2.5. Behavioral data analyses

We conducted a Spearman's correlation analysis between the MTASQ scores of the participants and the thermal sensation and comfort ratings during the fMRI experiment, expecting a relationship between a high emotion-focused coping tendency and sensitivity to discomfort (Amen, 2008; Schoenmakers et al., 2015). The average thermal sensation and comfort rating scores were used. Analyses were performed using SPSS version 25 for Windows and

a $p < 0.05$ and 0.10 were considered significant and tendency of correlation, respectively.

2.2.6. fMRI data analyses

A conventional two-level fMRI analysis was adopted using SPM12 (Friston et al., 1990, 1991). The heat (i.e., based on sensation rating) and discomfort (i.e., based on reverse-coded comfort rating) perceptions were modeled as a general linear model (GLM) for the first-level analysis. The individual model and average model were modeled as separate GLMs. The individual model used the raw rating score of each participant, as in our previous study (Oi et al., 2017). The average model, which was newly adopted in this study, used an average rating across all participants at each time point. The ratings were linearly interpolated at each scan time (i.e., TR = 2.5 s). The convolution of the hemodynamic response function was not adopted considering the significant delay in the rating from the actual thermal sensation. Six estimated head motion parameters were included in the GLMs as confounding factors. High-pass filtering with a frequency cut-off at cycle/1,200 s (i.e., twice the cycle of the change in the comfort rating) was applied to reduce low-frequency noise in the brain activity.

As a second-level analysis, two approaches were adopted to investigate effects of the MTASQ factors on discomfort-related neural activation in the regression analysis. For the first approach, we initially identified discomfort-related activation using a one-sample *t*-test, and then examined the effect of the MTASQ factors at the peak voxels of the identified activation clusters using a liberal statistical threshold for the region-of-interest (ROI) regression analysis. This approach assumed a modest level of individual difference. For the second approach, voxel-wise simple regression analyses using the MTASQ scores were directly performed; this approach assumed robust individual differences in activation, which may have prevented detection of discomfort-related activation using an across-participant one-sample *t*-test. For each approach, discomfort-related activation was estimated using the individual model and the average model separately, and analyzed for distinct MTASQ factors independently; gender was included as a covariate. As a *post hoc* analysis for the first approach, a one-sample *t*-test on the average model at the peak voxels was identified using the one-sample *t*-test on the individual model, and vice versa, were also applied. For the second approach, the same MTASQ regression on the average model at the peak voxels identified using the same MTASQ regression on the individual model, and vice versa, were also applied. The voxel-wise statistics used an uncorrected $p < 0.005$ for the cluster-forming threshold, which was thresholded at a family wise error-corrected $p < 0.05$ for cluster extent, following our previous study (Oi et al., 2017). The statistical threshold for the ROI analyses was set to an uncorrected $p < 0.05$. The identified brain structures were

TABLE 1 Results of factor analysis.

Environment	Items	F1	F2	F3
F1 motivational decline (α = 0.869)				
Hot	I don't smile as much	**0.687**	−0.015	−0.028
Cold	I don't smile as much	**0.867**	0.024	−0.049
Hot	I don't talk a lot	**0.676**	−0.061	−0.017
Cold	I don't talk a lot	**0.836**	0.015	−0.035
Hot	I have negative thoughts	**0.578**	−0.034	0.136
Cold	I have negative thoughts	**0.676**	0.004	0.113
F2 active behavior (α = 0.794)				
Hot	I try to sweat (sauna, heavy clothing, etc.)	0.003	**0.706**	−0.039
Cold	I try to sweat (sauna, heavy clothing, etc.)	0.060	**0.676**	0.084
Hot	I exercise (sports, training, etc.)	−0.111	**0.735**	0.082
Cold	I do winter sports (skiing, snowboarding, etc.)	0.086	**0.593**	−0.142
Hot	I go camping and barbecuing	0.022	**0.525**	−0.055
Cold	I actively go out	0.025	**0.487**	0.090
F3 proactive response (α = 0.728)				
Hot	I pay attention to the weather forecast	−0.003	0.059	**0.644**
Cold	I pay attention to the weather forecast	0.059	0.039	**0.668**
Hot	I hydrate frequently	−0.128	0.024	**0.464**
Cold	I take warm drinks and food	−0.110	−0.074	**0.612**
Hot	I take care not to get sunburned	0.053	−0.012	**0.404**
Cold	I worry about dryness	0.012	0.003	**0.589**

The results of the final factor analysis after selecting three pairs of the same or similar psychological or behavioral responses to the hot and cold environment. The items in a pair (i.e., for the hot and cold environments) and their factor loadings (in bold indicates >0.5) are given for each factor; the pairs are listed in the order of the average factor loading. Hot and cold for the environment indicate that the question is asked about hot ("When it's hot,") and cold ("When it's cold,") environments, respectively. α: Cronbach's α.

anatomically labeled using the SPM Anatomy toolbox (Eickhoff et al., 2005).

3. Results

3.1. MTASQ

3.1.1. Factor analysis

We accepted a three-factor solution based on the scree plot, which showed an abrupt drop in loading between the third and fourth factors and a subsequent gradual decline (30.9, 9.95, 6.24, 3.72, 3.16, 2.66, 2.49...). The results of the factor analysis after selecting six items (i.e., three pairs) for each factor are given in **Table 1**. The first factor was composed of loss of smile, decreased talk, and negative thoughts in an uncomfortable thermal environment, which we interpreted commonly to reflect "Motivational decline." The second factor was composed of "Active behaviors" including an attempt to sweat (sauna and heavy clothing), physical exercise, and going out. The third factor was composed of precaution actions aimed at preventing adverse effects of the uncomfortable thermal environment or related weather, such as attention to the weather forecast, drinks, food, and skin, which we labeled the "Proactive response." Each item had a loading of $\geq$0.404 on the relevant factor and $\leq$0.142 on the other factors. Each factor had good internal consistency and reliability with Cronbach's $\alpha \geq 0.728$.

3.1.2. Criterion-related validity

Table 2 shows the association between the factor scores and the demographic, physiological, and psycho-behavioral variables, and the scores for the other MTASQ factors. Several associations with

TABLE 2 Associations between the scores on the Multidimensional Thermal Adaptation Style Questionnaire and the variables.

		F1 motivational decline	F2 active behavior	F3 proactive response
Mean ± standard deviation				
Sex	Male	19.0 ± 7.5	17.7 ± 6.8	26.9 ± 5.9
	Female	19.4 ± 6.8	15.6 ± 6.5	31.8 ± 5.8
	U	222.246	179.069**	320.115**
	A	0.507	*0.408*	**0.730**
Spearman's ρ				
Age		*−0.112***	−0.029	0.018
BMI		−0.064*	0.021	*−0.169***
Subjective tolerance	Hot	*−0.100***	*0.209***	−0.053
	Cold	−0.083*	0.074*	0.014
Subjective intolerance	Hot	*0.197***	*−0.120***	*0.176***
	Cold	*0.181***	−0.005	*0.114***
Tolerable temperature	Max.	−0.098**	0.090*	−0.052
	Min.	*0.114***	−0.034	0.038
Power to live	Leadership	−0.035	**0.430****	0.003
	Problem solving	*−0.129***	*0.145***	*0.270***
	Altruism	0.039	*0.279***	*0.150***
	Stubbornness	0.012	*0.121***	*0.189***
	Etiquette	*−0.214***	−0.015	**0.378****
	Emotion regulation	*−0.147***	*0.204***	*0.149***
	Self-transcendence	−0.052	*0.189***	*0.236***
	Active wellbeing	−0.032	**0.358****	*0.180***
Big five	Extraversion	*−0.201***	*0.285***	−0.032
	Agreeableness	*−0.239***	−0.042	*0.199***
	Conscientiousness	*−0.198***	*0.104***	0.023
	Neuroticism	*0.278***	*−0.159***	0.097**
	Openness	−0.065*	*0.268***	−0.059*
MTASQ	F1 Motivational decline		*0.258***	0.083*
	F2 Active behavior			−0.068*

The effect of sex was assessed using a Mann-Whitney *U*-test and the other variables were tested using Spearman's correlation analysis. We reported *p*-statistics at uncorrected $p < 0.05$ (*) and Bonferroni's corrected $p < 0.05$ (**; #tests = 69) levels. Significant associations were identified based on the effect-size criteria due to the high sensitivity caused by a large sample size (Cohen, 1992): medium (in bold) and small (in Italic) effect sizes for Vargha and Delaney's $A > 0.64$ or < 0.34 and > 0.56 or < 0.44 (Vargha and Delaney, 2000), and Spearman's $\rho > 0.3$ and 0.1 (Ellis, 2010), respectively.

