KNOWING THE SELF: INTERDISCIPLINARY PERSPECTIVES ON SELF RELATED PROCESSING

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KNOWING THE SELF: INTERDISCIPLINARY PERSPECTIVES ON SELF RELATED PROCESSING

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The Experience of Beauty of Chinese Poetry and Its Neural Substrates

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Chinese poetry has a long history and high esthetic value. People who engage esthetically with Chinese poetry would feel the sense of beauty naturally. However, there is little information regarding what happens in the brain when an individual appreciates Chinese poetry, and how the brain processes the subject's appreciation of beauty. Herein, we used functional magnetic resonance imaging (fMRI) to investigate the neural substrates of experiencing beauty by appreciating Chinese poetry. The participants in our study were 28 college students and the stimuli consisted of 25 Chinese poetry and 25 prose selections. Based on an event-related paradigm, the findings of this study suggested that different areas scattered in both the left and right cerebral hemispheres are activated when an individual appreciates Chinese poetry. Compared to reading prose, appreciating Chinese poetry heightens the activation of the left inferior orbitofrontal cortex (OFC), the bilateral insula, the left fusiform, the left supplementary motor area (SMA), and the left precentral gyrus. In these areas, the left inferior OFC and the bilateral insula are considered closely related to experiencing beauty of Chinese poetry, which have been demonstrated that it is an important neural basis of esthetic beauty when using other types of materials. The findings of this study shed new light on the complex but ordinary processes of experiencing beauty when appreciating Chinese poetry and show that some key processes underlying the feeling of esthetic beauty are shared across different esthetic domains.

Keywords: Chinese poetry, reading, appreciation, beauty, OFC, insula, neuroesthetics, fMRI

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INTRODUCTION

Individuals who appreciate poems can feel a sense of beauty while doing so. In fact, this is one reason that they read poems. This has already been established in studies carried out at different times and in different cultures, as well as in individuals of all ages. Chinese poetry, which have high esthetic value, comprise an important form of poetry. Written forms of Chinese poetry have been found to exist as early as the first millennium BC. These poems were written based on the daily working lives of individuals, especially those involved in singing and dancing. Chinese poetry are representative of Chinese culture, and are concentrated expressions of Chinese art. Large numbers of Chinese individuals enjoy reading Chinese poems. In addition, these poems are popular among individuals who like poetry and have interest in Chinese culture. In general, like other forms of poetry, Chinese poetry is naturally associated with the expression and inspiration of affective and impressive meanings and emotions (Ludtke et al., 2014). The terms and speech used in Chinese poetry are esthetically and perceptually appreciated (Schrott and Jacobs, 2011). However, the

manner in which the brain processes Chinese poetry is unclear. In addition, the specific neural substrates for the feeling of beauty stimulated by these brain activities are still unknown. We investigated the neural substrates of the feelings induced by appreciating Chinese poetry and determined the regions whose activities are correlated with feelings of beauty. Investigating the activation of brains stimulated by the esthetic appreciation of Chinese poetry is of great value. First, it is important for the humanities to understand the problem of esthetic appreciation of poems at a basic level. Second, our investigation provides evidence for the cross-cultural consistency of the esthetic appreciation of poems. Third, our investigation is helpful in understanding human esthetics, and especially the neural basis of esthetics. Our research findings also provide empirical evidence that may be used to study the neural mechanisms of poetic esthetics.

Advances in non-invasive neuroimaging techniques have allowed us to research healthy participants under controlled situations, and to associate the appreciation of the beauty of poetry with the activities of several brain structures. We can also use neuroimaging to study the processes of underlying the appreciation of beauty in art forms other than poetry. The field of neuroesthetics has thus been developed to answer questions regarding the neural underpinnings of esthetics (Pearce et al., 2016). New theoretical work and experimental studies have led to remarkable progress in neuroesthetics.

Neuroimaging studies have been used to investigate the neurocognitive underpinnings of the esthetic appreciation of different art forms, such as paintings (Vartanian and Goel, 2004; Cupchik et al., 2009; Kirk et al., 2009b), sculptures (Di Dio et al., 2007), architecture (Kirk et al., 2009a), everyday designed products (Yeh et al., 2015), human faces (Aharon et al., 2001; Ishai et al., 2007; Winston et al., 2007), abstract geometrical patterns (Jacobsen et al., 2006), mathematics (Zeki et al., 2014), music (Blood and Zatorre, 2001; Koelsch, 2010; Ishizu and Zeki, 2011; Brattico and Pearce, 2013; Zatorre and Salimpoor, 2013; Koelsch and Skouras, 2014), dance (Calvo-Merino et al., 2005, 2008; Cross and Ticini, 2012), and literature (Bohrn et al., 2013). Research in the different esthetic domains listed above has thus far been unbalanced. The majority of empirical studies have been carried out to investigate visual and auditory domains, while research in other fields, such as literature appreciation, is less common.

Although relevant empirical studies are relatively few, some representative research has been reported. Zeman et al. (2013) studied brain activation by poetry and prose. O'Sullivan et al. (2015) studied the neural basis of literary consciousness. Bohrn et al. (2013) performed pioneering research in this field when they attempted to determine whether reading is accompanied by an implicit esthetic evaluation. In the experiments described in the above report, the participants were requested to read a number of proverbs without explicitly evaluating them. The authors found that large parts of the left frontal lobe, left medial temporal gyrus, left superior temporal gyrus, bilateral occipital lobes, and bilateral precentral gyri were activated during the reading activities. They also identified correlations between specific brain regions and feelings of beauty. These regions were the right caudate nucleus, the anterior cingulate, and the cerebellum. On the basis of empirical research results, Jacobs (2015) proposed a model called the neurocognitive poetics model (NCPM) to elucidate the mechanisms of poetry reception using a neural perspective. The NCPM postulates that different features of poetry texts can activate different neural networks and cognitive-affection processes.

Stimuli other than appreciating literature have also been found to have neural correlates of the feeling of beauty. Kawabata and Zeki (2004) found that the orbitofrontal cortex (OFC) is differentially engaged during the viewing of beautiful paintings. Previous research using other stimuli in the visual esthetic domain (Kirk, 2008; Kirk et al., 2009a,b; Lacey et al., 2011; Ishizu and Zeki, 2013; Flexas et al., 2014; Zhang et al., 2016) and the music esthetic domain (Ishizu and Zeki, 2011) has led to similar conclusions. The insula is another key brain region involved in feelings of beauty. This reflects the "viscerality" of esthetic perception (Cupchik et al., 2009; Brown et al., 2011; Flexas et al., 2014). Jacobs et al. (2012) found that the frontomedial cortex and the amygdala appear to be selectively sensitive to beauty during beauty judgments. In addition, the lingual gyrus has been shown to be activated in some studies of beauty (Kawabata and Zeki, 2004; Vartanian and Goel, 2004; Mizokami et al., 2014; Vartanian and Skov, 2014). There are no consistent conclusions regarding the brain regions that are important for the feeling of beauty thus far.

In sum, the main purpose of our experiment was to investigate the neural substrates of the experience of beauty induced by appreciating Chinese poetry. Changes in regional cerebral blood flow can be measured during the appreciation of Chinese poetry to test our hypothesis. Our study was based on the following hypotheses:

H1. *The basis of the esthetic appreciation of Chinese poetry is similar to that of German proverbs and English poems.*

Brain activity during the appreciation of literature has been investigated using other types of literary material, such as German proverbs (Bohrn et al., 2013) and English poems (Zeman et al., 2013; O'Sullivan et al., 2015). However, the brain activity induced by the appreciation of Chinese poetry is still unknown. We expect that there is some consistency in the neural basis of the effects of appreciating literature in any type or form.

H2. *Comparison of brain activity patterns observed during the appreciation of Chinese poetry to those observed during the reading of prose will reveal significant activation patterns in specific brain regions (e.g., OFC and insula) that are related to the appreciation of beauty. This is in accordance with previous research on the appreciation of beauty in the visual and auditory arts.*

Previous studies on the esthetic appreciation of visual and auditory arts have shown that the feeling of beauty may recruit cortical systems such as the OFC (e.g., Kawabata and Zeki, 2004; Kirk, 2008; Kirk et al., 2009a,b; Lacey et al., 2011; Ishizu and Zeki, 2013; Flexas et al., 2014; Zhang et al., 2016) and insula (e.g., Cupchik et al., 2009; Brown et al., 2011; Flexas et al., 2014). Therefore, we hypothesize that comparing brain activity patterns observed during the appreciating Chinese poetry to

those observed during the reading of prose can reveal significant activation in brain regions related to the appreciation of beauty induced by other art forms, especially in the OFC and the insula. Differences in brain activation induced by the reading of poetry vs. prose have previously been studies (Zeman et al., 2013; O'Sullivan et al., 2015). However, there are no consistent conclusions regarding this issue. Our study should validate the results obtained by other researchers and identify brain regions associated with the esthetic of poetry. The neural correlates of the appreciation of beauty induced by Chinese poetry should recruit the cortical system in a similar manner to those of the much better investigated esthetic appreciation of other art forms.

MATERIALS AND METHODS

Participants

Twenty-eight right-handed participants (mean age: 19 years; range: 18–21 year; 14 women and 14 men) who were healthy and had normal vision or corrected-to-normal vision participated in this study. The participants were good at reading[1]. Bad readers (e.g., those with dyslexia) were excluded. None of the participants had received special poetry education and all were naive to the hypothesis of this experiment. All participants voluntarily agreed to participate in this study and signed a written informed consent prior to their inclusion in the study. The study was supported and sponsored by the Human Ethics Committee of the Southwest University for the Brain Mapping Research. The participants received financial rewards at the end of the study.

Stimuli

Two types of stimuli were used: poetry and prose. Each group of stimuli comprised 25 items (samples of the materials are shown in **Figure 1**). The stimuli shown to the participants were identical. All of the selected poems were popular *Qi Yan Jue Ju* (*Qijue* in short; i.e., seven-character quatrain), which is a type of famous Chinese poetry. In order to better study and research the neural substrates of esthetic beauty induced by appreciating Chinese poetry, high-quality poems were chosen first. High-quality Chinese poetry has the following features:

(1) The language of the poetry is succinct and the wording of the poetry is fastidious.
(2) The poetry displays abundant and multiple artistic conception tastes.
(3) The rhythms of the poetry are strictly in accordance with the standards of Chinese poetry.
(4) There are only few words that are rarely used in poetry.
(5) The poetry is liked by individuals from different times.

There are many different types of high-quality Chinese poetry. In this study, we chose *QiJue* as our experimental stimuli for three reasons. First, *Qijue* has high artistic value, which individuals appreciate. Second, *Qijue* has a very formal style. *Qijue* has strict requirements for sentence number in each poem and for character number in each sentence. There are generally four sentences in each poem and seven characters in each sentence. Third, *QiJue* is marked by strict tonal patterns and rhyme schemes constituting a well-structured prosodic hierarchy (Li and Yang, 2010). Because of this feature, we were able to ensure that all poems had the same number of words, sentence length, tonal patterns, rhythm, and rhyme. The poems used in the experiment were chosen from *Chinese Literature Education* and were equally familiar to all participants. The prose selections, which served as the control condition stimuli, lacked poetry characteristics and stylistic features, but had valid literal interpretations. The topics of the carefully chosen prose selections were familiar to the participants (simple statements regarding world-knowledge). Lexical parameters, such as the number of words and sentence length, were matched across the prose selections and were identical to those of the poems. The font type, font color, font size, and line spacing were consistent in all of the texts.

Procedure

The trials were presented using an event-related design while the participants were in the scanner. The Chinese poetry and the prose selections were randomly sorted and appeared in succession. In order to directly compare our results to those of researchers who have explored brain activity correlated with beauty, using other types of stimuli (Vartanian and Goel, 2004; Jacobsen et al., 2006; Winston et al., 2007; Kirk et al., 2009b), we decided to adopt experimental procedures similar to those used in the above studies. While we based our procedures on the above research, we made some improvements to the procedures in our study. Chinese poetry and prose were read during the scan. Similar functional magnetic resonance imaging (fMRI) research regarding the appreciation of Chinese poetry has not been conducted before. Therefore, a behavioral pre-experiment was designed to test the durations of the stimuli. We found that the average time required for the participants to appreciate a poem sufficiently was 11.33 s. We therefore used 12 s as the reading time in the fMRI experiment. After reading and appreciating the stimuli, the participants were required to provide an explicit esthetic judgment. Our experiment was thus different from a previous study that used an implicit esthetic judgment (Bohrn et al., 2013). We chose to include an explicit esthetic judgment task during the fMRI because it was likely to enhance the effects of the stimuli by requiring the participants

[1]Our research focuses on the appreciation of Chinese poetry while reading silently by oneself. Reading aloud or being read to by others is not considered here.

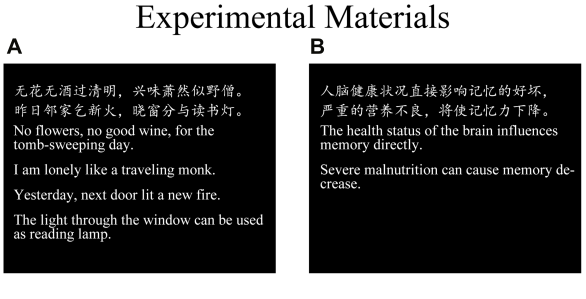

FIGURE 1 | Examples of experimental stimuli. **(A)** An example of a Chinese poetry. **(B)** A prose selection.

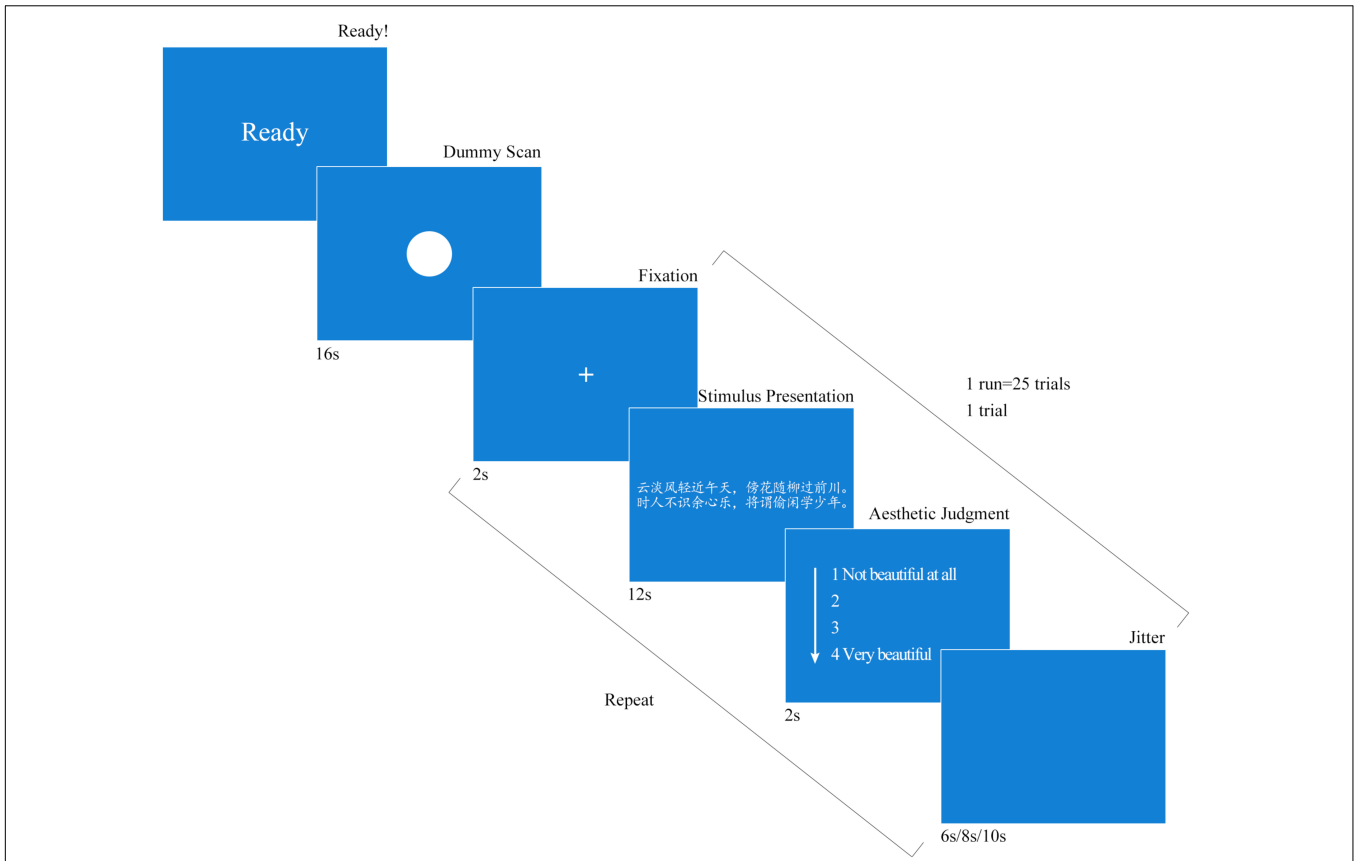

FIGURE 2 | Experimental design. The experiment was performed in two runs. Twenty-five stimuli were presented in each run.

to pay attention to the esthetic qualities of the stimuli. This task also increased the possibility that the participants would engage in the more advanced cognitive stages of the interpretation and evaluation of art-specific attributes despite the wide range of other processes that may subconsciously impact the esthetic experience (Leder et al., 2004). Furthermore, the time required to appreciate Chinese poetry was obviously longer than that required to read a proverb. This also contributed to our decision to choose an explicit esthetic judgment task.

Before entering the scanner, the participants received complete instructions regarding the research, a consent form, and a personal information form. A brief practice session was also carried out. Once inside the scanner, the participant's head was fixed using foam pads, which minimized the motions of the participant's head. The stimuli were displayed on a back-projection screen positioned at the bottom of the scanner. The stimuli were viewed via a mirror placed on top of the head coil. The responses of the participants were recorded using two fiber-optic button boxes tied to the participant's right and left hands. E-Prime (Psychological Software Tools, Inc., Sharpsburg, PA, United States) was used to present and time the stimuli, and to collect data.

Our experiment consisted of two runs, each of which consisted of 25 trials. Each run started with a display of the word "ready" on the screen, which was followed a dummy scan for 16 s. The 25 trials were then presented consecutively. Each trial was initiated by a 2-s display of a fixation cross at the center of the viewing screen and was followed by a stimulus. The stimulus was presented for 12 s. During the presentation of the stimulus, the participants were asked to focus on appreciating the stimulus in silence. After appreciating the stimulus, the participants were requested to complete an esthetic judgment task, which consisted of rating the beauty of the stimulus on a scale ranging from 1 (no sense of beauty) to 4 (great sense of beauty). The participants were asked to provide their ratings within 2 s. Two fiber-optic button boxes were held in the participants' right and left hands. Each button box had two buttons. The buttons represented 1, 2, 3, and 4, respectively. Half of the participants used their right hands to press 1 and 2, and the other half used their left hands to press 1 and 2 when entering their answers. A blank screen was displayed after the rating task. The inter-trial intervals were randomly chosen to last 6, 8, or 10 s. Each run lasted for approximately 616 s. Every subject took part in both runs. There was a 3-min break between the two runs. **Figure 2** illustrates the task and the procedures.

fMRI Acquisition

Whole-brain functional data were acquired using a 3T Siemens scanner (Siemens Magnetom Trio TIM, Erlangen, Germany). During the visual presentations, blood oxygen

level-dependent imaging was performed using a single-shot echo-planar imaging sequence with the following parameters: interslice skip = 0.99 mm; number of slices = 32; repetition time = 2,000 ms; echo time = 30 ms; flip angle = 90°; field of view = 220 mm × 220 mm; matrix size = 64 × 64; voxel size = 3.4 mm × 3.4 mm × 3 mm. Structural data were acquired using T1-weighted images recorded from 176 1-mm-thick slices with an in-plane resolution of 1 × 1 mm (repetition time = 1,900 ms; echo time = 2.52 ms; flip angle = 9°; field of view = 250 mm × 250 mm).

Data Analysis

Functional images were preprocessed using SPM8[2], which was implemented in MATLAB 2014 (Mathworks Inc., Sherborn, MA, United States). The first five images were discarded to achieve steady magnet states. For T2*-weighted images, the slice order was corrected through slice timing, and head movements > 2 mm or 2° were removed. The T1-weighted images were co-registered to the mean echo-planar images and segmented into white matter, gray matter, and cerebrospinal fluid. The echo-planar images were then normalized to the Montreal Neurological Institute space using structural information obtained during the co-registration and segmentation. The voxel size was 3 mm× 3mm × 3 mm. Spatial smoothing was performed using a Gaussian kernel of 8 mm × 8 mm × 8 mm at full width at half maximum.

As the first-level analysis, a general linear model was applied to the fMRI time-series wherein stimulus onset was modeled as a single impulse response function. The data were then convolved with the canonical hemodynamic response function. We modeled two conditions of interest: poetry and prose. Head movement parameters were calculated based on the realignment procedure, and were included in the model as covariates of no interest. A high-pass filter with a cutoff of 128 s was used to remove low-frequency signal drifts. As the second-level analysis, activation patterns induced by appreciating Chinese poetry were obtained using a one-sample *t*-test. We used the contrast between appreciating poetry and reading prose to identify brain regions related to feelings of beauty induced by the appreciation of Chinese poetry (poetry > prose). False discovery rate-corrected *p* values < 0.05 were considered significant. A cluster size threshold of 40 was used.

RESULTS

Behavioral Results

The mean esthetic judgment rating scores for the Chinese poetry and the prose selections were 3.58 ± 0.64 and 1.33 ± 0.70, respectively. The frequencies of the beauty ratings of the poetry and the prose selections by the participants are shown in **Figure 3**. The Chinese poetry had high beauty ratings, while the prose selections had low beauty ratings. Comparisons between the ratings of the Chinese poetry and those of the prose selections indicate that participants reading Chinese poetry provided significantly higher ratings than those reading prose (t = 61.49, $p < 0.0001$, Cohen's d = 3.35). Participants who read Chinese poetry felt more beauty than those reading prose.

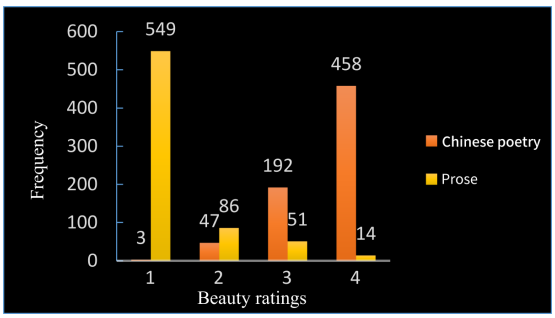

FIGURE 3 | Frequencies of beauty scores. The participants were requested to rate the stimuli on a beauty scale after reading the Chinese poetry or prose selections. The scale ranged from 1 to 4. A score of 1 indicated no sense of beauty, 2 indicated a weak sense of beauty, 3 indicated a fair sense of beauty, and 4 indicated a great sense of beauty.

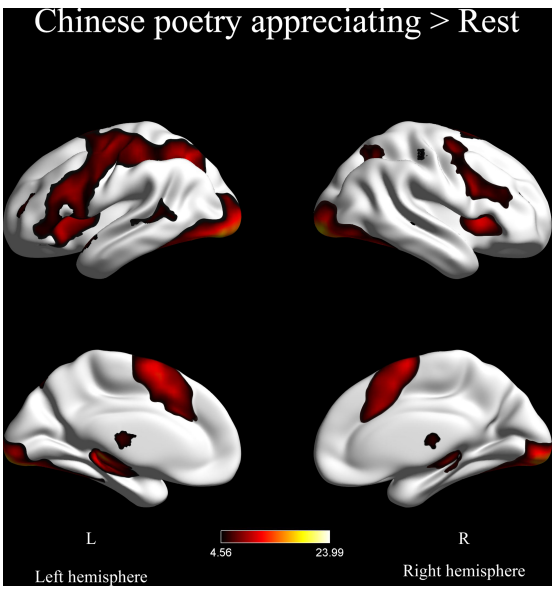

FIGURE 4 | Areas of brain activation during the appreciation of Chinese poetry ($p < 0.001$, FDR corrected).

fMRI Results

Areas of Brain Activation During the Appreciation of Chinese Poetry

The areas of brain activation during the appreciation of Chinese poetry are depicted in **Figure 4**. Significant activation was found in the bilateral inferior frontal gyri, bilateral inferior temporal gyri, left inferior parietal gyrus, left parahippocampal gyrus, left lingual gyrus, bilateral occipital lobes, left fusiform, bilateral insula, left supplementary motor area (SMA), and left precentral gyrus. Appreciating Chinese poetry induced massive activation of bilateral parts of the cerebral hemispheres.

[2]www.fil.ion.ucl.ac.uk/spm

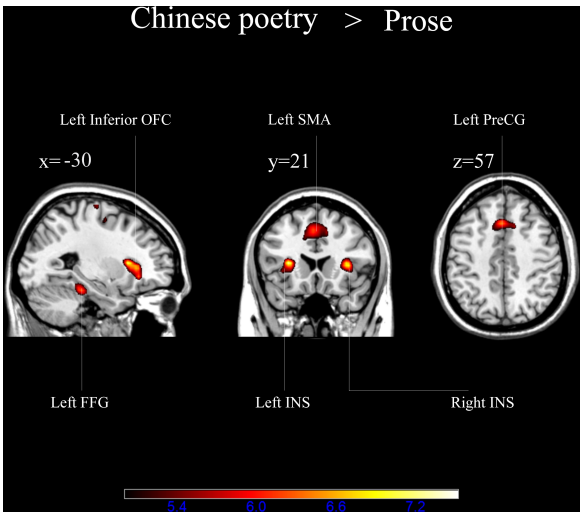

FIGURE 5 | Brain activation during the appreciation of Chinese poetry vs. that of prose ($p < 0.001$, FDR corrected). OFC, orbitofrontal cortex; INS, insula; FFG, fusiform gyrus; SMA, supplementary motor area; PreCG, precentral gyrus.

TABLE 1 | Areas of brain activation during the appreciation of Chinese poetry vs. that of prose ($p < 0.001$, FDR corrected).

Brain regions	Hemisphere	MNI coordinates			*t*-score	Cluster size
		x	*y*	*z*		
Inferior OFC	L	−30	29	−6	5.82	35
Insula	L	−30	21	9	7.38	100
	R	33	24	6	7.15	66
Fusiform	L	−30	−36	−18	6.70	87
SMA	L	−3	21	45	6.42	125
Precentral gyrus	L	−33	−6	57	6.24	212

FDR, false discovery rate; MNI, Montreal Neurological Institute; OFC, orbitofrontal cortex; SMA, supplementary motor area.

Differences Between the Appreciation of Chinese Poetry and That of Prose

To investigate the neural substrates of the feeling of beauty induced by appreciating Chinese poetry, a subtraction analysis comparing the appreciation of Chinese poetry to that of prose was conducted to determine potential differences in blood oxygenation level dependent signal levels during the reading. There were significantly higher activation levels in the left inferior OFC, left fusiform, bilateral insula, left SMA, and left precentral gyrus (**Figure 5** and **Table 1**).

DISCUSSION

Chinese poetry is a special form of poetry and is deeply loved by readers worldwide. Individuals appreciate Chinese poetry in a subjective and engaged manner while experiencing the mood of the work, the feelings it evokes, and the poetic imagery it implies. Poetry, as the interlude of language and music, has phonological features such as those found in music. These phonological features can influence the appreciation of poetry (Lerdahl, 2001; Li and Yang, 2010). The meter and rhyme of poetry also have an impact on esthetic appreciation (Obermeier et al., 2013). Individuals are able to feel beauty during the appreciation of poetry. This has been demonstrated by our behavioral results. Participants were requested to rate the beauty induced by appreciating Chinese poetry and that induced by prose on a scale ranging from 1 (no sense of beauty) to 4 (great sense of beauty). When reading Chinese poetry, the participants felt high levels of beauty (M = 3.58, standard deviation = 0.64) and assigned a rating 4 to 65.43% of the stimuli and a rating of 1 to only 0.43% of the stimuli. In contrast, the participants reading prose felt low levels of beauty (M = 1.33, standard deviation = 0.70) and assigned a rating of 1 to 78.43% of the stimuli, and a rating of 4 to only 2% of stimuli (**Figure 3**). The behavioral results thus indicate that the participants felt beauty when reading Chinese poetry and that the beauty felt was significantly higher than that felt during the reading of prose. The feeling of beauty is one of the reasons that we enjoy reading Chinese poetry, although the processes that occur in our brains during the appreciation of Chinese poetry and why we feel beauty while appreciating Chinese poetry are still unknown.

Previous researchers have explored the secrets of poetry at a neural level, e.g., Al'tman la (1995). However, earlier studies were devoted to analysis of the mental state under poetic inspiration and produced no consistent conclusions regarding the neural mechanisms underlying the appreciation of poetry. Here we were interested in brain activation related to the appreciation of Chinese poetry. Our analysis of the blood oxygenation level-dependent signals during the appreciation of Chinese poetry revealed significant activation in large parts of the brain (see **Figure 4**). Scattered regions in both cerebral hemispheres were activated. Some of the activated regions were related to visual stimulus perception, sentence reading, and semantic processing. This finding is partly in accordance with previous research on the esthetic appreciation of other forms of literature. Bohrn et al. (2013) have reported that large parts of the left frontal lobe, bilateral middle temporal gyri, bilateral superior temporal gyri, bilateral occipital lobes, and bilateral precentral gyri were activated during the reading of proverbs. The left inferior frontal gyrus, the bilateral occipital lobes, and the left precentral gyrus are areas that were activated in both studies. Zeman et al. (2013) showed that the reading of both poetry and prose can lead to activation of the left inferior frontal gyrus, left precentral gyrus, left middle temporal gyrus, bilateral middle occipital gyri, and left mid-fusiform cortex. The same regions were also activated in our study. Specifically, we observed activation of the left inferior frontal gyrus, left precentral gyrus, bilateral occipital gyri, and left fusiform. These findings suggest that reading literature or poetry of any kind leads to the activation of similar neural substrates. This supports our hypothesis H1. Among these related regions, the bilateral occipital lobes were strongly activated when reading Chinese poetry. This indicates that the brain can receive visual stimulation from the poetry and induce intense visual attention to beautiful visual objects (Cela-Conde et al., 2004). The activations of the bilateral inferior frontal gyri, bilateral inferior temporal

gyri, left inferior parietal gyrus, left parahippocampal gyrus, and left lingual gyrus have been reported during sentence reading and semantic processing (Mechelli et al., 2000; Keller et al., 2001; Binder et al., 2009). Activation of the bilateral middle frontal gyri is related to rhymes and tones in the reading of Chinese text (Gandour et al., 2003). These findings indicate that the process of appreciating Chinese poetry involves at a minimum the perception of the visual words, sentence reading, and the semantic interpretation of the poetry.

Appreciating Chinese poetry led to the activation of other parts of the brain in addition to those described above. These regions were differentially activated during the appreciation of Chinese poetry vs. the prose selections. The contrast between the appreciation of poetry and that of prose was reflected in the activation of a distributed network including the left inferior OFC, bilateral insula, left fusiform, left SMA, and left precentral gyrus (**Figure 5** and **Table 1**). Among these regions, the OFC and the insula are key substrates of the feeling of beauty. These two regions have been identified as important "esthetic centers" in the human brain (Brown et al., 2011). Brown et al. (2011) carried out the most comprehensive analysis of neuroesthetic processing by carrying out voxel-based meta-analyses of 93 neuroimaging studies of positive-valence esthetic appraisal across four sensory modalities. The results of the above investigation indicate that the most concordant area of activation across all four modalities is the right anterior insula. The authors of the above study the co-activation of the sensory-specific regions of the OFC and a supermodel area located in the anterior insula are involved in the overall process of esthetic appreciation. Furthermore, Blood and Zatorre (2001) found that the OFC and the insula took part in the appreciation of music and were related to musical "chills," which is a phenomenon that occurs during esthetic appreciation. In addition, Zeman et al. (2013) reported similar results using the experimental poetic material.

We observed differences in the activation of the left inferior OFC while the participants appreciate Chinese poetry vs. prose. The OFC, and especially the medial OFC, has been shown to be important for the feeling of beauty by previous studies on different art forms (Blood and Zatorre, 2001; Kawabata and Zeki, 2004; Jacobsen et al., 2006; Di Dio et al., 2007; Kirk et al., 2009b; Zhang et al., 2016). Kawabata and Zeki (2004) suggested that activation of the OFC correlates with judgments of beauty and ugliness. Kirk et al. (2009a) compared experts and non-experts in their appreciation of architectural stimuli and concluded that the response profile of the medial OFC in both groups had a positive linear correlation with esthetic ratings. The OFC is sensitive to the magnitude of the esthetic value. This is supported by studies of reward processing, which show that the relative reward values of the stimuli are reflected by the amplitudes of neural activity in the OFC (Kringelbach, 2005). The hypothesis of valence processing, which was introduced by Kringelbach (2005), states that the medial OFC is associated with positive valence, while the lateral OFC is involved in negative valence. As mentioned above, the OFC has an important role in the feeling of beauty. We thus assume that it also plays a key role in the feeling of beauty induced by Chinese poetry.

Activation of the bilateral insula in our study indicates that it may be involved in the generation of esthetic emotions when the participant is appreciating the beauty of Chinese poetry. This result agrees very well with previous studies of esthetics in other domains. Di Dio et al. (2007) have shown that the right anterior insula is activated when participants view objectively beautiful sculptures when compared to sculptures modified to be less proportional. The authors propose that the positive feeling elicited by viewing the canonical sculptures is mediated by a cortical network involving the anterior insula. Cupchik et al. (2009) have reported that esthetic perception activates the bilateral insula. They believe that the bilateral insula play important roles in esthetic emotions. Two other large-scale meta-analyses of neuroimaging studies on esthetic appreciation also concluded that the anterior insula is a key structure in experiencing esthetic emotions. The insula, and especially the anterior insula, is known to play a critical role in emotional processing (Craig, 2010). The left side of the insula is associated with the evaluation of positive emotions, while the right side is associated with the evaluation of negative emotions (Craig, 2005, 2010; Tsukiura and Cabeza, 2011). Leder et al. (2004) have suggested that the insula is involved in "continuous affective evaluation". Compared to prose, Chinese poetry contain more complex and abundant emotions. Therefore, appreciating the beauty of Chinese poetry produces many explicit esthetic emotions, which probably involve the function of the insula. We found significantly higher activation of the bilateral insula in participants appreciating Chinese poetry vs. those reading prose.

In addition to the left inferior OFC and the bilateral insula, the left fusiform, the left precentral gyrus, and the left SMA were significantly more highly activated during the reading of poetry vs. that of prose. Similar results have been reported in previous studies of esthetics using words as stimuli (Bohrn et al., 2013; Zeman et al., 2013; Hsu et al., 2014; Zhang et al., 2016). These areas are thus probably related to the process of reading and understanding of words and literature. The left fusiform is associated with reading single words, and is often described as the visual word form area (Jobard et al., 2003). Some researchers also hypothesize that this area is dedicated to determining and understanding word meanings (Devlin et al., 2006). The left precentral gyrus had heightened activation in response to Chinese poetry. This activation may be linked to motor activation via the processes of understanding (Pulvermuller et al., 2005). Activation of these regions is mainly involved in the perception of esthetics.

Based on the discussion above, the fMRI results confirm our hypothesis H2. We compared brain activity patterns during the appreciation of Chinese poetry to those during the reading of prose. We found significant activation in specific brain regions (e.g., OFC and insula) related to the appreciation of beauty. This result is in accordance with those of studies of brain regions related to the feeling of beauty induced by other art forms.

Here, we investigated the neural correlates of feeing beauty induced by the appreciation of Chinese poetry. Appreciation of Chinese poetry is a very complicated and complex process, and involves the perception of words, sentence reading,

comprehension of poetry, and the processing of esthetic emotion. Appreciating Chinese poetry thus requires different brain regions to work together. The bilateral inferior frontal gyri, bilateral inferior temporal gyri, left inferior parietal gyrus, left parahippocampal gyrus, left lingual gyrus, bilateral occipital lobes, left fusiform, bilateral insula, left SMA, and left precentral gyrus were more strongly activated during the appreciation of Chinese poetry. Our behavioral results indicate that reading Chinese poetry leads to much higher feelings of beauty than reading prose. Investigating the differences between the appreciation of Chinese poetry and that of prose can thus help us to better understand the neural substrates of beauty when appreciating Chinese poetry. We found increased activation in the left inferior OFC, left fusiform, bilateral insula, left SMA, and left precentral gyrus during the appreciation of Chinese poetry when compared to the reading of prose. These findings suggest that some of the neural correlates associated with feelings of beauty induced by Chinese poetry are the same as those activated by stimuli from other esthetic domains. While the present research is a tentative exploration, our findings suggest the possibility that the above regions are closely associated with feelings of beauty induced by Chinese poetry. The concrete mechanisms underlying the activation of these regions and their association with feelings of beauty induced by Chinese poetry merits further exploration in future studies.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Human Ethics Committee of the Southwest University for the Brain Mapping Research with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Human Ethics Committee of the Southwest University for the Brain Mapping Research.

AUTHOR CONTRIBUTIONS

All the authors worked together to design the experiment, prepared materials, conducted the experiment, and finally they analyzed the data and finished this paper. All the authors agreed that the final version of the manuscript is suitable for submission and approved to take responsibilities for every aspect of the whole work.

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Distraction Modulates Self-Referential Effects in the Processing of Monetary and Social Rewards

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A reward that is personally relevant tends to induce stronger pursuit motivation than a reward that is linked to other people. However, the role of attention in eliciting this "self-referential reward effect" remains unclear. In our two studies, we evaluated the significance of attention in self-referential reward processing utilizing an ownership paradigm, which required participants to complete a visual search task to win either monetary rewards (in Study 1) or social rewards (in Study 2) for themselves or for an acquaintance. Access to attentional resources was manipulated by sometimes including a distracting stimulus among the presented stimuli. The results of Study 1 revealed that a significant self-referential reward effect emerged under undistracted attentional conditions and was associated with improved task performance when self-owned monetary rewards were available. However, distracted attention impaired this self-referential reward effect. Moreover, distracted attention was also observed in the self-referential social reward processing in Study 2. These results suggested that distracted attention can impair the pursuit advantage for self-relevant rewards; self-referential processing is strongly dependent on attentional resources.

Keywords: self-relevance, attention, social reward, monetary reward, ownership

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INTRODUCTION

The influence of the self on attentional processes has been recognized by psychologists. It has been proposed that humans are equipped with a mechanism that enables self-relevant information to be attended to rapidly and reliably (Gray et al., 2004; Sui et al., 2006; Turk et al., 2011a). Numerous studies have reported that when a stimulus is cued as being relevant to one's self, event-related potentials (ERPs) suggest a rapid increase in both visuospatial and executive attention to the stimulus (Herbert et al., 2011; Turk et al., 2011b; Fan et al., 2013; Northoff, 2016; Sui and Gu, 2017). The tendency for self-cues to capture attention is clearly advantageous, as information that is coupled with the self is likely to be of greater personal importance than material linked with other people. Reflecting this potential importance, a reward associated with oneself elicits a robust motivating advantage compared to a reward linked to another person (Krigolson et al., 2013; Sui and Humphreys, 2015; Zhan et al., 2016). Thus, the question of interest in the present study is whether the increased motivation to earn self-relevant rewards depends on the attentional resources devoted to self-cues.

A number of studies have reported self-referential effects in reward processing and suggested that self- and reward-related processing either interacted or were independent in various external contexts (Northoff and Hayes, 2011). For instance, compared to other-relevant reward stimuli, self-relevant reward stimuli can be perceived faster during a series of perceptual matching tasks (Sui et al., 2015a,b), result in faster learning of reward rules in a social gambling task (Kwak et al., 2014), elicit larger P2 and P3, which indicate stronger respective attentional salience and motivational importance (Martín et al., 2016; Zhan et al., 2017), and evoke stronger neural activations in the reward region of the brain (Hassall et al., 2016). Therefore, these findings are consistent with the general notion that self-relevant items often have higher intrinsic value within individuals' subjective value systems compared to stimuli related to other people (Northoff, 2016). However, it is somewhat difficult to apply this to the nonevaluative self-referential reward effect described above, as participants were not required to relate the incoming rewards to the self. This theoretical gap could be bridged by consideration of the importance of attention in processing. Given the attention capture known to follow the perception of self-cues, this may enhance resource-intensive processing in self-referential processing contexts, such as owning objects and making outcome choices. This should elicit stronger pursuit motivation for self-relevant rewards relative to other-relevant rewards and improve subsequent task performance.

Supporting this reasoning, our study argues that self-referential reward effect can be described as a classical "endowment effect" (Hassall et al., 2016) that is dependent on the accessibility of attentional resources (van den Bos et al., 2010). Elaboration of incoming stimuli tends to be a process requiring additional attentional resources. For instance, previous studies have reported that distraction can influence the processing of emotional stimuli, as well as emotional regulation strategies (Paul et al., 2013; Li and Yuan, 2018). Moreover, studies on self-referential memory have observed that separating attention dramatically lowered recognition (Gardiner and Richardson-Klavehn, 2000; Gardiner et al., 2001; Turk et al., 2013). Such findings indicated that elaborative self-referential memory representations depended, to a greater extent, on the application of attentional resources at encoding compared to representations associated with other people. Additionally, Hickey and his colleagues have also demonstrated that distracted attention impairs the motivating effects of stimuli associated with rewards (Hickey et al., 2006, 2009, 2010). Specifically, participants' performance decreased when target stimuli were accompanied by distracting stimuli during a visual search task. These findings suggested that available attentional resources can impact the self-referential effect during the processing of rewards. Hence, we speculated that attentional allocation may be the mechanism that enables the existence of the self-referential reward effect, in which self-owned rewards evoke stronger pursuit motivation than other-owned rewards in full-attention conditions. However, distracted attention could impair this effect due to limited attentional resources.

To further confirm this speculation, the present study included two studies (using monetary and social rewards) to identify whether inadequate resources have a selectively deleterious role on the self-referential reward effect. More specifically, we predicted that self-relevant monetary rewards might require resource-intensive processing and would therefore be affected by distracted-attention (DA) manipulations (Study 1). Consequently, we expected that only monetarily rewarded visual searches would decrease under DA conditions and not unrewarded visual searches. Furthermore, we examined whether there was a similar impairing effect of distracted attention on the self-referential social reward effect in Study 2.

STUDY 1

Sample Population and Design

In this study, 89 right-handed college students (42 males and 47 females aged 17–23 years) were included. All participants had normal or corrected-to-normal vision and no known neurological impairments. Additionally, all participants were volunteers from Hunan Normal University and received academic credit in their undergraduate psychology courses for participation. We obtained specific informed consent from each participant for publishing information or images that could potentially reveal their identities in an online open-access publication. A 2 (referential cues: self-referential cue, other-referential cue) × 3 (reward cues: high monetary reward cue, low monetary reward cue, non-reward cue) × 2 (attentional condition: distracting stimulus, no distracting stimulus) within-subjects design was employed. All experimental procedures were conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Hunan Normal University. After fully understanding the study, each participant signed an informed consent form.

Stimuli and Tasks

Self-Association Task

Prior to the experiment, each participant was provided a name of an acquaintance with whom they were unfamiliar but greeted upon meeting. Throughout the coupling task, the red circle and triangle geometric shapes were, respectively assigned to labels representing the participant and the acquaintance in two sessions. For instance, participants were informed that "the triangle is your acquaintance" and "the circle represents yourself" (Sui et al., 2012). Among all participants, the orders of the shape-labeled pairs presented were randomized, and the associations between shape and label were counterbalanced. Following the associative directions, participants underwent a shape-label matched pair. A shape (covering 3.5° × 3.5° visual angle) was presented above a white central fixation cross (0.8° × 0.8° visual angle). Of the two labels, one (the name of the participant and their acquaintance) (covering 1.76°/2.52° × 1.76° of visual angle) was shown beneath the fixation cross. Participants were assigned the tasks of determining whether the shape-label pair was equivalent as initially shown or if the shape and label were altered. Participants were informed that they could only go on to the next stage if they responded correctly in all of the trials; otherwise, the cycle was repeated.

Visual Search Task

The visual search arrays included 10 object outlines (line thickness of 0.3° visual angle), each appearing equidistant (9.1°) from a central fixation point and from the other. Objects were either diamonds (4.2° × 4.2°) or circles (3.4° diameter), while each display contained only a singular uniquely shaped item. The unique item was either a diamond (while all other stimuli were circles) or a circle (while all other stimuli were diamonds). Among 80% of the trials, one of the homogenously shaped nontarget items were of unique color, such as red (with all other objects green) or vice versa. For each trial, distractor and target colors were determined randomly. A gray line, which was randomly oriented vertically or horizontally, was contained for each object (0.3° × 1.5°). The sequence of events on the visual search task is presented in **Figure 1**. The task began with a fixation cross presented for 500ms, followed by a cue for 1000ms. Each potential reward size differed on three levels, as stated by the number of parallel lines in the cue. Absence of a reward was identified by an empty white circle, while a low reward (a value of 10 Yuan) was identified by a white circle with a horizontal line and a high reward (a value of 20 Yuan) was identified by a white circle with two horizontal lines. After a random interval of 600–1000 ms, the visual search task was presented for 4000ms. Feedback stimuli were shown for 500 ms following a variable target-feedback interval of 800–1000 ms, based on the reward magnitude for the present trial and the participant's response. In the case of no-reward trials, a "√" or "×" was presented as a feedback stimulus based on whether the button pressed was correct. In monetary reward trials where participants provided quick correct responses, monetary rewards of 10 or 20 Chinese Yuan banknotes were given as feedback stimuli. Finally, the cumulative points of the participant and their acquaintances were presented for 500 ms. During that task, participants were informed of their performance by viewing the cumulative points for reward feedback stimuli.

Procedure

The full experiment includes the self-association task and the visual search task. Before the experiment, all participants completed some exercises to become familiarized with the procedures. During the self-association task, participants formed two special pairs between shapes (the red circle and triangle geometric shapes) and labels (the self and acquaintance). They were then given a two-minute break, after which the participants were asked to complete the visual search task for monetary reward. Finally, participants were asked to complete a 7-point subjective rating regarding motivation for the three types of reward cues; for example, answering "how much do you desire to correctly respond to the cue stimuli?" with ratings ranging from 1 (no desire at all) to 7 (strongly desire). Stimuli presentation and the recording of RTs and ACC were accomplished using E-Prime

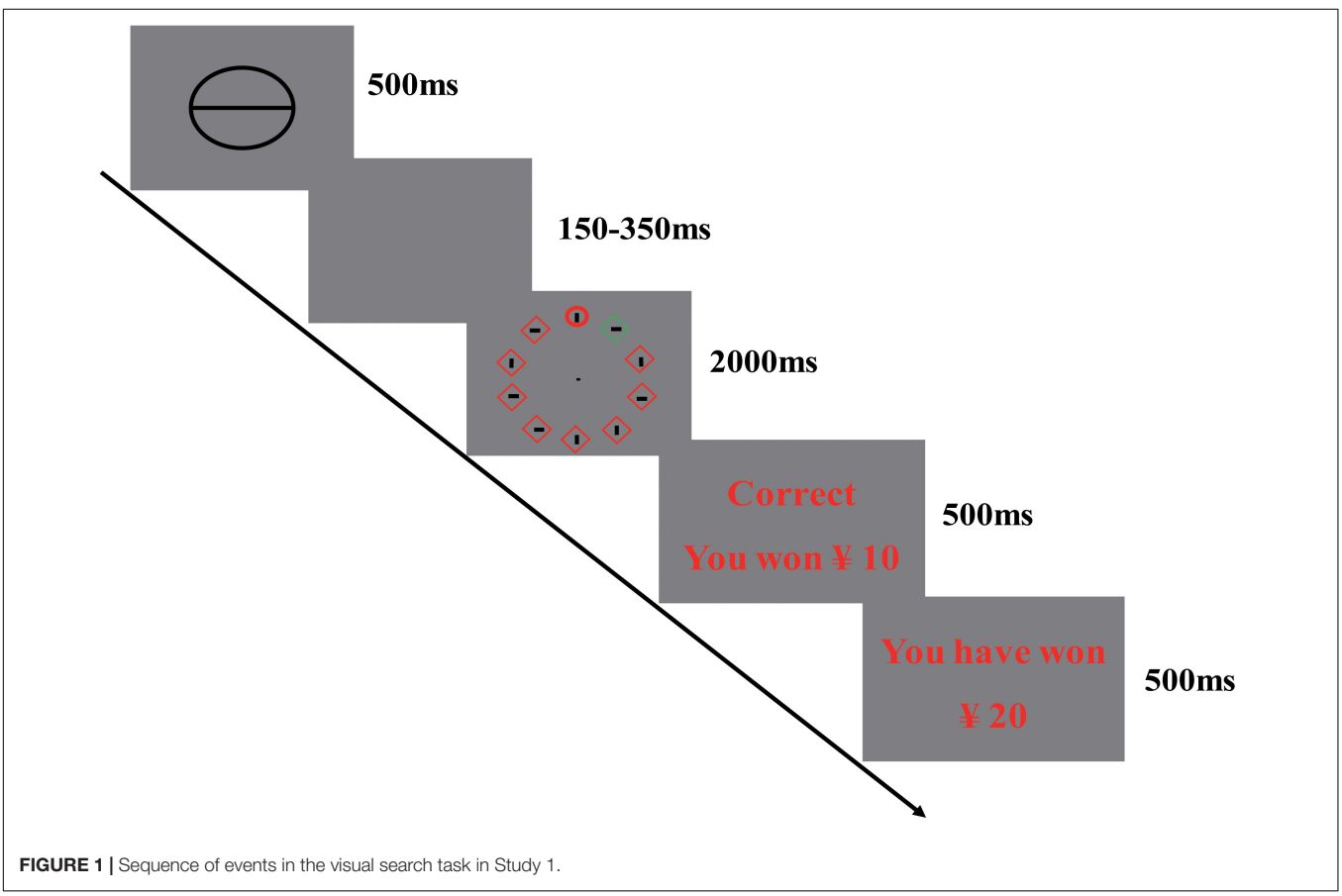

FIGURE 1 | Sequence of events in the visual search task in Study 1.

2.0 software (Psychology Software Tools, Pittsburgh, PA). The full experiment took about 25 min.

Data Analysis

Using repeated-measures of analysis of variance (ANOVA), RTs and accuracy were separately analyzed based on within-subjects factors, which were referential cues (self-referential and other-referential), reward cues (high monetary reward, low monetary reward, and no reward), and attentional condition (distracting stimulus, no distracting stimulus). All data analysis was performed using Statistical Package for the Social Sciences (SPSS) Version 20.0 (IBM Inc., New York, United States). Partial η^2 was shown as an effect size estimate. For all significant interactions, we conducted *post hoc* pairwise comparisons with Bonferroni adjustments.

Results

The analyses of subjective rating scores revealed that the 20 Yuan ($2.88) was more strongly desired than the 10 Yuan RMB ($1.44), $t_{1,87)} = 6.13$, $p < 0.001$. Also, the 10 Yuan RMB was more strongly desired than a same-sized blank paper, $t_{(1,87)} = 13.56$, $p < 0.001$. These results suggest that monetary reward was operationalized successfully.

Table 1 presents the mean accuracy rates and RTs. The accuracy rates reveal a main effect for the reward cues ($F_{(2,176)} = 27.05$, $p < 0.001$, $\eta_p^2 = 0.24$), with significantly higher average accuracy rates in the monetary reward condition compared to the no-reward condition; however, there were no significant differences between the high and low monetary reward conditions. Additionally, a main effect of referential cues ($F_{(1,88)} = 51.60$, $p < 0.001$, $\eta_p^2 = 0.37$) suggested a significantly higher average accuracy rate for the self-referential cues than for the acquaintance-referential cues. There was also a significant three-way interaction between reward cues, referential cues, and attentional condition, $F_{(2,176)} = 4.32$, $p < 0.05$, $\eta_p^2 = 0.11$. Further simple effect analysis revealed that in the undistracted condition, participants demonstrated higher average accuracy rates for the self-referential cues than for the other-referential cues under three kinds of rewards conditions ($Fs_{(1,88)} = 15.60$–18.75, $ps < 0.001$). However, in the distracted conditions, such self-referential reward effect was reduced under both high and low monetary rewards conditions ($F_{(1,88)} = 10.08$, $p < 0.001$, $F_{(1,88)} = 15.60$, $p < 0.001$) rather than in the no-rewards conditions, $F_{(1,88)} = 2.79$, $p > 0.05$ (**Figure 2A**).

Findings from the RTs show a main effect of reward cue ($F_{(2,176)} = 18.74$, $p < 0.001$, $\eta_p^2 = 0.18$), presenting an associated increase in RTs in the monetary reward condition compared to no-reward condition, as well as faster RTs for high monetary rewards than for low monetary rewards. Additionally, a main effect of referential cue was observed ($F_{(1,88)} = 8.60$, $p < 0.01$, $\eta_\rho{}^2 = 0.09$), suggesting significantly faster RTs for the self-referential cues than the acquaintance-referential cues. The main effect of attentional condition was significant ($F_{(1,88)} = 24.97$, $p < 0.001$, $\eta_p^2 = 0.22$), suggesting significantly faster RTs for the target stimuli in the undistracted conditions than in the distracted conditions. In addition, we observed a significant interaction between reward cue and referential cue ($F_{(2,176)} = 10.09$, $p < 0.001$, $\eta_p^2 = 0.10$). Further simple effect analysis revealed that in the high and low monetary reward conditions, the participants demonstrated faster RTs for the self-referential cues than for the acquaintance-referential cues ($F_{(1,88)} = 27.12$, $p < 0.001$, $F_{(1,88)} = 7.39$, $p < 0.01$). However, such differences in RTs were not observed in the no-reward condition ($F_{(1,88)} = 1.87$, $p > 0.05$). Furthermore, we found an associated interaction between referential cue and attentional condition ($F_{(2,176)} = 15.56$, $p < 0.01$, $\eta_p^2 = 0.11$). Additional simple effect analysis revealed that the self-referential reward effect was only observed in the undistracted conditions ($F_{(1,88)} = 14.74$, $p < 0.001$) and not in the distracted conditions ($F_{(1,88)} = 1.72$, $p > 0.05$, **Figure 2B**).

Discussion

The findings from Study 1 indeed show an obvious self-referential reward effect, suggesting that participants' performances are better (e.g., higher accuracy rate and faster RTs) when earning self-owned monetary rewards as opposed to acquaintance-owned monetary rewards. Importantly, this self-referential reward effect was impaired under distracted attentional conditions. This was observed when self-referential cues, rather than acquaintance-referential cues, were associated with reduced performance when distracting stimuli were present. The pattern of responses observed during the full-attention condition was similar to findings from van den Bos et al. (2010). Specifically, they found that ownership effects are observed during recognition along with recollective experience. Additionally, the authors suggested that the advantage for self-relevant items would diminish when participants were completing a task with divided attention at the time of encoding. Turk et al. (2013) reported

TABLE 1 | Mean and SD of accuracy rate (%) and RTs (ms) in study 1.

		Accuracy rate		RTs	
		Self-reference	Acquaintance-reference	Self-reference	Acquaintance-reference
Undistracted attention	No reward	0.65 ± 0.18	0.58 ± 0.22	722.55 ± 171.70	764.02 ± 202.29
	Low reward	0.71 ± 0.20	0.63 ± 0.21	797.38 ± 134.28	832.57 ± 168.45
	High reward	0.74 ± 0.19	0.66 ± 0.19	793.29 ± 124.34	848.28 ± 160.59
Distracted attention	No reward	0.64 ± 0.19	0.61 ± 0.17	804.61 ± 128.70	807.02 ± 159.42
	Low reward	0.74 ± 0.14	0.65 ± 0.15	798.28 ± 134.45	823.84 ± 158.15
	High reward	0.74 ± 0.17	0.62 ± 0.17	811.61 ± 147.88	850.72 ± 126.60

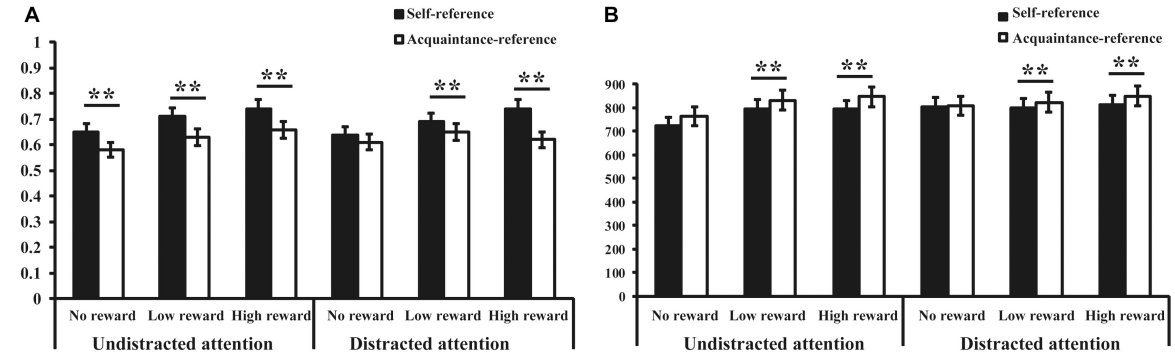

FIGURE 2 | Mean accuracy **(A)** and reaction time **(B)** under all conditions in Study 1. Asterisks represent the significant level, $^{*}p < 0.05$ and $^{**}p < 0.01$.

that while a self-referential effect in memory was observed under full-attention conditions, the memory benefit was lost during divided attention at the time of encoding. In the present study, self-owned rewards evoked stronger pursuit motivations and were associated with better performance than other-owned rewards in the undistracted conditions. However, the self-referential reward effects were impaired in the distracted conditions. According to literature on the general attentional requirements of elaborative encoding, as well as ownership studies on the patterns of brain activation (Cunningham et al., 2008; Huang et al., 2009; Krigolson et al., 2013), the present findings revealed that ownership effects occur solely when adequate attentional resources are available. However, other studies have reported the similarities and differences between monetary and social reward processing. For example, compared to monetary rewards, participants were given greater cognitive efforts for social rewards (Rademacher et al., 2014), and autistic children showed weaker attentional bias and lower performance for social rewards (Stavropoulos and Carver, 2014; Neuhaus et al., 2015). Recently, Wang et al. (2017) suggested that social and monetary rewards effectively improved performance for all age groups (children, adolescents, and adults) as reward size increased in the selection reaction time task, and social rewards showed resilient subjective incentive power compared to monetary rewards among children and adolescents. In sum, these studies indicated that monetary and social rewards have not only similar enhancement effects for cognitive processes, but also some considerable differences in intensity. However, it remains unclear whether the impairing effect of distraction was observed in the processing of social rewards.

STUDY 2

Participants and Design

In total, 108 right-handed college-aged participants (58 males and 50 females aged 16–24 years) were included in the study. All of the participants' vision was either normal or corrected-to-normal, and the subjects had no known neurological impairments. Additionally, all participants were volunteers who received academic credit in their undergraduate psychology courses at Hunan Normal University in exchange for participating. A 2 (referential cues: self-referential, other-referential) × 3 (reward cues: high social reward, low social reward, non-reward) × 2 (attentional condition: distracting stimulus, no distracting stimulus) within-subjects design was employed. We expected that when comparing undistracted attentional conditions, the task performance in the presence of both self-referential and acquaintance-referential cues would be reduced in the distracted attentional conditions. All experimental procedures were conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Hunan Normal University. After fully understanding the study, each participant signed an informed consent form.

Stimuli and Procedure

The same experimental methods from Study 1 were used in Study 2, and the SID task was adopted to examine how self-reference affected the processing of social rewards given different attentional resources. The social rewards were 10 or 20 cartoon smiley faces (low and high social rewards, respectively), and the no-reward stimulus was a neutral cartoon face (Rademacher et al., 2014; Wang et al., 2017). Hence, the only difference from Study 1 was the reward cues.

Results

The analyses of the subjective rating scores revealed that the 20 cartoon smiley faces were more strongly desired than the 10 cartoon smiley faces ($t_{(1,106)} = 13.11$, $p < 0.001$), and the 10 cartoon smiley faces were more strongly desired than the neutral faces ($t_{(1,106)} = 14.82$, $p < 0.001$). These results suggest that the social reward was operationalized successfully.

Table 2 presents the RTs and mean accuracy rates. The accuracy rates show a main effect of reward cue ($F_{(2,214)} = 22.70$, $p < 0.001$, $\eta_p^2 = 0.18$), presenting significantly higher average accuracy rates for the social rewards compared to no reward, as well as significantly higher average accuracy rates for high social rewards than low social rewards. Additionally, a main effect of referential cue ($F_{(1,107)} = 36.57$, $p < 0.001$, $\eta_\rho{}^2 = 0.26$) suggested a significantly higher average accuracy rate for the self-referential cues than for the acquaintance-referential cues. There were no

TABLE 2 | Mean and SD of accuracy rate (%) and RTs (ms) in study 2.

		Accuracy rate		RTs	
		Self-reference	Acquaintance-reference	Self-reference	Acquaintance-reference
Undistracted attention	No reward	0.63 ± 0.21	0.55 ± 0.19	687.30 ± 190.67	700.23 ± 197.34
	Low reward	0.68 ± 0.21	0.61 ± 0.18	750.04 ± 175.06	779.24 ± 191.06
	High reward	0.70 ± 0.20	0.64 ± 0.21	758.50 ± 179.11	803.67 ± 185.32
Distracted attention	No reward	0.63 ± 0.18	0.59 ± 0.18	718.24 ± 202.03	725.51 ± 206.41
	Low reward	0.69 ± 0.16	0.64 ± 0.18	759.24 ± 175.07	779.12 ± 196.39
	High reward	0.72 ± 0.15	0.65 ± 0.17	780.69 ± 172.47	789.69 ± 190.45

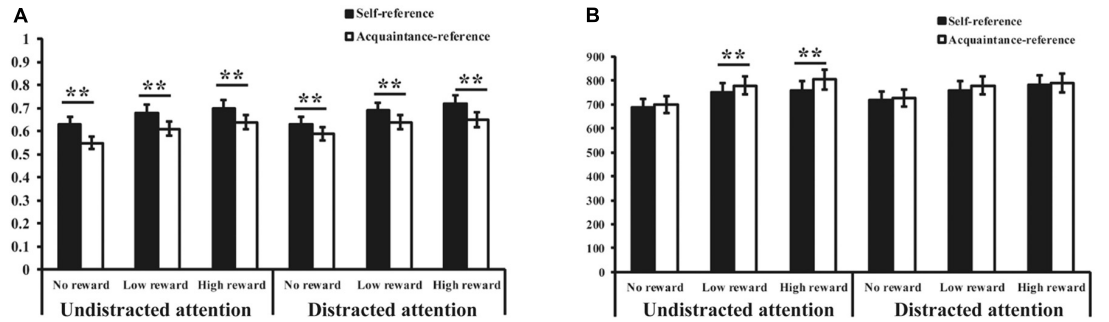

FIGURE 3 | Mean accuracy **(A)** and reaction time **(B)** under all conditions in Study 2. Asterisks represent the significant level, $^{**}p < 0.01$.

other significant main effects or interaction effects (each $p > 0.13$; **Figure 3A**).

The results for the RTs showed a main effect of reward cue ($F_{(2,214)} = 21.23$, $p < 0.001$, $\eta_p^2 = 0.17$), presenting significantly increased RTs for the social rewards compared to no reward and faster RTs for high social rewards than for low social rewards. Additionally, a main effect of referential cue was observed ($F_{(1,107)} = 8.36$, $p < 0.01$, $\eta_p^2 = 0.10$), suggesting associated faster RTs for the self-referential cues compared to the acquaintance-referential cues. A main effect of attentional condition was also observed ($F_{(1,107)} = 4.20$, $p < 0.05$, $\eta_p^2 = 0.09$), revealing significantly faster RTs in the undistracted conditions than in the distracted conditions. Additionally, we observed a significant three-way interaction between reward cue, referential cue, and attentional condition ($F_{(2,214)} = 6.72$, $p < 0.01$, $\eta_p^2 = 0.06$). Further simple effect analysis revealed that in the undistracted conditions, participants demonstrated faster RTs with the self-referential cues than with the other-referential cues under the low and high social reward conditions ($F_{(1,107)} = 6.56$, $p < 0.01$; $F_{(1,107)} = 16.36$, $p < 0.001$). However, a self-referential reward effect was not observed in the no-reward conditions. Moreover, in the distracted conditions, self-referential reward effects were not observed for any of the reward conditions ($Fs_{(1,107)} = 0.33$–0.58, $ps > 0.05$; **Figure 3B**).

Discussion

As observed in the first study, the findings from Study 2 further demonstrated that the self-referential social reward effect also was impaired under the distracted conditions. This evidence showed that self-reference could also promote the pursuit of motivation for social reward, but only under full-attentional conditions. However, previous research has shown that individuals demonstrate different behavioral and neural responses while pursuing monetary and social rewards (Stavropoulos and Carver, 2014; Neuhaus et al., 2015). For example, Rademacher et al. (2014) found that participants applied greater cognitive efforts toward earning monetary reward cues compared to social reward cues. Recently, Wang et al. (2017) revealed that both social and monetary rewards successfully improved responding in all age groups (children, adolescents, and adults) as reward size increased in the selection reaction time task, and social rewards showed resilient subjective incentive power compared to monetary rewards among children and adolescents. As seen in Study 1 with monetary rewards, Study 2 also found an obvious self-referential reward effect in the pursuit of social rewards, though divided attention impaired this advantage. However, there were some differences from Study 1. Study 1 found that the impairing effect of divided attention was only observed in the no-reward conditions and not in the low or high reward conditions. Nevertheless, in Study 2, this impairment was observed in all reward conditions. These findings revealed that the impairing effect of distracted attention on self-referential monetary reward effect was modulated by reward value rather than self-referential social reward effect.

GENERAL DISCUSSION

In the present study, we explored the extent to which distracted attention during monetary and social reward pursuit impacts

the reward advantage usually associated with self-owned items (Turk et al., 2011b; Krigolson et al., 2013). It was found that under undistracted conditions, an "ownership effect" (i.e., better performance for self-owned than for acquaintance-owned rewards) emerged in the low and high monetary conditions, whereas no effect of ownership was observed in the no-reward conditions. This pattern of responses in the undistracted attention condition replicated the behavioral findings from Krigolson et al. (2013), which reported that ownership effects were observed in a simple gambling task during which participants could "win" or "lose" prizes for themselves or for someone else. Moreover, this self-referential reward effect was observed in the pursuit of social rewards.

Given the effortful nature of elaborative encoding, it was expected that the advantage of self-referenced (i.e., self-owned) rewards would be diminished when participants were completing a distracted-attention task in pursuit of rewards. This pattern was found, with no ownership effect emerging under conditions of undistracted attention. It seems plausible to conclude from this pattern that attentional resources are required when engaging in elaborative reward processing for self-owned objects, which is not possible under conditions of serious resource depletion. This pattern of reward performance augments the evidence that self-referential reward processing, relative to the processing of objects associated with other people, triggers rich, elaborative reward processing (Sui et al., 2015a,b), which is attentionally demanding. To our knowledge, the current study provides the first evidence that the self-reference effect in reward processing is underpinned by differences in attentional processing during the pursuit of rewards.

Interestingly, pursuit of acquaintance-owned rewards was unaffected by distracted attention, suggesting that relatively little elaboration of other-owned rewards takes place, even under undistracted attentional conditions. It is possible that with more power, a small effect of distracted attention would also have been observed in the pursuit of acquaintance-owned rewards, as some elaboration would be expected to support reward processing in this condition. However, the interaction between self-reference and attention was expected, because distracted attention should have a larger effect on self-referential reward processing, reducing the elaboration with which it is distinguished. Importantly, the value of the reward could modulate the influences of self-reference and attention on the pursuit of monetary rewards rather than social rewards. This impairing effect of distracted attention on self-referential reward effect was weak or nonexistent with greater value of monetary rewards. However, this modulation of reward value was not observed in the pursuit of social rewards. We speculate that college students might not be as sensitive to social rewards as they are to monetary rewards. College students are gradually integrating into society and pay increasing attention to money due to their increasing economic independence. Therefore, the value of monetary rewards has an advantage for motivating behavior, compared to social rewards such as cartoon smiles, among college students (Wang et al., 2017). Moreover, this could also be because the incentive value of the social reward was reduced by repeated presentation (Demurie et al., 2012).

These novel findings suggesting that attention is crucial for the self-referential reward effects casts new light on the potential links between the ways in which the self influences human cognition. In particular, the link between the dependence on attention for self-reference effects and the well-known attentional-capturing effect of self-cues during reward processing is an interesting theoretical angle. The two effects could be causally related, as the attention recruited by self-cues could be the mechanism by which resource-dependent elaborative processing and proper motivation were evoked. Cues relating to other people, which do not attract the same degree of attention, could fail to benefit from these reward-enhancement processes; hence, distracted attention has little effect on pursuit motivation by other-relevant rewards. Moreover, this modulation of attention could be explained by the parallel relationship between self and reward, as the self-referential reward effect was indeed affected by the availability of attentional resources. However, the present study did not assess reward seeking motivation. According to reinforcement sensitivity theory, individuals show differences in subjective sensitivity and behavioral approaches toward earning the same reward (Jackson, 2003). Thus, future studies on self-referential reward effects should consider individual differences in reward sensitivity.

CONCLUSION

The current study indicated that the processes underlying the monetary and social rewards of elaborative encoding and pursuit in response to self-cues are attentionally demanding. While an ownership effect is elicited under undistracted attentional conditions, this self-referential reward effect was impaired when attention was divided by distracting stimuli. Moreover, the impairment caused by distracted attention was weaker or nonexistent along when the value of monetary rewards, rather than social rewards, increased. The present study offers clear evidence that the reward enhancement associated with self-referential reward processing is dependent on the availability of attentional resources.

AUTHOR CONTRIBUTIONS

JZ and YZ designed the experiments and wrote the manuscript. JZ recruited participants and collected the data. YZ performed the data analyses.

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Increasing the Difference in Decision Making for Oneself and for Others by Stimulating the Right Temporoparietal Junction

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The right temporoparietal junction (rTPJ) has been thought to be associated with the difference in self-other decision making. In the present study, using noninvasive transcranial direct current stimulation (tDCS), we examined whether stimulating the rTPJ could modulate the self-other decision-making difference. We found that after receiving anodal stimulation of the rTPJ, participants were more likely to choose a high-value item for others than for themselves in the situations where the win probability of the high-value item was equal to or greater than that of a low-value item, indicating that elevating the cortical excitability of the rTPJ might increase the self-other decision-making difference in certain decision contexts. Our results suggest that decision making for others depends on neural activity in the rTPJ and regulation of the excitability of the rTPJ can influence the self-other decision-making difference.

Keywords: social neuroscience, decision making, self-other decision making, temporoparietal junction (TPJ), transcranial direct current stimulation (tDCS)

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INTRODUCTION

In our social lives, we not only need to make decisions for ourselves but also often anticipate or make decisions for others. Indeed, decision making for others is the main content of social activities such as finance, medical treatment, consulting, and management, and acting for others in making risky decisions has gradually become an integral part of people's social and economic lives. In recent years, the difference in self-other decision-making has attracted the attention of various researchers, and some research results and theories have emerged. However, few studies have directly explored the brain mechanisms of the difference in decision making between oneself and others.

While, some studies in the field of risky decision making have examined the self-other decision-making difference, the results are inconsistent. Hsee and Weber (1997) found that people estimated that others were more likely than themselves to choose uncertain risk options, regardless of whether the choice was between gains or between losses. Using a risk decision-making task with a gain frame, Stone et al. (2002) found that anticipated regret increased risk aversion, but they found no significant difference between decision making for oneself and decision making for friends. Fernandez-Duque and Wifall (2007) compared participates' gambling behavior for themselves and advice giving to others regarding gambling, and found that participants showed more risk-taking tendencies in making decisions for themselves and relied less on objective probabilities when giving advice to others. Such inconsistencies arise because risk preference may be modulated by the gain/loss frame and risk probability (Liu et al., 2010, 2014; Duan et al., 2012). One study has found that people are less risk averse in a gain situation and less risk seeking in a loss situation when making decisions for a stranger than when making decisions for themselves (Zhang et al., 2017).

These findings suggest that we cannot generally say whether people are more risk adverse or more risk seeking when making decisions for others than when making decisions for themselves. Rather, we must consider the contextual characteristics of decision tasks.

Researchers have also proposed some theoretical explanations for the inconsistency of risk preference in self-other decision making. For example, Loewenstein et al. (2001) propose the risk-as-feelings hypothesis that people's response to risk anticipation is influenced by cognitive assessment and emotional response, with emotional response playing a decisive role in this process. The discrepancy between making decisions for oneself and predicting others' decision making is due to the "vividness" of others. The more vivid the other person is, the stronger the emotional response, which will affect the distinction in risk preference. Beisswanger et al. (2003) believe that compared with decision making for oneself, decision making on behalf of friends is associated with less anticipation of negative-emotion involvement and thus less risk aversion. Fernandez-Duque and Wifall (2007) found asymmetry in executor-observer risk decision making and proposed that when deciding for themselves, people rely more on empirical systems involving emotional and intuitive processing than on rational systems involving logical and analytical processing. This has been supported by some brain imaging studies, and the difference in decision making for oneself and that for others is reflected in the activation of the brain areas related to the emotional/empirical system and the cognitive/rational system. That is, decision making for oneself is more sensitive to rewards and perceived risks than decision making for others, as reflected in the greater involvement of the reward system and emotional-related brain areas, such as the ventral striatum, anterior cingulate gyrus, and amygdala (Albrecht et al., 2011; Jung et al., 2013). In contrast, decision making for others involves additional mentalizing and cognitive processing, as reflected in the activation of related brain areas, such as the temporoparietal junction (TPJ) and the medial prefrontal cortex (Janowski et al., 2013; Jung et al., 2013).

The right TPJ is a key brain area involved in processing different perspectives, reflecting and speculating mental states (Murray et al., 2012; Schurz et al., 2014, 2015; Krall et al., 2016; Mai et al., 2016). It is also an important part of other-processing networks and plays a role in promoting self-other distinction (Jardri et al., 2011; Venkatasubramanian et al., 2011; Murray et al., 2015; Steinbeis, 2016). Although relatively few studies have directly examined the brain mechanisms of the self-other decision-making difference, some studies have found that the TPJ plays an important role in this difference (Janowski et al., 2013; Jung et al., 2013; Ogawa et al., 2018). In an fMRI study, Jung et al. (2013) used a gambling task to directly compare the differences in brain activity when making risky decisions for oneself and for others. They found that different neural processes were involved in making risky decisions for oneself and for others; specifically, the reward system was more active in decision making for oneself, while the TPJ was more active in decision making for others. Ogawa et al. (2018) used a classical Theory-of-Mind task in an fMRI study and identified the rTPJ associated with cognitive perspective taking. They then examined whether activity in the identified rTPJ during the risky decision task (i.e., lottery-choice task) was modulated by the parameters of the behavioral-choice model, and found that rTPJ activity in the Other condition (i.e., decision making for an anonymous other) was modulated by the difference in expected value of the two lottery options, suggesting that individuals' cognitive perspective taking operates in a more risk-neutral manner when making decision for others.