the Motivational decline score (F1) had a small effect size, including a lower age, lower subjective tolerance for a hot environment, higher subjective intolerance for a hot or cold environment, higher tolerable low temperature, less problem solving, etiquette, emotion regulation, extraversion, agreeableness, conscientiousness, and higher neuroticism. Associations with a medium effect size for the Active behavior (F2) score were identified for higher leadership and active wellbeing. Additionally, associations with a small effect size were observed for the male sex, with higher subjective tolerance and lower subjective intolerance to a hot environment, greater problem-solving, altruism, stubbornness, emotion regulation, self-transcendence, extraversion, conscientiousness, openness, and lower neuroticism. Associations with a medium effect size for the Proactive response (F3) score were identified for the female

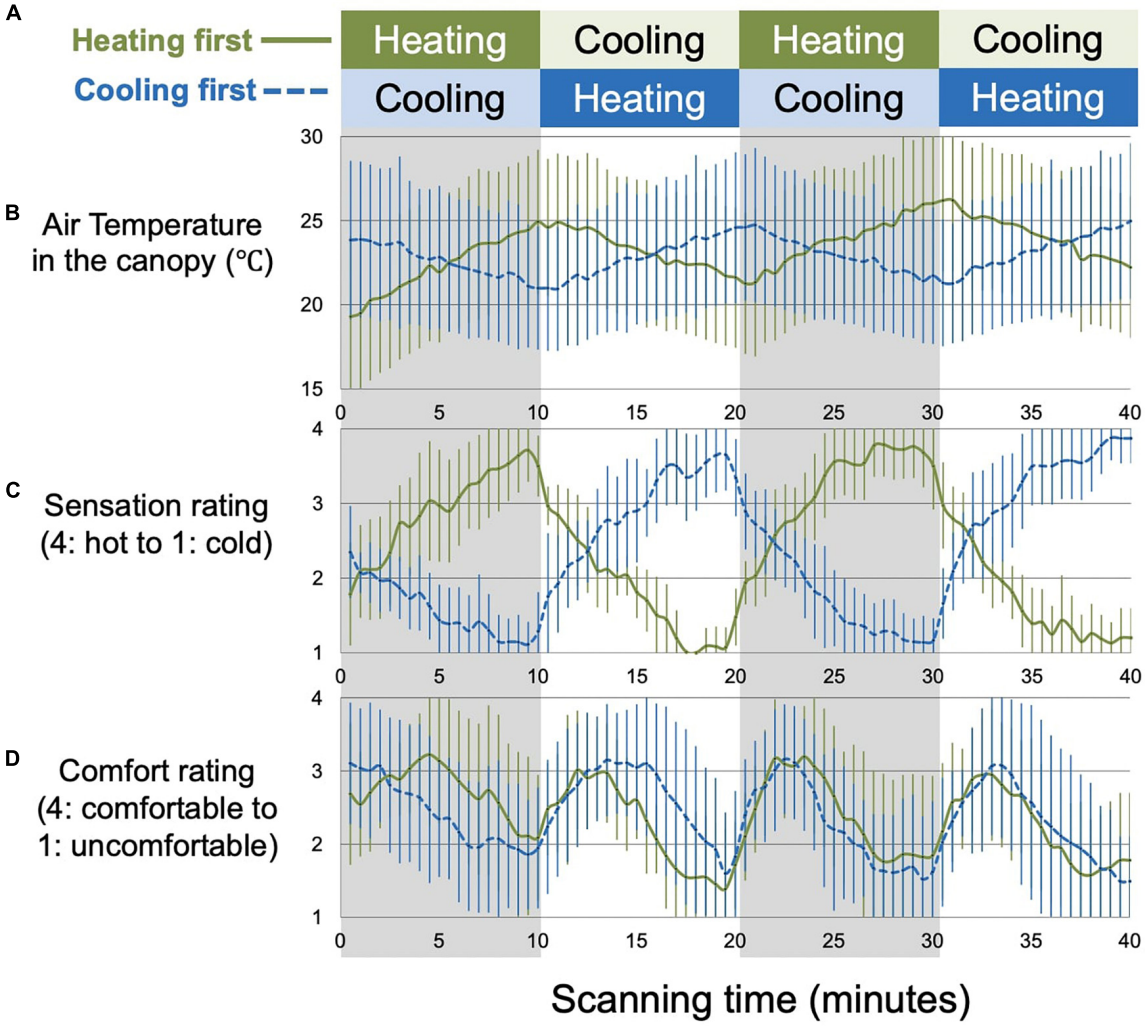


FIGURE 1
Thermal manipulation and perceptual measures. Each session consisted of two alternations of 10 min heating and 10 min cooling phases; the session began with the heating phase (heating first) for 14 participants and with the cooling phase (cooling first) for 14 participants **(A)**. The corresponding average time-series data for the air temperature in the canopy **(B)** and the two subjective measures [i.e., sensation and comfort/uncomfortable ratings: **(C,D)** respectively] are shown separately for the heating first (solid line) and cooling first (dashed line) groups. Error bars indicate standard deviations.

TABLE 3 Correlation between the MTASQ scores and the comfort and sensation ratings.

	Comfort rating		Sensation (heat) rating	
	ρ	*p*	ρ	*p*
Motivational decline	−0.36	0.06†	−0.02	0.93
Active behavior	0.10	0.60	0.18	0.35
Proactive response	−0.39	0.04*	−0.20	0.32

Spearman's correlation coefficients (ρ) between the MTASQ rating scores and the average thermal comfort and sensation (heat) ratings during the fMRI experiment. MTASQ: Multidimensional Thermal Adaption Style Questionnaire.
*$p < 0.05$, † < 0.10.

sex and greater etiquette. In addition, associations with a small effect size were observed for smaller BMI, higher subjective intolerance to a hot or cold environment, greater problem-solving, altruism, stubbornness, emotion regulation, self-transcendence, active wellbeing, and agreeableness. Among the three MTASQ factors, the Motivational decline (F1) score was correlated positively with that of Active behavior (F2) with small effect size; no significant correlation was detected between the Proactive response (F3) and other two factors.

3.2. fMRI

Eighteen participants were excluded from the fMRI analysis: two participants because of a technical problem associated with the capture of the behavioral response during the task, three participants showed excessive head motion (>7 mm) within the scanner; 11 participants reported insufficient variation in the level of comfort pressing discomfort or comfort buttons less than 3.75%, and the other two participants had problems with their normalized fMRI data during preprocessing, so these data were excluded from the statistical analysis. Thus, after the exclusions, the data from 28 participants (mean age = 21.2 years, *SD* = 1.3, age range = 19.0–24.0 years, 7 females) were included in the final analysis for the discomfort/comfort thermal perception investigation.

3.2.1. Behavioral data

Among the 28 participants whose data were analyzed, the fMRI session began with the heating phase for 14 participants and with the cooling phase for 14 participants (**Figure 1A**). The air temperature in the canopy increased and decreased almost linearly during the heating and cooling phases, respectively (**Figure 1B**). The thermal sensation rating (**Figure 1C**) generally changed in parallel with the inside-canopy temperature and tended to increase and decrease within each 10 min manipulation period. The thermal comfort rating (**Figure 1D**) was associated with the maximum discomfort at the hottest and coldest peak of the sensation rating with the highest degree reported during the transient periods between the peaks.

A tendency of and significant negative correlations were detected between the average comfort rating and the MTASQ score for motivational decline (F1) and the proactive response (F3), respectively; that is, participants with the higher scores on these two MTASQ dimensions perceived the thermal environment as more uncomfortable during the fMRI session (**Table 3**). No significant correlation was observed for the sensation rating during the fMRI task or the MTASQ score of the active behavior (F2) dimension.

3.2.2. First approach: Discomfort-related activation and the effect of the MTASQ score

Discomfort-related activation and the MTASQ effect at each peak activation are summarized in **Table 4** for the first approach to the fMRI data. Discomfort-related activation, but not deactivation, was observed for the individual and the average models. Activation in the individual model was detected in the right precuneus and was higher for the low proactive response (F3) individuals (**Figure 2A**). In the average model, activation was observed in the left STG and was higher for individuals with high motivational decline (F1) (**Figure 2B**).

3.2.3. Second approach: Voxel-wise search of MTASQ effect on discomfort-related activation

The results of the voxel-wise regression analyses of each MTASQ score on discomfort-related activation are summarized in **Table 5** for the second approach. For the individual model, a significant negative effect of proactive response (F3) was identified in a large cluster in the left lateral parietal cortex with peaks in the superior parietal lobule, angular gyrus, and supramarginal gyrus (**Figure 3A**). The observed negative effect in the superior parietal lobule was replicated in the average model at a liberal statistical threshold. A significant positive effect of motivational decline (F1) was identified in the left frontal cortex for the average model, with peaks in the inferior frontal gyrus and middle frontal gyrus, STG, and superior parietal lobule (**Figure 3B**). The observed positive effect in the middle frontal gyrus and STG was replicated in the average model at a liberal statistical threshold.

4. Discussion

In this study, we aimed at formulating major dimensions of the individual difference in responses and coping strategies to thermal environmental stress as well as understand the neural correlates of each factor. We first created a multidimensional inventory of individual difference in response and coping strategies to thermal environmental stress (i.e., MTASQ). We then examined how each factor was reflected in the neural response under environmental thermal stress using fMRI. We identified three factors for the MTASQ: motivational decline (F1), active behavior (F2), and the proactive response (F3). These factors were associated with different sets of apparently reasonable demographic, physiological, and psycho-behavioral variables, suggesting their construct validity. In addition, motivational decline factor (F1) score was positively associated with common neural response to thermal stress in the frontal and temporoparietal regions, implicated in emotion regulation, while proactive response factor (F3) score negatively with the neural responses related to subjective discomfort in the medial and lateral parietal cortices, implicated in problem-solving.

4.1. MTASQ factors

Motivational decline (F1) seems to reflect an inefficiency in the use of an adaptive emotion-focused coping strategy under environmental thermal stress. This factor was negatively associated with extraversion, agreeableness, conscientiousness, and subjective tolerance for a hot environment, and positively associated with neuroticism, subjective intolerance to hot or cold temperatures, and minimal tolerable high temperature. The combination of high neuroticism combined with low extraversion, agreeableness, and conscientiousness constitutes the most maladaptive personality type among participants who report more severe childhood maltreatment, such as emotional neglect or emotional abuse (Spinhoven et al., 2016) and followed a review study showing that the predominance of these personality traits predisposes

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TABLE 4 Discomfort-related activation and the effect of the MTASQ score (first approach).

Brain region	Peak				Cluster		Another model (t)	Effect of MTASQ scores (t)			
	x	y	z	t	k	p		Motivational decline	Active behavior	Proactive response	
Individual model											
R. Precuneus	4	−38	48	4.99	657	0.001	3.20	*		−1.89	*
Average model											
L. STG	−54	−30	8	4.61	433	0.002	2.22	*	3.11	*	

The coordinates (x, y, z) and *t*-value of peak activation, and size and its *p*-value of the cluster are given for discomfort-related activation (voxel-wise one-sample *t*-test), separately for the individual and average models. At each peak voxel, the *t*-value is given for discomfort-related activation on another model (i.e., average and individual models for the peak obtained on individual and average models, respectively), as well as *t*-values for significant effects of MTASQ scores (regression analyses separately for three dimensions). L, left; R, right; STG, superior temporal gyrus. $^{*}p < 0.05$, uncorrected.

to maladaptive emotion-focused coping (Carver and Connor-Smith, 2010). In particular, neuroticism is consistently positively associated with passive and ineffective coping mechanisms and negatively associated with the acceptance of the reality of what has happened or learning something useful from an experience (Watson and Hubbard, 1996). Neurotic individuals, who are stress-prone, react to stress more intensely, leading to emotional exhaustion (Hudek-Knežević et al., 2006), which may explain the positive association between the decline in motivation and subjective intolerance to hot or cold temperature or minimal tolerable high temperature in our study.

Active behavior (F2) was difficult to attribute to either an emotion-focused or problem-focused coping strategy. It appeared that individuals with this trait perceive high or low temperatures within the daily life range not as stress but as an opportunity for exciting or enjoyable activities. A sauna or taking a cold shower is recognized as a pleasurable activity with an additional health benefit (Heinonen and Laukkanen, 2018; Schmid, 2018). This view is consistent with the positive association between this factor score and subjective tolerance to hot and cold temperatures. Temperature tolerance may be related to relatively high adaptability of humans to hot and cold environments (Heinonen and Laukkanen, 2018). It is also understood that such tolerance is positively associated with many survival-relevant characteristics (i.e., factors of the "power to live").

The proactive response (F3) appeared to reflect individual efficiency in taking a problem-focused coping strategy related to thermal stress. This factor was positively associated with female sex and prosocial personality traits (i.e., altruism and agreeableness), consistent with a previously reported association between problem-focused coping and prosocial behaviors in females (Khamis, 2018); other associated power-to-live factors, such as problem-solving, etiquette, and self-transcendence, have been shown to enhance pro-social helping behavior (Sugiura et al., 2020). The remaining associated power-to-live factors, such as stubbornness, emotion regulation, and active wellbeing, are associated with better physical and mental health (Sugiura et al., 2015), consistent with the previously reported associations between problem-focused coping and the maintenance of positive affect (Folkman and Moskowitz, 2000), wellbeing (Mayordomo-Rodríguez et al., 2015), and solving problems that elicit negative emotions (Sun et al., 2021).

4.2. fMRI data

4.2.1. Behavioral data

The negative correlations between the average comfort rating and the scores of the two MTASQ factors, including motivational decline (F1) and proactive response (F3), were reasonable given their likely association with stress coping. The correlation with motivational decline is consistent with the previously demonstrated relationship between emotion-focused coping tendency and sensitivity to discomfort (Amen, 2008; Schoenmakers et al., 2015). The correlation with proactive response was consistent with our hypothesis that problem-focused coping is triggered by subjectively perceived thermal discomfort.

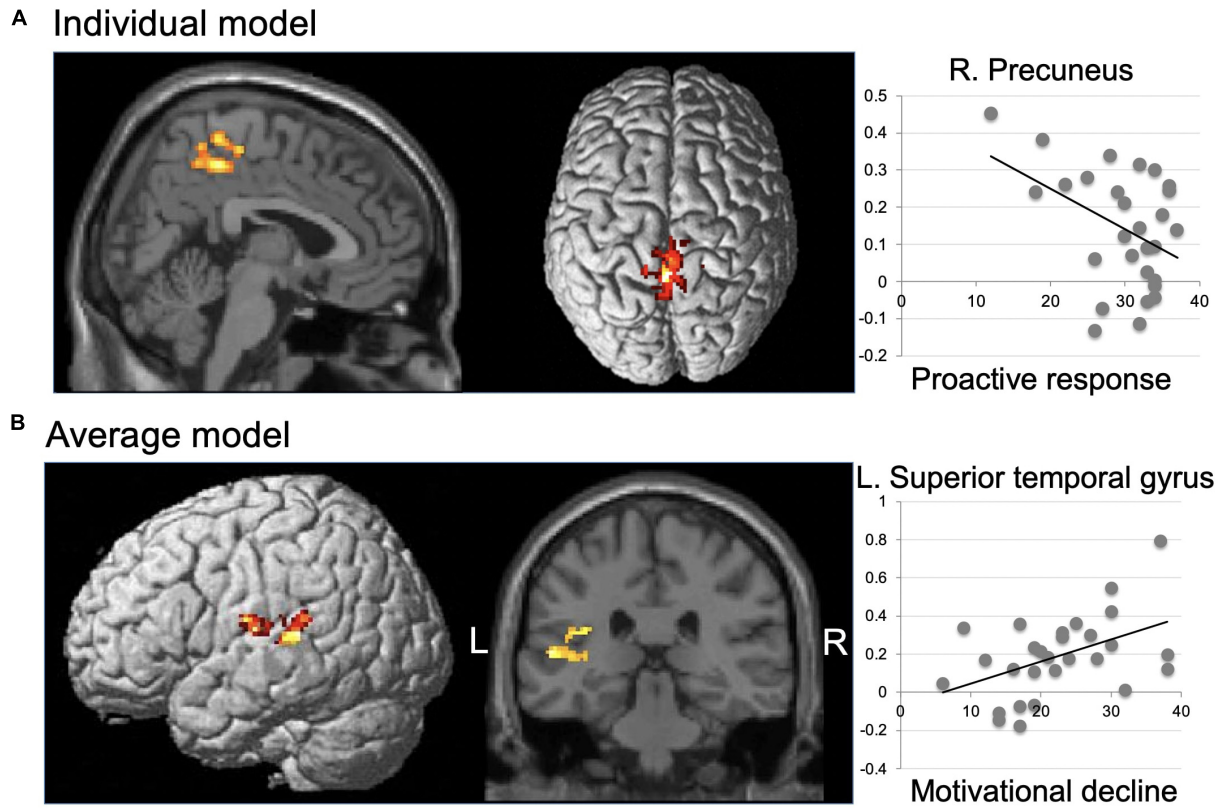

FIGURE 2
Discomfort-related activation and the effect of the MTASQ score (first approach). Left panels, significant activation in the individual model **(A)** and the average model **(B)** are superimposed on the standard SPM12 anatomical brain. Right panel, estimate (β) of discomfort-related activation (vertical axis) of each individual plotted against the significantly associated MTASQ score (horizontal axis); that is, the proactive response for the individual model **(A)** and motivational decline for the average model **(B)**; regression line is given for each plot. R, right; L, left.