The transcranial direct current stimulation (tDCS) is a noninvasive brain stimulation technique, by which researchers can explore the casual relationship between neural activity in specific brain regions and cognitive function. It contains two electrodes, cathode and anode, which act on the cerebral cortex with weak current and regulate the activity of cerebral cortical nerve cells. Generally, the stimulation of anode electrode enhances the cortical excitability (i.e., anodal-excitation effect), while the cathode electrode causes an inhibition effect. The former is quite stable in cognitive studies (Jacobson et al., 2012). The tDCS has several advantages over other brain stimulation techniques. It is noninvasive, painless, safe, and easy to administer. The equipment is cheap and easily portable.

The purpose of the present study was to use tDCS to examine whether directly stimulating the rTPJ could modulate the self-other decision-making difference. In the present study, we used the gambling task adapted from the study of Jung et al. (2013). Considering that the decision context might affect the self-other decision-making difference, three decision situations were created in this task through two options in terms of value (high value and low value) and the probability of winning. The three decision situations are high-value option disadvantage, equal probability, and high-value option advantage. In the situation of high-value option disadvantage, choosing the high-value option is irrational and risky due to the high probability of loss; in the equal probability situation, choosing the high-value option is risky because of the high variability; and in the situation of high-value option advantage, choosing the high-value option is rational due to the high probability of winning. We hypothesized that elevating the cortical excitability of the rTPJ through anodal stimulation might increase the difference between decision making for oneself and that for others by inducing people to be more rational in making decisions for others; in contrast, inhibiting the excitability of the rTPJ through the cathodal stimulation was hypothesized have the opposite effect. Therefore, in the situations of high-value option disadvantage and equal probability, the anodal stimulation of the rTPJ would reduce the choice of the irrational or high-risk high-value option in decision making for others relative to decision making for oneself; in the situation of high-value option advantage, the anodal stimulation of the rTPJ would increase the choice of the rational high-value option in decision making for others.

MATERIALS AND METHODS

Participants

Seventy-five adults (mean age 22.3 ± 1.7 years, 18 males) participated in this study as paid volunteers. They were randomly assigned to three groups of 25 participants each: the anodal,

cathodal, or control sham. All participants were right-handed and had normal or corrected-to-normal vision. None of them reported a history of psychiatric or neurological disorders or a family history of epilepsy or a personal history of epilepsy. This study was carried out in accordance with the recommendations of the ethics committee of Department of Psychology at Renmin University of China. All participants gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the same ethics committee.

Experimental Procedure

At the beginning of the experiment, each participant was informed to play the gambling game for him- or herself (self condition) and a stranger (other condition). They were given the phone numbers of 10 strangers and were asked to choose one of them. They would make decisions for the selected stranger in the following gambling game. In the condition of decision-making for oneself, each participant had 100 initial game points, and they were informed that the final game points were related to their own reward. In the condition of decision-making for others, the selected stranger also had 100 initial game points. Participants made decisions on behalf of the strangers and were told that the points they won for others would be converted into money and transferred to the stranger's phone account, which means making decisions for others has nothing to do with the interests of the participants themselves.

The experimental task was adapted from the gambling task designed by Jung et al. (2013) to examine the distinction between decision making for oneself and decision making for others. As illustrated in **Figure 1**, each trial began with a fixation cross presented on the screen for 2000 ms. Then, a word "for self" or "for other" in Chinese appeared for 1000 ms, which cued the participant to make decisions for themselves or to make decisions for others. Afterward, six squares distinguished by pink and blue were presented, with the numbers 10 and 90 below the squares. The color of the squares represented the number of points (that is, value) that participants would win or lose: the value of the pink square was 10 points (low value), and the value of the blue square was 90 points (high value). The number of squares indicated the probability of winning or losing the corresponding number of points. There were five probability situations: 17, 33, 50, 67, and 83%. Each participant was asked to choose the pink or blue square by pressing the F or J key on the keyboard with their left or right index fingers. Pressing the F key represented selecting the pink square and pressing the J key represented selecting the blue square. After the participant responded, a coin represented by a yellow disk appeared randomly on any one of the six squares. If the coin appeared in the selected color square, the participant gained the corresponding value (add 10 or 90 points); if it did not appear in the selected color square, the participant lost the corresponding value (minus 10 points or 90 points). For example, when the participant chose the blue square and the coin appeared in one of the blue squares, he or she would get 90 game points. If it appeared in the pink square, he or she would lose 90 game points. The next trial began when the participant pressed the space key.

The formal experiment started after 4 trials of practice for each participant. There were 60 trials for the formal experiment, two decision roles (for themselves or others) and 5 high-value option probabilities (17, 33, 50, 67, and 83% chance of winning when choosing the blue square), resulting in 10 types of trials with 6 trials for each type. The order of the different types of trials was random. The stimuli were presented and behavioral data were recorded using E-Prime 2.0 software (PST, Inc., Pittsburgh, PA, United States).

tDCS Protocol

The tDCS was delivered by a stimulator (DC-STIMULATOR MC, NeuroConn GmbH, Germany). The current stimulated the cerebral cortex through a pair of sponge coated electrodes (5 cm × 7 cm in size) soaked in saline. To stimulate the rTPJ, the anodal or cathodal electrode was placed between CP6 and C6 according to the international 10–20 EEG system and previous fMRI studies (Jurcak et al., 2007; Jung et al., 2013). This area covers the MNI coordinates [58, −66, 24] of the rTPJ reported in previous fMRI research (Jung et al., 2013). The reference electrode was placed on the left cheek. For the anodal and cathodal groups, a relatively weak direct current (1.5 mA) was continuously delivered for 20 min. For the reason of physical safety, current intensity is usually limited to 2 mA. If the duration is long enough, the excitability of cerebral cortex can reach more than 1 h after stimulation (Jacobson et al., 2012). In studies exploring the social cognitive function of the rTPJ, setting the current intensity at 1.5 mA is sufficient (Mai et al., 2016; Tang et al., 2018). For the sham group, although the electrode was placed over the rTPJ for 20 min, the current stimulation lasted only 15 s. The fade in and fade out time were both 15 s for each stimulation condition.

Data Analysis

In this gambling task, the probability of the two options was variable, while the value attached to the option was fixed, and the difference multiplier of the value was greater than the maximum difference multiplier of the probability condition (i.e., the value of the blue/pink square was 90/10 greater than the 5/1). According to the equate-to-differentiate (ETD) strategy (Li, 2004; Li, 1994, Unpublished), individuals tend to focus on the high-value option for the invariant value dimension (i.e., the blue square of 90 points). Therefore, in the data analysis, we used the frequency of choosing the high-value option as the dependent variable.

In addition, the two value options were significantly different and fixed, and the win probability of each option varied between 17 and 83%. In previous research using this task, the risk level of the options was based only on the option values (Jung et al., 2013). However, the risk level of an option should take into account both the value and the probability. High-risk options thus generally refer to options with high value and a low probability of winning (Krain et al., 2006; Smith et al., 2009). According to the expected utility theory (von Neumann and Morgenstern, 1947), the rational choice in decision making is to choose the option with greatest expected utility. When the probability changes, the expected utility of the option also changes. The high-value option thus does not always represent the irrational risk-taking alternative to the rational choice. Therefore, in this study, we considered the size of value, the probability of winning, and the

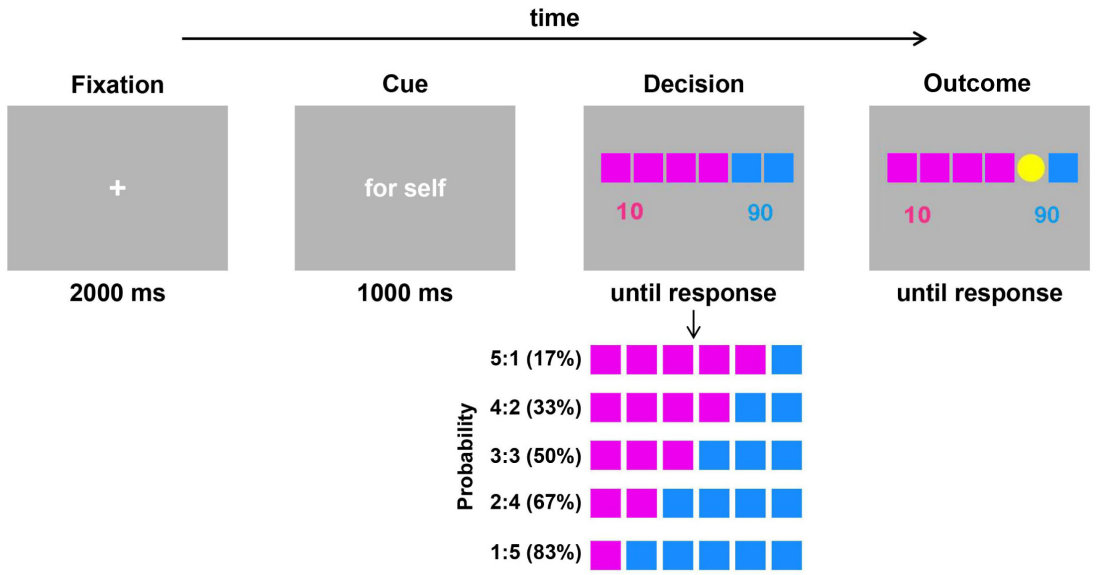

FIGURE 1 | Schematic illustration of a single trial of the gambling task (adapted from Jung et al., 2013). Each trial began with a fixation cross, and a cue ("for self" or "for other") then reminded participants whether the decision was for themselves or for a stranger. During the decision phase, there were five probability conditions for the two fixed value options. The percentage in parentheses represents the win probability of the blue square. Participants were asked to select one of the two colors (pink or blue) by pressing the "F" or "J" key. The outcome was presented after participants made responses.

expected utility. According to the probability of winning of the high-value option, we divided them into three types of probability situations: high-value option with low probability/disadvantage situation (17% and 33%), equal probability situation (50%), and high-value option with high probability/advantage situation (67 and 83%). When the probability of wining the high-value option is lower (17 and 33%), the high-value option is the irrational, high-risk choice with a high probability of loss; when the probability of winning the high-value option is 50%, the high-value option is the high-risk choice; and when the probability of winning high-value option is greater (67% and 83%), the high-value option is the rational choice with a high probability of winning (see **Table 1**).

The frequency of choosing the high-value option was subjected to a two-way repeated-measures analysis of variance (ANOVA) with one between-subjects factor (tDCS groups: cathodal, sham, and anodal) and one within-subject factor (decision-maker role: for self and for other) evaluated for the three probability situations: high-value option disadvantage, equal probability, and high-value option advantage. The data were statistically analyzed using SPSS software (version 21.0, IBM Corp., Armonk, NY, United States).

TABLE 1 | Meaning of the options under the different probability situations.

Option	High-value option disadvantage (17% and 33%)	Equal probability (50%)	High-value option advantage (67% and 83%)
High value (90 points)	Irrational, high risk	High risk	Rational
Low value (10 points)	Rational, low risk	Low risk	Irrational

RESULTS

In the situation of high-value option disadvantage, the 3 (tDCS group: cathodal, sham, and anodal) × 2 (decision maker role: for self and for other) repeated-measures ANOVA did not show any significant main effect or interaction effect on the frequency of choosing the high-value option, indicating that there was no self-other difference in decision making in each tDCS group in the situation of high-value option disadvantage, i.e., when choosing the high-value option was irrational and risky (**Figure 2A**).

In the situation of equal probability, the main effect of decision-maker role was significant, $F(1, 72) = 5.74$, $p = 0.019$, $\eta_p^2 = 0.07$, indicating that the frequency of choosing the high-value option for others was higher than that for oneself. The interaction effect between decision-maker role and tDCS group was marginally significant ($F(2, 72) = 2.48$, $p = 0.091$, $\eta_p^2 = 0.07$). Pairwise comparisons were conducted to further examine the self-other difference in decision making for each tDCS group. The results showed that in the anodal group, the frequency of choosing the high-value option for others ($M = 0.67$, $SD = 0.26$) was significantly higher than that for oneself ($M = 0.49$, $SD = 0.25$, $p = 0.003$), but this self-other difference was not found for the cathodal and sham groups. In addition, to examine the difference in decision making among the three tDCS groups for each decision-maker role, a one-way ANOVA was conducted separately between decision making for oneself and decision making for others. The results showed that the frequency of

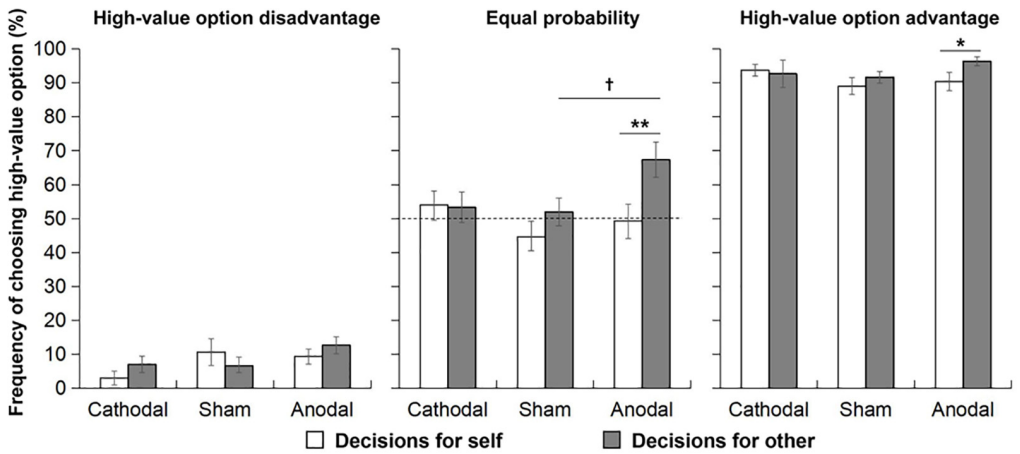

FIGURE 2 | In three probability situations, the frequency of choosing the high-value option for oneself and others in the three tDCS groups. The dashed line represents risk-neutral behavior (choosing the high-value option in 50% of trials). Error bars indicate SEM. †$P < 0.1$; *$P < 0.05$; and **$P < 0.01$.

choosing the high-value option was different among the three tDCS groups only for decision making for others ($F(2, 72) = 3.35$, $p = 0.041$, $\eta_p^2 = 0.09$). *Post-hoc* comparisons found that the frequency of choosing the high-value option for others was higher in the anodal group ($M = 0.67$, $SD = 0.26$) than in the sham group ($M = 0.52$, $SD = 0.21$), marginally significant, $p = 0.067$. Moreover, in the anodal group, the frequency of choosing the high-value option for others was more than 50% (t (24) = 3.32, $p = 0.003$, $d = 0.92$), see **Figure 2B**.

In the situation of high-value option advantage, only the main effect of decision-maker role was marginally significant ($p = 0.093$). Based on our hypothesis, we focused on the comparison between the "self" and "other" condition in each stimulation group. In order to avoiding missing some meaningful information due to just relying on omnibus F-test, we conducted pairwise comparisons to further examine the self-other difference in decision making for each tDCS group. The results showed that in the anodal group, the frequency of choosing the high-value option for others ($M = 0.96$, $SD = 0.06$) was significantly higher than that for oneself ($M = 0.90$, $SD = 0.14$, $p = 0.024$), but this self-other difference was not found in the cathodal and sham groups (see **Figure 2C**). In addition, one-way ANOVA was conducted to examine the difference in decision making among three tDCS groups for each decision-maker role, but the frequency of choosing the high-value option was not different among the three tDCS groups for both decision-maker roles.

DISCUSSION

The present study examined the effects of regulating the excitability in the rTPJ by tDCS on self-other differences in risky decision making. We found that in different situations of win probability, the participants behaved differently when we elevated the excitability of their rTPJ. Specifically, in the situation of high-value option disadvantage, in which choosing the high-value option was irrational and risky, exciting or inhibiting rTPJ activation did not influence decision making for oneself and others. Further, in the situation of equal probability, in which the high-value option had high risk, increasing the rTPJ excitability made participants more likely to choose the high-risk item for others (exceeding risk-neutral value 50%) than for themselves. This finding indicates that individuals are more adventurous when making decisions for others, which is contrary to our hypothesis. Finally, in the situation of high-value option advantage, in which the high-value item was the rational option, exciting the rTPJ made participants choose more high-value items for others than for themselves. It suggests that individuals are more rational when making decisions for others, which is consistent with the hypothesis. Overall, these results suggest that the rTPJ plays an important role in decision making for others and that regulation of the excitability of the rTPJ can influence the self-other decision-making difference.

When elevating the cortical excitability of participants' rTPJ, the frequency of choosing the high-value option for others was significantly higher than that for oneself in the situations of high-value option advantage and equal probability, suggesting that the rTPJ is involved in self-other differences in decision making. When making decisions for others, individuals as decision-makers need to distinguish themselves from others, realize that they are making choice on behalf of others (i.e., change perspectives), and even consider the impact of potential outcomes on others (i.e., theory of mind). Brain imaging studies has also found that the TPJ is related to perspective taking (Santiesteban et al., 2012; Schurz et al., 2015) and theory of mind (Schurz et al., 2014; Krall et al., 2016; Mai et al., 2016). It is more active in making decisions for others (Jung et al., 2013).

However, the high-value potion is the rational choice in the high-value option advantage situation, but the high-risk choice in the equal probability situation. It indicated that participants made more rational decisions for others than for themselves in the high-value option advantage situation, while they made more risky decisions for others than for themselves in the equal probability situation. These results are contradictory with each

other and partly contrary to our hypothesis. Nevertheless, if we ignore the context-dependent meaning of the option and focus on the option itself, we can find that the frequency of choosing high-value option with high potential gain and high potential loss values was in fact greater for others than for oneself in both situations. It seems to be caused by the weakening of the impact of the high potential loss (may be the aversion to potential loss) in the "other" condition. Jung et al. (2013) reported that right amygdala activation was positively correlated with individuals' probability of choosing high-value items for themselves, while the activity of the left dorsomedial prefrontal cortex (DMPFC) was positively correlated with the probability of choosing high-value items for strangers. In addition, further analysis found a stronger functional connectivity between the rTPJ and the left DMPFC in decision making for others than that for oneself (Jung et al., 2013), while amygdala activation could be regulated by the DMPFC through the functional connectivity between these two brain areas (Banks et al., 2007; Phillips et al., 2008; Leiberg et al., 2011; Potvin et al., 2017). Brain imaging studies of risky decision making have found that the amygdala is not only sensitive to potential loss in decision making but also closely related to loss aversion (Bechara et al., 1999; De Martino et al., 2010; Sokolhessner et al., 2013; Phelps et al., 2014). Therefore, we believe that the TPJ may not only play a role in perspective taking and interpreting other's mental state, but also may indirectly regulate some cognitive processes through its connection with the DMPFC. Moreover, the activation of the left DMPFC can negatively regulate amygdala activation, which inhibits the avoiding response to potential high losses of the high-value option and makes individuals more likely to choose it. Hence, we can explain the seemingly contradictory results in this way. In situations in which the win probability of the high-value item is equal to or greater than that of the low-value item, the anodal stimulation of the rTPJ may reduce the emotional response to the potential loss of the high-value option by increasing the inhibition of the DMPFC on the amygdala in decision making for others, and thus increase the frequency of choosing high-value items for others rather than for oneself.

In the high-value option disadvantage situation, anodal stimulation of the rTPJ did not increase the self-other decision-making difference. One explanation is that because the high-value item is the irrational and high-risk choice in this situation, a floor effect may arise owing to the low frequency of choosing the high-value item. Another possible explanation is that amygdala activity is strong when the win probability of the high-value item is low and the loss probability is high (i.e., the disadvantage situation for the high-value item), and although exogenous enhancement of rTPJ activity can promote the regulation of the amygdala by the DMPFC, the amygdala activity remains strong enough to induce the individuals to avoid options with a high probability of a large loss. Therefore, the role of anodic stimulation in the situation of high-value option disadvantage is not obvious.

We did not observe any cathodal effect on the participants' decision making, which was inconsistent with our assumptions that cathodal stimulation of the rTPJ could reduce the difference in self-other decision making. This may be because there was no self-other decision-making difference in the sham group. Therefore, although inhibiting the rTPJ activation can reduce the difference in self-other decision making, it is impossible to show such a reduction in this study due to the floor effect. In addition, the inhibition effect of negative stimulation may usually be influenced by the initial activation state of neurons and the functional compensation of related brain regions in cognitive studies (Jacobson et al., 2012). The left TPJ (LTPJ) is also involved in theory of mind (Gallagher et al., 2000; Samson et al., 2004; Ye et al., 2015), and it is functionally connected with the prefrontal lobe in decision making for others (Janowski et al., 2013). Thus, the LTPJ might play a compensatory role in inhibiting the rTPJ, resulting in a lack of behavioral changes when the cortical excitability of the rTJP is inhibited.

The self-other difference of decisions was not shown in the sham group for each of the decision situations. Previous studies have reported inconsistent results regarding risk preference in self-other decision making, which might be caused by the different decision contexts (Hsee and Weber, 1997; Stone et al., 2002; Fernandez-Duque and Wifall, 2007). Some researchers have found that the self-other difference in risk decision-making can be affected by the gain/loss framework, the decision makers' self-esteem level, and the mental distance between decision makers and others (Liu et al., 2010; Duan et al., 2012; Zhang et al., 2017, 2018). Thus, the gambling task we applied in the present study may not be sensitive enough to examine differences in decision-making between for oneself and for others when no stimulation is applied to the rTPJ. The lack of a self-other decision-making difference in the sham group may restrict our investigation of the role of cathodal stimulation. Therefore, to better understand the function of the rTPJ, in future research, it is necessary to consider the possible factors that influence the self-other decision-making difference and design a task by which we can observe the difference in decision making between for oneself and for others when no stimulation is applied to the rTPJ.

There are some limitations to our study. First, we designed the sham stimulation group as a control group in which participants did not receive effective stimulation. But the general effect of the anodal stimulation on cerebral cortex cannot be ruled out. To help us better understand the specific function of the rTPJ, in the future studies we can stimulate another brain region to serve as a control region, such as the occipital cortex which does not associate directly with decision making or some other regions which are responsible for decision making in general but not specifically for self-other differences in decisions. In addition, the manipulation of "others" is relatively rough compared to real life. Prior studies have found that similarities, relationships, and preferences for others relate to different neural systems (Guroglu et al., 2008; Krienen et al., 2010; Wang et al., 2012; Braams et al., 2014; Zhao et al., 2016). Some researchers believe that the fundamental difference between oneself and others is mental distance (Liu et al., 2014). Braams et al. (2014) compared neural activity when participants engaged in gambling tasks for themselves, good friends, and disliked others and found that brain areas associated with social information processing,

such as the DMPFC and TPJ, showed greater activation with respect to the win or loss outcome of gambling for others than for themselves and friends. Therefore, to comprehensively examine the neural mechanisms of the self-other decision-making difference, further studies involving different mental distance between oneself and others are needed.

The present study validates the crucial role of the rTPJ in the self-other decision-making difference through elevating the cortical excitability suggesting that decision making for others depends on the neural activity in the rTPJ, which has important implications for us to understanding the function of the TPJ in self-other decision making. The TPJ may not only associate with perspective taking and theory of mind, but also indirectly regulate emotion responses through its functional connection with the medial prefrontal lobe. Combining the tDCS with other techniques that can record neural and peripheral physiological activity in future studies would help us further reveal the neural mechanism of decision making for others and understand specific economic phenomena (e.g., loss aversion) from the perspective of decision making for oneself and others.

AUTHOR CONTRIBUTIONS

XM and SC designed the study. SC, YZ, and XH collected and analyzed the data. YZ wrote the manuscript. XM and XH edited the manuscript. All authors approved the final version of the paper for submission.

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The Influence of Self-Relevance and Cultural Values on Moral Orientation

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Moral orientation refers to moral values that have a consistent guiding orientation toward an individual's moral cognition and behavior. Gilligan (1982) proposed that individuals have two moral orientations, namely "justice" and "care." In the current study, we investigated the influence of self-relevance and cultural values on justice and care by using Single Attribute Implicit Association Test (SA-IAT). In Experiments 1 and 2, we adopted cultural icon prime paradigm to examine the effects of different self-referential stimuli (self, friend, and stranger) on implicit moral justice and care orientation under two cultural value conditions: traditionality, modernity, and neutral cultural values. Participants exhibited more difference toward different self-referential stimuli in the traditionality condition than in the modernity condition; the priming of traditional culture aggravated the differential order, whereas the priming of modernity weakened the differential order regarding implicitly just moral orientation. In the implicit care orientation, participants in the modern culture group exhibited the least difference to different self-referential stimuli compared with the other two groups, and the traditional group and the control group did not differ significantly. These findings indicate that psychological modernity weakens the degree of self-related effect in implicit justice and care orientation, whereas traditional culture aggravates the differential order in justice orientation. The current studies provide empirical support for theories relating moral orientation, also informing the literature on the role of self-relevance information and cultural values in moral decision making.

Keywords: moral orientation, justice, care, degree of self-reference, differential effect, cultural value

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INTRODUCTION

Moral orientation refers to moral values that have a consistent guiding orientation toward an individual's moral cognition and behavior and consists of two types: reward good cops and punish bad ones. Kyte (1996) suggested that moral orientation plays an integral role in moral decision-making.

Piaget and Kohlberg are recognized as representatives of the "justice" moral orientation. Kohlberg's (1976) proposed model for moral justice orientation focuses on adjudicating between individual interests or rights while solving moral dilemmas. This orientation depends on the application of fairness, reciprocity, and universal moral principles in the abstract features of ethical situations. At the pretraditional level of moral reasoning, individuals are egocentric while selecting behaviors that will help them avoid punishment and maximize self-interest (Kohlberg, 1969, 1976). By contrast, Gilligan (1982) proposed the ethics of care in response to methodological concerns

about Kohlberg's(1969; 1976) research. Kohlberg examined hypothetical dilemmas among male respondents instead of the real moral dilemmas they experienced. Gilligan examined women who experienced real moral dilemmas and revealed evidence of an alternative moral orientation characterized by authentic relationships that reflect concerns about understanding the subjective experience and requirements of others, and responding to them in a genuine manner. Unlike Kohlberg, Gilligan proposed that individuals who demonstrate a care orientation do not focus on adjudicating between competing rights. According to Gilligan, individuals with a care orientation focus on identifying creative methods of simultaneously fulfilling competitive responsibilities for others (Jaffee and Shibley-Hyde, 2000).

Moral orientation refers to the manner in which an individual handles dilemma decisions. This topic is not often discussed in the context of cognitive scientific development and practice. In addition, when the stimuli related to an individual's self-concept differ (i.e., self-relevance), the individual's judgment about the orientation of justice and care also differ. Studies have demonstrated that individual factors (such as attitudes and motivations) and cultural values are two integral sources of influence (Cottone and Claus, 2000; Haidt and Joseph, 2004; Yang, 2004; Greene, 2013). For example, some studies have noted that cultural values (traditionality and modernity) provide a better reflection of individuals' performance and objectively interpret the internal motivation of their participation in social activities (Miller and Bersoff, 1992; Hong and Mallorie, 2004; Kagitcibasi, 2013; Shin et al., 2013). Traditionality (modernity) refers to a cluster of most common psychological characteristics, such as needs, attitudes, beliefs, values, temperaments and behaviors in traditional (modern) society. Therefore, when the degree of association between the target stimulus and an individual differs (i.e., self-relevance), the behavioral reactions of individuals with different cultural values may vary in justice and care moral orientation.

The modern society is presented as a multimodernity of the convergence of Eastern and Western cultures that entangles traditionality with modernity, because these basic forms of cultural values are the key psychological elements in modern society (Shin et al., 2013). Some studies have noted that examining the psychological influences of traditionality and modernity can provide a better explanation of individual behaviors and effectively interpret the internal source of our participation in modern social activities (Chan and Palley, 2005; Kagitcibasi, 2013; Frías et al., 2014). Researches have suggested that cultural values influence moral judgment. Kohlberg's theory of moral cognitive development and Gilligan's moral dualism propose that the principle of moral orientation is applicable in various social cultures (Kyte, 1996; Jaffee and Shibley-Hyde, 2000; Ellis and Shute, 2007; Tucker et al., 2014). Few scholars also believe that moral principles are culturally specific. For example, Shweder et al. (1987) noted that individuals acquired different core moral values of the society through cross-cultural studies. These moral values reflect the cultural significance of a particular group, and indicate that when they are confronted with a moral dilemma, they exhibit preference for a specific moral orientation. Miller and Bersoff (1992) examined the differences between Americans and Indians and found that Americans indicated a typical moral justice orientation, whereas Indians indicated a typical care orientation for an identical moral dilemma. Therefore, (Yang, 2004) noted that Chinese and Western culture have different origins in terms of moral principles. The fundamental difference is that both cultural systems have different assumptions about the relationship between the individual and society. Other studies have also obtained similar findings. For example, Roberts (2017) noted that both gender and cultural dilemmas play an integral role in the judgment of justice. Suh et al. (2008) used an icon paradigm to examine that the independent (Americans) vs. interdependent (Korea) self-construal process leads to different cultural behaviors. Furthermore, the results strongly suggested that differences in self-construal processes underlined cross-cultural differences in life satisfaction judgments.

Recent studies have demonstrated that examining the cultural icon prime paradigm is an effective method for studying the dynamic interaction between culture and psychology. To examine how cultural values affect the corresponding psychological processes, most studies have used experiments with higher internal validity with regards to various elements, such as cultural symbols, representations, and norms. For instance, Friedman et al. (2012) used cultural priming paradigm to reveal that managers who have been abroad switch their cultural orientation as a result of being shown Western or Chinese cultural icons, and this effect occurs when "environmental" priming is used, and also confirmed that this effect is found when examining pay allocation decisions in addition to attribution patterns. In addition, Hu and Liu (2009) recently used a classic cultural icon prime paradigm to reveal that Chinese young people showed priority to the principles of justice and care in moral dilemmas under traditional and modern cultural values.

Observations regarding the behavioral interactions in terms of moral decisions, cultural values, and self-relevant processing have triggered researchers to consider a pertinent question: does the priming of psychological modernity or traditionality substantially influence self-relevant processing on moral orientation? One of the problems that arise is that most studies have taken an explicit rather than implicit approach. Few studies in this domain have reported on the implicit level. More importantly, some studies have indicated the discrepancy between findings based on the implicit and explicit levels (Deshon and Alexander, 1996; Asendorpf et al., 2002; Schnabel et al., 2010).

Research has indicated that the IAT is a flexible and relatively straightforward tool for assessing the strengths of associations between different concepts, thus contributing notably to its widespread use in research (Nosek et al., 2007). IAT scripts are based on a seven-block (seven-task) structure; if no opposite category is evident, single-attribute IATs (SA-IATs) are deemed superior to traditional bipolar-attribute IATs (Penke et al., 2006; Seval Gündemir et al., 2014). Therefore, our research employed an SA-IAT to derive the relevant results. Thus, we aimed to use cultural icon prime paradigm to uncover the influence of self-relevance and cultural values (psychological tradition and

modernity) on implicit justice and care level. Previous studies suggested that effect of self-relevance of moral orientation exists both at the implicit and explicit level (Hu and Liu, 2009, November.; Bian and Yan, 2015). More importantly, the results on the implicit level were more stable (Schneider et al., 2015; Shi et al., 2015; Burnside et al., 2018).

Based on the aforementioned studies, we sought to clarify their relationship at the implicit level by examining the following hypotheses: (1) cultural values can predict the self-reference effect on moral justice or moral care; (2) participants in the traditional culture group exhibit more differential effects on different self-referential stimuli (self, friend, or stranger) at the implicit justice level, whereas those in the modern culture group exhibit less differential effects at the implicit justice level; and (3) participants in the traditional culture group exhibit more differential effects on different self-referential stimuli (self, friend, or stranger) at the implicit care level, whereas those in the modern culture group exhibit less differential effects at the implicit care level.

METHODS

Overview of Procedure and Design

We collected data using two experiments with similar procedures. Therefore, the procedures and results of both experiments are reported together. We used moral justice as the trait category label for an SA-IAT in Experiment 1, whereas moral care was used as the trait category label for Experiment 2. These trait categories were represented using single-attributes (e.g., "fairness" and "concern"). We informed the participants that the experiments focused on personality traits. The experiments lasted for approximately 25 min, and we promised and delivered feedback to the participants about their results after they completed the tasks. The cultural value icons and order of combined tasks within IATs were counterbalanced among participants. We designed each experiment using a 3 (cultural value icon: traditionality vs. modernity vs. no culture) $\times$ 3 (self-referential stimulus: self vs. friend vs. stranger) mixed factorial design, with repeated measures on the first factor. The dependent variables were the response time of the implicit moral justice and moral care experiments.

Participants

A total of 126 (63 pairs of friends; 59 male participants; and 67 female participants; average age of 23.93 years; age 18–26 years) and 114 (57 pairs of friends; 54 male participants; and 60 female participants; average age of 21.56 years; age 17–26 years) healthy college students participated in Experiment 1 and 2, respectively. The participants were right-handed, had normal or corrected-to-normal vision, and had no history of neurological or psychiatric disorders. After the experiments concluded, we paid the participants ¥50. The Ethics Committee of Hunan Normal University approved this study.

Materials

Based on the cultural icon paradigm, cultural icons were used as a stimulus (Hong et al., 2000; Hu and Liu, 2009). Similarly sized sheets of blank paper were used as the control stimulus (no culture cue; 470 pixels $\times$ 220 pixels; Hu, 2011). We asked 30 respondents to indicate their responses using a 9-point Likert scale (1 = not at all, 9 = to a great extent) to determine the extent to which cultural icons were represented.

The results indicated that the ratings of traditional cultural icons (8.23) was significantly higher than the sheets of similarly sized sheets of blank paper [1.21, $t_{(29)} = 25.34$, $p < 0.001$], and the ratings of modern cultural icons (8.16) was significantly higher than that those for similarly sized sheets of blank paper [1.32, $t_{(29)} = -27.61$, $p < 0.001$]. Therefore, we used 72 pictures (24 pictures of traditional culture, modern culture, and no culture) as the cultural cue stimuli for these Chinese participants. After reviewing recent studies (Chen et al., 2011; Fan et al., 2016), we presented self-relevant names with varying degrees of correlation as the target stimuli: (a) those with high correlations to self-material, such as the participant's name; (b) those moderately correlated with self-material, such as the name of the participant's friend; and (c) those with low correlations to self-material, such as a stranger's name. We presented stimuli from each class of self-referential stimulus.

TABLE 1 | Single-attribute IAT for justice: Task sequence (One example of justice SA-IAT).

Block	No. of trials	Task	Response key assignment	
			Left key (Key F)	Right key (Key J)
1	40	Target justice	Jie Deng	Yin Wang
2	40+80	Initial combined task	Jie Deng	Yin Wang, justice
3	40+80	Reversed combined task	Jie Deng, jusitice	Yin Wang

Procedure

Trial Blocks

In both studies, Single-attribute IAT (SA-IAT) used a standard seven-block procedure (Greenwald et al., 1998; Nosek et al., 2007). Target concepts were the names of self, friend and stranger, but only justice/care served as the (unipolar) attribute. The testing and analysis procedures were the same as for the justice/care IAT. **Table 1** presents an example of justice SA-IAT task.

Participants started with single tasks (20 trials each) of the target concepts ("self" vs. "friend") and the attribute concepts ("justice"/"care"). This was followed by the combined task of these concepts. Finally, the second combined task employed the reversely paired justice of target and attribute concepts.

Timing Details

In each trail, a fixation cross was presented for 200 ms, followed by a black screen presented for a random interval between 250 and 500 ms. A priming stimulus then were presented in white letters against the black background screen, centered in the display and remaining on screen until the subject's response. A feedback ("Right"/"Wrong") was given and appeared for 500 ms,

followed by a black screen presented for 1,000 ms before the next trials.

RESULTS

Data Reduction

The data for each trial block included response latencies (in milliseconds) and error rates. The solution used for these was to recode values below 300 to 300 ms and those above 3,000 to 3,000 ms (Greenwald et al., 1998). We then log-transformed latencies in order to use a statistic that had satisfactory stability of variance for analyses (Greenwald et al., 1998). Also, the first two trials of each block were dropped because of their typically lengthened latencies. Analyses of error rates are not described in detail.

IATs

IAT scores (i.e., the "IAT-effect") were based on the difference in mean response latencies between the two combined blocks of different target–attribute pairings. Scores were calculated as using the d' algorithm (Greenwald et al., 1998). A positive IAT-effect is interpreted as a stronger association for the category pairing in the initial combined task—for attitude-IATs it may as well be interpreted as a preference for one concept over the other (Greenwald et al., 1998).

Scores in both studies were coded such that high scores represent high level of justice/care. Internal consistencies were estimated over separate scores for the two sub-blocks of the combined tasks (i.e., one sub-block of 40 and one sub-block of 80 trials).

Attribute stimuli were selected from Zhang et al. (2007) collection of 215 traits that had been rated for valence, arousal and social desirability. We selected 24 Words that were rated as prototypical for their respective attributes and balanced the IAT categories for social desirability and valence.

Descriptive Statistics and Mean Differences

The descriptive statistics and internal consistencies of the main variables are depicted in **Table 2**. As shown in **Table 2** all IATs showed satisfactory internal consistencies. IAT error rates were $M = 7.48\%$, $SD = 4.39\%$ and $M = 6.32\%$, $SD = 5.91\%$, for justice and care attribute IATs in Study 1 and Study 2, respectively. No participant had error rates higher than 25%.

Effects of Priming Different Cultural Values on Implicit Justice Judgment

To examine the influence of self-relevance on implicit justice judgment, we used the effect size measure "d" as the dependent variable, whereas the correlation between self-relevance and cultural values was determined using a 3 × 3 ANOVA with repeated measures on the first factor (**Figure 1**). The results indicated that the effect of self-relevance and cultural values were both significant, [$F_{(2,492)} = 228.89$, $p < 0.001$, $\eta_p^2 = 0.65$], and [$F_{(2,123)} = 4.18$, $p < 0.05$, $\eta_p^2 = 0.36$]. The *post hoc* comparisons indicate that participants' implicit justice judgments varied among the self-referential stimuli, as presented in the following differential order: self < friend < stranger, thus suggesting that the participants' justice judgments were more strict toward strangers than those for their friends and themselves. [$ts_{(125)} = -19.28 \sim -5.05$, $ps < 0.001$]. Moreover, the modernity group indicated smaller IAT effects than the control group [$t_{(82)} = -2.22$, $p < 0.05$] and the traditionality group [$t_{(82)} = -2.90$, $p < 0.01$]. However, the correlation between the control and traditionality groups was not significant ($p > 0.05$). In addition, the interaction between self-relevance and cultural values were significant [$F_{(5,492)} = 2.69$, $p < 0.01$, $\eta^2{}_p = 0.45$]. A simple effects analysis revealed that regardless of the priming conditions, the target stimulus elicited more strict justice judgments toward strangers than friends and themselves. Specifically, the target stimulus under traditional culture conditions elicited stronger justice awareness [$F_{(2,120)} = 52.68$, $p < 0.001$] than the control group under neutral conditions [$F_{(2,120)} = 37.03$, $p < 0.001$] and modern culture conditions [$F_{(2,120)} = 24.69$, $p < 0.001$]. The *post hoc* multiple comparisons indicated that the highly self-relevant (self) stimulus elicited more strict justice judgments than other names, whereas moderately self-relevant names (friend) elicited more strict justice judgments than non-self-relevant names (stranger) [all $Fs_{(2,120)} > 21.94$, all $p < 0.001$].

TABLE 2 | Internal consistencies (Cronbach's α) and descriptive statistics of implicit measures.

Variable	Experiment 1 ($N = 126$) (Justice SA-IAT)			Experiment 2 ($N = 114$) (Care SA-IAT)		
	α	*M*	*SD*	α	*M*	*SD*
IATs (in ms)						
Traditionality	0.83	679.86	120.05	0.76	644.67	90.73
Modernity	0.78	516.19	109.46	0.85	506.20	105.55
No culture	0.75	542.89	119.30	0.71	538.01	95.38

Effects of Priming Different Cultural Values on Implicit Care Judgment

To examine the influence of self-relevance on the implicit care judgment, the effect size measure "d" was used as the dependent variable, the correlation between self-relevance and cultural values was determined using a 3 × 3 ANOVA with repeated measures on the first factor (see **Figure 2**). The results showed that the effect of self-relevance and cultural values were both significant, [$F_{(2,440)} = 234.26$, $p < 0.001$, $\eta_p^2 = 0.68$], and [$F_{(2,110)} = 4.86$, $p < 0.05$, $\eta_p^2 = 0.28$]. The *post hoc* comparisons indicated that participants' implicit care judgments varied among the self-referential stimuli, as presented in the following differential order: self > friend > stranger, thus suggesting that the participants showed less concern attitudes toward strangers than those for friends and themselves. [$ts_{(113)} = -19.33 \sim -8.35$, $ps < 0.001$]. Besides, the traditionality group indicated larger IAT effects than the modernity group [$t_{(74)} = 3.18$, $p < 0.05$], the control group

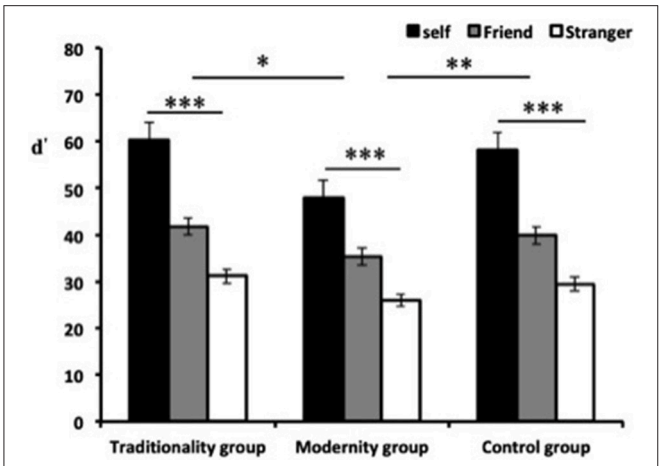

FIGURE 1 | d′ values of implicit justice SA-IATs under varying cultural value conditions. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

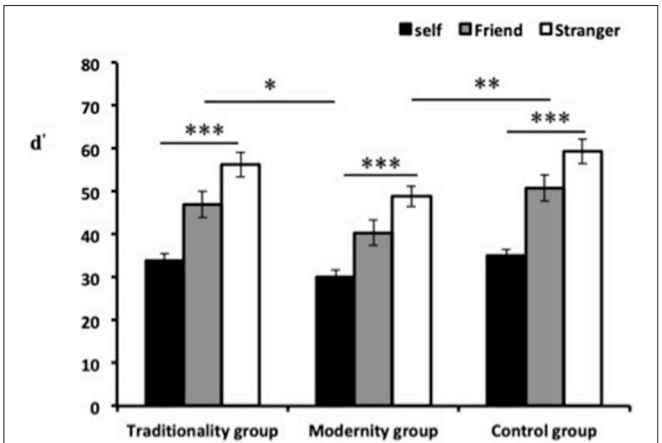

FIGURE 2 | d′ values of implicit care SA-IATs under varying cultural value conditions. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

indicated larger IAT effects than the modernity group [$t_{(74)} = 2.26$, $p < 0.01$]. However, the correlation between the traditionality and control groups was not significant ($p > 0.05$). In addition, the interaction between self-relevance and cultural values were significant, [$F_{(5,440)} = 3.05$, $p < 0.01$, $\eta_p^2 = 0.25$]. A simple effects analysis revealed that regardless of the priming conditions, the target stimulus elicited less care judgments toward strangers than friends and themselves. Specifically, the target stimulus under traditional culture conditions elicited stronger care awareness [$F_{(2,120)} = 54.66$, $p < 0.001$] than the control group under neutral condition [$F_{(2,107)} = 35.06$, $p < 0.001$] and modern culture conditions [$F_{(2,107)} = 25.86$, $p < 0.001$]. The *post hoc* multiple comparisons indicated that the highly self-relevant stimulus (self) elicited more care attitudes than other names, while as moderately self-relevant names (friend) elicited more concern judgments than non-self-relevant names (stranger) [all $Fs_{(2,107)} > 22.64$, all $p < 0.001$].

DISCUSSION

We employed the SA-IAT and the cultural icon prime paradigm to examine whether and how self-relevance and cultural values influence implicit moral orientation (justice and care) processing. The findings showed a clear self-relevance effect: the highly self-relevant stimulus (self-names) elicited a stronger justice attitude than the names of friends and strangers in the modern cultural setting (context), whereas they elicited a weaker care attitude than the names of friends and strangers in the traditional cultural context. Moreover, the findings demonstrated variations in the justice and care orientation of the participants of the control and modernity groups, thus indicating that different cultural value orientations influence the moral justice or care attitudes of the target objects of different self-relevance at the implicit level.

The results of Experiment 1 indicate that participants' implicit justice judgments varied among the self-referential stimuli, as presented in the following differential order: $d'_{self} > d'_{friend} > d'_{stranger}$. Participants spent the shortest response time to associate justice attributes with strangers, followed by those for their friends. Moreover, participants spent the longest response time to associate justice attitudes with themselves. In other words, participants strongly associated justice with the low self-relevant stimulus (names of strangers) compared with the moderate self-relevant stimulus (names of friends) and high self-relevant stimulus (their own names). This indicates that participants' sensibility to self-relevant stimuli related to justice gradually increased; that is to say, the tendency to adapt a justice attitude toward different self-relevant stimuli gradually became stricter. Moreover, the priming of different cultural values has varying effects on the differential order of justice attitude. Participants exhibited the lowest differential order in justice attitude in the context of the modernity group, whereas no significant difference was observed between the traditionality and control groups ($p > 0.05$). This result is consistent with that of explicit justice orientation (Hu and Liu, 2009; Bian and Yan, 2015). Pluralistic modern information, such as autonomy, democracy, and equality, modulates the "privateness" of justice judgments, whereas the differential order of justice was not exacerbated in the traditionality group. This may be due to the deep-rooted feudalistic ideology in China. The self-relevance effect remained significant even in the blank context (control group), indicating that no difference was evident with the traditional culture context (Chun, 1995; Tan et al., 2015).

The correlation between self-relevance and cultural values was significant, thus demonstrating that both cultural values and self-relevance influenced the implicit justice attitude. Compared with the control group, the priming of traditional cultural values aggravated the differential order of justice attitude, and the differential sequence was performed from near to far and from close to sparse, which caused differences in the justice attitude toward different self-relevant stimuli to further expand (Otten and Epstude, 2006; Le et al., 2007). Therefore, justice attitudes strengthen in response to estranged targets, thus reflecting the phenomenon of "being tolerant toward those who are close to you, but strict toward those who are unfamiliar" in the context of traditional culture. Studies

have also noted that traditional traits have been internalized into people's subconscious and become automatic behaviors. The priming of traditional cultural values only affects the differential level of justice attitude and causes no other differences (Chan and Palley, 2005; Jin, 2007; Wang et al., 2016).

However, the results indicate a significant difference in the justice attitude toward self-relevant stimuli between the modern culture and control groups. The differences in the attitude tendency gradually decreased, indicating that the modernity context moderated the differential order of justice attitude. Moreover, regardless of the self-relevance level, the priming of modern cultural values can weaken the performance of the differential order and reduce the degree of "privateness."

The results of Experiment 2 indicated that participants' implicit care judgments varied among the self-referential stimuli, as presented in the following differential order: $d'_{self} < d'_{friend} < d'_{stranger}$, thus suggesting that participants spent the longest response time to associate care attributes with strangers, followed by that of their friends, whereas participants had the shortest response time to associate care attitudes with themselves. In other words, participants strongly associated care with the high self-relevant stimulus (their own names) compared with the moderate self-relevant stimulus (names of their friends) and high self-relevant stimulus (names of strangers). This indicates that participants' sensibility toward self-relevant stimulus in relation to care gradually decreases; therefore, the tendency of care attitude toward different self-relevant stimuli gradually weakens. Moreover, the priming of different cultural values has varying effects on the differential order of justice attitude. Participants exhibited the highest differential order in care attitude in the context of the modernity group, and the differential performance was more significant in the control group than in the modernity group. Therefore, participants indicated the lowest differential order in the care orientation in the modernity context. Studies have also demonstrated that individuals associate positive stimuli with high self-relevance in the traditional context, whereas they exhibit a weaker differential attitude in the modernity context (Northoff et al., 2009; Fan et al., 2013; Zhan et al., 2016).

Consistent with the aforementioned findings, we also found that the priming of traditional cultural values accelerated the differential order in care orientation, whereas this "privateness and differential order" phenomenon was weakened in the modern culture context. The reason may be that traditional cultural values activate Confucian beliefs, such as "*Qinqin,*" "*Zunzun,*" and "*Renlun,*" which have a deep-rooted influence on people's care orientation (Yan et al., 2013). By contrast, the elements of modernity reflect more democratic, equal, independent, and inclusive thoughts. Individuals may exhibit less consideration for relationships with the self-relevant stimulus in terms of care judgment for diversified characteristics in modern society context. The correlation between self-relevance and cultural values was significant, indicating that both cultural values and self-relevance influence the implicit care attitude. Compared with the control group, those who were subject to the priming of traditional cultural had an aggravated differential order of care attitude, and the differential sequence was performed from near to far and from close to sparse, which caused further expansions in the differences between care attitudes and self-relevance (Otten and Epstude, 2006; Tan et al., 2015). Participants also expressed increased concerns regarding the privacy of highly self-relevant stimulus, whereas they had less concerns regarding those of lower self-relevance.

Studies have also noted that participants responded with increased positivity toward those they had personal relationships with; whereas they responded with increased negativity toward those they were unfamiliar with (Fan et al., 2013; Tan et al., 2015; Wang et al., 2016). Our findings are consistent with these studies, and revealed that the differences in care attitude for different self-relevant stimuli were negligible between the modernity and control groups; in other words, the modernity context moderated the differential order of care attitude. Therefore, unlike other factors, the effects of the modern cultural context were reconciled, and individuals' weakened differential performance in terms of care was universal. Therefore, the modern cultural context weakened the performance of the differential order and reduces the extent of moral "privateness" regardless of the proximity or unfamiliarity of relationships between individuals and others.

CONCLUSION

Taken together, in addition to the weakening effect of partial on justice and care orientation processing such as task-switching, perceptual matching reported in the previous studies, the present study further showed that culture values can weaken social cognitive processing, such as that associated with self-relevance. This self-related weakening effect occurred at both implicit justice and care orientation in the modern culture context, but not in the traditional culture context, whereas traditional culture aggravates the self-related effect in justice orientation. These findings suggest that culture values can influence self-perception in an implicit manner. Future studies should focus on specific characteristics of modern culture and self-relevant stimuli to investigate the weakening effect of moral orientation on self-processing, particularly using high-spatial-resolution fMRI to uncover neural substrates that mediate this weakening effect, and how these neural activities are related to the justice and care attitudes.

AUTHOR CONTRIBUTIONS

JB and LY: conceived and designed the experiments. JB, LL, QL, and JS: performed the experiments. JB, LL, XZ, and JD: analyzed the data. JB and LY: contributed reagents, materials, and analysis tools. JB and LL: wrote the paper.

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The Effect of Negative Feedback on Positive Beliefs in Self-Deception

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In the present study, we applied the forward-looking paradigm to examine how positive beliefs appear in self-deception and to further reveal the influence of negative feedback on positive beliefs to decrease self-deception. In Experiment 1, the answer group (with answer hints provided below the test material) and the control group (without answer hints) completed two tests. Participants estimated their Test 1 scores, predicted their performance on the upcoming Test 2 without answer hints, and completed Test 2. Their actual scores on the two tests were recorded. The results showed that the answer group predicted higher Test 2 scores than the control group, but the two groups did not differ in their actual scores. These results showed that the answer group had positive self-deception. In Experiment 2, the two groups were given negative feedback (vs. no feedback) after Test 1, and the changes between their estimated scores on Test 1 and their predicted score and actual score on Test 2 were measured. The results indicated that there was no significant difference in the estimated scores and the predicted score between the two groups under the feedback condition compared with the negative feedback condition. These findings demonstrated that the effectiveness of the forward-looking paradigm can activate participants' positive beliefs and cheat behaviors by providing the answers to induce self-deception, and negative feedback can decrease the occurrence of self-deception by reducing the positive beliefs of individuals and improving self-awareness to prevent or eliminate the negative impact of self-deception.

Keywords: self-deception, positive beliefs, forward-looking paradigm, negative feedback, cheating

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INTRODUCTION

Self-deception is considered a positive belief about the self that persists despite specific evidence to the contrary (Mitchell, 2000; Mele, 2002). Many studies about biased self-evaluation suggest that people are motivated to overestimate their abilities or to believe that they are doing better than they truly are (Burson et al., 2006). This motivation is so strong that individuals rationalize or ignore negative evaluations of themselves to uphold a positive belief (Norton, 2009). For example, overconfidence that overestimates one's actual abilities is a form of self-deception and positive belief (Li et al., 2016). In our view, no overconfidence process is fully self-deceptive. Self-deception is a special case in which an individual maintains a positive self-view and evaluation when faced with negative information. Some researchers believe that self-deception is an act of focusing on the

positive to defend oneself and repress the influence of negative feedback to adjust one's mental state (Fan et al., 2017), to fortify self-enhancement and self-confidence, and to recalibrate an individual's imbalanced cognition to improve the fit with his or her own perception (Lopez and Fuxjager, 2012; Seiffert-Brockmann and Thummes, 2017).

As of now, knowledge on self-deception mainly comes from two sources: laboratory researches and assessment of scales. Earlier studies mainly obtained data from the self-deception (SD) and impression management (IM) scales from the Balanced Inventory of Desirable Responding (BIDR, Paulhus, 1984). These two scales are widely used as credible assessments of individual self-deception and impression management. Moreover, methods for studying self-deception mainly include retrospective paradigms and forward-looking paradigms. The retrospective paradigms generally focus on measuring the inconsistency between an individual's evaluation of past experience and the actual behavior of a real event. For example, Quattrone and Tversky (1984) used a classical pain experiment that asked participants to report whether their self-evaluated pain tolerance was affected by the relationship of pain tolerance and heart disease that was previously described to them. The scores of the pain experiment showed that all participants denied the existence of this influence, but their actual behavior proved that they were affected. Participants who were told that a higher pain tolerance means a healthier heart indicated much higher levels of self-evaluated pain tolerance than other participants who were not told so (Quattrone and Tversky, 1984). Gur and Sackeim (1979) adapted a voice recognition task to examine self-deception. Participants were asked to distinguish their own voice from many other voices that had been given positive or negative evaluations, and then they reported "mine" or "not me" for each voice while being connected to a polygraph to test their emotional reaction. This experiment found that participants tended to recognize voices with positive evaluations as themselves and negative evaluations as others, but their physiological response measured by the polygraph was inconsistent with the subjective judgment. Lie detector monitoring showed that the participants' physical reactions to their own voices or other participants' voices differed from their subjective reports; that is, the physiological indicators measured by the polygraph showed that the subjects' physiological responses to the sounds were inconsistent with their subjective reports (Gur and Sackeim, 1979). Additionally, Sloman et al. (2010) used the dot-tracking task to explore self-deception. The dot-tracking task was a video game in which participants started with the cursor on the left side of a computer screen and moved the cursor as fast as possible to a dot that appeared in a random position on the right half of the screen. After completing the initial phase, the fast group was given the instruction that people who moved the cursor faster tended to have higher than average general IQ (intellegence quotient) scores. The slow group was given the instruction that people who moved the cursor slower tended to have higher than average general IQ scores. Then, the participants completed the task in the test phase when the computer screen displayed vague speed feedback (fast, slow, or normal) according to the participants' speed of cursor movement. The results showed that there was no difference in cursor speed between the two groups in the initial phase. Under the influence of the instructions, the cursor speed of the fast group was significantly higher than that of the slow group. However, all the participants denied that they were affected by the instructions. Accurate speed feedback was provided to the participants in the second experiment. The results showed that there was no significant difference between the fast group and the slow group in the test phase in the second experiment. That is, accurate feedback reduced the occurrence of self-deception. This dot-tracking paradigm established the theory that self-deception occurs under ambiguous conditions, as has been widely recognized. Although the above experimental methods illustrate the classic paradigm for studying self-deception, they cannot be used to measure the unconscious processes of self-deception (Ren et al., 2018) or applied stably and repeatedly to follow-up studies of self-deception. Therefore, advances in the experimental paradigms are an important prerequisite for further exploration of self-deception.

Recently, Chance et al. (2011) applied the forward-looking paradigm to investigate the mechanism of self-deception. In this paradigm, participants were informed of the correct answer before they answered the questions, which offered them the chance to cheat and obtain a better score. Researchers regard this process of seeing answers as cheating (Chance et al., 2011, 2015). The participants overestimated their future test scores by self-deception. These participants chose to deceive themselves into believing that better scores were obtained not because they had the answers beforehand but because of their actual talent. This experiment consisted of two knowledge tests. Participants completed 10 knowledge questions in Test 1 (e.g., "How many US states border Mexico?" and "In which US state is Mount Rushmore located?"), estimated the scores of Test 1 and predicted their future scores on Test 2 (100 knowledge questions similar to Test 1). Specifically, in Test 1, the answer group had the opportunity to see the answer at the bottom of the question sheet, while the control group did not. Then, both groups of participants continued to Test 2, for which neither group had answer keys. Through a comparison of the difference between the actual and estimated scores on Test 1, the behavioral aspects of cheating and establishing positive beliefs could be examined. If both the actual scores and the estimated scores of the answer group were significantly higher than those of the control group, then it could be deduced that the answer group was cheating and established a positive belief: "I am good at this task." Self-deception was examined through the difference between the predicted scores and the actual scores for Test 2. If the scores predicted by the answer group were significantly higher than those predicted by the control group and the actual scores were not different, this result indicated that self-deception occurred in the answer group. The results showed that the actual scores and the estimated scores of the answer group were significantly higher than those of the control group, which indicated that the answer group was cheating and established a positive belief in Test 1. In Test 2, the prediction scores made by the answer

group were significantly higher than those by the control group, and the true scores were not significantly different. The answer group deceived themselves into believing that they would perform better in the future than they actually did (holding positive beliefs about their ability being better than their actual ability) despite knowledge of negative evidence, such as "I saw the answer."

Deceiving others is beneficial, but why do people deceive themselves? Evolutionary psychologists believe that self-deception can help individuals ignore clues such as cognitive load, conscious repression, and tension in order to better deceive others (von Hippel and Trivers, 2011). Deception and self-deception are like two sides of the same coin that are mutually dependent and interactive. Self-deception slowly becomes a strategy to persuade or deceive others without being detected, and then deceiving others also becomes a means of self-deception (Dings, 2017). In the forward-looking paradigm, participants do not interpret their cheating behavior as "I am a liar," a negative belief, but use the positive scores of deception to enhance their positive beliefs ("I am capable") and the logical belief that "I am capable, I am not a cheater." The forward-looking paradigm could not only be used to study self-deception in individuals but also be extended to interpersonal self-deception. Such an approach would be easy to carry out and could avoid the difficult problem of the retrospective paradigm, which is not having an objective measure of unconscious decisions. Chance et al.'s (2011) experiment is based on knowledge of material familiar to people in the United States, but it is not applicable for Chinese participants more broadly. Furthermore, some studies have shown that there are significant differences in social cognition and behavior between people in the East and the people in the United States (Norenzayan and Nisbett, 2000; Yukiko and Shinobu, 2009). Hence, not only does the forward-looking paradigm experimental material need to be studied, but the validity of the experimental paradigm must also confirm in the Eastern cultural context. Therefore, the first purpose of this study was to verify the effectiveness of the forward-looking paradigm to induce self-deception in the context of Chinese culture and to expand and enrich the experimental material.

In addition, many studies have proven that self-deception has positive effects on individuals, such as improving subjective well-being (Ford, 2004; Lopez and Fuxjager, 2012) and increasing self-confidence (Ren et al., 2018) and self-perceived personal charm (Linton and Wiener, 2001). However, other studies have shown that self-deception has a negative effect on individuals. The negative impact of self-deception on individuals makes it impossible for individuals to clearly recognize themselves, and self-deception is not conducive to long-term development. Self-deception has benefits from a short-term perspective, but there is a high price to pay in the long term (Chance et al., 2011; Lauria et al., 2016). Self-deception can be misleading for social policy and may cause disasters for groups and society; war is the most expensive price that we have paid, as illustrated by Hitler's Nazi party (Trivers, 2000). Self-deception can be a strategy of moral hypocrisy to misperceive one's behavior as moral and avoid comparing one's behavior with moral standards (Batson et al., 1999). Self-deception promotes unethical behavior, cheating, the bankruptcy of enterprises and governments (Chance et al., 2015), corrupt behavior (Desai et al., 2017), and the undermining of corporations (Babino et al., 2018). Thus, it is important to prevent and eliminate the negative impact of self-deception. It is of great theoretical and practical significance to explore how reducing such costly self-deception helps individual better monitor their self-deception behavior to prevent individual losses and prevent the harmful effects of self-deception on society.

How can self-deception be decreased? Self-deception is considered a positive belief about the self that persists despite specific evidence to the contrary. In our view, self-deception can be decreased by weakening the positive beliefs of self-deceivers. How do these positive beliefs change? According to belief adjustment theory, when people find new information that conflict with their original beliefs, they will adjust their original beliefs to accept the inconsistent information to adapt to the new environment. When confronted with inconsistent information, individuals readjust the strength of their belief rather than completely revising their original belief (Johnson-Laird et al., 2004). Does positive belief in self-deception follow belief adjustment theory? That is, will this positive belief be weakened when people face inconsistent negative beliefs? We examine the decline of self-deception by manipulating the negative feedback to influence positive beliefs in self-deception. We support the theory suggested by Sloman (2011) that self-deception depends on ambiguous conditions. However, it remains unclear how negative feedback affects self-deception in the forward-looking paradigm, and non-feedback has the greatest ambiguity with regard to self-deception. Therefore, the second purpose of this study was to provide relatively truthful and accurate feedback to the participants and to examine whether the answer group would be aware of the good scores obtained by cheating on Test 1 and whether their predictions for Test 2 would be closer to the control group's scores. According to the theory of belief adjustment and the idea that self-deception depends on ambiguous conditions, we hypothesize that self-deception can be decreased by weakening individuals' positive beliefs.

Based on the above, this study used a forward-looking paradigm to examine how the positive beliefs of self-deception occurs and to further explore the impact of negative feedback on that positive beliefs to decrease self-deception.

EXPERIMENT 1: POSITIVE BELIEFS IN SELF-DECEPTION IN THE FORWARD-LOOKING PARADIGM

Purpose and Hypothesis

The purpose of this study was to examine how positive beliefs occur in the forward-looking paradigm during self-deception. The study assumed that compared to the control group participants, the participants in the answer group would establish positive beliefs about their scores because of cheating

in Test 1 and predict higher scores for their future Test 2 to show self-deception.

Methods

Participants

The experimental procedure was approved by the IRB of the Institute of Psychology, Hunan Normal University. A total of 47 college students (19 male and 28 female, average age 22.48 ± 0.69 years) were recruited, none were psychology majors. All participants were right-handed, with normal or corrected-to-normal vision. They were randomly divided into the answer group (25 people, with answer hints) and the control group (22 people, without answer hints). All participants signed their written informed consent to the experiment and were given appropriate compensation after the experiment.

Experimental Design

A 2 (group type: answer group vs. control group) × 2 (score: estimation/prediction scores vs. actual scores) mixed design was conducted in Experiment 1. The group type was the between-subject variables, and the within-subject variable was the score. The dependent variable was the estimated and actual scores for Test 1 and the predicted and actual scores for Test 2.

Material

Dot estimation task: Each graph is a problem, and there are 60 rectangular red dot graphs (see **Figure 1** for an example). Ten of the 60 graphs had an answer hint written at the bottom right corner and were used for Test 1 by the answer group, and the same type of graphs without answer hints was used for Test 1 by the control group. The remaining 50 graphs without the answer hint were used for Test 2 for both groups. Each graph is a rectangle divided into two halves by a diagonal line. In each graph, 39 or 40 red dots are evenly distributed on both sides of the diagonal line. To increase the ambiguity of the answer, the number of points on both sides of the graph was either nearly equal or equal. There were three types of answers: more dots the left side, more dots on the right side and an equal number of dots on each side. Among these graphs, 20 graphs have the same number of dots on both sides, 20 graphs have one more dot on the right side, and the remaining 20 graphs have one more dot on the left side. The task of estimating the number of points without counting is quite difficult, and the answer is chosen based on intuition. The red dots are randomly presented in the graph. Each graph is rendered randomly by a computer program. Each graph appears as a trial, and the time taken for each trial is 6 s. The participants would press the "F" key if they think there are more dots on the left side, "J" for the right side, and "Y" for an equal number of dots.

Procedure

Forty-seven participants completed the test on computers equipped with Eprime 2.0. The test consisted of Test 1 and Test 2 (see **Figure 2**). Before the test, a sample dot estimation task with instructions was presented to participants, and the participants were informed about the requirements and specific operations of the test. Participants were informed that the dot estimation task was designed to investigate the visual observation ability of the college students. In the answer group, the participants were also given this instruction "There is an answer below and to the right of the screen; you can check your answer, but please do your own work." This was an ambiguous instruction, they did not forbidden to look at the answer, but they did imply that using the answer hint to answer the question would be wrong (Chance et al., 2015). The control group completed the same test task but without the answer hints and the ambiguous instructions. After the participants completed Test 1 with 10 questions, they needed to estimate their score for Test 1 and predict their future score for Test 2, which had 50 graphs, by entering the scores on the computer screen. Finally, they completed Test 2 with no answer hints. In Test 1, because of the influence of the answer hint (participants of the answer group saw the answer hint, the control group did not have the answer hint), the answer group had a significantly higher score than the control group on both the estimated scores and actual scores. If the actual score of the answer group was significantly higher than that of the control group, this result indicated that the answer group was cheating by looking at the answer; if the estimation of the score made by the answer group was significantly higher than that of the control group, this result meant that the answer group had set up a positive belief: I am good at this test. In Test 2, these participants chose to deceive themselves into believing that the better scores were obtained not because they had the answers beforehand but because of their actual talent. Then, participants of answer group more estimated their scores in Test 2 by self-deception than those of the control group. If the predicted scores made by the answer group were significantly higher than those of the control group but the actual scores were not different, then the answer group was self-deceptive; that is, they had a positive belief and still persisted in this belief in the face of the opposite evidence.

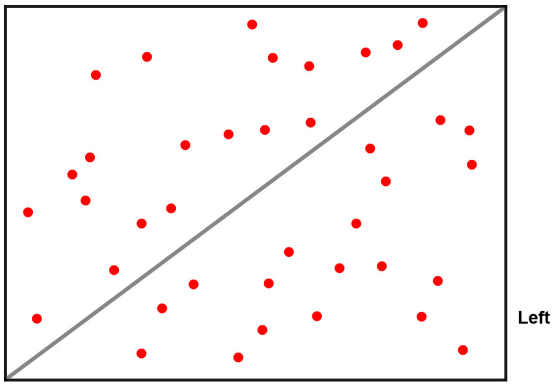

FIGURE 1 | A dot graph with an answer hint.

Results

Estimated and Actual Scores for Test 1

Repeated-measures analyses of variance (ANOVA) were performed on the estimated scores and actual

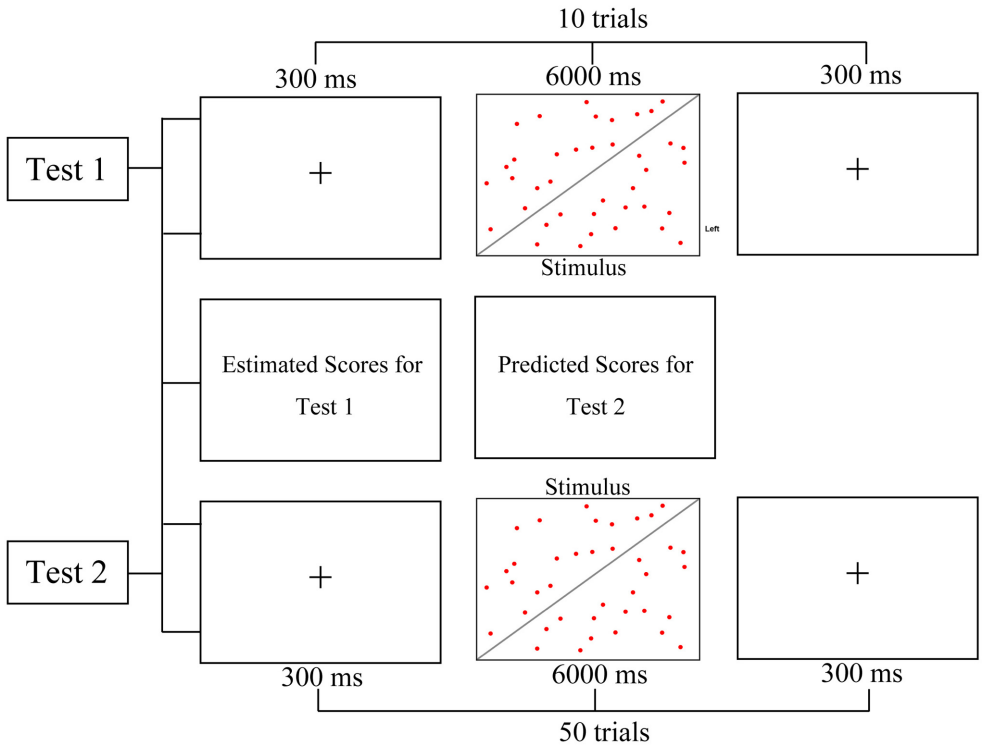

FIGURE 2 | Procedure of Experiment 1.

TABLE 1 | Estimated and actual scores for test 1 and predicted and actual scores for test 2 ($M \pm SD$).

	Test 1		Test 2	
	Answer	**Control**	**Answer**	**Control**
Score	6.57 ± 1.50	5.46 ± 1.42	33.81 ± 9.47	27.00 ± 9.62
Actual Score	5.67 ± 2.15	4.23 ± 1.17	19.90 ± 2.37	20.65 ± 3.81

scores in the two groups for Test 1 (see **Table 1** and **Figure 3**). The results showed that the main effect of the group type was significant, $F_{(1,45)} = 14.33$, $p < 0.001$, $\eta_p^2 = 0.24$, and the scores of the answer group were higher than those of the control group. There was a significant main effect of score, $F_{(1,45)} = 17.34$, $p < 0.001$, $\eta_p^2 = 0.28$, and the estimated scores were higher than the actual scores. There was no significant interaction effect for the group type and the score, $F_{(1,45)} = 0.33$, $p > 0.05$, $\eta_p^2 = 0.01$.

To further verify whether the answer hints could cause cheating behavior and positive beliefs, we used an independent-sample t-test to compute the difference of the estimated scores and the actual scores between the two groups. The results showed that the estimated scores of the answer group were higher than those of the control group, $t(45) = 2.84$, $p = 0.007$, *conhen's d* = 0.76, and the actual scores of the answer group were significantly higher than those of the control group, $t(45) = 3.07$, $p = 0.005$, *conhen's d* = 0.71.

Predicted and Actual Scores for Test 2

Repeated-measures ANOVAs were performed on the predicted and actual scores in the two groups for Test 2 (see **Table 1** and **Figure 3**). The results showed that the main effect of the group type was significant, $F_{(1,45)} = 5.26$, $p < 0.05$, $\eta_p^2 = 0.11$, and the scores of the answer group were higher than those of the control group. There was a significant main effect of the score, $F_{(1,45)} = 52.52$, $p < 0.01$, $\eta_p^2 = 0.54$, and the predicted scores were higher than the actual scores. There was a significant interaction effect for the group type and the score, $F_{(1,45)} = 7.32$, $p < 0.01$, $\eta_p^2 = 0.14$. We conducted a simple effect analysis for the answer group and the control group. The results showed that the answer group had higher predicted scores than the control group, $F_{(1,45)} = 7.11$, $p < 0.05$, and the actual scores of the two groups were not significantly different, $F_{(1,45)} = 0.64$, $p > 0.05$. In addition, the predicted scores of the answer group and the control group were significantly higher than the actual scores, $F_{(1,45)} = 44.76$, $p < 0.001$, $F_{(1,45)} = 11.54$, $p < 0.001$.

To further verify whether the answer hints could affect the actual scores of the answer group to induce self-deception by the participants' cheating, we converted raw scores to percentages and used a paired-sample t-test to compute the difference between the scores and the actual scores in Test 1 and Test 2 for the two groups. The results showed that the percentages of estimated scores for Test 1 were not significantly higher than the

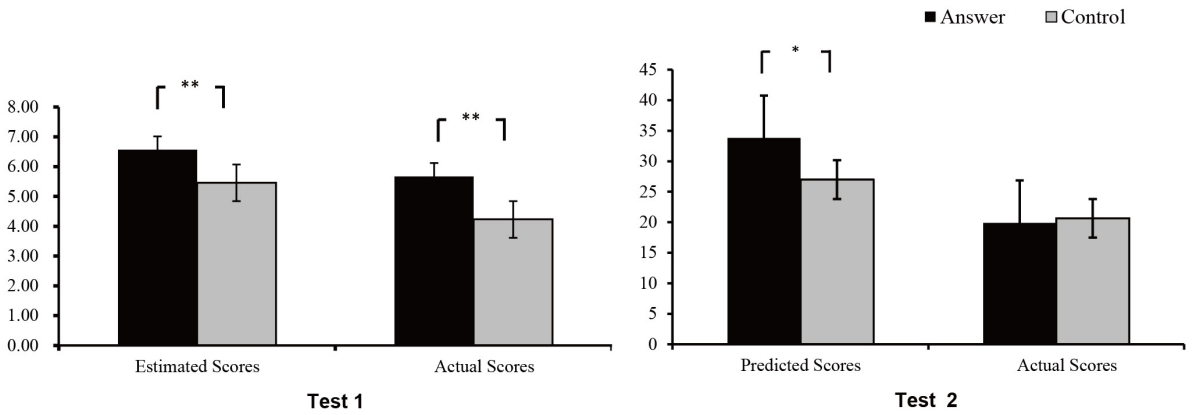

FIGURE 3 | Estimated and actual scores for Test 1 and predicted and actual scores for Test 2 in the control and answer groups. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

percentages of predicted scores for Test 2 in the answer group, $t(24) = -0.66$, $p = 0.52$, *conhen's d* $= -0.15$, and the percentages of actual scores for Test 1 were significantly higher than the percentages of predicted scores for Test 2, $t(24) = 3.99$, $p = 0.001$, *conhen's d* $= 1.24$. In contrast, the percentages of estimated scores for Test 1 were not significantly higher than the percentages of predicted scores for Test 2 in the control group, $t(21) = 0.22$, $p = 0.83$, *conhen's d* $= 0.06$, and the percentages of the actual scores for two tests were not significantly different, $t(21) = 0.50$, $p = 0.62$, *conhen's d* $= 0.11$.

Discussion

In Experiment 1, the main effect of the group type was significant, and the actual scores of the answer group were significantly higher than those of the control group in Test 1, which indicated that the answer group was affected by the answer hints and cheated by seeing the answers. The answer group had higher estimated scores than the control group in Test 1, which indicated that the participants in the answer group had established positive beliefs. In Test 2, the main effect of the group type was significant, the predicted scores of the answer group were significantly higher than those of the control group, and the actual scores were did not differ between the groups, which indicated that the answer group occurred self-deception. These results are not only consistent with the previous hypothesis but also consistent with the study by Chance et al. (2011). By ignoring the influence of negative evidence, people deceive themselves to maintain a positive belief about their future performance to reflect their abilities (Chance et al., 2011, 2015).