4.2.2. Motivational decline

The neural finding for motivational decline agrees with the view that this factor reflects an individual tendency for the use of an emotion-focused coping strategy. First, the factor score was primarily correlated with discomfort-related activation in the average model. It is congruent with our hypothesis that emotion-focused coping taps into the early stage, first-level valuation before second-level valuation or emotional responses develop. Second, the correlation was identified in the frontal, parietal, and temporal cortices previously implicated in emotion regulation (Ochsner et al., 2012; Picó-Pérez et al., 2017). Specifically, the VLPFC plays a role in emotional inhibition; the DLPFC and superior parietal lobule play roles in attentional control, and the STG is involved in modulating the generation of emotions through perceptual and semantic processing (Ochsner et al., 2012).

Our findings suggest that motivational decline reflects inefficiency in the use of the emotion-focused coping strategy. These areas were more activated in individuals with a large decline in motivation, suggesting that activation reflects more difficulties in regulating the emotional response to environmental thermal stress. The finding is consistent with previous observations that show less activation in these regions in adaptive individuals during the task under potential emotional stress (Preis et al., 2015; Kober et al., 2019; Messina et al., 2021).

4.2.3. Proactive response

The neural finding for proactive response agrees with the view that this factor reflects the tendency to follow a problem-focused coping strategy in an uncomfortable thermal environment. First, the factor score was correlated with discomfort-related activation in the individual model. It is congruent with our hypothesis that problem-focused coping is responsive to the subjective perception of thermal discomfort related to late-stage, second-level valuation, or an emotional response. Second, a correlation was identified in the medial and lateral parietal cortices, which has been implicated in a wide range of creative problem-solving (Bartley et al., 2018) and future thinking (Stawarczyk and D'Argembeau, 2015; Schacter et al., 2017). These skills are likely to be involved in the initial planning process for problem-focused coping.

Our findings suggest that a proactive response reflects the efficiency of the problem-focused coping process. Minimal activation of the medial and lateral parietal cortices in individuals with a high factor score is likely to be related to their efficiency in such a planning process. They may spend few cognitive resources thinking of appropriate and practical measures to address climate-related problems in daily life, such as collecting necessary information (i.e., weather forecast) or preparing for a relevant health concern (e.g., dehydration, coldness, sunburn, and dryness). The suggested association between adaptability and low

TABLE 5 Significant effects of the MTASQ score on discomfort-related activation (second approach).

MTASQ dimensions	Brain region	Peak				Cluster		Another model (t)	
		x	y	z	t	k	p		
Individual model									
Motivational decline	*n.s.*								
Active behavior	*n.s.*								
Proactive response	L. Superior parietal lobule	−30	−54	52	−5.34	506	0.001	−1.72	*
	L. Angular gyrus	−30	−66	42	−4.33				
	L. Supramarginal gyrus	−38	−46	42	−4.01				
Average model									
Motivational decline	L. Inferior frontal gyrus	−50	28	8	4.87	464	0.001		
	L. Middle frontal gyrus	−46	32	14	4.58			1.72	*
	L. Superior temporal gyrus	−50	−50	18	4.19	852	0.001	1.93	*
	L. Superior parietal lobule	−14	−56	56	4.58	257	0.029		
Active behavior	*n.s.*								
Proactive response	*n.s.*								

The results of the voxel-wise exploration of the significant effect of the MTASQ scores (i.e., regression analysis) on discomfort-related activation. At each peak voxel, the *t*-value for the effect of the same MTASQ score on discomfort-related activation in another model is given when significant. Other details are the same as for Table 4.

activation follows the previous observation that high problem-solving performance is associated with low activation in these areas (Miura et al., 2020; Oba et al., 2020).

4.3. Theoretical and practical implications

Our results thus demonstrated that individual differences in the way people respond to and cope with thermal environmental stress can be summarized into three dimensions in part congruent with the stress-coping model by Lazarus and Folkman (Folkman and Lazarus, 1980, 1985); motivational decline (F1) and proactive response (F3) were related to emotion-focused and problem-focused strategies, respectively. The correspondence was supported by the related psycho-behavioral variables and neural correlates under the environmental thermal stress in this study. The results may also have academic significance in demonstrating the generalizability of Lazarus and Folkman's model for environmental thermal stress. In addition, the three dimensions results will expand the frontiers of meteorological human science in various directions. Previous studies in this field have explored the factors affecting environmental thermal stress primarily on population bases. They included environmental factors (Shi et al., 2016; Gao et al., 2018), physiological and demographic factors (Foster et al., 2020), and technical interventions (Coudevylle et al., 2019). Although the necessity of including individual psycho-behavioral factors has been suggested (Nikolopoulou et al., 2001; Coudevylle et al., 2019), a relevant theoretical framework has not been available. The current three-dimensional framework may fill this gap.

The current three-dimensional framework may have practical implications in understanding how people respond and prefer to cope with thermal environmental stress, which need is more pressing than ever in the increasing prevalence of temperature change on earth and movement of people across intercontinental borders. For example, the answers to these questions will help develop optimization technology for the thermal environment on an individual basis. We may identify an air-conditioning set-point to balance subjective discomfort and energy efficiency based on individual levels of motivational decline (F1). In the design of living spaces and cities, a more comfortable thermal environment could be achieved by adjusting the behavior of users based on individual levels of proactive responses (F3). Finally, further research on the active behavior (F2) dimension from an anthropological perspective may shed new light on this topic.

4.4. Strengths and limitations

The strengths of study are that we first identified three dimensions in how people react to and cope with thermal environmental stress, of which two complied with an influential two-dimensional framework for stress coping developed by Lazarus and Folkman (Folkman and Lazarus, 1980, 1985). There were also several limitations. First, one major limitation of the present study is the sample size for the fMRI experiment. We only included 28 participants in the final fMRI analysis. However, considering the relatively long scanning time and duration of each condition, it may be inappropriate to simply compare the statistical characteristics of the current study with simulation data from studies with a larger number of participants. Second, the limited temperature range. More severe thermal stress could have provided different results. Third, the representativeness of our participants was limited. As we only recruited Japanese demographic profiles, our results may not cover the psycho-behavioral characteristics that exist in other populations with other geographic, physiological, or socio-cultural profiles.

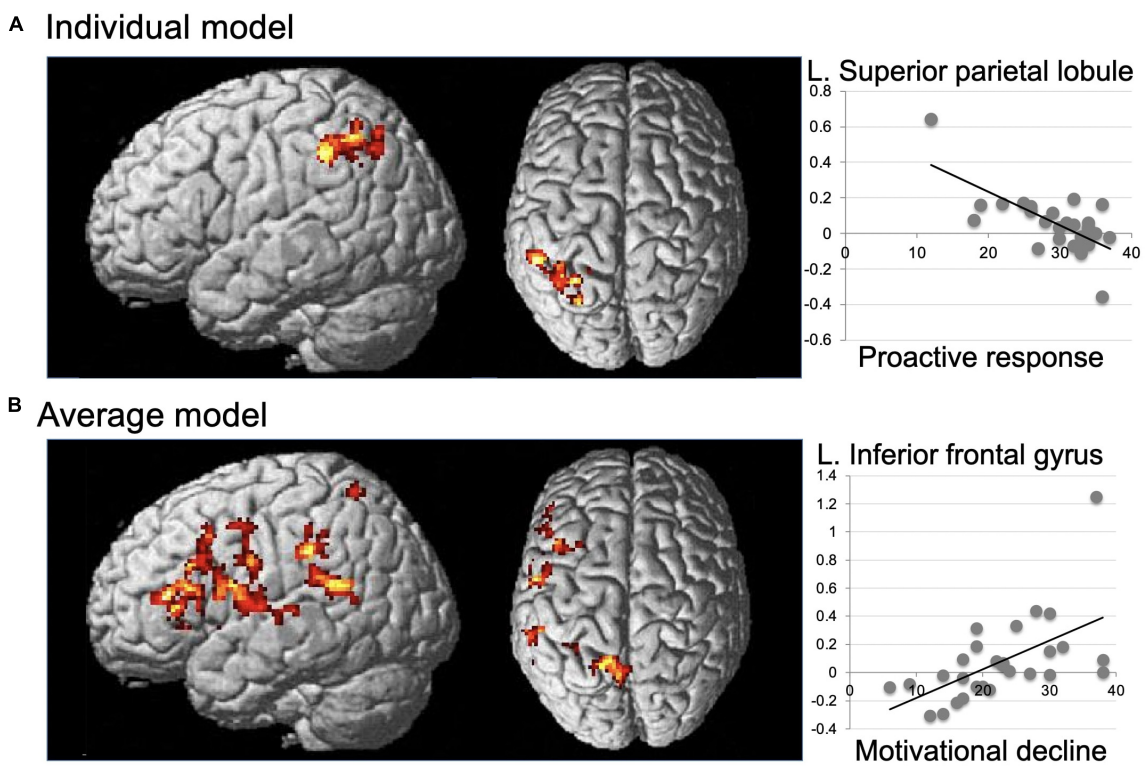

FIGURE 3
Significant effects of the MTASQ score on discomfort-related activation (second approach). Left panels, significant negative effect of the proactive response on individual-model-derived discomfort-related activation **(A)** and significant positive effect of motivational decline on average-model-derived activation **(B)** are superimposed on the standard anatomical brain. Other details are the same as for **Figure 2**.