In addition, the main effect of score was significant in the two tests, and the estimated or predicted scores were higher than the actual scores. These findings indicate that the participants in the two groups overestimated their actual ability and that they enhanced and maintained a positive self-concept by evaluating their traits above their actual level (Greenwald, 1980; Taylor and Brown, 1988; Burson et al., 2006). However, there was no significant difference in the percentages of scores between Test 1 and Test 2 in the control group and a significant difference in the percentages of actual scores between Test 1 and Test 2 in the answer group. These results support the effect of the answer hints on the answer group. That is, the positive beliefs of the control group were not self-deception, but the positive beliefs of the answer group when they were faced with the negative evidence (answer hints) were regarded as self-deception. However, the question remains whether this positive belief can be changed by presenting opposing negative beliefs. Therefore, Experiment 2 further explored the variability of positive beliefs in self-deception by investigating the effect of negative feedback on positive beliefs in self-deception. In Experiment 1, the average actual scores for Test 2 in the two groups were 20.65 (the control group) and 19.9 (the answer group). Both groups had scores lower than their self-evaluation, so the feedback in Experiment 2 was the negative feedback of the "low test scores of your test".

EXPERIMENT 2: THE EFFECT OF NEGATIVE FEEDBACK ON POSITIVE BELIEFS IN SELF-DECEPTION

Purpose and Hypothesis

The purpose of this experiment was to examine the effect of negative feedback on positive belief in self-deception. We hypothesized as follows: (1) compared to the control group participants, the participants in the answer group would establish positive beliefs about their higher scores because of cheating in Test 1 and predict higher scores for their future Test 2 to show self-deception under the no-feedback condition; (2) compared to the control group participants, the participants in the answer group would reduce positive beliefs about their scores in Test 1 to decrease the occurrence of self-deception in Test 2 under the negative-feedback condition.

Methods

Participants

The experimental procedure was approved by the IRB of the Institute of Psychology, Hunan Normal University. A total of 93

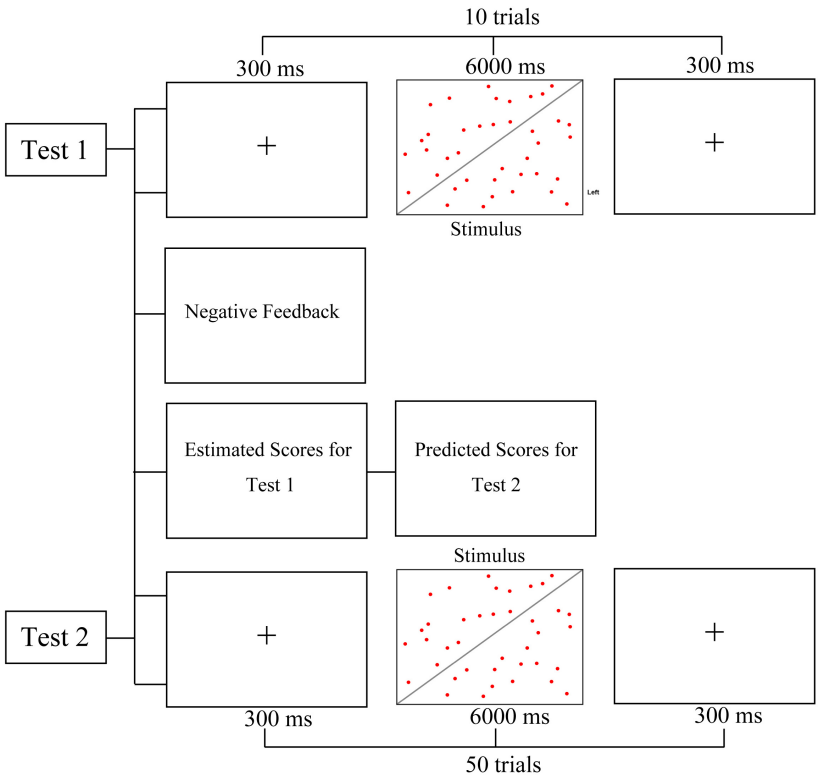

FIGURE 4 | Procedure of Experiment 2.

college students (40 male and 53 female; average age 23.45 ± 0.71 years) were recruited. The participants were all right-handed, had normal or corrected-to-normal vision, and were randomly assigned to the answer group (28 participants in the negative feedback condition, 20 participants in the no-feedback condition, with answer hints) and the control group (25 participants in the negative feedback condition, 20 participants in the no-feedback condition, without answer hints). All participants signed their written informed consent for the experiment and were given appropriate compensation after the experiment.

Experimental Design

A 2 (group type: answer group vs. control group) × 2 (feedback condition: negative vs. no-feedback) × 2 (score: estimation/prediction scores vs. actual scores) mixed design was conducted in Experiment 2. The group type and feedback condition were the between-subject variables, and the within-subject variable was the score. The dependent variable was the estimated and actual scores for Test 1 and the predicted and actual scores for Test 2.

Material

The same dot estimation task material used in Experiment 1 was used for Experiment 2.

Procedure

At the end of Test 1, the computer gave the participants negative feedback that said "low test score for your test." Then, the participants were asked to estimate their scores for Test 1 and predict their scores for Test 2. The other procedures were the same as those in Experiment 1 (**Figure 4**).

TABLE 2 | Comparison of estimated, predicted, and actual scores between groups (*M* ± *SD*).

	Estimated score for Test 1 Actual score for Test 1		Predicted score for Test 2 Actual score for Test 2	
	Answer	**Control**	**Answer**	**Control**
Negative	4.57 ± 1.69	4.10 ± 1.37	23.40 ± 6.53	24.90 ± 8.57
Feedback	5.89 ± 2.77	4.25 ± 1.45	19.46 ± 2.73	19.55 ± 4.20
No feedback	6.60 ± 1.50	5.64 ± 0.32	34.00 ± 9.54	27.49 ± 10.13
	5.50 ± 2.35	4.32 ± 1.11	20.05 ± 2.42	20.12 ± 4.52

Results

Estimated and Actual Scores for Test 1

Repeated-measures ANOVAs were performed on the feedback condition and score in the two groups for Test 1 (**Table 2**). The results showed that the main effect of the group type was significant, $F_{(1,89)} = 12.76$, $p < 0.001$, $\eta_p^2 = 0.13$, and the scores of the answer group were higher than those of the control group. There was a significant main effect of the feedback condition, $F_{(1,89)} = 7.43$, $p < 0.01$, $\eta_p^2 = 0.08$, and the score of the no-feedback condition were higher than those of the negative feedback condition. There was no significant main

effect of the score, $F_{(1,89)} = 0.92$, $p > 0.05$, $\eta_p^2 = 0.01$, and the estimated scores were not different from the actual scores. There was no significant interaction effect of group type and score, $F_{1,89)} = 1.99$, $p > 0.05$, $\eta_p^2 = 0.02$, and no significant interaction effect for group type, feedback condition and score, $F_{(1,89)} = 0.93$, $p > 0.05$, $\eta_p^2 = 0.01$. However, there was a significant interaction effect for the feedback condition and the score, $F_{(1,89)} = 15.53$, $p < 0.001$, $\eta_p^2 = 0.15$. We conducted a simple effect analysis for the answer group and the control group. The results showed that the estimated scores of the no-feedback condition were significantly higher than those of the negative feedback condition, $F_{(1,89)} = 25.41$, $p < 0.001$, and the actual scores were not significantly different between the two conditions, $F_{(1,89)} = 0.65$, $p > 0.05$. In addition, the estimated scores of the no-feedback condition were higher than the actual scores, $F_{(1,89)} = 11.98$, $p < 0.01$, and the estimated scores of the negative feedback condition were lower than the actual scores, $F_{(1,89)} = 5.93$, $p < 0.05$.

To further verify whether negative feedback could decrease positive beliefs by reducing the estimated scores and whether the answer hints could cause cheating behavior and positive beliefs, we used an independent-sample *t*-test to compute the difference between the estimated scores and the actual scores between the two groups (see **Figure 5**). The results of the negative feedback condition showed that the estimated scores of the answer group were not significantly different from those of the control group, $t(46) = 1.03$, $p = 0.31$, *conhen's d* = 0.31, and the actual scores of the answer group were significantly higher than those of the control group, $t(46) = 2.67$, $p = 0.01$, *conhen's d* = 0.74. The results of the no-feedback condition showed that the estimated scores and the actual scores of the answer group were significantly higher than those of the control group, $t(43) = 1.20$, $p = 0.05$, *conhen's d* = 0.89, $t(43) = 2.07$, $p = 0.04$, *conhen's d* = 0.64.

Predicted and Actual Scores for Test 2

Repeated-measures ANOVAs were performed on the feedback condition and score in the two groups for Test 2 (see **Table 2** and **Figure 5**). The results showed that the main effect of the group type was not significant, $F_{(1,89)} = 1.55$, $p > 0.05$, $\eta_p^2 = 0.02$, and the scores of the answer group were not different from those of the control group. There was a significant main effect of the feedback condition, $F_{(1,89)} = 13.51$, $p < 0.001$, $\eta_p^2 = 0.13$, and the scores of the no-feedback condition were higher than those of the negative feedback condition. There was a significant main effect of the score, $F_{(1,89)} = 58.97$, $p < 0.01$, $\eta_p^2 = 0.40$, and the predicted scores were higher than the actual scores. There was a significant interaction effect for group type, feedback condition and score, $F_{(1,89)} = 4.05$, $p < 0.05$, $\eta_p^2 = 0.04$. We conducted a simple effect analysis for the answer group and the control group. The results showed that the predicted scores and the actual scores were not significantly different between the answer group and the control group under the negative feedback condition, $F_{(1,89)} = 0.92$, $p > 0.05$, $F_{(1,\ 89)} = 0.03$, $p > 0.05$. Under the no-feedback condition, the predicted scores of the answer group were higher than those of the control group, $F_{(1,\ 89)} = 4.33$, $p < 0.05$, and the actual scores did not differ between the answer group and the control group, $F_{(1,\ 89)} = 0.02$, $p > 0.05$.

Discussion

In Experiment 2, the results of Test 1 showed that the main effect of the group type and the feedback condition were significant, and the main effect of the score was not significant, which indicated that the scores of the participants were affected by the negative feedback. Under the no-feedback condition, the estimated scores of the answer group were significantly higher than those for the control group, and the estimated scores were higher than the actual scores, which indicated that the participants cheated on the test by seeing the answer hints and obtained a positive belief. These results are consistent not only with the previous hypothesis and the results of Experiment 1 but also with the study by Chance et al. (2011). Under the negative feedback condition, the estimated scores of the answer group were not significantly different from those of the control group, and the predicted scores were lower than the actual scores. The actual scores of the answer group were significantly higher than those of the control group, which indicated that the negative feedback reduced the positive beliefs in Test 1, even if the participants cheated on the test by seeing the answer hints.

The results of Test 2 showed that the main effect of the feedback condition and score was significant and the main effect of the group type was not significant, which indicated that the positive beliefs of the answer group reduced their scores to the level of the control group because of the impact of negative feedback. There was a difference between Test 1 and Test 2 in the main effect of the score because the actual scores of the answer group reduced by the lack of answer hints provided to the participants in Test 2. Under the no-feedback condition, the predicted scores of the answer group were significantly higher than those of the control group and the actual scores of the two groups did not differ, which indicated that the participants in the answer group occurred self-deception. These results are consistent not only with the previous hypothesis and the results of Experiment 1 but also with the study by Chance et al. (2011). Under the negative feedback condition, the estimated scores and the actual scores of the answer group were not significantly different from those of the control group, which indicated that negative feedback decreased self-deception to the level of the control group. The results of Experiment 2 suggest that negative feedback might have decreased the occurrence of self-deception in Test 2 by reducing the positive beliefs in Test 1 to reduce such costly self-deception.

GENERAL DISCUSSION

The present study used the forward-looking paradigm to examine how positive beliefs appeared in self-deception and further revealed the influence of negative feedback on positive beliefs to decrease self-deception. The findings of Experiment 1 and the no-feedback condition for Experiment 2 showed that the estimated scores and the actual scores of the answer group were higher than those of the control group in Test 1. The predicted scores of the answer group were higher than those of the control group in Test 2, but the actual scores did not differ between the groups in Test 2. However, the findings of the negative feedback condition

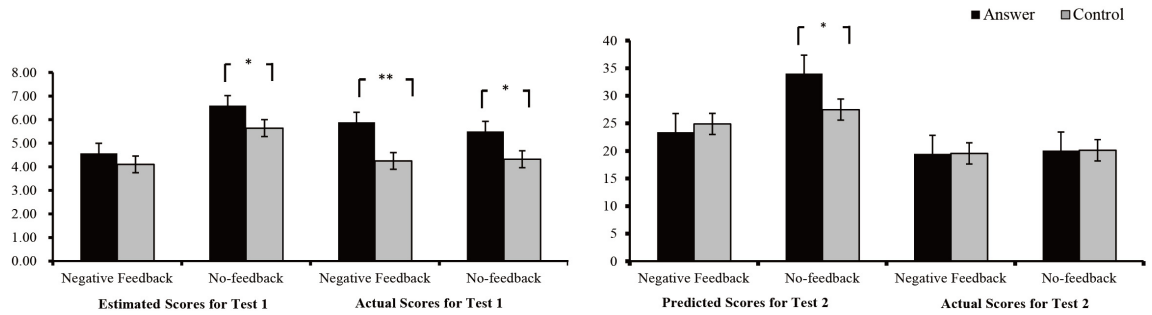

FIGURE 5 | Comparison between the two groups across conditions. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

for Experiment 2 showed that the estimated scores, the predicted scores and the actual scores (Test 2) of the answer group were not significantly different from those of the control group, and the actual scores of the answer group were significantly higher than those of the control group in Test 1. These findings demonstrate that the effectiveness of the forward-looking paradigm can induce self-deception to expand and enrich the experimental material used, and negative feedback may have decreased the occurrence of self-deception in Test 2 by reducing the positive beliefs in Test 1 to prevent or eliminate the negative impact of self-deception.

The Effectiveness of the Forward-Looking Paradigm to Induce Self-Deception

To further improve and develop the experimental methods to study self-deception, we used computer programs and graph materials to examine the effectiveness of the forward-looking paradigm to induce self-deception and to verify the applicability of the dot estimation material to more general participants. The results of Experiment 1 and the no-feedback condition of Experiment 2 showed that the estimated scores, the actual scores in Test 1 and predicted scores of the answer group were significantly higher than those of the control group, but the actual scores did not differ between the groups in Test 2. These findings indicate that the answer group occurred self-deception. The participants in the answer group deceived themselves into believing that they would perform better in the future than they actually did despite knowledge of negative evidence, such as seeing the answers. These results are consistent with Chance et al.'s (2011) research and prove that the "forward-looking" paradigm can better induce self-deception in an Eastern cultural context. The dot estimation material can induce self-deception and can be widely used in academic settings to study self-deception (Ren et al., 2018). To our knowledge, this is the first time that the forward-looking paradigm has been tested using a computer program and graph materials. Our research results represent an improvement in the experimental methods used to study self-deception. It is expected that improvements in this method can provide an experimental basis for the study of the neural mechanisms of self-deception.

Negative Feedback Decreases Positive Beliefs in Self-Deception

To effectively prevent the occurrence of self-deception, we provided negative feedback after Test 1 in Experiment 2 to explore whether this negative feedback could decrease self-deception by reducing the positive beliefs of participants. The results of Experiment 2 showed that the estimated scores, the predicted scores and the actual scores in Test 2 of the answer group were not significantly different from those of the control group, and the actual scores of the answer group were significantly higher than those of the control group in Test 1. These results indicated that negative feedback may have decreased the occurrence of self-deception in Test 2 by reducing the positive beliefs in Test 1. Our results are consistent with belief adjustment theory, which suggest that individuals adjust their original beliefs to accept inconsistent information (Johnson-Laird et al., 2004). Most previous studies on self-deception have used the retrospective paradigm to promote the generation of self-deception through negative feedback (Gur and Sackeim, 1979; Quattrone and Tversky, 1984; Sloman et al., 2010). The negative feedback of the retrospective paradigm is a type of threatening information that can induce self-deception in participants by changing their behavior and denying the change of behavior. However, in our research, negative feedback affected the positive beliefs of the participants to reduce the occurrence of self-deception. Therefore, the difference in the results between the retrospective paradigm and our study was due to the difference in the operation of the experimental conditions and the measurement of self-deception. Sloman et al. (2010) found that self-deception occurred under ambiguous conditions, and compared with ambiguous feedback, accurate feedback could effectively reduce the occurrence of self-deception. The findings of our study demonstrated that no-feedback conditions have more highly ambiguous conditions to facilitate the occurrence of self-deception than do relatively accurate negative feedback conditions. Thus, our results also support the theory of Sloman et al. (2010) that self-deception depends on ambiguous conditions. In addition, high self-awareness has been positively correlated with low self-deception (Lynn et al., 2014), and negative feedback might increase the level of awareness of self-competence to reduce positive beliefs in self-deception by improving self-perception.

Biased Information Processing of Positive Beliefs in Self-Deception

Many studies have shown that individuals tend to overestimate their positive traits of intelligence, capability and morality (Taylor and Brown, 1988). Our study found the same psychological phenomena. The results showed that the main effect of scores was significant in Experiment 1 and Test 2 of Experiment 2, and the predicted scores were higher than the actual scores of the control group and the answer group. These results showed that the participants generally overestimated their real scores due to overconfidence. von Hippel and Trivers (2011) suggested that not all biased processing of information is self-deception, however, when people are consciously inclined toward positive information, unconsciously avoiding negative information and reflecting individual motivation is regarded as self-deception. That is, the positive beliefs of the control group were not self-deception, but the positive beliefs of the answer group when faced with negative evidence (answer hints) were regarded as self-deception. The pursuit of truth is important in human survival and reproduction. Why do individuals have unrealistic positive beliefs about themselves through self-deception? Most researchers now use the theory of biased information processing to explain the mechanism of positive beliefs in self-deception (van der Leer and McKay, 2017). Self-deception can occur at any stage of biased information processing, and people maintain a positive self-evaluation according to their willingness to deviate, ignore their memory and rationalize improper behavior. Furthermore, self-deception can occur at any stage of information processing, and people are biased according to their willingness to extract and block information or reconstruct memories. When individuals search for or receive information, they are sometimes inclined to avoid further searches for information and even automatically question the validity and authenticity of the information because it does not match their own goals and ideas. As individuals attempt to interpret the information they obtain, some unwelcome information may be recoded as being more positive. When information is extracted from memory, it is not guaranteed that unwelcome information is retrieved even if it has been acknowledged or even accepted for encoding. Information that is not consistent with an individual's own preferences is easily forgotten or misunderstood.

Logic of the Relationship Between Cheating and Self-Deception

From the interpersonal point of view, some researchers have suggested that self-deception is contributes to interpersonal deception (von Hippel and Trivers, 2011). For example, it has been proposed that self-deception can promote interpersonal persuasion by maintaining positive self-image (Seiffert-Brockmann and Thummes, 2017; Smith et al., 2017), which shows that deception and self-deception are interdependent and mutually promoting. Cheating is a fraudulent way of doing illegal or unregulated things; that is, cheating is a kind of deceit. Therefore, cheating and self-deception are also interdependent and mutually beneficial, and our experiment is in line with this logic. However, people generally think that the problematic behavior of cheating will make individuals feel worse about themselves; that is, if they have the ability to obtain the desired scores, they do not need to cheat. However, in reality, when self-deception appears, the sense of morality will fade (Tenbrunsel and Messick, 2004). Self-deception reduces the cognitive dissonance caused by unethical behavior (Lauria et al., 2016). Self-deception is regard as a strategy to deal with conflict between self-interest and moral standards (Batson et al., 1999; Tang et al., 2017, 2018). Even if unconsciously one thinks of it as a kind of immoral behavior, the conscious mind rationalizes this immoral behavior. People tend to focus on the positive scores of cheating, leading to their neglect of the disagreeable process of cheating in order to maintain positive beliefs for self-view.

Limitations and Future Study

Previous studies have found that it is difficult for real feedback to reduce self-deception to the level of the control group after repeated feedback (Chance et al., 2015; Tang et al., 2018). However, our research found that one incident of negative feedback decreased self-deception to the level of the control group. This difference might be because the negative feedback in our experiment appeared after Test 1 and before the estimated scores (Chance included feedback after Test 2). Thus, we could reduce the occurrence of self-deception by influencing the establishment of positive beliefs among our participants. Our study did not examine self-deception at different points of feedback (after Test 1 or Test 2), which is one of our limitations. Future research should place negative feedback at different time points in an experiment to test whether self-deception differences exist. Furthermore, the results of our research only explained and examined ubiquitous self-deception with positive beliefs but not broader self-deception, such as negatively twisted self-deception (Mele, 2002; Leeuwen, 2007). In addition, our study did not examine self-deception other than negative feedback types (ambiguous vs. real) and social situations. Future studies can investigate the cognitive mechanism of self-deception depending on ambiguous or real negative-feedback conditions and social situation factors. The neural mechanisms of individual self-deception can be further explored using ERP technology or fMRI technology.

CONCLUSION

This study contributes to experimental methods and suggests ways to reduce self-deception. On the one hand, we used computer programs and "dot estimation" materials in the forward-looking paradigm to prove that the effectiveness of the forward-looking paradigm can induce self-deception in an Eastern cultural context, and to expand the experimental material used. On the other hand, our research demonstrated that negative feedback can decrease the occurrence of self-deception by reducing the positive beliefs of individuals and improving self-awareness to avoid or eliminate the negative impact of self-deception on the basis of belief adjustment theory. No-feedback conditions have more ambiguous conditions to facilitate the occurrence of

self-deception than do negative feedback conditions. In other words, the forward-looking paradigm is an effective experimental method to explore self-deception by inducing cheating, and negative feedback can decrease self-deception.

AUTHOR CONTRIBUTIONS

JL was responsible for the preparation of experimental procedures and wrote the manuscript. YZ and LS analyzed the data. PG, DK, and JJ performed the experimental procedures and organized the participants for the experiments. RC and ML examined the experimental material. WZ reviewed the manuscript.

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Temporal Features of Psychological and Physical Self-Representation: An ERP Study

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Psychological and physical-self are two important aspects of self-concept. Although a growing number of behavioral and neuroimaging studies have investigated the cognitive mechanism and neural substrate underlying psychological and physical-self-representation, most of the existing research on psychological and physical-self-representation had been done in isolation. The present study aims to examine the electrophysiological responses to both psychological (one's own name) and physical (one's own voice) self-related stimuli in a uniform paradigm. Event-related potentials (ERPs) were recorded for subjects' own and others' names uttered by subjects' own or others' voice (own voice-own name, own voice-other's name, other's voice-own name, other's voice-other's name) while subjects performed an auditory passive oddball task. The results showed that one's own name elicited smaller P2 and larger P3 amplitudes than those of other's names, irrespective of the voice identity. However, no differences were observed between self and other's voice during the P2 and P3 stages. Moreover, an obvious interaction effect was observed between voice content and voice identity at the N400 stage that the subject's own voice elicited a larger parietal N400 amplitude than other's voice in other name condition but not in own name condition. Taken together, these findings suggested that psychological (one's own name) and physical (one's own voice) self-representation induced distinct electrophysiological response patterns in auditory-cognitive processing.

Keywords: psychological-self, physical-self, own name, own voice, P3, N400

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INTRODUCTION

Self-recognition is an essential biological and social function for human species, which represents a capacity to identify the distinction between self and others (Candini et al., 2014; van Veluw and Chance, 2014; Conde et al., 2015). Multiple behavioral and neuroimaging studies have revealed the cognitive and neural mechanisms of self-reference effect (Kalenzaga et al., 2015; Humphreys and Sui, 2016; Tamura et al., 2016), self-relevant effect (Chen et al., 2011, 2015a,b), and self-positive bias (Watson et al., 2007; Fields and Kuperberg, 2015; Kiang et al., 2017). However, these studies usually characterized the self at a single and unidimensional structure (Platek et al., 2004). From the time of William James, the multidimensionality of self-concept has been emphasized and highlighted (Marsh, 1990), some psychologists suggest

that the self-concept cannot be understood sufficiently and accurately if its multidimensionality is ignored (Marsh, 1990; Walla et al., 2008; Klein, 2010; Uddin, 2011; Philippi et al., 2017). For example, Gillihan and Farah (2005) reviewed a series of self-related studies and divided the self-concept into two aspects: physical and psychological self (Gillihan and Farah, 2005). The physical-self contains the sensory and image-based representations of our face, voice, proprioceptive and motor-based representations of our body (Gallagher, 2005; Gillihan and Farah, 2005; Keyes et al., 2010; Uddin, 2011; Sugiura, 2013), which is the biological basis of the self. The psychological-self involves the processing of self-related knowledge (e.g., autobiographical memory, semantic memory knowledge about oneself) and the first-person perspective, such as personality trait adjectives, own name, own born place (Gray et al., 2004; Gillihan and Farah, 2005; Su et al., 2010; Uddin, 2011; Tateuchi et al., 2015). Moreover, Kircher et al. (2000) suggested that the physical and psychological self-processing might involve different cognitive and neural mechanism (Kircher et al., 2000). Hu et al. (2016) examined the commonalities and distinctions between physical and psychological self-representation using an ALE meta-analysis. They found that physical self-representation was particularly linked to lateral brain regions with a right hemispheric dominance, while psychological self-representation significantly and predominantly activated the cortical midline structures. Moreover, the anterior cingulate cortex (ACC) and left inferior frontal gyrus (IFG) were activated both in physical and psychological self-processing (Hu et al., 2016).

However, most of these existing studies on physical- and psychological-self had been done in isolation, and there was relatively limited research directly examing the physical and psychological self-processing in the same study. Kircher et al. (2000) firstly studied the neural correlates of physical (self-face) and psychological (self-related trait) self-processing using the functional magnetic resonance imaging (fMRI). Their results showed that physical self-processing is related to the right limbic areas, right middle temporal lobe, left inferior parietal, and the left prefrontal regions, while the psychological-self activated the precuneus, left parietal lobe, left insula/IFG, and the left ACC (Kircher et al., 2000). Lou et al. (2004) further found that the right lateral parietal regions not only played an important role in physical-self (e.g., imagination of agency, body representation) but also activated in the psychological-self task (Lou et al., 2004). Although these studies have advanced our understanding of the similarities and differences in terms of the neural mechanism underlying physical and psychological self-related processing, little is known about the dynamical temporal features of physical and psychological self-related processing.

With the advantages of high temporal resolution and direct measure of neural activity, event-related potential (ERP) is an ideal methodology for exploring the dynamical temporal features of cognitive processing (Graux et al., 2013, 2015; Pinheiro et al., 2016, 2017). A growing number of ERP studies have provided evidences of the self-relevant effect. For example, the P3 component could be the most noticeable marker of the self-relevant effect, larger P3 amplitude was almost always elicited by self-relevant stimulus (e.g., the subject's own name) than non-self-relevant stimulus (Berlad and Pratt, 1995; Gray et al., 2004; Chen et al., 2013; Humphreys and Sui, 2016). Recent studies also have suggested that the N400 component is sensitive to the meaning processing and memory retrieval of self-concept (Metzler et al., 2014; Fields and Kuperberg, 2015; Coronel and Federmeier, 2016). In addition, the P2 component may also index privileged automatic process of self-related stimulus. Thus, the current study uses ERP measures to investigate the dynamical temporal course of physical- and psychological self-related processing.

Four types of vocal stimuli (subject's own name and other's name uttered by subject's own and other's voices) were recorded as the physical/non-physical and psychological/non-psychological self-related stimuli. We examine the psychological self-relevant effect by comparing the difference between subject's own and other's name (Gray et al., 2004; Gillihan and Farah, 2005; Su et al., 2010), while we examine the physical self-relevant effect by comparing the difference between subject's own and other's voice (Su et al., 2010; Xu et al., 2013; Conde et al., 2015). Moreover, in order to set the experimental design similar to natural situation, our study adopted an oddball paradigm, and the setting of experimental stimuli can well match the stimulus and task properties during physical- and psychological self-related processing. Four types of vocal stimuli were presented as rare and task-irrelevant stimuli. Participants were instructed to distinguish and recognize an 800 Hz pure tone from 1,000 Hz pure tone standard stimuli. Besides, we also conducted a control task with two unfamiliar other's names uttered by two unfamiliar other's voices as small probability and task-irrelevant stimuli, the control task aims to test the controlling effect of unrelated acoustic properties (such as the F0, see Graux et al., 2013; Conde et al., 2015).

Thus, as previous neuroimaging studies demonstrating differences in terms of the neural mechanisms underlying physical and psychological self-processing (Kircher et al., 2000; Lou et al., 2004; Hu et al., 2016), we hypothesized that the physical and psychological self-processing might also elicit different electrophysiological responses in P2, P3, or N400 components, which were sensitive to different types of self-relevant processing (Chen et al., 2011, 2013, 2015a; Metzler et al., 2014; Fields and Kuperberg, 2015). We also hypothesized that there is no statistically significant effect in each condition of control task.

MATERIALS AND METHODS

Participants and Design

Thirty-one undergraduates (eight males), age between 18 and 25 years (M = 21.3 years), participated in the experiment. All participants were native Mandarin speakers without any local accent, right-handed, with normal hearing, normal or corrected-to-normal vision, and no history of neurological or psychiatric disorders. Each participant was given written informed consent prior to the experiment and received a certain amount of money for their reward after the experiment. The experiment

was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Liaoning Normal University. The experiment includes two tasks, and all subjects participated in the experimental task, while only 25 subjects participated in the control task due to the long time interval. Besides, one subject's nose reference was invalid in whole experimental procedure, and the valid trials of two subjects were too less (invalid trials >25%) to accepted in control task. Thus, only 30 valid subjects in experimental task and 22 valid subjects in control task are included in the ERP analysis.

Stimuli and Materials

A pool of voices was recorded by Philips SHM1000 microphone[1] with Adobe Audition CS6 (Adobe Systems Inc., San Jose, CA, USA) at a sampling rate of 44,100 Hz and16-bit resolution 1–2 weeks before the ERP experiment. We created a voice template by a trained female speaker before the recording. Each participant was instructed to pronounce names (subject's own name and names of other subjects in the present study) according to the voice template with neutral prosody, and each name was repeated 10 times. All names are three Chinese characters. The voice materials were further edited to 600 ms in duration and with sound intensity in 70 dB by Audition CS6 and Praat[2]. Finally, four types of vocal stimuli (subject's own name and other's name uttered by subject's own and other's voices) were selected for the experiment. Voice stimuli were gender-matched and have similar mean fundamental frequency (F0) for each participant.

Procedure

An auditory passive oddball paradigm was used in the present study, in which the 1,000-Hz pure-tone was presented 600 times (60%), the 800-Hz pure-tone was presented 80 times (8%), and each set of voice stimuli 80 times (8%). Each trial began with a fixation cross presented for 200 ms, followed by an intertrial interval (ITI) of 300–500 ms. Then, the experimental stimuli (voice stimuli, 800-Hz and 1,000-Hz pure-tones) were presented for 600 ms. The task of the participants was to detect the 800-Hz pure-tone and to press the "F" key on the keyboard with their right index finger if the 800-Hz pure-tone was presented. No responses were required for other stimuli. Each experimental stimulus was followed by a blank with 800 ms duration. There were totally five blocks, and the sequence of stimuli was randomized across conditions in each block.

The whole experiment includes the experimental and control task. The experimental procedures for the two tasks were identical except the set of voice stimuli. During the experiment task, the voice stimuli were one's own name uttered by his/her own voice (ov-on), one's own name uttered by unfamiliar other's voice (uv-on), unfamiliar other's name uttered by own voice (ov-un), and unfamiliar other's name uttered by unfamiliar other's voice (uv-un). During the control task, the voice stimuli were two unfamiliar other's names uttered by two unfamiliar people (uv1-un1, uv1-un2, uv2-un1, and uv2-un2) (see **Figure 1**). Participants were required to do eight trial exercises to familiarize the 800-Hz and 1,000-Hz pure-tones before the formal experiment. Stimulus presentation was accomplished with E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, USA).

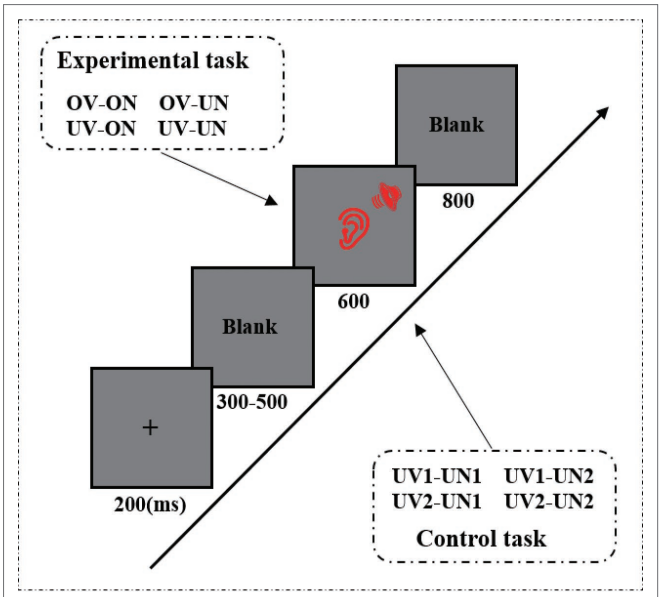

FIGURE 1 | An illustration of the oddball paradigm sequence in a single trial (including experimental task and control task). The only difference between experimental task and control task is that the rare and task-irrelevant stimuli. The experimental task used the ov-on, ov-un, uv-on, and uv-un as task-irrelevant stimuli, but the control task adopted the uv1-un1, uv1-un2, uv2-un1, and uv2-un2 as task-irrelevant stimuli.

ELECTROPHYSIOLOGICAL RECORDING AND DATA ANALYSIS

EEG Recording

Continuous EEG signals were recorded using an "EEGo Sports" EEG system (ANT Neuro, Enschede, the Netherlands) with 65 Ag/AgCl electrodes arranged in an international 10/10 system layout. Additional electrodes were applied on the nose for offline analysis, above and below the left eye to record the electro-oculogram (EOG). The signals were recorded with a sampling rate of 500 Hz. The online reference is CPz and the impedance of each electrode was maintained below 5 kΩ. The EEG data were re-referenced offline to the nose and filtered at 0.1–30 Hz by Butterworth filter.

Data Analysis

The EEG data were pre-processed by the EEGLAB toolbox (Delorme and Makeig, 2004). We visually inspected the EEG data and removed trials containing high amplitude noise, such as large body movements-related high-frequency noise and other

[1]https://www.philips.com.cn
[2]http://www.fon.hum.uva.nl/praat/

easily identifiable confounds such as sudden electrode drifts and jumps. Then, the eye-blinks, saccades, and any other consistent artifacts were removed using independent component analysis (Delorme and Makeig, 2004). Bad channels were interpolated based on the data of neighboring electrodes. And the continuous data were epoched into single trials beginning 200 ms before sound stimuli presentation and ending 800 ms after stimuli presentation. The data were baseline-corrected according to the 200 ms before the onset of sound stimuli. ERP trials with residual artifacts (mean voltage exceeding ±80 μV) were excluded from averaging, and if the number of artifact trials is more than 25% of the total trials, the subject was deleted. Artifact-free ERP trials were averaged separately for each experimental condition.

After a cautious inspection of the topographic maps and grand-averaged ERP waveforms (see Luck and Gaspelin, 2017; Jack et al., 2019), a central N1 (averaged of C3/z/4) in the time-window of 110–210 ms, central P2 (averaged of C3/z/4) in the time-window of 210–310 ms, parietal P3 (averaged of P3/z/4) in the time-window of 310–410 ms, and parietal N400 (averaged of P3/z/4) in the time-window of 420–480 ms were identified. These scalp areas and time-windows are also consistent with the previous literature (see Duncan et al., 2009; Kutas and Federmeier, 2011; Stekelenburg and Vroomen, 2012). Consistent with the experimental task, a scalp central area (averaged of C3/z/4) for the time-window 110–210 ms and 210–310 ms was selected in the control task. As no prominent late components were elicited in the control task, a parietal area (averaged of P3/z/4) for the time-window 310–410 ms and a frontal area (averaged of F3/z/F4) for the time-windows 410–510 ms and 510–610 ms were selected according to the collapsed localizer methods (Luck and Gaspelin, 2017). A two-way repeated measures analysis of variance (ANOVA) was performed on all measured amplitudes for each component. ANOVA factors were the voice identity (two levels: own voice vs. unfamiliar other's voice), voice content (two levels: own name vs. unfamiliar other's name). The ERP results were calculated by the ERPLAB toolbox (Lopezcalderon and Luck, 2014), and the statistical analysis was conducted by the IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA). The degree of freedom of F-ratios was corrected according to the Greenhouse-Geisser method. The Bonferroni correction was used in multiple comparison correction, and the partial eta-squared (η_p^2) was reported as a measure of effect size.

RESULTS

The Results of Experimental Task

The grand-averaged ERP waveforms of four conditions (ov-on, ov-un, uv-on, and uv-un) were illustrated in **Figure 2**, with scalp voltage topographical maps for N1, P2, P3, and N400 components.

N1: The left panel of **Figure 2** shows the grand-averaged ERP waveforms and scalp voltage topographic maps of central N1 component for each condition at Cz electrode. There was neither a significant main effect for the voice identity, $F_{(1,29)} = 0.006$, $p = 0.941$, nor for the voice content, $F_{(1,29)} = 0.598$, $p = 0.446$. There was also no interaction effect between voice identity and voice content ($F_{(1,29)} = 0.061$, $p = 0.807$). These results revealed a similarity of early auditory processing of the four types voice stimuli.

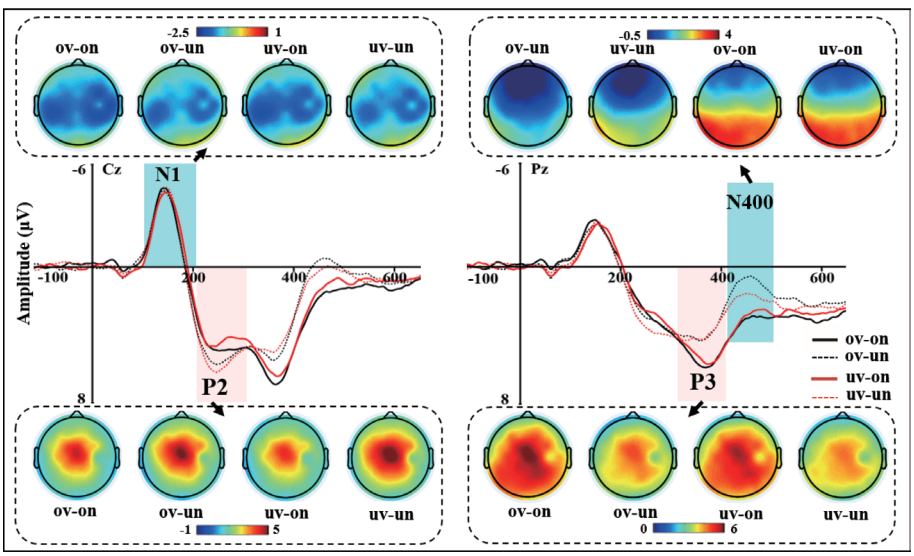

FIGURE 2 | The grand-averaged ERP waveforms at Cz and Pz and the topographic maps of N1, P2, P3, and N400 for four experimental conditions. The light blue bar of left panel highlighted the time-window of the N1 (110–210 ms), no any significant differences were found. The light pink bar of left panel highlighted the time-window of the P2 (210–310 ms). Difference in P2 mean amplitudes between psychological-self and non-psychological-self are shown in the left panel. The light pink bar of right panel highlighted the time-window of the P3 (310–410 ms), difference in P3 mean amplitudes between psychological- and non-psychological-self are also shown in right panel. The light blue bar of right panel highlighted the time-window of the N400 (420–480 ms). Difference in N400 means amplitudes between physical- and non-physical-self are also shown in right panel.

P2: The two-way repeated ANOVA measures for mean amplitude of central P2 component demonstrated significant main effect of voice content ($F_{(1, 29)}$ = 6.496, p = 0.016, η_p^2 = 0.183), own name (3.036 μV) elicited smaller P2 amplitude than other's name (3.641 μV). However, there was neither a significant main effect for voice identity ($F_{(1, 29)}$ = 0.030, p = 0.864) nor significant interaction effect for voice identity and voice content ($F_{(1, 29)}$ = 1.775, p = 0.193) (see **Figure 2**).

P3: The grand-averaged ERP waveforms of P3 at Cz and Pz electrodes and topographic maps of parietal P3 for each condition were showed in **Figure 2**. The two-way repeated ANOVA results showed a significant main effect for voice content ($F_{(1, 29)}$ = 10.399, p = 0.003, η_p^2 = 0.264). Compared to the unfamiliar other's name (3.761 μV), subject's own name (4.941 μV) elicited larger P3 amplitude. It means that psychological-self elicited a larger P3 component than non-psychological-self. However, the main effect of voice identity ($F_{(1, 29)}$ = 0.032, p = 0.860), the interaction effect between voice identity and voice content ($F_{(1,29)}$ = 0.121, p = 0.731), did not reach significance.

N400: The two-way repeated ANOVA results of parietal N400 component demonstrated a significant main effect of voice content ($F_{(1, 29)}$ = 18.737, p < 0.001, η_p^2 = 0.393); unfamiliar other's name (1.450 μV) elicited more negative N400 amplitude than subject's own name (3.165 μV). More importantly, the interaction between voice identity and voice content was also significant, $F_{(1, 29)}$ = 4.691, p = 0.039, η_p^2 = 0.139. The further simple main effect analysis revealed that there is no difference between subject's own voice and other's voice under the own name condition ($F_{(1, 29)}$ = 0.191, p = 0.665), while own voice (1.076 μV) elicited more negative N400 amplitude than other's voice (1.823 μV) under the unfamiliar other's name condition, $F_{(1, 29)}$ = 5.048, p = 0.032 (see **Figure 2**). Besides, the main effect of voice identity failed to reach significance, $F_{(1, 29)}$ = 2.061, p = 0.162.

Taken together, these results indicated that psychological-self elicited a small P2, large P3, and N400 component than non-psychological-self. More importantly, there is an interaction effect between voice identity and voice content, specifically, physical-self (own voice) elicited a more negative N400 component than non-physical-self (other's voice) under the non-psychological-self condition.

The Results of Control Task

The two-way repeated ANOVA measures for mean amplitudes of the five time-windows were performed. The grand-averaged ERP waveforms of four conditions (uv1-un1, uv1-un2, uv2-un1, and uv2-un2) were illustrated in **Figure 3A**, with scalp topographical voltage maps for the five time-windows (see **Figure 3B**). The results showed that there was neither a significant main effect for the voice identity (Fs < 0.582, ps > 0.454) nor for the voice content (Fs < 4.191, ps > 0.053) during the five time-windows. Besides, no significant interaction effect was observed between voice identity and voice content during the five time-windows (Fs < 1.267, ps > 0.273) (**Figure 3**).

DISCUSSION

The present study examined the dynamical temporal features of the physical-self and psychological-self representation using ERP measures. Our results showed that subjects' own name elicited smaller P2 and larger P3 amplitudes compared to other's name, irrespective of the voice identity. However, no P2 and P3 differences were observed between subjects' own voice and other's voice until the late N400 stage, in which a significant voice identity by voice content interaction effect was observed. Subject's own voice elicited more negative N400 amplitude than other's voice under the other's name condition, and no such effect was observed under own name condition. Thus, in addition to previous fMRI studies showing the different neural representation underlying the physical-self and psychological-self (Kircher et al., 2000; Hu et al., 2016), the present study further demonstrated different temporal features of physical-self and psychological-self representation using ERP measures.

The N1 component reflects the early auditory processing of the physical properties of the voice stimulus (Naatanen and Picton, 1987). In our current study, neither main effects nor interaction effects were observed at N1 stage perhaps due to the mean fundamental frequency (F0) was matched, and the voice intensity and duration were identical for the four types of voices for each participant.

Meanwhile, the present study found that subject's own name elicited a smaller P2 component than unfamiliar other's name, irrespective of the voice identity. It has been suggested that the P2 component reflects a selective attention (Chen et al., 2015b, 2017), a small P2 component may reflects an automatic attention. Minati et al. (2010) also confirmed that a melody-like sound sequence elicited a reduced P2 component than a random-generated sound sequence (Minati et al., 2010). Similar effects were also found in the Chinese phonograms processing. Hsu et al. (2009) found that characters with high combinability and high consistency elicited smaller P2 amplitude than low combinability and low consistency characters (Hsu et al., 2009). The high combinability and consisting obtained a more automatic process, which demonstrated a less positive P2 effect. Analogously, unlike unfamiliar other's name that processed in phoneme unit, subject's own name may be processed in syllable unit due to the binding effect of self (Sui and Humphreys, 2015). The decreased amplitude observed for own name suggest an easier detection and processing of the own name relative to the other's name in auditory presented condition and indicates that psychological-self and non-psychological-self was discriminated at an early auditory attentional processing stage.

More importantly, our results demonstrated that subject's own name elicited a larger P3 component than unfamiliar other's name, irrespective of the voice type. In other words, the psychological-self elicited a larger P3 component than non-psychological-self. As previous studies claimed that the P3 component is a significant index of psychological self-representation, significant P3 component was elcitied even

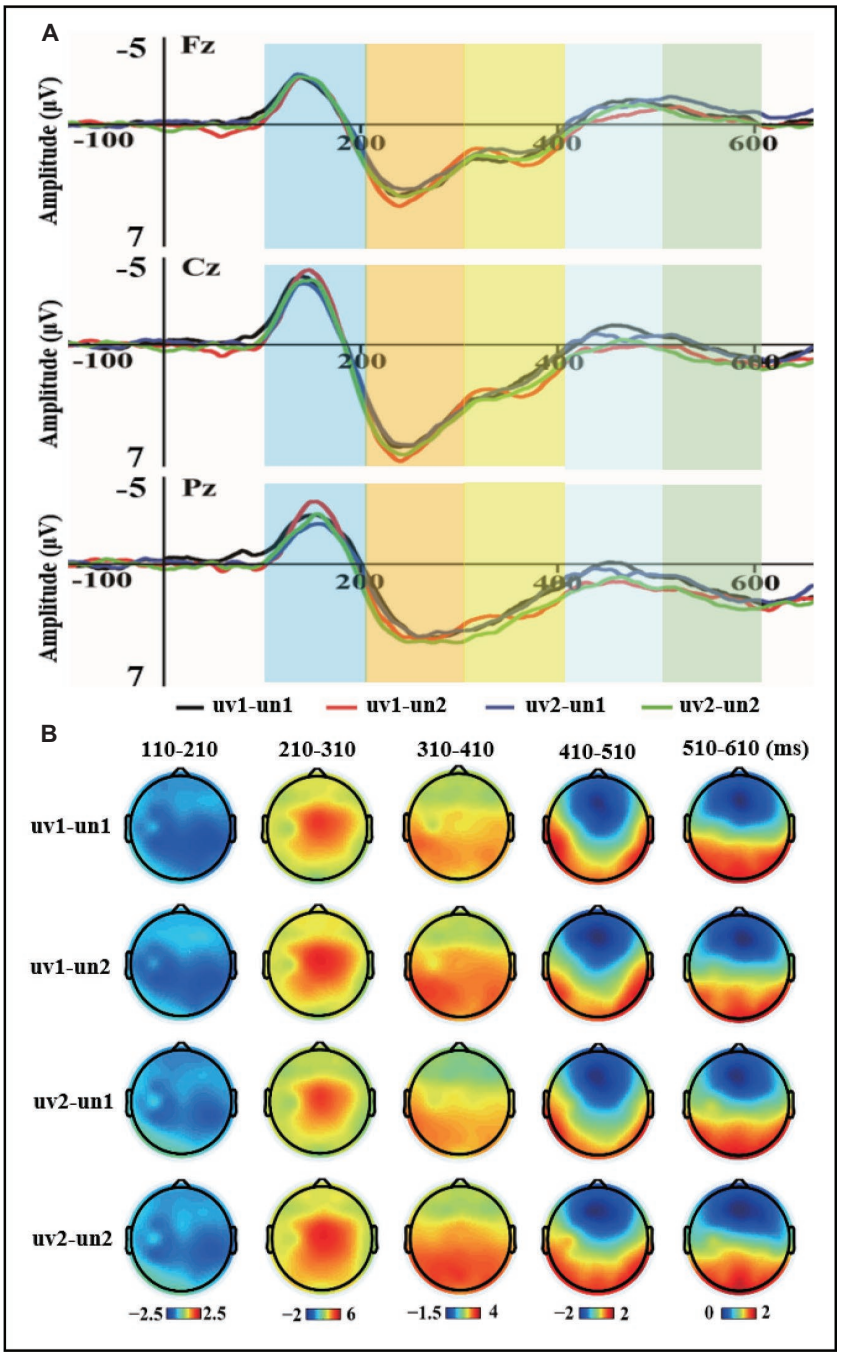

FIGURE 3 | The grand-averaged ERP waveforms at Fz, Cz, and Pz and the scalp voltage topographic maps of five time-windows for four conditions. **(A)** The grand-averaged ERP waveforms with different color bars for five time-windows were shown in the upper panel. **(B)** The scalp voltage topographic maps of five time-windows for four conditions were shown in the bottom panel.

when participants was passive hearing their own name under either sleep or minimally conscious state (Perrin et al., 1999, 2006). It has been suggested that the P3 is related to attentional resource allocation (Polich, 2007), the larger P3 amplitude of psychological-self suggest that the psychological self-recruits a larger amount of attention resource than non-psychological-self. Moreover, this finding is consistent with previous studies that used other psychological-self-related stimuli, such as autobiographical information (Berlad and Pratt, 1995; Gray et al., 2004; Chen et al., 2011) and possessive pronouns (Zhou et al., 2010). Thus, the larger P3 effect of psychological-self could be illustrated by the fact that psychological-self evoked enhanced saliency and motivational expression.

Moreover, there was an interaction effect observed between voice identity and voice content on the N400 component. Subject's own voice elicited more negative N400 amplitude than other's voice when the voice content was other's name, whereas no difference was observed between self and other's voices when the voice content was subject's own name. In other word, an obvious self-voice effect (physical self-relevant effect) was occurred when the voice content was other's name. The N400 component was first proposed by Kutas and Hillyard, which typically occurs between 200 and 500 ms and maximal over the scalp of central-parietal sites (Kutas and Hillyard, 1980; Kutas and Federmeier, 2011). Some studies suggest that the N400 reflects the semantic violation, which usually elicits more negative N400 amplitude (Baetens et al., 2011; Kiang et al., 2017). One more general opinion proposes that the N400 indexes the access to long-term memory (Kutas and Federmeier, 2011). When participants starting to detect and identify their own voice, the heard record voices are not totally same as their own voices heard naturally due to different sound conducting ways. Specifically, we hear recorded sounds *via* air conduction only, whereas hearing own natural voice *via* both air and bone conduction (Graux et al., 2013). Thus, subjects' own voices detected during the experiment was not totally and absolutely consistent with those stored in long-term memory, which might contribute to the larger N400 for subjects' own than others' voices when voice contents were others' names. However, no N400 differences were observed between subjects' own and others' voices when voice contents were subjects' own names. It was more likely because that the preference of processing subjects' own names (psychological-self) inhibited the processing of subjects' own voices (physical-self).

Furthermore, using unfamiliar others' names uttered by different unfamiliar others' voices as voice stimuli, the control task showed no significant main effects or interaction effects during the 110–210, 210–310, 310–410, 410–510, and 510–610 ms time intervals. Moreover, all vocal stimuli have similar mean fundamental frequency (F0) for each participant. Thus, these results might reflect that the psychological self-related and physiological self-related effects observed in the experimental task was due to the self-relevance rather than the acoustic properties of these voice stimuli.

In conclusion, the results of this study suggest that the psychological self-effect appeared in both the early P2, P3, and late N400 stages, while the physiological self-effect did not appear until the late N400 stage. Consistent with previous neuroimaging studies, the present study demonstrated a different temporal pattern between physical and psychological self-representation.

ETHICS STATEMENT

The experiment was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Liaoning Normal University. Each participant was given written informed consent prior to the experiment.

AUTHOR CONTRIBUTIONS

LL, JC, and JL designed the study. LL, JC, WL and JL wrote the the manuscript. LL, JC, WL and LNL carried out all data analyses. LL, LNL conducted data collection. All authors contributed to and approved the final version of the manuscript.

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Effect of Probability Information on Bayesian Reasoning: A Study of Event-Related Potentials

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People often confront Bayesian reasoning problems and make decisions under uncertainty in daily life. However, the time course of Bayesian reasoning remains unclear. In particular, whether and how probabilistic information is involved in Bayesian reasoning is controversial, and its neural mechanisms have rarely been explored. In the current study, event-related potentials (ERP) were recorded from 18 undergraduates who completed four kinds of Bayesian reasoning tasks. It was found that compared with the high hit rate task, the low hit rate task elicited more significant N1 (100∼200 ms) and N300 (250∼350 ms) components, suggesting that N1 might be associated with the attention to stimulus materials, and N300 might be associated with the anchor to hit rate. In contrast to the low base rate task, the high base rate task elicited more significant late positive components (LPC, 350∼700 ms), indicating that LPC might reflect the adjustment of probability estimation based on the base rate. These results demonstrate that both the base rate and hit rate play significant roles in Bayesian reasoning, and to some extent, these findings verify that people may follow the "anchoring-adjustment" heuristic in Bayesian reasoning. The current findings provide further proof for the information processing mechanism of Bayesian reasoning.

Keywords: Bayesian reasoning, base rate, hit rate, ERPs, "anchoring-adjustment" heuristic

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INTRODUCTION

People are prone to adjust the existing point of view according to new emerging information or evidence to make an appropriate judgment and decision under conditions of uncertainty, called Bayesian inference (Samuel and Wu, 2000). Although Bayesian reasoning is vital in our daily lives, the performance by an individual is poor. The Bayesian reasoning problem textual paradigm (Gigerenzer and Hoffrage, 1995) is as follows:

The probability of breast cancer in the population is 1% for a woman who participates in a routine screening. If a woman has breast cancer, the probability that she will have a positive mammography is 80%. If a woman does not have breast cancer, the probability that she will also have a positive mammography is 9.5%. If a woman in this group had a positive mammography, what's the probability that she has breast cancer?

The probability information can be written according to Bayes' rules:

$$P(d|h) = \frac{P(h)\,P(d|h)}{P(h)\,P(d|h) + P(-h)\,P(d|-h)}$$

In the equation above, P(h) stand for the base rate as 1%, P(d|h) represents the hit rate as 80%, P(d|−h) is the false alarm rate as 9.6%, and P(h|d) is the posterior probability. Whether people follow the Bayesian rules in the Bayesian reasoning process has been widely debated since Edward initially researched the Bayesian reasoning process in the 1960s (Edwards, 1968; Slovic et al., 1976; Gould, 1992; Tang and Shi, 2011). Tversky and Kahneman (1974) introduced the concept of "base rate neglected" to explain the human reasoning process and they argued that people ignored the base rate 1% when did the Bayesian reasoning problems then made an overestimate result. Samuel and Wu (2000) suggested that people didn't follow the Bayesian rules when did calculation in the reasoning process and they proposed "to assume a probability value – to find the evidence – to modify the probability value," or "anchoring and adjusting" strategy for short, might be the main strategy of human reasoning (Shi and Zhang, 2009). However, whether probabilistic information is fully involved in Bayesian reasoning and whether its calculations follow Bayesian criteria are not supported by empirical evidence.

As a kind of classical probabilistic reasoning, Bayesian reasoning consists of the selection and processing of various probabilistic, and arithmetic information. However, the time course of Bayesian reasoning in the context task is still unclear, whether the base rate and hit rate were used in Bayesian reasoning and whether the calculation of probability information follows Bayesian rules was deduced reversely, and indirectly on the basis of reasoning results for the subjects in existing studies. Researchers found that the fixation time of the probability information can reflect the attention and use of the information and confirmed the possibility to speculate on the reasoning process of the subjects (Cohen and Staub, 2015; Reani et al., 2017). An eye movement study that monitored and analyzed the time course in the reasoning process revealed that people did not neglect the base rate and presented three stages of the Bayesian reasoning process. Stage 1 is the problem representation stage, in which attention to stimulus materials is involved in the reasoning process; Stage 2 consists of information integration and the selection of probability estimation strategy, in which people construct and select the "anchoring and adjusting" probability estimation strategy; and Stage 3 is the probability judgment stage (Shi et al., 2015).

Event-related potential (ERP) techniques have been applied to observe the time course of higher-level cognitive functions in many other studies, such as reasoning, problem solving, etc., as these techniques can provide a visual indicator for information processing (Liang et al., 2010). Some related ERP components were identified and discussed. Chen et al. (2005) adopted ERP to explore the neural mechanism of inductive reasoning and found that the amplitude of the late positive component (LPC) for the inductive task was significantly higher; namely, subjects consumed more cognitive resources and mental energy when conducting inductive tasks. Similarly, the LPC and N2 (200 ∼ 300 ms) amplitudes were also found to be positively correlated with the input amount of psychological resources in series Bayesian reasoning studies (Kolossa et al., 2015; Kopp et al., 2016; Seer et al., 2016). An urn-ball task was used to investigate the neural bases of the cognitive processes of Bayesian reasoning. The LPC (P3a, P3b, and slow wave) provided dissociable measures of the Bayesian reasoning process, and the N2 (N300) component was stronger when the prior probability could not be computed (Seer et al., 2016). This research did not address the N2 wave and attributed the prior probability to the P3a wave.

In many other studies, the N2 (N300) components were related to the anchoring effect. The prior probability cannot be computed means the anchoring effect needs more cognitive resources and arouses stronger N300. The study of Qu et al. (2008) provided strong evidence for the anchoring effect related to N300, and the N300 and LPC were aroused by psychological scale and reflected the same psychological component – psychological calculation, thus supporting the anchor adjustment heuristic model. Additionally, N300 was detected to be a representation of algorithmic feature recognition and selection (Zhou et al., 2006). However, Kolossa et al. (2015) provided an example for us to combine the ERP techniques and the context Bayesian reasoning paradigm in this study. In this way, the time procedure of the Bayesian reasoning process was explored, and whether and how probabilistic information is involved in Bayesian reasoning would be tested.

Therefore, this study assumes that: (1) People do not neglect the base rate; thus, both the base rate and hit rate information plays an important role in the Bayesian inference process. (2) The calculation of probability information does not follow the Bayesian rules, and the "anchoring – adjustment" heuristic strategy is adopted in Bayesian inference.

EXPERIMENT

Purpose and Hypothesis

The experiment aimed to research how base rate and hit rate effect on the Bayesian reasoning textual paradigm. This study hypothesized that the EEG data shows a significant difference in the amplitude and latency of ERP components induced by high and low level basal rate and hit rate task. (2) The calculation of probability information does not follow the Bayesian rules, and the "anchoring – adjustment" heuristic strategy is adopted in Bayesian inference; therefore, the EEG data showed N300 related to the anchoring effect, whereas the LPC components related to the adjustment procedure.

Materials and Methods

Participants

This experiment was approved by the Ethics Committee of Hunan Normal University in China, and written informed consent was obtained from all participants prior to the experiment. Twenty paid students were recruited from a university for this study, ten males and ten females. The average age of the subjects was 20.55 years, ranging from 19 to 22

years. All participants were right-handed and had no physical or mental illness and had normal eyesight and keyboard operation ability. Two students were removed for showing relatively higher artifacts. Thus, eight males and ten females, whose average age was 20.38 years, were recorded validly.

Materials

This experiment used the classical Bayesian reasoning problem, with two levels of base rate and hit rate, high and low, and a false positive of 10%. The participants needed to make posterior probability estimations based on the probabilistic information given in the problems. Thus, there were four conditions: low base rate and low hit rate (low-low for short), low base rate and high hit rate (low-high for short), high base rate and low hit rate (high-low for short), and high base rate and high hit rate (high-high for short) (Tang and Shi, 2011). In addition, to strictly control the irrelevant variables and meet the needs of the ERP experiment, the experimental materials were reorganized as follows: an integer was chosen randomly as the base rate and hit rate from 70 to 80% (high level) and 1–10% (low level) to construct 100 reasoning problems of each kind, i.e., "low-low," "low-high," "high-low," "high-high," and "high-high." Then, 35 Bayesian reasoning problems were chosen as formal experimental materials for each kind, namely, 140 problems were chosen in total. For example, the "low-high" experiment could be constructed when 1% was chosen as the low-level base rate and 80% as the high-level hit rate, and the probabilistic information in the problems was marked in red to for easier visualization and comprehension in reading (see **Figure 1**).

Procedure

The participants were seated 60 cm away from a computer screen and tasked to estimate the Bayesian problems. Some practices were made prior to the experiment to ensure that the participants could understand and become familiar with the experimental task.

The formal experiment consisted of 2 blocks, and there were 70 questions for each block. The questions were presented in a random order in each block, and the blocks were counterbalanced between participants.

The procedure is illustrated in **Figure 1**. A "+" was shown in the center of the screen at the beginning of a trial for 500 ms, and the Bayesian problem appeared on the screen. The subjects were asked to press the space key within 3000 ms to enter the answer interface and then press the estimated value relying on the integer in 2000 ms. Finally, a 2000 ms empty screen was shown before the next trial began. The tasks were presented in the style of black background and white foreground, except for the two numbers highlighted in red. After each block, the participants were permitted to take a rest for 2 min.

EEG Recording

EEG was collected by 10∼20 system expansion 64-channel electrode caps produced by Brain Products of Germany. The two mastoids in the ears were linked and served as the reference electrodes. Two channels were placed at the outside canthi and downside canthi of oculus dexter to record the horizontal electrooculogram (HEOG) and vertical electrooculogram (VEOG). The impedance of all electrodes was maintained below 5 kΩ. The bandpass of the filtering was set at DC∼100 Hz. The sampling rate was 500 Hz.

ERP Data Analyses and Statistics

After recording the EEG, the offline method was used to analyze the datum. Then, trials with amplitudes over ± 80 μv, after autocorrecting VEOG and HEOG, were observed as artifacts, and removed. The Bayesian reasoning process occurred after the tasks were presented; thus, an epoch from 200 ms prestimulus until 800 ms poststimulus was chosen for analysis, and 200 ms prestimulus served as the baseline. According to the kinds of Bayesian reasoning tasks, the EEG needed to be overlaid and averaged, and trials with artifacts or unfinished tasks were removed. The overlaid times for each kind of task exceeded 30 trails. Based on this study, the total average chart and the voltage topographic map, nine electrode points located in the central part of the brain were selected (FC_Z, FC1, FC2, C_Z, C1, C2, CP_Z, CP1, and CP2) (Kolossa et al., 2015), and a three factors repeated measure variance analysis (ANOVA) of each electrode point was conducted. Three factors included the base rate, the hit rate and the recording spot. The *P* value of variance analysis was revised by the Greenhouse – Geisser method, and the EEG topographic map was drawn based on data from the 64 channels.

RESULTS

Behavioral Results

In this study, the posterior probability was estimated, and the reaction times for four reasoning tasks are given in **Table 1**.

By repeated measures ANOVA of the reaction time, the results indicated that there was no significant main effect of the hit rate and the base rate [$F(1,17) = 0.54$, $p > 0.05$, $\eta_p^2 = 0.03$; $F(1,17) = 0.36$, $p > 0.05$, $\eta_p^2 = 0.02$], and the effect between the base rate and hit rate was significant [$F(1,17) = 7.25$, $p < 0.05$, $\eta_p^2 = 0.30$]. Furthermore, the reaction time in the low-low conditions was significantly less than that in the low-high conditions. The simple effect test showed that the simple effect of the hit rate was significant in the low level base rate condition [$F(1,17) = 7.02$, $p < 0.05$]. The reaction time in the high hit rate task was longer than that in the low hit rate task. The simple effect of the hit rate was not significant in the high level base rate condition [$F(1,17) = 1.60$, $p > 0.05$]. This finding indicates that the effect of the hit rate was affected by the low base rate.

TABLE 1 | The average posterior probability and reaction times for the four reasoning tasks from 18 participants (M ± SD).

Task type	Probability estimates	Response time (ms)
Low base rate – low hit rate	14.92 ± 15.00	1072.21 ± 306.07
Low base rate – high hit rate	35.99 ± 24.60	1162.55 ± 401.19
High base rate – low hit rate	32.69 ± 19.60	1168.17 ± 392.50
High base rate – high hit rate	66.13 ± 14.22	1112.32 ± 371.24

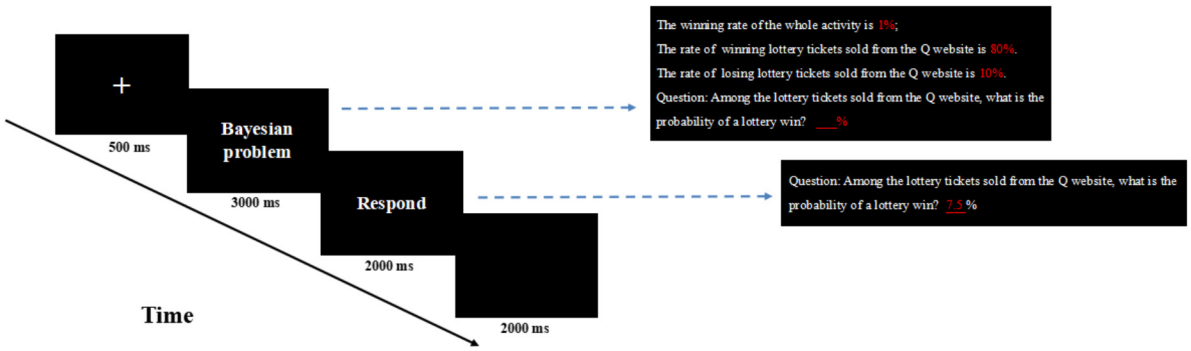

FIGURE 1 | The presentation of the Bayesian reasoning stimulates.

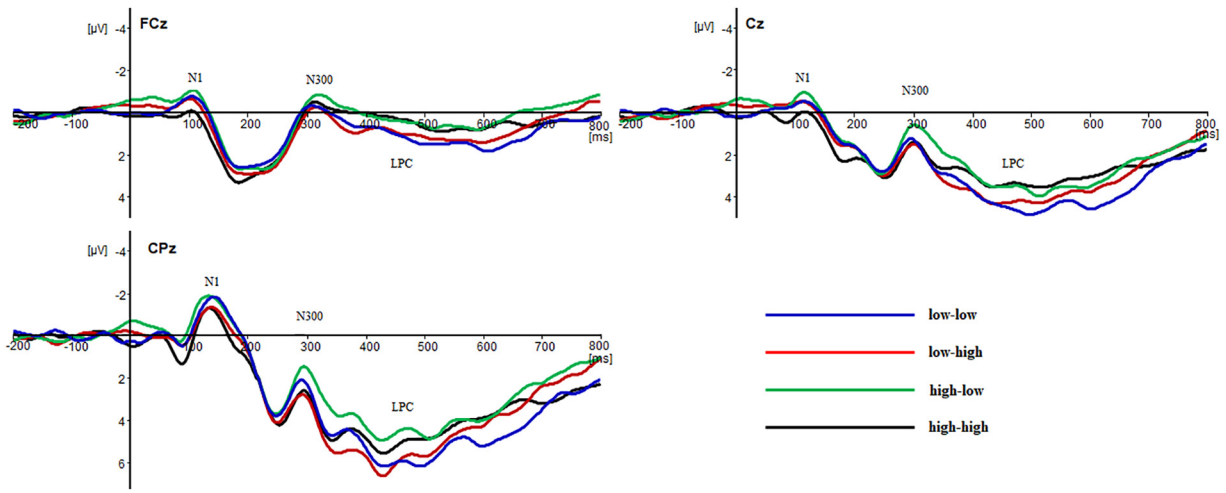

FIGURE 2 | The grand average of event-related potentials (ERP) elicited for the four Bayesian reasoning tasks.

EEG Results

The ERP results induced by the four reasoning tasks are shown in **Figure 2**.

According to the grand mean (see **Figure 2**) and the differential wave topographic map (see **Figure 3**) in this study, 100∼200 ms (N1), 250∼350 ms (N2), and 350∼700 ms (LPC) were identified as time windows for the ERP components analysis, and ANOVA was used to analyze the base rate, hit rate and electrode point. The results were as follows.

The Average Amplitude of the Time Window: 100∼200 ms (N1)

Three factors repeated measures ANOVA of the average amplitude of 100∼200 ms found that the main effect of the hit rate was significant, and the elicited amplitude in the low hit rate task was more negative than that in the high hit rate task [$F(1,17) = 13.89$, $p < 0.01$, $\eta_p^2 = 0.45$]. In addition, the main effect of the electrode point was significant, CPz > FCz > Cz [$F(8,136) = 15.30$, $p < 0.01$, $\eta_p^2 = 0.47$]. The main effect of the base rate was not significant [$F(1,17) = 0.34$, $p > 0.05$, $\eta_p^2 = 0.02$], and the interaction of the base rate and hit rate was not significant [$F(1,17) = 0.87$, $p > 0.05$, $\eta_p^2 = 0.05$]. In addition, there were no significant interaction effects between the electrode point and the base rate [$F(8,136) = 0.45$, $p > 0.05$, $\eta_p^2 = 0.03$] or between the electrode point and the hit rate [$F(8,136) = 0.55$, $p > 0.05$, $\eta_p^2 = 0.03$].

The Average Amplitude of the Time Window: 250∼350 ms (N2)

Three factors repeated measures ANOVA of the average amplitude of 250 350 ms demonstrated a significant main effect of the hit rate, and the elicited amplitude in the low hit rate task was more negative than that in the high hit rate task [$F(1,17) = 7.92$, $p < 0.05$, $\eta_p^2 = 0.32$]. In addition, the main effect of the electrode point was significant, CPz > FCz > Cz, [$F(8,136) = 10.74$, $p < 0.01$, $\eta_p^2 = 0.39$]. However, no significant main effect was observed for the base rate [$F(1,17) = 2.59$, $p > 0.05$, $\eta_p^2 = 0.13$], no significant interaction was observed for the base rate, and the hit rate was not significant [$F(1,17) = 0.07$, $p > 0.05$, $\eta_p^2 = 0.01$]. In addition, the interaction of the electrode point and the base rate was not significant [$F(8,136) = 0.57$, $p > 0.05$, $\eta_p^2 = 0.03$],

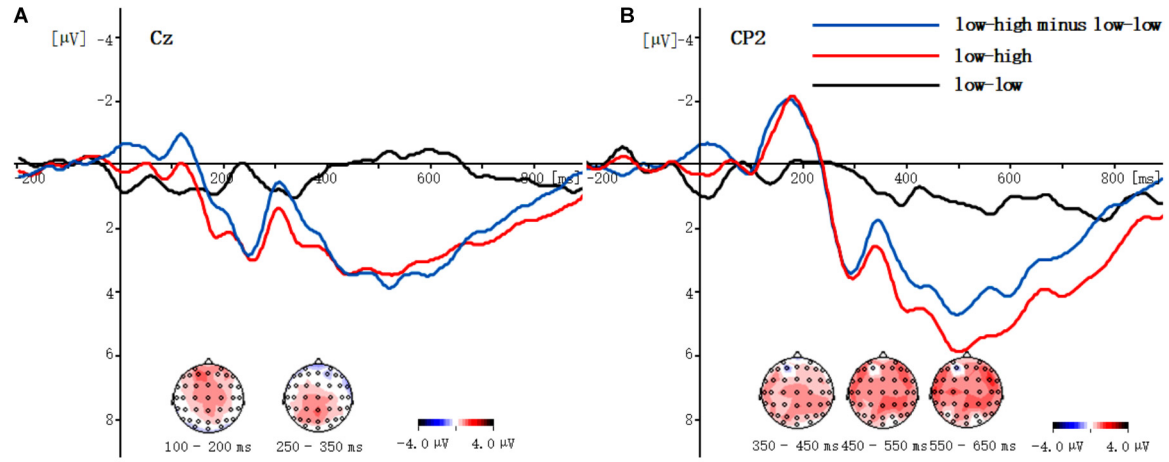

FIGURE 3 | The difference waves in Cz **(A)** and CP2 **(B)** ("low-high" task minus "low-low" task) and the voltage topographic maps.

and the interaction of the electrode point and the hit rate was not significant [$F(8,136) = 1.53$, $p > 0.05$, $\eta_p^2 = 0.08$].

The Average Amplitude of Time Window: 350∼700 ms (LPC)

Three-factor repeated measures ANOVA of the average amplitude of 350∼700 ms indicated that the main effect of the base rate was significant, and the elicited amplitude in the high hit rate task was more positive than that in the low hit rate task [$F(1,17) = 8.77$, $p < 0.01$, $\eta_p^2 = 0.34$]. The main effect of the electrode point was significant, CPz > FCz > Cz [$F(8,136) = 21.45$, $p < 0.01$, $\eta_p^2 = 0.56$], while the main effect of the hit rate was not significant [$F(1,17) = 0.13$, $p > 0.05$, $\eta_p^2 = 0.01$], and there were no significant interaction effect between the base rate and hit rate [$F(1,17) = 0.12$, $p > 0.05$, $\eta_p^2 = 0.01$]. In addition, the interaction of the electrode point and the base rate [$F(8,136) = 0.90$, $p > 0.05$, $\eta_p^2 = 0.05$] and the interaction of the electrode point and the hit rate were not significant [$F(8,136) = 0.78$, $p > 0.05$, $\eta_p^2 = 0.04$].

The Different Wave and Topographic Maps in Different Hit Rate Tasks

Considering the grand mean (see **Figure 2**) and the analyses of the behavioral results, we could see that the effect of the hit rate was affected by the low base rate. Thus, the performance of the subjects in "low-low" and "low-high" tasks was selected to conduct the different wave analysis.

Figure 3A shows that compared to the high hit rate task in the 100∼200 ms time window, the low hit rate task could elicit a more negative component at Cz.

Figure 3B indicates that compared to the low base rate task in the 350∼700 ms time window, the high base rate task could elicit a larger positive component, and the different waves manifested as the LPC at CPz.

Analysis of the topographic maps for the 4 types of tasks every 100 ms. As shown in **Figure 4**, four different types of reasoning tasks activate the temporal lobe, the parietal occipital region and the lateral region of the frontal. Combined with the different wave topographic map in **Figure 3**, it can be further concluded that, compared with the high hit rate task, the low hit rate task mainly activates the prefrontal and the parietal regions. Compared with the low-rate task, the high-rate task activates parts of the parietal, lobi temporalis and frontal lobes.