5. Conclusion

We identified three dimensions among the responses to environmental thermal stress, as formulated in the MTASQ. Motivational decline (F1) reflected individual inefficiency in the use of an adaptive emotion-focused coping strategy under thermal stress. Active behavior (F2) reflected the tendency to perceive high or low thermal temperature not as stress but as an opportunity for some exciting or enjoyable activity. Proactive responses (F3) reflected individual efficiency in taking a problem-focused coping strategy related to environmental thermal stress. Our neural findings on the correlation of these factor scores and discomfort-related activation provide further support for the association between motivational decline (F1) and inefficient emotion-focused coping in terms of its relevance to high early stage (i.e., average model) activation in the frontal and temporoparietal regions, which has been implicated in emotion regulation. Although the active behavior (F2) was associated with many survival-relevant characteristics (i.e., "power to live" factors), we failed to identify its neural correlates in terms of the response to environmental thermal stress. The expression of this trait dimension may be triggered by neural dynamics other than stress perception. The association between the proactive response (F3) and efficient problem-focused coping was also supported by its relevance to low late-stage (i.e., individual model) activation in the medial and lateral parietal cortices, which has been implicated in creative problem-solving and future thinking. Thus, within the context of environmental thermal stress and as the theoretical implication, we have shown that motivational decline and proactive response factors were conformed to an influential two-dimensional framework of stress coping by Lazarus and Folkman (Folkman and Lazarus, 1980, 1985). An important practical implication is that the current three-dimensional model may expand the frontiers of meteorological human science in both basic and application domains.

Data availability statement

The raw data supporting the conclusions of this article are not publicly available due to the risk of identifying the participants from the reconstructed images. However, the data are available from the corresponding author upon a reasonable request.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Tohoku University, Graduate School of Medicine, and the Nissan Motor Ethics Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

KHdSK and MS conceived the experiments, analyzed the data, and drafted the manuscript. KHdSK, KH, YH, AK, and MS collected the data. KHdSK, KH, YH, AK, RK, and MS critically reviewed and approved the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

HO was employed by Nissan Motor Co., Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

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Social-coalitional trait is related to coping capacity with mortality threat: association with leadership and a reduced parietal response to mortality salience

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Introduction: Coping with mortality threat, a psychological threat unique to humans and distinct from general emotional distress, is traditionally characterized by immediate suppression and prolonged worldview defense within the framework of the influential terror management theory (TMT). Views regarding the personality-trait concepts for this coping capacity diverge: some favor a broad definition based on general psychological attitudes (e.g., hardiness), while others prefer a narrow definition linked to interpersonal attitudes related to social coalition (e.g., attachment style and self-transcendence).

Methods: Using functional MRI, we presented healthy older participants with death-related words and explored correlations between the neural responses to mortality threat and the factor scores of the Power to Live questionnaire, which measures eight resilience-related psychobehavioral traits.

Results: We observed a significant association between the factor score and a neural response only for leadership; individuals with a high leadership score exhibited reduced neural response to mortality salience in the right inferior parietal lobule.

Discussion: Within the TMT framework, our findings align with the concept of the immediate suppression of death-thought accessibility associated with a secure attachment style, a trait conceptually linked to leadership. These findings highlight the unique role for the narrowly defined social-coalitional trait during the immediate stage of the coping process with mortality salience, in contrast to the broadly defined resilience-related personality traits associated with a prolonged worldview defense process. The deterioration of this coping process could constitute a distinct aspect of psychopathology, separate from dysfunction in general emotion regulation.

KEYWORDS

death threat, mortality salience, terror management, fMRI, attachment style, leadership, disaster, parietal cortex

1. Introduction

Mortality salience, or the awareness that one's death is inevitable, poses a unique psychological threat to humans. According to the influential terror management theory (TMT), the coping response to this threat enhances state self-esteem or leads to interesting human behaviors, including punishment of cultural norm violators, nationalistic acts, and racial prejudice, namely, worldview defense (Burke et al., 2010). This process is assumed to be distinct from general emotional distress coping mechanisms, despite ongoing debate concerning the process-specificity of the threat-induction methods (Lambert et al., 2014) and its connection to mental disorders (Simon et al., 1998; Menzies et al., 2021). TMT assumes two processes by which individual differences in the coping response are exhibited: first, when a reminder of death is being presented, the degree of increase in accessibility to death-related thoughts varies across individuals (Hayes et al., 2010). Second, the worldview defense involves a prolonged unconscious process that varies across individuals (Burke et al., 2010).

Researchers have proposed that several personality traits related to psychological resilience are also associated with coping capacity for mortality threats, but they vary in terms of the level of conceptual breadth. A broadly defined resilience trait is that of hardiness, a constellation of personality characteristics that function as a resistance resource in encounters with stressful life events (Kobasa et al., 1982). This trait describes psychological attitudes known as the "3 Cs," commitment, control, and challenge, which are common across multiple resilient-personality characteristics. Hardiness decreases the effects of stressful life events (e.g., a military setting) with regard to producing illness (Maddi, 2007). In the context of TMT, under an experimentally induced mortality threat, hardiness was associated with less worldview defense, without an effect on accessibility to death-related thoughts (Florian et al., 2001). Some investigators have discussed the resistant effect of this trait against mortality threat within the framework of self-esteem, which is also a broadly conceptualized psychological resource that buffers existential anxiety (Joireman and Duell, 2007).

Two other views are related to more specific or narrowly defined resilience-related personality traits in the domain of interpersonal attitudes related to social coalition. One view focuses on the secure attachment style as a key coping ability for mortality threat. This style is based on the belief that proximate others are supportive at one's time of need or distress (Bowlby, 1973; Waters and Waters, 2006) and provides psychological resilience and adjustment (Mikulincer and Shaver, 2016). In the context of TMT, after a reminder of death, secure attachment is associated with a lesser degree of death-thought accessibility and worldview defense compared to avoidant or anxious-ambivalent attachment (Mikulincer and Florian, 2000; Taubman-Ben-Ari et al., 2002).

Another view considers the self-transcendent personality trait as an important coping ability for mortality threat. Self-transcendence refers to expansion beyond the boundaries of the self in diverse dimensions, including physical and social; it often also includes expanded, prosocial, spiritual, and religious worldviews (Garcia-Romeu, 2010). In the context of TMT, a study demonstrated that worldview defense, in terms of an increase in the importance of charity activity (for people or the environment), after mortality salience manipulation was lower in people with a higher self-transcendence value (benevolence and universalism) orientation (Joireman and Duell, 2007). Another study showed that Christians were less vulnerable than atheists to a reduction in the meaning of life when reminded of death (Vail and Soenke, 2018).

Neuroimaging studies have not examined the associations of resilient-personality traits with the processing of mortality threat. Multiple studies have examined the neural response to mortality threat, typically contrasting it with negative emotional conditions (e.g., dental pain). They demonstrated increased activity in the amygdala (Quirin et al., 2012) and various frontoparietal regions (Yanagisawa et al., 2016; Klackl et al., 2018; Qin et al., 2018; Hirano et al., 2021), decreased activity in the insular cortex (Han et al., 2010; Shi and Han, 2013; Klackl et al., 2014; Qin et al., 2018), and increase (Quirin et al., 2012) and decrease (Qin et al., 2018) in the activity in the anterior cingulate cortex. However, few studies have investigated individual differences in neural activity. Three studies have exhibited conflicting effects of self-esteem (Klackl et al., 2014; Yanagisawa et al., 2016; Luo et al., 2017). Other studies have demonstrated the effects of serotonin transporter gene polymorphisms, interdependence (Luo et al., 2017), sex (Qin et al., 2018), and fear of death (Hirano et al., 2021), whereas no study has examined the associations with resilience-related personality traits.

The recently developed Power to Live questionnaire (Sugiura et al., 2015) can be used to evaluate the different views regarding the resilient-personality trait to mortality threat, owing to its multidimensional structure that encompasses different levels of personality traits. The Power to Live questionnaire measures eight major psychobehavioral characteristics related to survival, which were identified by factor analysis based on interviews of 1,400 survivors of the 2011 Great East Japan Earthquake and Tsunami disaster. The eight factors, namely, leadership, problem solving, altruism, stubbornness, etiquette, emotion regulation, self-transcendence, and active wellbeing, comprise a constellation of resilient personality characteristics related to commitment, control, and challenge; thus, they are relevant to hardiness. On the other hand, specific Power to Live factors, leadership and self-transcendence, correspond to narrowly defined resilient-personality trait concepts related to social coalition, i.e., secure attachment style and self-transcendence, respectively. Leadership describes the social-coalitional response to distress, similar to the secure attachment style, and is composed of items such as, "To resolve problems, I gather together everyone involved to discuss the matter," and, "In everyday life, I often take the initiative to gather people." These items appear to reflect a sense of secure attachment, i.e., an implicit belief that proximate others are supportive at one's time of need or distress (Bowlby, 1973; Waters and Waters, 2006). This factor has been shown to provide psychological resilience and adjustment during tsunami evacuation (Sugiura et al., 2019, 2020), emergency problem-solving (Sugiura et al., 2021), and housing recovery (Sato et al., 2021) in the disaster aftermath. Self-transcendence is evaluated using items such as, "I am aware that I am alive, and I have a sense of responsibility for my life," and, "I am aware of the path and teachings I should follow as a person." This is in line with the conventional concept of self-transcendence and overlaps with religiosity, which is related to the ability to cope with a

mortality threat (Joireman and Duell, 2007; Vail and Soenke, 2018). This factor has been behaviorally demonstrated to be associated with the sense of self-agency (Niikuni et al., 2022) and to have an adaptive and prosocial nature (Sugiura et al., 2020; Sugiura, 2022). Furthermore, emotion regulation appears to reflect the capacity to cope with general emotional distress (Sugiura et al., 2023) rather than with mortality threat.

In the present functional magnetic resonance imaging (fMRI) study, we examined whether views regarding resilience to mortality threat are supported by neural evidence. We presented healthy older participants with death-related and death-unrelated negative (i.e., control) words, and evaluated correlations between differential neural activation and the eight factors of the Power to Live questionnaire. We were initially interested in the breadth of factors showing a correlation. The view that the broadly defined resilient-personality trait, hardiness, provides coping capacity for the mortality threat predicts that multiple Power to Live factors will be associated with the neural response to mortality salience, probably by reducing the neural response to mortality threat (e.g., reduced activation of the amygdala and frontoparietal cortices and increase in the activation of insula). On the other hand, the view that the narrowly defined resilience-related personality traits in the domain of social coalition provide coping ability seemed to predict the association with a specific Power to Live factor, namely, leadership or self-transcendence. We anticipated that there would not be an association with the emotion regulation factor, given its link with coping capacity for general emotional distress.

2. Materials and methods

2.1. Dataset

This study analyzed a dataset that had originally been obtained for different research purposes (Hirano et al., 2021). In the original experiment, participants were asked to judge the relevance of the presented word to themselves or other individuals. The prior study identified the self-specific neural response to the death-related word and its association with the fear of death. For the current study, we focused on the correlations between the Power to Live factors and the neural responses to death-related words, without distinguishing between the judgment type (i.e., self vs. other). The study protocol was approved by the Institutional Review Board of the Graduate School of Medicine of Tohoku University, Japan, and was conducted in accordance with the Declaration of Helsinki.

2.2. Participants

The dataset was obtained from 34 community dwelling older individuals (aged 66.3 ± 3.9 years; range: 60–72 years; 19 males and 15 females). All participants were right-handed native Japanese speakers, had a high school-level or higher education, were not using medications for hypertension or diabetes, and had no past or present neurological or psychiatric illnesses. Written informed consent was obtained from all participants. See Hirano et al. (2021) for further details.

2.3. Questionnaires

The Power to Live questionnaire (Sugiura et al., 2015) includes 34 items related to thinking style, attitude in daily life, and habits; some of these items are related to stressful situations. While the original questionnaire was developed from a survey of disaster survivors, the factor structure was validated in normal adults (Ishibashi et al., 2019) and younger (Matsuzaki et al., 2022) populations. The participants rated the self-applicability of each item on a 6-point scale (0: not at all; 5: very much). Each factor consisted of three to five items; the summed item scores were used to calculate the factor score based on the percentage of the maximum value (% maximum). The representative items are presented in **Table 1**.

The dataset also included the self-esteem scores from the Rosenberg Self-Esteem scale (Yamamoto, 1982; Rosenberg, 2015). Considering the relevance of this trait to TMT (Burke et al., 2010), and to allow comparison with previous neuroimaging studies (Klackl et al., 2014; Yanagisawa et al., 2016; Luo et al., 2017), associations of the self-esteem score with the Power to Live questionnaire scores (**Table 1**) and neural activity were analyzed.

2.4. Stimuli

The participants were presented with 40 death-related words (e.g., sudden death, cremation, and metastasis) and 40 death-unrelated negative words (e.g., stomachache, cold, and eye disease). Each word was a noun consisting of two Japanese Kanji (Chinese characters). The former set had higher death relatedness than the latter. The arousal, emotional valence, imageability, familiarity, and self-relevance were matched between the two word sets in a preparatory behavioral experiment (see Hirano et al., 2021 for details).

2.5. Task and procedure

The task comprised a factorial design composed of two stimulus types [death-related (D) and death-unrelated (ND) words] and two task types [judgments related to self (S) and another (O; prime minister)]. As a result, there were four task conditions: DS, DO, NDS, and NDO. Each participant alternated between the S and O blocks. Each block consisted of five trials composed of pseudorandomly ordered two or three D and ND words. Each word was displayed for 6 s, during which a self-relevance judgment ("How relevant the word is to you") or an other-relevance judgment ("How relevant the word is to the prime minister") was required using a four-point scale ("relevant" to "irrelevant") by pressing one of the four response keys. The inter-stimulus interval was 1–9 s, during which a fixation cross was presented. The experiment included a total of four runs (160 trials in total), each containing eight blocks (four S and four O blocks). Each task block lasted for 60 s and began with a 5-s instruction screen that indicated the task type. Each stimulus was presented twice during the experiment (i.e., once in the S block and again in the O block). The visual stimulus was projected on a semi-lucent screen attached to the head-coil of the MRI scanner and was viewed via a mirror (see Hirano et al., 2021 for further details).

2.6. MRI data acquisition

For functional data, 38 transaxial images (echo time = 30 ms, flip angle = 81°, slice thickness = 3.0 mm, slice gap = 0.5 mm, field of view = 192 mm, matrix = 64 × 64, and voxel size = 3 × 3 × 3 mm) covering the entire cerebrum were acquired with a repetition time of 2,500 ms using a gradient-echo echoplanar imaging sequence and a 3-Tesla Philips Achieva scanner (Philips Medical Systems, Best, the Netherlands). In each run, 197 volumes were acquired during a total scanning period of 492.5 s; in total, 788 volumes were acquired in four runs. After the runs, T1-weighted anatomical images (thickness = 1 mm, field of view = 192 mm, and matrix = 240 × 240) were acquired using a magnetization-prepared rapid gradient-echo pulse sequence.

2.7. MRI data analysis

Statistical Parametric Mapping software (SPM12; Wellcome Department of Imaging Neuroscience, London, UK) was used for preprocessing and statistical analyses. The following procedures were performed for preprocessing using the default parameter settings of the software: correction for head motion, adjustment of acquisition timing across slices, co-registration of the anatomical image to realigned functional images, segmentation of the structural image into six tissue classes, spatial normalization to the Montreal Neurological Institute template using the co-registered anatomical image, and smoothing with an isotropic Gaussian kernel with an 8-mm full-width at half-maximum.

A conventional two-level approach for a multi-subject dataset was adopted for statistical analyses of the fMRI data. In the first-level analysis, the degree of neural activation was estimated based on a voxel-by-voxel multiple regression analysis of the time-series models of neural blood oxygenation level-dependent signals. For each participant, a general linear model was developed using the hemodynamic response function. The general linear model contained regressors that represented the four conditions (i.e., DS, DO, NDS, and NDO). Each regressor modeled neural activation during the 6-s period in which the stimulus was presented. Six estimated head-motion parameters (three for translation and three for rotation) were also included as covariates of no interest. A high-pass filter with a cutoff frequency of 1/128 Hz was applied for detrending. A contrast image D–N [i.e., (DS + DO)–(NDS + NDO)] was generated for each participant to identify the neural response to mortality salience.