DISCUSSION

The Role of the Base Rate and Hit Rate in Bayesian Inference

To a certain extent, this study provided new evidence for the fact that both the base rate and hit rate played important roles in Bayesian inference. First, high and low base rate information had a significant influence on the posterior probability estimation, and there were significant differences in amplitude induced by high and low base rate information in LPC. This result showed that the participants pay attention to the base rate information in Bayesian reasoning. Second, in the 100∼200 ms time window, the low hit rate task evoked a more negative component than the high hit rate task, indicating that the brain processing stages underlying the high, and low hit rates were different. Third, in the 250∼350 ms time window, the low hit rate task evoked a more negative component than the high hit rate, and the N300 peak appeared; then, LPC appeared in the next window. This finding might suggest that in Bayesian reasoning, the subjects initially anchored the hit rate information, adjusted up and down in line with the base rate, and then finally obtained the estimated posterior probability value. In this way, the hit rate information was successful at this stage. The current results also showed that the hit rate information was processed earlier than the base rate information in the time course. These results were completely consistent with the results of a previous eye movement experiment (Shi et al., 2015) of Bayesian reasoning,

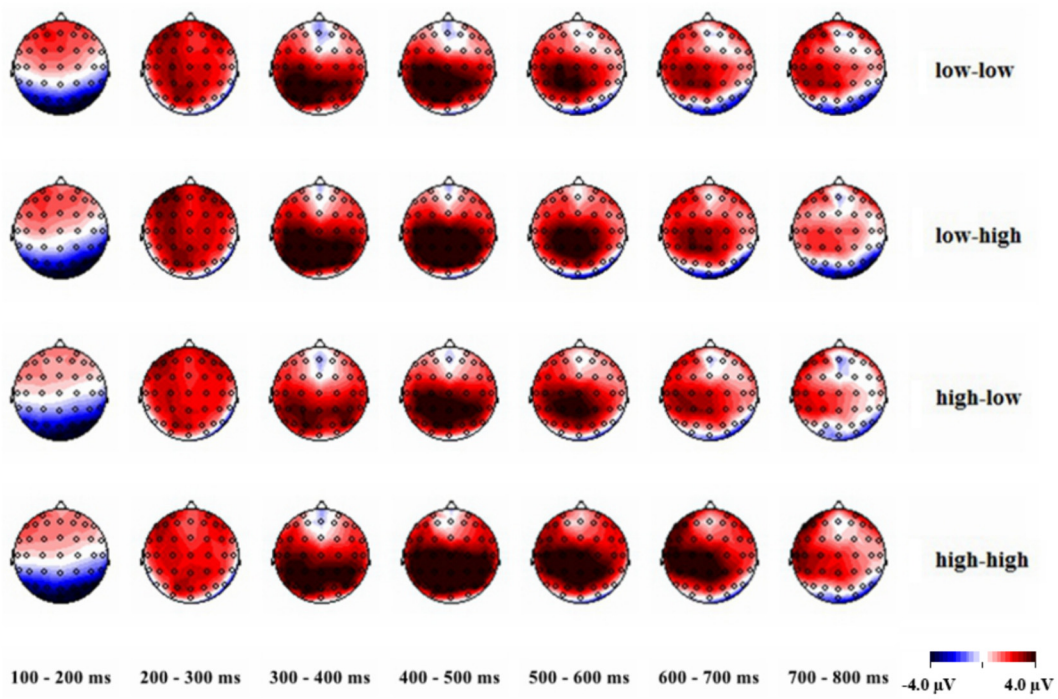

FIGURE 4 | Comparison of the voltage topographic maps for the four different tasks.

namely, the subjects paid more attention to the hit rate than the base rate, indicating that hit rate got processed at a priority. The present study has provided further evidence, different from the eye movement results, from the proposed model of Bayesian reasoning and in accordance with Kopp et al. (2016), suggesting that probability information played an important role in the reasoning task, even in the Bayesian inference textual paradigm, and shows a significant difference in N300 and LPC between the high and low level of the base rate and hit rate.

The "Anchoring and Adjustment" Heuristic in Bayesian Reasoning

Tversky and Kahneman (1974) introduced the concept of the "heuristic method" and used it to explain why the human mind does not conform to the rules of logic. Samuel and Wu (2000) proposed that people may employ the "anchor and adjustment" strategy to conduct Bayesian reasoning. Subsequently, some attempts have been made to verify the proposed strategy/theory for Bayesian reasoning (Zhu and Gigerenzer, 2006; Shi and Zhang, 2009). However, most of these studies mainly conjectured the reasoning process only from the posterior probability and cannot fully explain the "base rate neglected" effect as well as how people reasoned by using the "anchoring and adjustment" heuristic.

Based on previous studies, this study further used the ERP technique to directly examine the Bayesian reasoning process. First, the behavior performance indicates that both the hit rate and the based rate are considered simultaneously during the Bayesian reasoning process, as the two main effects of the base rate and hit rate were significant, and the posterior probability varied with the level of the two kinds of probability information. These results supported the view that "the participants do not ignore the base rate" (Over and Perham, 2002; Shi and Zhang, 2009; Johnson and Tubau, 2015). This idea is also consistent with that of previous studies (Tang and Shi, 2011). Second, the ERP results have provided direct evidence (at least partially) for the "anchoring and adjustment" strategy, as the base rate and hit rate evoked N300 related to the anchoring based on accessibility, and LPC was associated with the anchoring based on adjustment (Qu et al., 2008; Kolossa et al., 2015). This finding indicates that people may adopt an "anchorage-adjustment" strategy in the Bayesian reasoning process, but which components accurately link to the anchoring effect and adjustment effect also need further research.

Three-Stage Model of the Bayesian Reasoning Process

This study provided electrophysiological evidence for the time course of probability information processing in Bayesian reasoning. In the 100∼200 ms time window, compared with the high hit rate task, the low hit rate task elicited a more negative N1 in the frontal region. The N1 components appeared after the stimulation was presented, and was significantly affected by attention, which showed the increase of amplitude. It's related to the visual auditory stimulation and attention. This earlier ERP component might reflect the early visual processing of stimuli in Bayesian reasoning. This result was congruent with a previous study indicating that N1 was associated with the attention to stimulus materials in the reasoning process (Lei et al., 2010).

Kolossa et al. (2015) and Seer et al. (2016) used urn-ball task to investigate the neural bases of Bayesian inference. They argued that the N2 and P3 comonents has been considered to anticipate events and to react to unexpected discrepancies (Hillyard and Picton, 1987). What's more, their researches found that the N2 amplitudes were enhanced when probability informations were unknown. Then, in the 250∼350 ms time window, the difference of N300 elicited by the high or low hit rate information was significant in our research, which might suggest that N300 in this study was associated with the anchor to the hit rate. This explanation is also consistent with the anchoring effect from Qu et al. (2008). In the 350∼700 ms time window, the high base rate task elicited a more significant LPC compared with the low base rate task. According to the current experimental task, it was argued that LPC might be correlated with the adjustment of the probability estimation based on the base rate.

Together, the process of Bayesian reasoning could be divided into three stages: first, Bayesian reasoning tasks were visually processed as reflected by N1. Second, the "anchoring and adjusting" heuristic method was used to solve Bayesian reasoning tasks as reflected by N300 and LPC. Third, the posterior probability was estimated. This idea is consistent with the results from Shi et al. (2015), which suggested the three-stage model by using eye movement technique, we may research this theory next.

In summary, the neural bases and time process in Bayesian reasoning were investigated by combining the classical Bayesian reasoning paradigm with ERPs in this experiment. The present results demonstrated that people did not neglect the base rate in Bayesian inference, and both the base rate and the rate had an important effect on the Bayesian reasoning process. The calculation of probability information did not follow the Bayesian rules, while the "anchoring – adjustment" heuristic strategy was adopted in Bayesian inference. These findings have new implications for an in-depth understanding of the time procedure of Bayesian reasoning as well as the functional role of probability information in the reasoning process.

ETHICS STATEMENT

This experiment was approved by the Ethics Committee of Hunan Normal University in China, and written informed consent was obtained from all participants prior to the experiment.

AUTHOR CONTRIBUTIONS

ZS, LY, and JD contributed to conception and design of the study and wrote the first draft of the manuscript. JD, XM, and BL performed the experimental procedures and organized the participants for the experiments. LY and JD analyzed the data. XM and BL wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Corrigendum: Effect of Probability Information on Bayesian Reasoning: A Study of Event-Related Potentials

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In the published article, there was an error in affiliations 1 and 2. Instead of "Cognition and Human Behavior Key Laboratory of Hunan Province, Changsha, China," and "School of Educational Science, Hunan Normal University, Changsha, China," it should only be "Cognition and Human Behavior Key Laboratory of Hunan Province, School of Educational Science, Hunan Normal University, Changsha, China."

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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The Impact of Self-Relevance on Preschool Children's Sharing

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This study was designed to investigate the impact of self-relevance between preschool children and recipients on children's sharing behavior in dictator games using a forced-choice resource distribution paradigm. Experiment 1: A total of 75 children aged 3–6 years were evaluated in a first-party situation in which they were distributed as recipients and dictators and shared resources with distracting recipients with different extents of self-relevance under three different payoff structures, including non-costly, costly, and envy structures. Children could choose between a sharing option and a non-sharing option. The results showed that, in a first-party situation, children aged 3–6 years old typically share more resources with highly self-relevant recipients (friends) than with moderately self-relevant recipients (acquaintances) and lowly self-relevant recipients (strangers) and that they share more resources with moderately self-relevant recipients (acquaintances) than lowly self-relevant recipients (strangers). Experiment 2: A total of 62 children aged 3–6 years old were evaluated in a third-party situation in which they were distributed not as recipients but only dictators, making decisions between the options of sharing more or sharing less with distracting recipients who had different extents of self-relevance under three different payoff structures, such as non-bias, high self-bias, and low self-bias. The results showed that, in a third-party situation, children typically share in a similar manner to that of Experiment 1, meaning that children display selective generosity and that the self-relevance between the children and recipients played a key role. Across age groups, this study of preschool children (total $N = 137$) demonstrates a degree of effect of self-relevance on preschool children's sharing in first-party and third-party situations, with highly self-relevant recipients receiving a more preferential share in the dictator game than those with low self-relevance, although this effect was stronger in the older preschool children.

Keywords: self-relevance, recipient, resource sharing, preschool children, dictator game

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INTRODUCTION

Sharing behavior is a vital research topic in the field of children's moral and developmental psychology. Sharing resources with others is an important prosocial behavior (Markovits et al., 2003; Steinbeis and Over, 2017). Recently, many studies have focused on sharing behavior in early childhood (Rochat et al., 2009; Svetlova et al., 2010; Baumard et al., 2012; Paulus et al., 2015). The growing focus of these studies was mainly on the many factors that influence

sharing behavior and decisions in young children, including recipients, distributors, objects and situations related to sharing resources (Kanngiesser and Warneken, 2012; Crittenden and Zes, 2015; Kogut et al., 2015; Gasiorowska et al., 2016; Hao et al., 2016; Malti et al., 2016). Rogers first discovered the self-reference effect, he thought the memory effect of the self-associated memory material was significantly better than that of other coding conditions, namely the self-referential effect (Rogers et al., 1977). Symons and Johnson believe that the self-reference effect occurred because the ego was a well-developed and frequently used structure (Symons and Johnson, 1997), which facilitated the fine processing of information (Brown et al., 1986) and tissue processing (Klein et al., 1994). The generation of self-referential effects was related to the degree of development of self-concepts.

A study by Sui and Zhu (2005) found that 5-year-old children already exhibit self-reference effects (Sui and Zhu, 2005). Zhou further found that 4-year-old children already have a self-reference effect (Zhou et al., 2010). Later, some researchers found that 3-year-old children already have a self-reference effect (Mei Haibo, 2013). The above research showed that the self-concept of 3–6 age year children was fully developed, which could not only distinguish themselves from others, but also could produce memory self-referencing processing effects according to this familiarity.

Researchers often described the level of familiarity and association between individuals and others using self-relevance (Farb et al., 2007; Zhou et al., 2017). Researchers often used the IOS scale to measure the degree of self-relevance between individuals and others. Those who scored 5–7 points to be highly self-related (such as close friends), and those who scored 3–4 points were moderately self-related (such as acquaintances), those who will score at 1–2 points for others as low self-related (such as strangers) (Aron et al., 1992; Zhong et al., 2015).

Studies (Fehr et al., 2008; Moore, 2009) have provided evidence that preschool children already react differently to different kinds of recipients in resource allocation tasks and that they are very sensitive to the principle of reciprocity in social interaction and communication (Kenward et al., 2015; Paulus et al., 2015; Lu and Chang, 2016; Mulvey et al., 2016; Paulus, 2016b; Xiong et al., 2016; Scharpf et al., 2017). In resource allocation tasks, children share more generously with in-group members or recipients with similar interests than with out-group members (Sparks et al., 2017). Studies from some western cultures have shown that preschool children tend to share more resources with friends than with mere acquaintances (Costin and Jones, 1992; Rao and Stewart, 1999; Paulus and Moore, 2014), or they share more with friends than with disliked peers, non-friends or strangers (Birch and Billman, 1986; Fehr et al., 2008; Olson and Spelke, 2008). However, recent studies (Scharpf et al., 2016, 2017; Cowell et al., 2017) pointed to cross-cultural differences in young children's sharing. A study from eastern Africa (Scharpf et al., 2017) points out that sharing among young children in Uganda did not depend on the social relationship between the sharer and the recipient. One study (Rochat et al., 2009) indicated that children from a collectivist culture are more likely to share goods with others.

The social relationships from previous theories (Newcomb and Bagwell, 1995) were divided into kin, friends, acquaintances, strangers and disliked peers or enemies. Friends are defined as people with close, interpersonal ties and positive, amiable preexisting relationships (Jehn and Shah, 1997). Acquaintances, strangers, and disliked peers or enemies belong to the group of non-friends. Acquaintances are defined as people with limited familiarity, intimacy and contact. Strangers are defined as people with hardly any familiarity or common experience. Enemies or disliked peers are defined as people with a few common experiences and negative or even contemptuous relationships. However, acquaintances, strangers, and disliked peers or enemies were not strictly distinguished in many previous studies about early sharing. For example, acquaintances were mixed with disliked peers in one study (Moore, 2009), which defined peers who dislike one another yet play together as acquaintances. Additionally, in a number of studies (Birch and Billman, 1986; Costin and Jones, 1992; Olson and Spelke, 2008; Cowell et al., 2017), acquaintances were recipients in resource sharing tasks, but the familiarity and intimacy between participants and recipients were not strictly and systematically manipulated (Blake et al., 2015). Therefore, these studies only compared two levels of relationships between participants and recipients, preexisting and non-existing, such as friends and strangers, and positive and negative relationships, such as friends and disliked peers.

According to the self-relevance concept from China, interpersonal relationships present differences depending on whether a subject is close to oneself or distant from oneself thus; self-relevance should be manipulated to different degrees, such as high self-relevance, moderate self-relevance and low self-relevance (Fan et al., 2013; Tan et al., 2015). One study (Zhong et al., 2015) from China supposed that self-relevance influences prosocial behavior among adults and found that the higher the degree of overlap was between oneself and others, the more obvious the presence of helping behavior. What about the impact of self-relevance on prosocial behavior in preschool children? This study will systemically manipulate self-relevance based on the familiarity and intimacy between distributors and recipients as well as explore the differences when children make sharing decisions about recipients with different degrees of self-relevance, such as friends, acquaintances, and strangers.

In addition to the relationship between recipients and distributors, the situations of resource allocation were thought to affect sharing behaviors among young children. In previous studies, situations based on different payoff structures were mainly divided into non-costly, costly, and envy situations. Studies indicated that children aged 2 years old start to display a strong tendency to share with others (especially with intimate peers) in non-costly situations (Brownell et al., 2009) but that children aged 3–6 exhibit a reduction in sharing and are not willing to sacrifice their own interests when in costly situations (Fehr et al., 2008; Smith et al., 2013). Similarly, children aged 3–8 often refuse to deprive themselves of their own dominant position to choose the option of benefiting

others. Researchers (Brownell et al., 2009) found that children dislike others who get more than them (motivated by social comparison); thus, children are less willing to share with others in envy situations (Shaw et al., 2014; Sheskin et al., 2014; Williams et al., 2014). For example, 5-year-old children will refuse the option of two resources for each child to choose the option of one resource going to themselves and others getting nothing. Therefore, these studies indicate that young children aged 3–6 are very sensitive to situations that affect their payoff. One study (Kanngiesser and Warneken, 2012) indicated that children in early childhood have an ability to take merit into account in third-party situations but that merit-based sharing in first-party situations does not appear until school age. Do young children take self-relevance into account in sharing? Additionally, is there any difference between first-party and third-party situations? Most studies (Rochat et al., 2009; Paulus et al., 2013) demand that young children share a resource between themselves and others in first-person scenarios and rarely exclude the self-interests of participants. Therefore, it remains an open question whether children will behave in accordance with self-relevance when sharing resources in first-person and third-person situations.

EXPERIMENT 1 THE IMPACT OF SELF-RELEVANCE ON PRESCHOOL CHILDREN'S SHARING IN FIRST-PARTY SITUATIONS

Aim and Hypothesis

Aim: Experiment 1 requires participants to share resources between themselves and others and participants also as resource recipients. The study allowed participants to choose "sharing" or "non-sharing" based on three different conditions (non-costly, costly, and envy). The study records the number of times the participants choose to "sharing" with others, and explore the role of self-relevance in participants' sharing behavior.

Hypothesis: Compared with acquaintances and strangers, the participants shared more behaviors with close friends; compared with strangers, the participants shared more behaviors with acquaintances; compared with 3–4 years old children, 5–6 years old children will share more behaviors, which means that the degree of self-relevance in the 5–6 years old children was more stable.

Research Method

Participants

The participants in Experiment 1 consisted of 75 children aged 3–6 years from an urban kindergarten located in China. The participants were divided into two groups based on age: 3–4 years (n = 39, 21 males and 15 females; M = 53.00 months, SD = 5.09, range = 38–58) and 5–6 years (n = 36, 15 males and 21 females; M = 68.19 months, SD = 5.44, range = 60–77). No children were suffering from mental or neurological disorders, and all spoke Chinese as their first language. This study was approved by the ethics committee of Hunan Normal University. Informed written consent was obtained from the parents of all participants. The participants received gifts.

Materials

Experiment design

This experiment used a two-factor mixed design of 3 (self-correlation: high self-related – friends, medium self-related – acquaintance, low self-related – stranger) × self 2 (age group: 3–4 years old, 5–6 years old group). Self-relevance is the intra-group variable, including high, medium, and low levels; the age group is the inter-group variable, including the 3–4-year-old group and the 5–6-year-old group. The dependent variable is the number of times the participants chooses to share generously with the recipient.

Photos of recipients

Photos of friends, acquaintances and strangers served as three different self-relevance recipients, the friends, acquaintances, and strangers selected in this study had the same age as the participants. All photos were standardized at a size of 2.5 × 3.5 cm, containing an image of the head with a neutral facial expression. The genders of the three recipients were matched.

IOS scale

The degrees of self-relevance between oneself and others were measured using the IOS scale. The people whose scores ranged from 5 to 7 were highly self-relevant others (e.g., friends), those whose scores ranged from 3 to 4 were moderately self-relevant others (e.g., acquaintances), and these whose scores ranged from 1 to 2 were lowly self-relevant others (e.g., strangers) (Aron et al., 1992; Zhong et al., 2015).

Food in sharing task

Researchers chose the children's favorite food, M&M chocolates, as the sharing resource. Children were required to rate their preference for the food using a cartoon expression with one of three associate point values (like, neither like nor dislike, dislike) before the experiment (Birch and Billman, 1986; Crittenden and Zes, 2015).

Procedure

Food preference ratings

The experiment was conducted in a quiet room located in the kindergarten. The experimenter provided a sample of food (M&M's, M&M is a chocolate bean in the United States, in 2004, M&M's was named the most favorite food in the United States) to the children. After tasting, the children chose a cartoon expression (like, neither like nor dislike, dislike) to rate the food. If a child reported that they liked the food, the child would continue with the experiment as a participant.

Recipients' selection

First, photos of all classmates were provided, with a corresponding name written on the back of each photo. The participants were asked to find their own photo and divide the other photos into three categories: like, neither like nor dislike, and dislike. Second, the participants chose their three favorite photos from the "like" category, one of which had a score of 5–7 on the IOS scale, indicating high self-relevance,

and was identified as a close friend. Third, the experimenters randomly chose three photos from the "neither like nor dislike" category, one of which had a score of 3–4, indicating moderate self-relevance, and was identified as a regular acquaintance. Finally, the experimenters provided three photos of strangers, one of which had a score (Zhong et al., 2015). In addition, when the experimenters selected photos, they made sure that the three recipients (close friends, acquaintances, and strangers) were the same gender.

Resource sharing task

After the completion of the two procedures above, the participants sat on a chair facing a desk. The experimenters introduced the resource sharing task to the participant and told him/her how to share chocolates with the recipients (close friends, acquaintances, and strangers). The experimenters put the photo of the participant before him and one of recipients' photos opposite him on the desk and then displayed two options (as shown in **Figure 1**). During the experiment, the experimenters not only stated the experimental content but also assisted with the physical operation to help participants understand it. After children decided, the experimenters would record the selected options.

Experiment 1 presented 3 blocks to participants (3–4-year-olds and 5–6-year-olds), which consisted of 9 trials in each block, amounting to 27 trials in total. Each block contained three different trial types according participants' payoff: non-costly, costly, and envy situations, non-costly situations. The experimenter asked the participants to choose between two options [the participant and the recipient, respectively, have a sugar (1/1), the other is the participants have a sugar and the recipient have not a sugar (1/0)], costly situations [the experimenter asked the participants to choose between two options. One option was that the participants and the recipient, respectively, have one sugar (1/1), and the other option was that the participants had two sugars while others had no sugar (2/0)], envy situations [he experimenter asked the participants to make a choice between the two options. One option was that the participant and the recipient did not have sugar (0/0), the other option was that the participant had one sugar and the recipient had two sugars (1/2)]. In each trial, the participants made decisions between two options by using forced-choice resource sharing to form a simple dictator game. The dictator game is a very simple, one-shot decision situation in which the dictator can distribute resources to recipients in any way, and the recipient has to accept the allocation (Gummerum et al., 2008; Moore, 2009; Wilkening, 2009). The orders of the trials and options were balanced between the blocks and participants.

Data Analysis

The experimenter scored the results of the participant selection (Paulus, 2016a). If the participant chooses to share generously with the recipient (friend, acquaintance, stranger) and benefit from others, then the participant will get 1 point in this trial. For example, for costly conditions and non-costly conditions, the participant selects the option (1/1), scores 1 point; the envy condition, the participants select the option (1/2), scores 1 point. If the participant chooses another option and record 0 points. The scores obtained by all the trials of all blocks are accumulated according to the trial type and are regarded as the share scores of the accepted objects.

Experiment 1 mainly investigated the influence of self-relevance on children's sharing behaviors and, specifically, whether higher self-relevance between recipients and participants made it more likely that children would share resources with the recipients. Therefore, this experiment adopts a repeated measure analysis of variance (ANOVA) using a mixed model with two factors, 3 self-relevance (high self-relevance – friends, moderate self-relevance – acquaintances, and low self-relevance – strangers) × 2 age (the 3–4-year-old group and the 5–6-year-old group). The degrees of freedom of the F-ratio were corrected according to the Greenhouse–Geisser method.

Results

Self-Relevance Ratings

The post-experiment assessment using an IOS scale showed a significant main effect of self-relevance in the recipients, $F(2,72) = 1381.54$, $p < 0.001$, $\eta_p^2 = 0.95$; *post hoc* testing revealed the self-relevance scores of friends' recipients to be significantly higher than those of acquaintances recipients and strangers' recipients and the self-relevance scores of acquaintances recipients to be higher than those of strangers' recipients, $p < 0.001$.

Sharing Behavior in Non-costly Situations

Under non-costly conditions, a multiple ANOVA showed a highly significant main effect of self-relevance, $F(2,146) = 30.96$, $p < 0.001$, $\eta_p^2 = 0.30$; *post hoc* multiple comparison

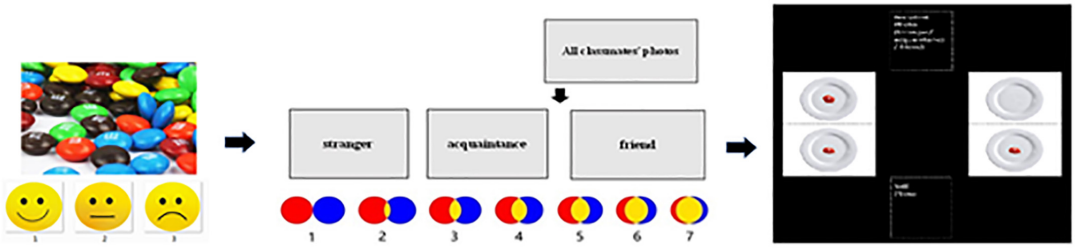

FIGURE 1 | Experimental process.

revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers and that the sharing scores of acquaintances recipients were significantly higher than those of strangers, $p < 0.05$. The main effect of age group was not significant, $F(1,73) = 0.08$, $p > 0.05$, $\eta_p^2 = 0.01$. There were no significant interactions between age and self-relevance, $F(2,146) = 2.30$, $p > 0.05$, $\eta_p^2 = 0.03$.

For the data of the 3–4-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,114) = 10.49$, $p < 0.001$, $\eta_p^2 = 0.22$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients ($p < 0.01$) and strangers' recipients ($p < 0.001$), and there was no significant difference in the sharing scores of moderately self-relevant recipients and lowly self-relevant recipients ($p > 0.05$).

For the data of the 5–6-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,115) = 21.99$, $p < 0.001$, $\eta_p^2 = 0.39$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients ($p < 0.01$) and strangers' recipients ($p < 0.001$), and the sharing scores of acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.001$) (as shown in **Figure 2**).

Sharing Behavior in Costly Situations

Under costly conditions, a multiple ANOVA showed a highly significant main effect of self-relevance, $F(2,146) = 26.17$, $p < 0.001$, $\eta_p^2 = 0.26$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers' recipients, and the sharing scores of acquaintances recipients were significantly higher than those of strangers' recipients, $p < 0.001$. The main effect of age was marginally significant, with children aged 5–6 sharing more than those aged 3–4, $F(1,146) = 3.68$, $p = 0.06$, $\eta_p^2 = 0.05$. There was also a marginally significant interaction between self-relevance and age, $F(2,146) = 2.70$, $p = 0.07$, $\eta_p^2 = 0.04$. Simple effects analysis showed that, for participants aged 3–4, the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients ($p < 0.01$) and strangers' recipients ($p < 0.01$), and the sharing scores of acquaintances recipients were not significantly different than those of strangers' recipients ($p > 0.05$). For participants aged 5–6, the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients ($p < 0.05$) and strangers' recipients ($p < 0.001$), and the sharing scores of acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.01$) (as shown in **Figure 3**).

Sharing Behavior in the Envy Situation

Under envy conditions, a multiple ANOVA showed a highly significant main effect of self-relevance, $F(2,146) = 8.82$, $p < 0.01$, $\eta_p^2 = 0.11$. *Post hoc* multiple comparison revealed

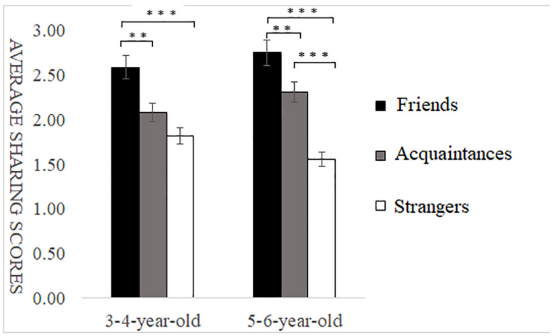

FIGURE 2 | Sharing scores of different types of self-relevant recipients in non-costly situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers' recipients, and the sharing scores of acquaintances recipients were significantly higher than those of strangers' recipients, $p < 0.01$. The main effect of age was highly significant, with children aged 3–4 sharing more than those aged 5–6, $F(1,146) = 16.52$, $p < 0.001$, $\eta_p^2 = 0.19$. There was also a significant interaction between self-relevance and age, $F(2,146) = 4.70$, $p < 0.05$, $\eta_p^2 = 0.06$. Simple effects analysis showed that, for participants aged 3–4, sharing scores were not significantly different among friends' recipients, acquaintances recipients and strangers' recipients ($p > 0.05$). For participants aged 5–6, the sharing scores of friends and acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.01$), and the sharing scores of friends' recipients were not significantly different than those of acquaintances recipients ($p > 0.05$) (as shown in **Figure 4**).

Discussion

Before the resource allocation task, the results of the self-relevance rating between participants and recipients using an IOS scale showed that the scores of self-relevance were extremely significantly different since the scores of highly self-relevant

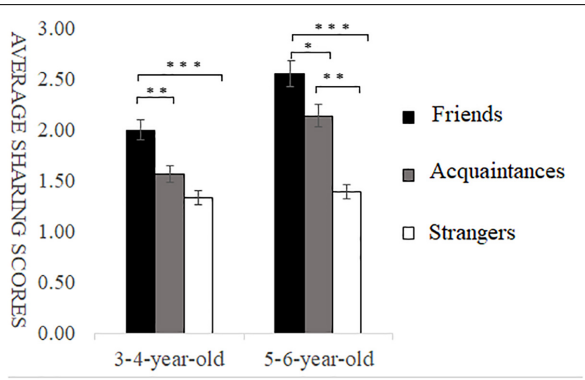

FIGURE 3 | Sharing scores of different types of self-relevant recipients in costly situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

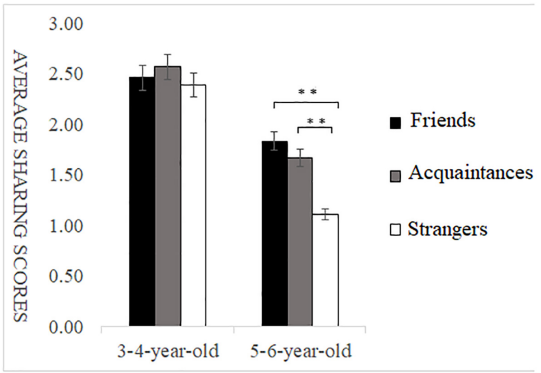

FIGURE 4 | Sharing scores of different types of self-relevant recipients in envy situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

recipients were significantly higher than those of moderately self-relevant recipients, and the scores of moderately self-relevant recipients were significantly higher than those of lowly self-relevant recipients. These results indicate that participants were able to distinguish the different degree of self-relevance among recipients and prove the validity of manipulating self-relevance in the experiment.

In Experiment 1, the results in non-costly situations showed that preschool children shared more with highly self-relevant recipients than moderately self-relevant recipients as well as more with moderately self-relevant recipients than with lowly self-relevant recipients, which indicated that preschool children could not only distinguish the different degree of self-relevance among recipients but also demonstrate different sharing behavior and decisions based on this distinction. Preschool children are able to take self-relevance into account when sharing resources with others. The experimental results bear our hypothesis in the experiment. These results were consistent with those reported in previous research. Previous studies found that children are more likely to share with friends and acquaintances (Birch and Billman, 1986; Fehr et al., 2008; Olson and Spelke, 2008) and that children share more with friends than acquaintances (Costin and Jones, 1992; Olson and Spelke, 2008). These studies showed that early sharing behavior is obviously influenced by the closeness and intimacy of relationships between oneself and recipients and that parochialism plays an important role in early sharing behaviors (Bernhard et al., 2006).

However, the results under non-costly conditions did not reveal a significant difference between the age groups of 3–4 and 5–6. Many studies (Brownell et al., 2009) about early sharing behavior often examined children's sharing behavior in non-costly situations. In resource distribution tasks without a sacrifice of self-interest, young children exhibited a strong tendency for sharing (Olson and Spelke, 2008; Kenward and Dahl, 2011; Baumard et al., 2012). For example, at the age of two, young children have shown a strong willingness to share with others in non-costly situations (Brownell et al., 2009). These studies indicated that children are more willing to share under non-costly conditions. Therefore, participants in non-costly situations tended to share resources at the ages of 3–4 and 5–6, and there was no difference between the two age groups.

Experiment 1 under costly conditions also showed that, when children shared resources with others, the scores of highly self-relevant recipients were significantly higher than those of moderately self-relevant recipients, and the scores of moderately self-relevant recipients were significantly higher than those of lowly self-relevant recipients. These results indicated that, even in situations where participants need to sacrifice self-interest, children still perform differently in sharing behaviors and decisions based on the self-relevance between participants and recipients. The experimental results bear our hypothesis in the experiment. This result is similar to the results in non-costly situations, and the effect of self-relevance on children's sharing behaviors is observed. Unlike in non-costly conditions, the effect of age difference on sharing behaviors was significant in costly situations, with the scores of 3–4-year-old children being significantly lower than those of 5–6-year-old children. This result was consistent with those of previous studies. Other researchers (Thompson et al., 1997) pointed out that, when self-interests are decreased, children's willingness to share is weakened. In costly situations, children will start to occasionally share goods that they gained with others when they are 3 years old. Previous researchers (Ugurel-Semin, 1952) pointed out that children could make the leap to generously sharing with others at the age of 5 or 6. Thus, the loss of self-interest led to the decline of the sharing tendency in children aged 3–4, but children aged 5–6 were still willing to generously share with others. In addition, the results in costly situations showed that children aged 3–4 were able to distinguish highly self-relevant recipients from moderately self-relevant recipients and lowly self-relevant recipients but were unable to distinguish moderately self-relevant recipients from lowly self-relevant recipients; however, children aged 5–6 were able to clearly distinguish among the three different kinds of self-relevant recipients. These results suggest that preschool children could be able to take self-relevance into account when performing sharing behaviors in costly situations. However, in costly situations, children aged 5–6 showed a stronger and steadier degree of effect on sharing behaviors and decisions than did children aged 3–4.

The results of Experiment 1 under envy conditions also showed that scores of highly self-relevant recipients were significantly higher than those of moderately self-relevant recipients, and the scores of moderately self-relevant recipients were significantly higher than those of lowly self-relevant recipients. Thus, even in cases where self-interest advantages were threatened, children still performed differently in sharing behaviors and decisions based on the self-relevance between participants and recipients. The experimental results bear our hypothesis in the experiment. Interestingly, the results in envy situations indicate that there was a significant difference based on age in the sharing behaviors among preschool children, with children aged 5–6 years sharing significantly less than those aged 3–4. Jealousy is a kind of negative feeling experienced by

individuals; when individuals realize others have an advantage that they lack, they display mixed feelings of inferiority, hostility, and resentment (Hart and Behrens, 2013; Mize et al., 2014). Recently, research (Sheskin et al., 2016) pointed out that, when their own resource advantage was threatened, children's sharing behaviors developed very slowly. Children compare themselves to others, and when, they realize others have more resources than them, jealousy is induced (Shaw and Olson, 2012). Awareness of competition will decrease prosocial and sharing behaviors in preschool children (Pappert et al., 2016). In this case, children tend to choose the options favoring themselves and accept the unfair advantage (Blake and Mcauliffe, 2011; Lobue et al., 2011).

In envy conditions, recipients in sharing tasks were peers, which induced strong feelings of envy in the children aged 5–6. Early social comparison emotions, including envy, reduced early prosocial motivation (Steinbeis and Singer, 2013). Fehr and Schmidt (1999) pointed out that, when the participants' income was lower than others, they experienced envy. Therefore, in envy conditions, the sharing behaviors of children aged 5–6 were significantly reduced under feelings of intense jealousy. Even so, the self-relevance of recipients was still considered when children aged 5–6 shared resources. This result indicated that, in envy conditions, children aged 5–6 would make a sharing decision according to self-relevance, and the effect of the degree of self-relevance still exists. However, there was no significant difference among children aged 3–4 in sharing behaviors, and the effect of the degree of self-relevance disappeared. On the one hand, this may be due to the immaturity of self-consciousness and self-relevance among children aged 3–4 (Gerardi-Caulton, 2000). The participants could not distinguish among the three types of self-relevant recipients very well because of their envy. On the other hand, it may be the limitations of recognition (Paulus et al., 2015) that make it so that children aged 3–4 could not distinguish situations that elicited jealousy (Masciuch and Kienapple, 1993). In envy conditions, children aged 3–4 failed to compare themselves with others who faced different payoffs. Thus, the lack of envy generated by social comparison made no difference among these recipients.

The results of Experiment 1 proved that children are more generous to highly self-relevant recipients, regardless of whether in non-costly conditions, costly conditions or, even, envy conditions. This finding suggests that young children are able to distinguish between different self-relevant recipients and discriminate differently in sharing behaviors. This is the effect of the degree of self-relevance on children's sharing behavior. Of course, the effect of self-relevance is steadier in children aged 5–6 than in children aged 3–4.

Experiment 1 investigated the tendency of children to share with different self-relevant recipients when they allocate resources between themselves and recipients. Previous studies (Benenson et al., 2007; Blake and Rand, 2010; Gummerum et al., 2010) have shown that children's sharing behaviors are inevitably disturbed when their own interests are involved, although children exhibit a strong tendency of sharing from an early age. To eliminate the interference of self-interests, participants were asked to allocate resources between two recipients, and participants are dictators but not recipients in Experiment 2. In third-party situations, will children share resources with others according to the self-relevance of recipients?

EXPERIMENT 2: THE IMPACT OF SELF-RELEVANCE ON PRESCHOOL CHILDREN'S SHARING IN THIRD-PARTY SITUATIONS

Aim and Hypothesis

Aim: Experiment 2 requires participants to allocate resources to other people (close friends, acquaintances, and strangers) as distributors and participants no accepted resources. According to the resource allocation paradigm, the study sated three task scenarios (no bias, high self-bias, low self-bias) and each task scenarios provides two distribution options (multiple sharing, less sharing). Last, the study records participants' choice of "multiple sharing" and explore the role of self-relevance in children's sharing behavior.

Hypothesis: Compared with acquaintances and strangers, the participants shared more behaviors with close friends; compared with strangers, the participants shared more behaviors with acquaintances; compared with 3–4 years old children, 5–6 years old children will share more behaviors, which means that the degree of self-relevance in the 5–6 years old children was more stable.

Research Method

Participants

The participants in Experiment 2 consisted of 62 children aged 3–6 years from a kindergarten located in urban China. The participants were divided into two groups based on age: 3–4 years (n = 30, 15 males and 15 females; M = 52.50 months, SD = 3.34, range = 46–59) and 5–6 years (n = 32, 16 males and 16 females; M = 65. 97 months, SD = 2.95, range = 61–71). No children suffered from mental or neurological disorders, and all spoke Chinese as their first language. This study was approved by the ethics committee of Hunan Normal University. Informed written consent was obtained from the parents of all the participants. The participants received gifts.