In the second-level analysis, to identify the cortical areas in which the neural response to mortality salience was correlated with the scores of the Power to Live factors or self-esteem, voxel-wise multiple regression analyses were performed. Age and sex were included as covariates of no interest. The activation clusters of significant effects (i.e., regression coefficients) were identified, based initially on a voxel-level threshold of $p < 0.001$ (uncorrected) and finally on a cluster-level threshold ($p < 0.05$). The cluster-level threshold is used to correct for multiple comparisons in terms of searching activation over the entire brain applying a voxel-size threshold based on the random field theory (Friston et al., 1994). As we performed this analysis for each of the nine trait scores (i.e., eight factors of the Power to Live and self-esteem) for both positive and negative effects, we also reported the results after correcting for multiple comparisons in this term (i.e., testing multiple traits) using the Bonferroni method (i.e., dividing the p-value threshold by the number of tests; 0.05/18 = 0.0028).

3. Results

3.1. Behavioral data

Table 1 presents the basic statistics, Cronbach's α, and correlations of the self-esteem score with the eight factors of the Power to Live questionnaire. All factors had good internal reliability (i.e., Cronbach's $\alpha > 0.6$). The self-esteem score had significant positive correlations with leadership and problem-solving factors.

3.2. fMRI data

A significant negative effect of the leadership score on D–ND activation was identified in the right inferior parietal lobule (Table 2; Figure 1). This finding remained significant even after correcting for multiple traits. The plots of D–ND activation against leadership score (Figure 1) implied a low neural response to mortality salience in individuals with a high leadership score. At this activation peak, the trait effects of the other Power to Live factors or self-esteem score on D–ND activation were not significant, even at the voxel-level statistical threshold (i.e., without correcting for searching over the entire brain; voxel-level $p < 0.05/18$; Table 3).

No significant effects of the other Power to Live factors or self-esteem score were detected on D–ND activation in the entire-brain voxel-wise multiple regression analyses.

4. Discussion

A significant trait effect on neural response to mortality salience was identified for the leadership factor only, suggesting that the association of a resilient personality with the neural response to mortality salience may be better explained by a narrowly, rather than broadly, defined trait concept related to social coalition. Although the leadership score was significantly correlated with the self-esteem score, the latter did not significantly affect the neural response. Considering the conceptual similarity between the leadership factor of the Power to Live questionnaire and the secure attachment style, our findings may be in line with the view that the secure attachment style provides a key coping ability for mortality threat (Mikulincer and Florian, 2000; Taubman-Ben-Ari et al., 2002).

The negative effect of the trait on the inferior parietal lobule activation may be related to an immediate suppressive process previously suggested for the secure attachment style. In the TMT framework, two stages are assumed for the coping process after the presentation of a death reminder: an immediate suppression of accessibility to death-related thoughts (Hayes et al., 2010) and a

TABLE 1 Responses to the Power to Live questionnaire.

Factor	Representative item	Mean score (SD)	Cronbach's α	Correlation with self-esteem (*r*)
Leadership	To resolve problems, I gather together everyone involved to discuss the matter.	61.4 (17.4)	0.878	0.562**
Problem solving	When I am fretting about what I should do, I compare several alternative actions.	73.1 (11.5)	0.681	0.475**
Altruism	I like it when other people rely on me and are grateful to me.	66.1 (18.1)	0.851	0.122
Stubbornness	I am stubborn and always get my own way.	56.7 (16.3)	0.767	−0.184
Etiquette	On a daily basis, I take the initiative in greeting family members and people living in the neighborhood.	87.3 (12.0)	0.751	0.085
Emotion regulation	During difficult times, I endeavor not to brood.	72.2 (11.9)	0.718	0.302
Self-transcendence	I am aware that I am alive, and I have a sense of responsibility for my life.	73.5 (12.9)	0.701	0.330
Active wellbeing	In everyday life, I have habitual practices that are essential for relieving stress or giving me a change of pace.	74.5 (14.6)	0.673	0.358*

A representative questionnaire item, mean and standard deviation (SD) of the factor score (% maximum), Cronbach's α, and Pearson's correlation coefficient (r) with the self-esteem score are shown for the Power to Live questionnaire factors. *$p < 0.05$, uncorrected; **$p < 0.05/8$ (Bonferroni correction: threshold p is divided by the number of tests).

TABLE 2 Significant negative effect of the leadership score.

Structure	L/R	MNI coordinate				Cluster	
		x	*y*	*z*	*t*	# voxel	*p*
Inferior parietal lobule	R	46	−62	38	5.26	742	<0.001*
		50	−52	48	5.17		

Anatomical label, Montreal Neurological Institute (MNI) coordinate, t value of the activation peak and cluster size in the number of voxels ($2 \times 2 \times 2$ mm^3), and its p-value are given for the significant negative trait effect. *$p < 0.05/18$ (Bonferroni correction).

worldview defense taking place as a prolonged unconscious process (Burke et al., 2010). A unique finding for the secure attachment style is its association with the former immediate process (Mikulincer and Florian, 2000). The remaining resilience-related personality traits are mainly related only to the latter process (Florian et al., 2001; Joireman and Duell, 2007; Hayes et al., 2010). A previous neuroimaging study demonstrated that the degree of activation in the frontoparietal cortices, including the right inferior parietal lobule, during the presentation of death-related words is associated with the death-relevance ratings of the presented death-related words (Shi and Han, 2013). Therefore, the identified negative effect of the leadership factor on the activation of this cortical region may be related to the presumed association between the secure attachment style and reduced death-thought accessibility (Mikulincer and Florian, 2000).

If our fMRI data primarily reflect an immediate suppressive process of accessibility to death-related thoughts, the observed lack of neural correlation with other factors may be reasonable. Hardiness and self-transcendence are associated with a reduced degree of worldview defense, but not with differences in death-thought accessibility (Florian et al., 2001; Joireman and Duell, 2007). If our fMRI analysis is sensitive only to the immediate response to death-related words, individual differences in prolonged processes, such as worldview defense, might not be detected (Burke et al., 2010). This is also supported by our finding of no significant effects of self-esteem, which primarily affects worldview defense, on neural activation (Hayes et al., 2010). This consideration may explain the inconsistent findings related to the effects of self-esteem on the immediate neural response to mortality salience in previous studies (Klackl et al., 2014; Yanagisawa et al., 2016; Luo et al., 2017).

Our findings highlight the unique functional characteristics of the immediate suppressive process in contrast to the prolonged worldview defense process, which has been discussed primarily in terms of the difference in time sequence. The current findings suggest that the former is affected by the narrowly defined social-coalitional tendency; that is, a leadership factor or the secure attachment style, mediated by the suppressed response in the right inferior parietal lobule. On the other hand, the latter has been implicated in the broadly-defined resilience-related personality trait (i.e., hardiness; Florian et al., 2001) and the broadly conceptualized anxiety-buffering resource (i.e., self-esteem; Schmeichel et al., 2009), although its neural correlates remain unclear. These findings seem congruent with a cautious stance regarding the existence of the worldview defense, as recent pre-registered studies have failed to replicate the foundational studies that the theory is based on (Schindler et al., 2021).

Our research supported the notion that the coping processes for mortality threat differ from those for general emotional distress, and the findings have some clinical implications. The resilient-personality trait and neural processes in response to the mortality threat identified in our study diverged from those previously

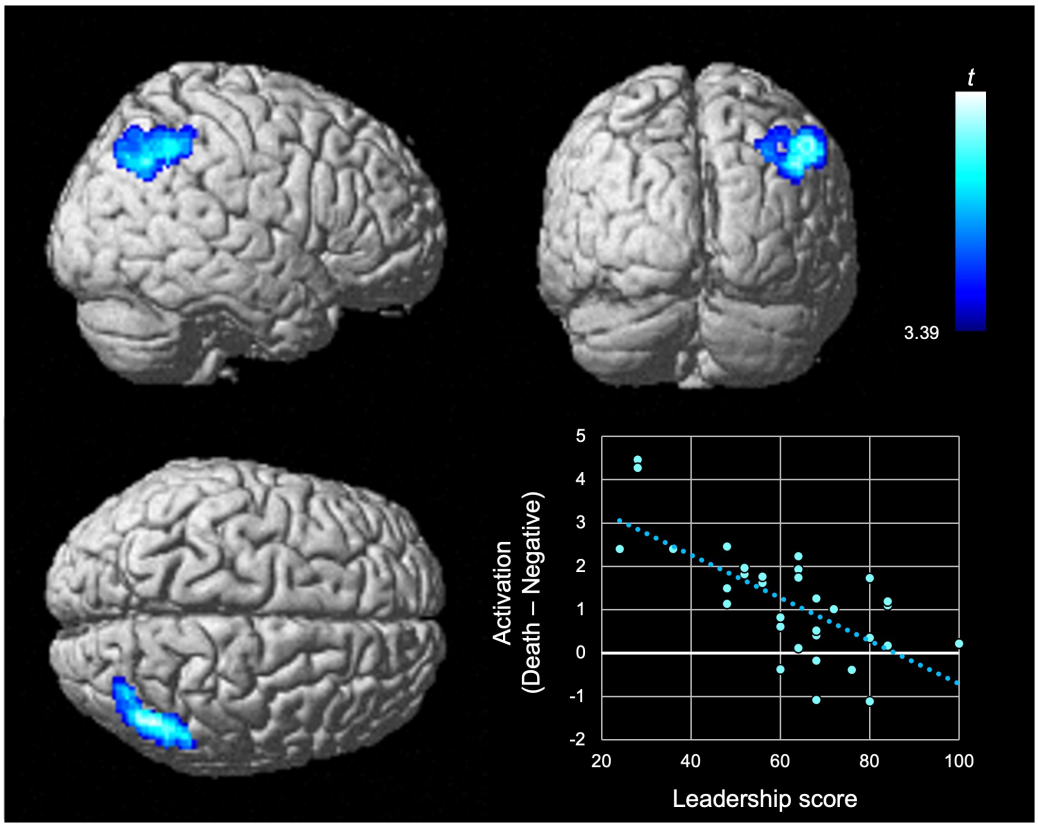

FIGURE 1
Negative effect of the leadership score on the neural response to mortality salience. Significant effects (*t*-values) of the leadership score from the Power to Live questionnaire in the second-level multiple regression model are represented by a blue-cyan scale, rendered on the surface of an SPM12 standard structural brain image (from the right, back, and top of the brain in the top left, top right, and bottom left panels, respectively). Statistical significance was determined using a cluster-forming threshold of uncorrected $p < 0.001$, further corrected to $p < 0.05$ (family-wise error) to account for multiple comparisons across the entire brain using cluster size, as well as testing the positive and negative effects of nine trials. No positive trait effects were detected. The bottom right panel shows the scatter plot of differential activation (i.e., Death−Negative) against the leadership score. The dotted line shows the regression line.

TABLE 3 Effects of all the trait scores in the right inferior parietal lobule.

Trait	*t*	*p*
Leadership	−5.26	<0.001*
Problem solving	−2.53	0.008
Altruism	−1.79	0.042
Stubbornness	−0.33	0.374
Etiquette	−1.80	0.041
Emotion regulation	−2.64	0.006
Self-transcendence	−0.67	0.254
Active wellbeing	−2.06	0.024
Self-esteem	−2.29	0.015

The *t* values and associated *p*-values are given for the effects of all trait scores at the activation peak of the negative effect of the leadership trait in the right inferior parietal lobule (46, −62, 38). A negative *t* value indicates a negative effect. *$p < 0.05/18$ (Bonferroni correction).

linked to general emotional stress. In a previous fMRI study, the neural response to negative emotional pictures was negatively correlated with emotion regulation score in various prefrontal, sensorimotor, and temporal cortices (Sugiura et al., 2023). This finding is consistent with the impaired emotion regulation and dysregulated multilevel neurophysiological responses commonly implicated in mental disorders (Tanaka et al., 2022; Battaglia et al., 2023). Conversely, in our study, leadership was associated with a reduced parietal response during the mortality salience manipulation. This finding may be related to distinct aspects of psychopathology in mental disorders, where sociopsychological characteristics and observed response tendencies can be linked to mortality salience. That is, reduced proneness to social coalition (Zhang et al., 2022) and insecure attachment style (Mikulincer and Shaver, 2012) in mental disorders seem to be associated with diminished leadership and unsuppressed access to death-related thoughts, which may explain the increased anxiety-related behavior (Menzies et al., 2021) and worldview defense (Simon et al., 1998) seen in these patients.

5. Conclusion

Out of the eight factors of the Power to Live and self-esteem, a significant effect of the trait score on the neural response to

mortality salience was observed only for the leadership factor. In individuals with a high leadership score, the neural response to mortality salience was low in the right inferior parietal lobule. Given the conceptual similarity between leadership and the secure attachment style, our findings may reflect an immediate suppressive process of death-thought accessibility, previously suggested for the secure attachment style.

Within the TMT framework, the findings highlight the unique characteristics of the immediate stage of the coping process with mortality salience, which may be affected by the narrowly defined social-coalitional trait. This stands in contrast with prolonged worldview defense, which may be affected by the broadly defined resilience-related personality traits. Our results lay the groundwork for future studies investigating the psychological processes underlying human social-coalition formation in the context of stress coping.

From a wider translational perspective, the findings may enhance understanding of the role of individual differences in the psychological response to mortality threat in psychopathology. Although the identified resilient-personality traits and neural processes arising in response to mortality threat are distinct from those related to general emotion regulation, dysfunction of the relevant coping process may party explain psychopathology through the association between a low level of social coalition and unsuppressed access to death-related thoughts.

6. Limitations and future directions

The current study, though insightful, is not without limitations. Four issues in particular merit further exploration to improve understanding of the psychological processes underlying human social-coalition formation in the context of stress coping.

First, the conceptual distinction and overlap between the two social-coalition-related traits should be examined. On the one hand, the attachment style typically addresses two-person relationships with a familiar other in an emotional context (Hazan and Shaver, 1987), whereas the leadership factor of the Power to Live questionnaire encompasses multi-party relationships in a utilitarian community context (Sugiura et al., 2015). On the other hand, early developmental processes are underscored for both traits (Bowlby, 1973; Matsuzaki et al., 2022). Second, specificity of the processes to mortality salience needs further investigation. Studies of the TMT framework have addressed processes specific to mortality salience using the negative emotional condition as control, similar to the present study. However, the social coalitional response may also occur in aversive situations unrelated to death, which may be better explained from an evolutionary perspective (Navarrete et al., 2004). Third, the distinct roles and consequences of the two stages need further exploration. Although the social-coalitional trait may contribute to the immediate suppression of death-thought accessibility, it may also facilitate certain aspects of worldview defense, such as those related to religiosity (Shults et al., 2018). Lastly, the non-significant effect of traits other than leadership should be carefully reassessed. The current findings are based on a relatively small sample (n = 34) of elderly individuals, who exhibit lower levels of worldview defense, despite maintaining the same level of death-thought accessibility as young people (Maxfield et al., 2007).

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: not publicly available due to the risk of identifying the participants from the reconstructed images. Requests to access these datasets should be directed to MS, sugiura@tohoku.ac.jp.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Graduate School of Medicine of Tohoku University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

KH and MS contributed to the study conception and design, performed the statistical analysis, and wrote the first draft of the manuscript. KH, KO, and TS prepared the experimental stimuli and conducted the MRI experiment. All authors contributed to the manuscript revision and read and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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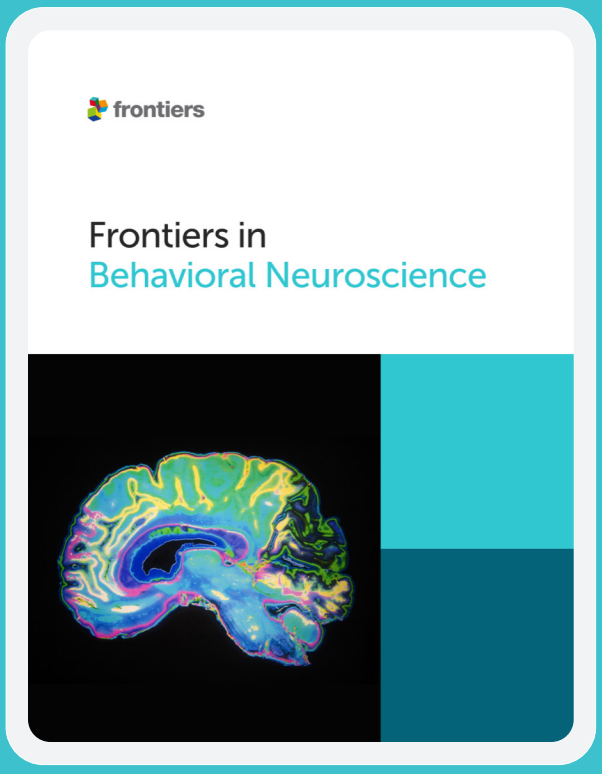

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