Experimental Materials

Same as Experiment 1.

Procedure

(1) Food preference ratings (same as Experiment 1).
(2) Recipients' selection (same as Experiment 1).
(3) Resource sharing task (similar to Experiment 1).

The difference between Experiments 1 and 2 at this step is that participants need to allocate chocolates to two recipients (close friends, acquaintances, and strangers), but participants themselves are not recipients. Experiment 2 presented 3 blocks of 27 trials in total in the same manner as Experiment 1. Each block contained three different trial types according to participants' payoffs: non-bias, high self-bias, and low self-bias. For example, participants made the decision between a 3/1

option and a 1/3 option in non-bias trials (under the non-bias condition, there were two options for the participant, one option 3/1 was to give the friend three sugars and give the acquaintance a sugar, the other option 1/3 was to give the friend a sugar and give the acquaintance three sugars), between a 3/1 option and a 2/2 option in high self-bias trials (under the high self-bias condition, the participant had two options, one option 3/1 was given friends three sugars and give acquaintances one sugar; the other option 2/2 was, respectively, giving friends and acquaintances two sugars), between 1/3 and 2/2 options in low self-bias trials (under the low self-bias condition, the participant had two options, one option 1/3 was given friends one sugars and give acquaintances three sugar; the other option 2/2 was, respectively, given friends and acquaintances two sugars). In each trial, participants allocated resources to a higher self-relevant recipient and a lower self-relevant recipient. The orders of trials and options were balanced between the blocks and participants.

Data Analysis

The experimenter recorded and coded the participant's decision into sharing scores (Paulus, 2016a). When participants chose an option to benefit one of the recipients, the corresponding recipient would get a score of one. For example, if participants chose to share more (3/1) instead of sharing less (1/3) with higher self-relevant recipients in non-bias trials, then the higher self-relevant recipients would get a score of one. Scores in all trials were calculated according to the trial type, which was considered the sharing scores of the corresponding recipients.

This experiment adopted a repeated measures analyses of variance (ANOVA) using a mixed model with two factors, 3 self-correlations (high self-related – friends, medium self-related – acquaintances, low self-related – strangers) × 2 (age: 3 to 4 years old group, 5 to 6 years old group). The degrees of freedom of the F-ratio were corrected according to the Greenhouse–Geisser method.

Results

Self-Relevance Ratings

The post-experiment assessment using an IOS scale showed a significant main effect of the type of self-relevance in the recipients, $F(2,59) = 1056.91$, $p < 0.001$, $\eta_p^2 = 0.95$. *Post hoc* testing revealed the self-relevance scores of friends' recipients to be significantly higher than those of acquaintances' recipients and strangers' recipients, and the self-relevance scores of moderately self-relevant recipients were higher than those of strangers' recipients, $p < 0.001$.

Sharing Behavior in Non-bias Situations

Under non-bias conditions, a multiple ANOVA showed a highly significant main effect of self-relevance, $F(2,120) = 57.95$, $p < 0.001$, $\eta_p^2 = 0.49$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances' recipients and strangers' recipients, and the scores of acquaintances' recipients were significantly higher than those of strangers' recipients, $p < 0.001$. The main effect of age was not significant, $F(1,60) = 1.07$, $p > 0.05$, $\eta_p^2 = 0.02$. There were no significant interactions between age and self-relevance, $F(2,120) = 0.02$, $p > 0.05$, $\eta_p^2 = 0.001$.

For the data of the 3–4-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,87) = 31.53$, $p < 0.001$, $\eta_p^2 = 0.52$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers' recipients, and the scores of acquaintances recipients were higher than those that of strangers' recipients ($p < 0.001$).

For the data of the 5–6-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,93) = 27.42$, $p < 0.001$, $\eta_p^2 = 0.47$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers' recipients ($p < 0.001$), and the scores of acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.01$) (as shown in **Figure 5**).

Sharing Behavior in High Self-Bias Situations

In high self-bias conditions, a multiple ANOVA showed a significant main effect of self-relevance, $F(2,120) = 33.88$, $p < 0.001$, $\eta_p^2 = 0.36$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients and strangers' recipients, and the scores of acquaintances recipients were significantly higher than those of strangers' recipients, $p < 0.001$. The main effect of age was not significant, $F(1,60) = 1.07$, $p > 0.05$, $\eta_p^2 = 0.02$. There were no significant interactions between age and self-relevance, $F(2,120) = 1.60$, $p > 0.05$, $\eta_p^2 = 0.03$.

For the data of the 3–4-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,87) = 10.83$, $p < 0.001$, $\eta_p^2 = 0.27$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients ($p < 0.001$) and acquaintances recipients ($p < 0.01$) were significantly higher than those of strangers' recipients and that there was no significant difference between highly self-relevant recipients and acquaintances recipients ($p > 0.05$).

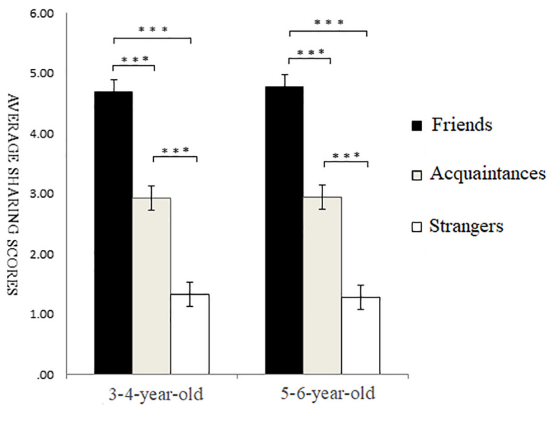

FIGURE 5 | Sharing scores of different types of self-relevant recipients in non-bias situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

For the data of the 5–6-year-old participants, the one-factor ANOVA of self-relevance showed a highly significant main effect of self-relevance, $F(2,93) = 24.37$, $p < 0.001$, $\eta_p^2 = 0.44$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients were significantly higher than those of acquaintances recipients ($p < 0.01$) and strangers' recipients ($p < 0.001$), and the scores of acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.001$) (as shown in **Figure 6**).

Sharing Behaviors in Low Self-Bias Situations

In low self-bias conditions, a repeated measures ANOVA showed a highly significant main effect of self-relevance, $F(2,120) = 26.72$, $p < 0.001$, $\eta_p^2 = 0.32$. *Post hoc* multiple comparison revealed that the sharing scores of friends' recipients and acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.05$), and there was no significant difference between friends' recipients and acquaintances recipients ($p > 0.05$). The effect of age was not significant, $F(1,60) = 0.001$, $p > 0.05$, $\eta_p^2 = 0.001$.

There was also a marginally significant interaction between self-relevance and age, $F(2,120) = 2.76$, $p = 0.06$, $\eta_p^2 = 0.05$. Simple effects analysis showed that, for participants aged 3–4, the sharing scores of friends recipients and acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.05$), and there was no significant difference between friends recipients and acquaintances recipients ($p > 0.05$); for participants aged 5–6, the sharing scores of friends recipients and acquaintances recipients were significantly higher than those of strangers' recipients ($p < 0.001$), and there was not significant difference between friends recipients and acquaintances recipients ($p > 0.05$) (as shown in **Figure 7**).

Discussion

To eliminate the interference of self-interest, participants were distributors but not recipients of resources in Experiment 2. The results in non-bias conditions showed that children aged 3–4 and aged 5–6 both clearly distinguished among highly self-relevant, moderately self-relevant and lowly self-relevant recipients, and effects of the degree of self-relevance appeared in preschool children's sharing behaviors, which is in accordance with the experimental hypothesis. Some studies point out that children share more generously with in-group recipients than with out-group members (Olson and Spelke, 2008; Moore, 2009; Sparks et al., 2017). Usually, highly self-relevant recipients are closer to oneself and more likely to belong to in-group recipients. Lowly self-relevant recipients are more likely to belong to out-group members. When choosing between options without any bias, children will choose to share more resources with those recipients who have higher self-relevance.

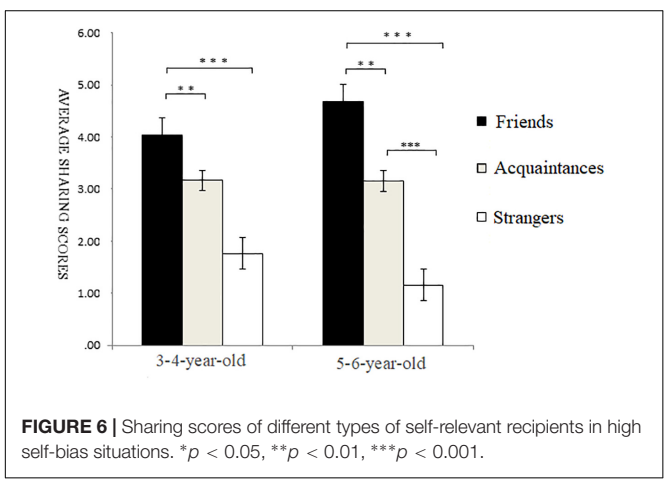

FIGURE 6 | Sharing scores of different types of self-relevant recipients in high self-bias situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

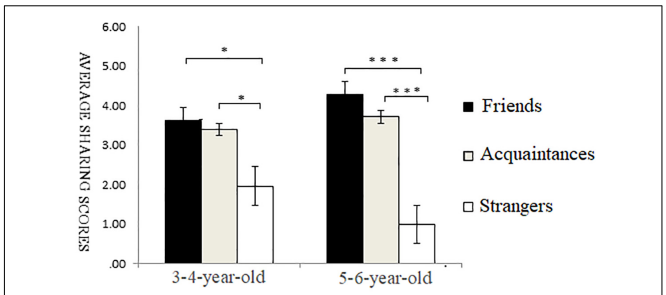

FIGURE 7 | Sharing scores of different types of self-relevant recipients in low self-bias situations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The results from the high-self bias situations show that children clearly distinguished between highly self-relevant, moderately self-relevant, and lowly self-relevant recipients, and the effect of the degree of self-relevance appeared in preschool children's sharing behaviors, which is in accordance with the experimental hypothesis and the results in the non-bias conditions. However, the results of the data of participants aged 3–4 showed that they could not distinguish between more highly self-relevant recipients and moderately self-relevant recipients, but the results of the data of participants aged 5–6 showed that they could distinguish among all three types of self-relevant recipients. This result indicated that children aged 5–6 could better share resources according to the self-relevance of recipients than children aged 3–4. The effect of the degree of relevance became steadier as the children developed.

The results in low self-bias conditions found that children aged 3–4 and children aged 5–6 could distinguish the highly self-relevant recipients from the lowly self-relevant recipients and distinguish the moderately self-relevant recipients from the lowly self-relevant recipients. However, neither could distinguish the highly self-relevant recipients from the moderately self-relevant recipients. In low self-bias conditions, one option provides more resources to the lower self-relevant recipients. This tendency to provide an advantage of resources to the lower self-relevant recipients may betray children's psychological preference to in-group recipients (Bauer et al., 2014; Jordan et al., 2014) or higher self-relevant groups (Wood et al., 1996; Thibaut, 2017). In this situation, children may need more cognitive resources to distinguish between highly self-relevant recipients and lowly self-relevant recipients so that the effect of the degree of self-relevance may be decreased in children's sharing.

GENERAL DISCUSSION

More Self-Relevant Recipients, More Sharing: The Effect of the Degree of Self-Relevance on Preschool Children

Experiments 1 and 2 explored the impact of self-relevance on children's sharing behaviors in first-party and third-party situations. The results of Experiment 1 and Experiment 2 both showed that children aged 3–6 could treat recipients differently based on self-relevance. In fact, the higher the self-relevance was, the more sharing that occurred among preschool children. These results were consistent with those of western studies. Previous studies found that preschool children tend to share more resources with friends than mere acquaintances (Costin and Jones, 1992; Rao and Stewart, 1999; Paulus and Moore, 2014) and share more with friends than with disliked peers, non-friends, or strangers (Birch and Billman, 1986; Fehr et al., 2008; Olson and Spelke, 2008). These studies showed that early sharing behavior is obviously influenced by the closeness and intimacy of relationships between oneself and recipients, and parochialism played an important role in early sharing behaviors (Bernhard et al., 2006). Therefore, the results of both experiments showed that preschool children could take the self-relevance of recipients into account. The self-relevance between children and recipients will have an impact on sharing behaviors and decisions.

More Mature Self-Relevance Awareness Develops Gradually: The Effect of the Degree of Self-Relevance on Children's Sharing Behavior Becomes Steadier With Age

The results in the non-costly, costly and envy conditions from Experiment 1 and those in the high self- and low self-bias situations from Experiment 2 showed that children aged 3–4 sometimes could not distinguish between moderately self-relevant and lowly self-relevant recipients and sometimes could not distinguish between highly self-relevant and moderately self-relevant recipients in terms of sharing behaviors. The self-concept and self-consciousness of children aged 3–4 are not mature enough, which leads to the unsteady effect of the degree of self-relevance in sharing behavior. However, children aged 5 to 6 were more likely to share according to the self-relevance of recipients in any situation observed in this study. As age increased, the self-concept and self-consciousness of children aged 5–6 tended to mature. Children could delicately process self-concept and differentiate among the three kinds of self-relevant recipients well. Therefore, the effect of the degree of self-relevance tends to be stable.

In recent years, most studies in psychology seem to be more inclined to support the concept of energy preservation rather than the concept of energy exhaustion (Muraven et al., 2006). For instance, Muraven asked all subjects to perform two different self-control tasks; however, before the second task, the experimental group was told that there was a third more important self-control tasks awaiting them; hence, the subjects in experimental group were observed to give up faster than those in the control group while performing the second self-control task, meaning that an individual might save certain self-control resources for a subsequent more important task (Muraven et al., 1998, 2006). Similar results were obtained in the study of Tyler and Burns (2008, 2009).

In Experiment 2, we examined the impact of self-control resources on deceptive behavior. Participants in the group of depletion of self-control resource had to complete a 15-min color discrimination Stroop task, then perform the operation test, and finally complete the red dot task. The control group participants only needed to complete a simple word recognition task (non-color noun), then perform the operation test, and, finally, finish the red dot task. The subjective assessment results showed that compared to the subjects in the control group, those in the group with depletion of the self-control resource believed that the task was more difficult; however, the differences in the evaluation of the level of effort by the two groups were not significant. These results might indicate that the subjects in the group of depletion of the self-control resource exhibited more deceptive behaviors or tendencies; however, in the previous task of self-control resource consumption (the Stroop task), the self-control resource was not depleted, and reserves of self-control resources were still available to cope with emergency incidents. Hence, our experiments also support the concept of energy preservation. Individuals fail to control themselves without completely depleting self-control resources, which is then followed by increased deceptive behaviors and tendencies.

Strong Self-Interest Awareness: Preschool Children Are Willing to Share Resources in Unrelated Self-Interest Situations

The results from the non-costly situation in Experiment 1 and all results from the third-party situation in Experiment 2 showed a difference based on age. The non-costly condition of Experiment 1 provided two options, one to participants and zero to the recipients (1/0), or one to participants and one to the recipients (1/1). In the non-costly condition from experiment 1, participants would get 1 resource when they chose either of the two options and could not reduce or threaten their own self-interest. This condition is similar to all situations in experiment 2 since participants were not recipients of resources so that all options were unrelated to their self-interest. Research (Scharpf et al., 2017) from Uganda, a collective socialist country in Africa, adopted the same paradigm as our study and found that children aged 4–5 and children aged 6–7 also did not display an age difference in sharing. A cross-cultural study (Rochat et al., 2009) supposed that children growing up in a collectivist social culture are more likely to share to benefit others than those brought up in individualistic cultures, regardless of the age of the children. Chinese children live in a collectivist social culture and are educated based on a tradition of sharing and equity. Children aged 3–4 and aged 5–6 were both willing to share with others when sharing did not reduce their self-interest. Young children are sensitive to self-interest, and

such self-interest influences children's trust and trustworthiness (Reyes-Jaquez and Echols, 2015). Moreover, self-interest impacts children's prosocial behaviors and decisions (Dietz, 2015; Zlatev and Miller, 2016). The results of this study provided more evidence of children's awareness of self-interest. When under conditions related to self-interest in costly and envy situations, differences based on age appear in children's sharing behaviors. These results may indicate that children aged 3–6 have a very strong awareness of self-interest when sharing resources.

ETHICS STATEMENT

This study was approved by the ethics committee of Hunan Normal University.

AUTHOR CONTRIBUTIONS

WZ prepared the experimental procedures. WF and HD analyzed the data and wrote the manuscript. SX and YS performed the experimental procedures and organized participants to the experiments. WZ and MR contributed to the experimental materials. YZ reviewed the manuscript.

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BRIEF RESEARCH REPORT
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The Moderation Effect of Self-Enhancement on the Group-Reference Effect

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Previous studies have documented that people tend to respond faster and memorize better to the in-group traits. It may be particularly manifest for ethnic minorities, due to their salient ethnic identity. However, few studies have explored how the valence of traits modulates the in-group preference effect. The present study examined the impacts of ethnic identity salience and the valence of traits on the group-preference effect among 33 Han Chinese in a Tibetan-dominant area and 32 Tibetan participants in a Han-dominant area. Two weeks before the experiment, we measured the ethnic identity salience of participants in both groups. In the formal experiment, we used the group-reference effect (GRE) paradigm with three encoding tasks. The results showed that, regardless of whether ethnic identity was salient, both groups responded faster to positive traits than to negative traits when evaluating their own group, whereas there were no significant difference between the processing of positive traits and negative traits in the out-group evaluation and font judgment tasks. This suggested a pervasive processing advantage of the in-group positive characteristics. The results imply that self-enhancement motivation had a moderation effect on the GRE, as well as the ethnic identity salience may not be necessary for a GRE.

Keywords: group-reference effect, self-enhancement motivation, social identity, ethnic minorities, salience

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INTRODUCTION

Research on the self can be traced back to the age of ancient Greece. According to Turner et al. (1987), the self-concept includes three basic components: the individual self, the relational self, and the collective self. The collective self reflects the individual's social identity at the group level. A number of studies have reported that the individual's social identity may have an impact on how people process information that is related to themselves, e.g., face recognition (Anastasi and Rhodes, 2005; Chiao et al., 2006; Ng et al., 2015; Marsh et al., 2016) and attitudes toward their in-group (Yang et al., 2008; Li H. et al., 2016).

The group-reference effect (GRE) is a kind of processing advantage (e.g., better memory performance, faster reaction time) to the in-group stimuli over the out-group stimuli (Greenwald et al., 1998, 2003; Johnson et al., 2002; Bennett et al., 2010). The in-group is an extension of the self, and people tend to think of themselves as being similar to their in-group (Smith and Henry, 1996). Therefore, individuals may tend to base in-group judgments on the self (Cadinu and Rothbart, 1996).

Ethnic identity is one of the representative identities that an individual can hold. Existing research has shown that ethnic identity can induce the GRE and result in better recognition

performance (Mamat et al., 2014). Some studies have also demonstrated that the GRE was more obvious when considered in the context of the salience of the ethnic identity. For example, when Tibetans move to a Han Chinese dominant area, their identity would be highly salient. Therefore, a significant in-group (ethnic) memory advantage was observed; however, no such effect was observed for the Han Chinese, who were already dominant in the area (Yang et al., 2008). A study with Tibetan students who lived in a predominantly Tibetan area showed that when ethnic identity was primed, a significant in-group effect on memory performance was present (Li H. et al., 2016). These findings demonstrated that ethnic identity could induce the GRE, and it might be modulated by the salience of the individual's ethnic identity. Therefore, the first aim of the present study was to replicate the modulation effect of the salience of ethnic identity on GRE in Tibetan and Han Chinese who lived where their ethnicity was not dominant.

Based on self-enhancement viewpoints, individuals tend to think that they and their in-group have better personality traits than others and out-groups (Sedikides and Gregg, 2008; Alicke and Sedikides, 2009; Sedikides and Alicke, 2012) while sorting the combination of self/other and positive/negative traits (Brown, 1986; Dunning et al., 1989; Gebauer et al., 2012). Thus, positive traits would be integrated quickly and automatically into the self-concept or the in-group concept. Meanwhile, negative traits would be excluded from the self-concept or the in-group concept (Watson et al., 2007; Cai et al., 2016). This self-enhancement effect can be observed even without any explicit requirement for self-referential appraisal (Herbert et al., 2011). Therefore, people may process positive traits and negative traits differently in the GRE paradigm. However, most studies on GRE did not differentiate the valances of traits. The second aim of the present study was to explore how self-enhancement influences the GRE and examine the interaction between self-enhancement and the salience of ethnic identity.

In the present study, we examined the effect of ethnic identity salience and the valence of the traits on GRE in two groups of participants. One group was Han Chinese, which came from a Tibetan dominant area, the other group was Tibetan, which came from a Han Chinese dominant area. Most studies have used memory performance as the GRE index (Johnson et al., 2002; Yang and Huang, 2007; Bennett et al., 2010; Liu et al., 2015; Lee et al., 2016). However, in the present study we used reaction times (RT) as the GRE index. RT have been well documented as sensitive in differentiating between the in-group's and out-group's attitudes and cognitive processing (Greenwald et al., 2003; Cai et al., 2016). We expected that the GRE effect would primarily occur in positive trait judgments and would be modulated by self-enhancement.

MATERIALS AND METHODS

Participants

Thirty-two Tibetan students (17 female and 15 male, Mean age = 20.25 years, *SD* = 1.34) were recruited from Northwest Normal University and thirty-three Han Chinese students (23 female and 10 male, mean age = 22.56 years, *SD* = 0.77) were recruited from Gansu Normal University for Nationalities. All participants had normal or corrected-to-normal vision, and no participants had any prior experience with this study. All students were paid for their participation. The scientific and research Ethics Committee of the School of Psychology, Northwest Normal University approved the experimental protocol, and written informed consent was obtained from all participants prior to the study. The participants were free to withdraw at any point in the experiment without penalty. If, for any reason, they did not feel comfortable during this study, they could leave the laboratory. Participants were informed that all information they provided would remain confidential and would not be associated with their name. The experiment lasted for approximately 30 min, and participants received feedback regarding their results after they completed the tasks.

Experimental Design

A 3 (encoding task: Han Chinese vs. Tibetan vs. font) × 2 (valence: positive vs. negative) × 2 (ethnic group: Tibetan vs. Han Chinese) mixed experimental design was conducted, with both encoding task and valence as within-subjects variables, and ethnic group as a between-subjects variable. Reaction time was the dependent variable.

Stimulus Material

The stimuli of the current study included 126 (half positive and half negative) personality trait adjectives. The participants first practiced the task with six words (three positive and three negative). The remained 120 words were used in the formal experimental task. The adjectives were selected from existing studies (Zhou et al., 2013; Li S. et al., 2016). All selected words were two-character trait adjectives. We matched the familiarity ($M_{pos.}$ = 5.69, *SD* = 0.94, $M_{neg.}$ = 5.68, *SD* = 1.23), frequency ($M_{pos.}$ = 22.52 per million, $M_{neg.}$ = 20.63 per million) and the number of strokes ($M_{pos.}$ = 16.52, *SD* = 3.73, $M_{neg.}$ = 17.30, *SD* = 4.51) of the words. *T*-test showed no significant differences between the positive and negative words on the three dimensions (*p*s > 0.05). Moreover, the valence of words ($M_{pos.}$ = 5.12, *SD* = 0.64, $M_{neg.}$ = 2.24, *SD* = 0.62) differed significantly between the positive and negative words ($p < 0.05$). In order to avoid mutual interference between the various encoding tasks, each word was presented only once across all judgment tasks. Each word was randomly assigned to one encoding tasks for each participant. 63 positive and 63 negative trait adjectives were evenly distributed across the three encoding tasks.

Experimental Tasks

Participants were asked to perform three encoding tasks, respectively, the in-group encoding task, the out-group encoding task, and the font structure judgment task. In the in-group and the out-group encoding tasks, the participants were asked to make judgments on whether the trait words presented on the screen appropriately described people of their own or another ethnic group. For the Tibetan participants, judgments of Han Chinese was the out-group encoding task; for the Han Chinese, judgments of the Tibetans was the out-group encoding task. As a

TABLE 1 | The mean scores and standard deviance of Reaction time (ms) in three encoding tasks for Tibetan and Han Chinese.

	Tibetan encoding task		Han Chinese encoding task		Font structure task	
	M	*SD*	*M*	*SD*	*M*	*SD*
Tibetan	1537.79	69.95	1726.67	71.46	1661.14	66.75
Han Chinese	1534.29	68.88	1417.78	70.37	1503.82	65.73

control condition, the participants were asked to judge the words' font structure (Are there characters with left-right structure?). Participants responded to each of the stimuli by pressing the appropriate keys. The keys for each of the participants were counterbalanced. Half of the participants were instructed to press "f" for "yes" and "j" for "no," while the other half were given the opposite instructions. All stimuli were randomly presented.

Procedure

Two weeks before the experiment all participants were asked to complete the Twenty Statements Test (Kuhn and Mcpartland, 1954). This test is often used to examine whether one's ethnic identity is salient in their self-schema. The more salient the ethnic identity, the more likely it is to be mentioned (Yang et al., 2008).

Before the formal experimental task, each of the participants performed a six-trial (two trials for each encoding task) practice. The six trials were identical to the formal experimental tasks. The participants' reaction time to the practice trials were not included in the data analysis. Each trial started with a fixation cross at the center of the screen for 500 ms and a follow-up blank screen for 250 ms. Next, a trait adjective was presented together with a label for the current encoding tasks (Han Chinese, Tibetan, or font) above it until the subject made a response. Three encoding tasks were randomly distributed in each of the trials. Then a blank screen showed up for 500 ms before the next trial. The stimuli procedure were programed and presented using E-Prime 2.0. The data were analyzed using the SPSS 21.0.

RESULTS

Ethnic Identity Salience

Tibetan participants showed higher ethnic identity salience than Han participants. In the Twenty Statements Test (Kuhn and Mcpartland, 1954), 29 of the 32 Tibetan participants mentioned their own ethnic identity, such as "I am a Tibetan" or "I am from Tibet." However, only 5 of 33 Han participants mentioned their own ethnic identity, χ^2 (1, N = 65) = 37.10, $p < 0.001$.

Reaction Times

Responses were scored if the appropriate key was pressed between 300 and 3000 ms after the adjective was displayed on the screen. A mixed measures ANOVA was conducted with encoding task and valence as within-subject variables and ethnic group as a between-subjects variable. The results showed that the main effects of encoding task, ethnic group, and valence were not significant Fs < 2.94, ps > 0.05. Also, the interactions between encoding task and valence, and ethnic group and valence were also not significant, Fs < 2.13, ps > 0.05.

However, there was a significant interaction between encoding task and ethnic group, $F_{(2,63)} = 13.59$, $p < 0.001$, $\eta^2_p = 0.18$. A simple effects analysis showed that the trait judgment for the in-group was significantly faster than that for out-group (Bonferroni-corrected ps < 0.001, Cohen's ds ≥ 1.67) for both Tibetans and Han Chinese, and Tibetans also responded faster for the in-group encoding task than for the font encoding task (Bonferroni-corrected $p < 0.01$, Cohen's $d = 1.80$).Whereas there was no significant difference between the out-group and the font encoding tasks (ps ≥ 0.13) (shown in **Table 1** and **Figure 1**). These results suggest that both Tibetan and Han Chinese exhibited the advantage effect of the in-group reference processing.

Importantly, the results also revealed a significant three-way interaction for encoding task, valence, and ethnic group, $F_{(2,63)} = 5.96$, $p < 0.01$, $\eta^2_p = 0.09$. A simple effects analysis comparing valences indicated that for both Tibetans and Han Chinese, participants showed faster RT for the in-group positive traits than that for negative traits (ps < 0.05, Cohen's ds ≥ 0.97). However, there was no significant difference for trait valence both in the out-group (ps > 0.05) and the font encoding tasks (ps > 0.05). These results suggested that the processing superiority effect on the in-group positive traits was apparent for both Tibetans and Han Chinese (shown in **Table 2** and **Figure 2**).

Another simple effects analysis of comparing encoding tasks also showed that for both Tibetans and Han Chinese, judgments for the in-group positive characteristics were significantly faster than that for the out-group characteristics (Bonferroni-corrected

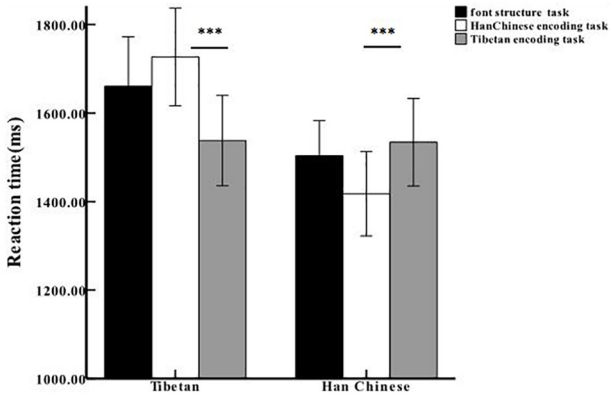

FIGURE 1 | Reaction time in three encoding tasks for Tibetan and Han Chinese. ***$p < 0.001$. Error bars represent one standard error from the mean.

TABLE 2 | The mean scores and standard deviance of Reaction time (ms) of positive and negative adjective in three encoding tasks for Tibetan and Han Chinese.

	Tibetan encoding task						Han Chinese encoding task						Font structure task					
	Positive		Negative		*P*	*d*	Positive		Negative		*P*	*d*	Positive		Negative		*P*	*d*
	M	*SD*	*M*	*SD*			*M*	*SD*	*M*	*SD*			*M*	*SD*	*M*	*SD*		
Tibetan	1502.88	71.94	1572.71	72.06	0.045	−0.97	1722.46	69.49	1730.88	77.87	0.082	−0.11	1688.78	66.04	1633.49	71.50	0.104	0.80
Han Chinese	1549.33	70.85	1519.24	70.95	0.374	0.42	1365.43	68.43	1470.12	76.68	0.005	−1.44	1486.24	65.03	1521.39	70.41	0.291	−0.52

*p*s < 0.001, Cohen's *d*s ≥ 2.64) and the font encoding task (Bonferroni-corrected *p*s ≤ 0.01, Cohen's *d*s ≥ 1.81), and no significant differences between the font and out-group encoding tasks were observed (*p*s ≥ 0.24). For the negative characteristics, Han Chinese showed no significant difference among three encoding tasks for in-group, out-group and font (*p*s ≥ 0.26), however, Tibetan participants showed faster RT in the in-group encoding tasks than in the out-group tasks (Bonferroni-corrected $p = 0.001$, Cohen's $d = 2.11$).

Finally, due to the significant difference of salience of ethnic identity that was found between Tibetan and Han Chinese, we repeated the analyses of reaction time with ethnic identity salience as a covariate variable and similar results were obtained with and without ethnic identity salience in the analyses.

DISCUSSION

The current study explored how self-enhancement motivation and the salience of ethnic identity affected GRE among Tibetan and Han Chinese groups at two universities. Firstly, the results indicated that Tibetan participants had stronger ethnic identity salience than Han Chinese participants, even though Tibetan participants were in a Han Chinese dominant area and the Han Chinese participants were in a Tibetan dominant area. Both groups demonstrated significantly faster RT under the in-group encoding task in comparison to the out-group encoding and font encoding tasks. This was the case regardless of ethnic identity salience and confirmed the existence of the GRE. Most importantly, both Tibetans and Han Chinese exhibited faster RT when judging positive traits, rather than negative traits, in the in-group encoding task. However, in the out-group and the font encoding tasks, no such valence effect was observed. These findings suggested that self-enhancement motivation modulates the GRE.

In the present study, Tibetan participants exhibited higher ethnic identity salience than did the Han Chinese students. These results are consistent with previous findings on ethnic identity for Tibetan groups (Yang et al., 2008; Li H. et al., 2016). The present study's Tibetan participants came from a predominantly Han Chinese university and the Han Chinese participants came from a predominantly Tibetan university. However, Han Chinese is considered the default ethnic category in China, due to being the majority ethnicity, and is seldom reflected upon by its members (Yang et al., 2008), and ethnic identity may not be as salient in the Han Chinese self-concept in comparison to the Tibetan self-concept (Mamat et al., 2014; Li H. et al., 2016). Since Tibetan is an ethnic minority group in China, Tibetan students living in a Han Chinese dominant area may frequently confront issues surrounding their ethnic identity. Thus, ethnic identity may be a salient characteristic of their overall self-concept (Li H. et al., 2016). Illustrating this salience in other groups, Mcguire et al. (1978) demonstrated that Black ethnic minorities in the United States of America spontaneously mentioned their ethnicity when asked to answer the question "Who am I?" Therefore, ethnic identity being

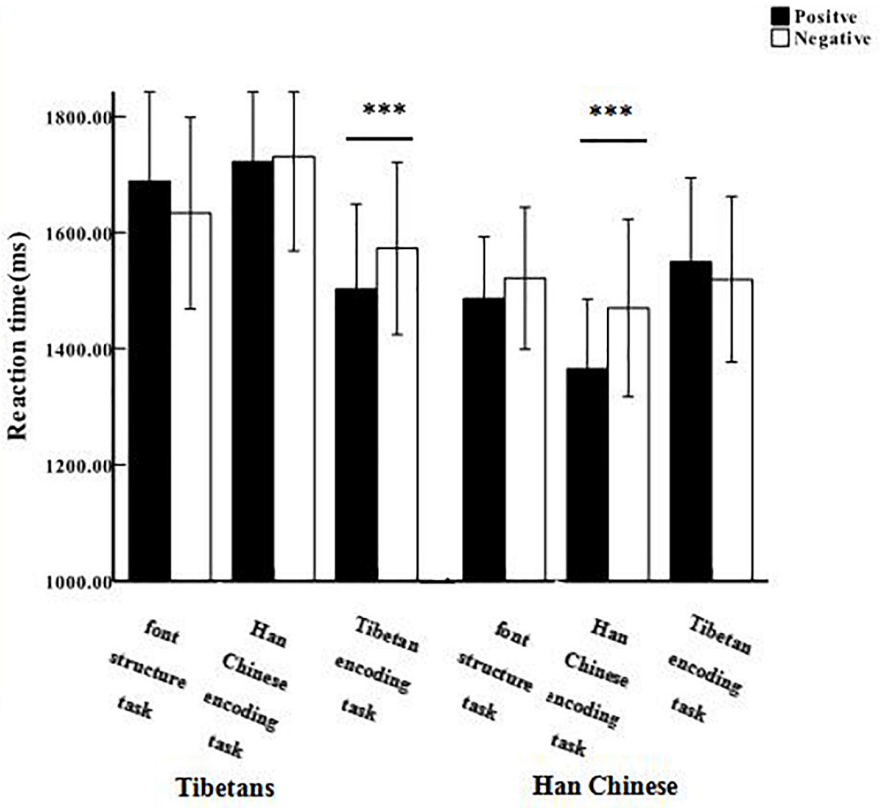

FIGURE 2 | Reaction time of positive and negative adjective in three encoding tasks for Tibetan and Han Chinese. ***$p < 0.001$. Error bars represent one standard error from the mean.

a salient characteristic within the self-concept of minority groups is an over-arching phenomenon and not specific to the Tibetan population.

Regardless of the salience of their ethnic identity, both Tibetans and Han Chinese showed significant GRE in the present study. These results are congruent with previous studies on GRE (Johnson et al., 2002; Bennett et al., 2010). For example, Bennett et al. (2010) reported that in-group referential recall was significantly greater than out-group referential recall. The collective identities (e.g., ethnic) provide a useful organizational framework, which would facilitate memory due to the organizational, elaborative, mental cueing, or evaluative properties of the group-reference encoding task, or the combination of these characteristics (Johnson et al., 2002). The present study further showed that such organizational framework would also facilitate the categorization of the in-group information. However, our results were inconsistent with those of Yang et al. (2008) and Li H. et al. (2016), which demonstrated that Han Chinese participants did not show a significant GRE. One possible explanation for this inconsistency may be the use of a different index in the present and previous studies (Johnson et al., 2002; Bennett et al., 2010; Liu et al., 2015; Lee et al., 2016). In contrast to using memory performance, as done by Yang et al. (2008) and Li H. et al. (2016), RT is a more sensitive index for categorizing and measuring inter-group attitudes (Greenwald et al., 2003; Watson et al., 2007; Gebauer et al., 2012). The present study used RT rather than memory performance and found that Han Chinese participants also showed a significant GRE. This suggested that extrinsic ethnic identity salience might not be a necessary condition for inducing the GRE. It should be noted that the group descriptiveness task itself may highlight ethnic identity and make in-group membership very salient and relevant on a situational level. This may also have contributed to the GRE observed for the two groups in the present study. Further studies are needed to examine whether the GRE depends on which index is used. Also, future studies should use an implicit task to examine how ethnic identity salience affects the GRE.

The present results showed that GRE was modulated by the self-enhancement motivation. Both Tibetans and Han Chinese showed faster judgments for the in-group positive traits than that for negative traits. However, this tendency toward positive response priority was not found in the out-group encoding task or the font encoding task. These results suggested that individuals tend to integrate positive traits more easily than negative traits into their in-group members (Dasgupta, 2004). This tendency of more easily recognizing positive personality characteristics of one's own ethnic group may satisfy their needs for self-enhancement and self-esteem (Sedikides et al., 2013). The pursuit of self-enhancement, which is prevalent across persons, groups, nations, and cultures, promotes and helps to

maintain a positive self-schema (Hepper et al., 2013). Such self-enhancement motivation would lead to the individuals' evaluating their own membership group as more favorable (e.g., inter-group bias), and, sometimes, even to derogate the out-group (e.g., group-serving bias). In-group preference is an essential human characteristic, and in-group favoritism is a form of self-identification (Tajfel and Turner, 1986). People tend to evaluate in-group members more positively, thereby validate their own cultural worldview (Hewstone et al., 2002; Sedikides et al., 2013). Therefore, in-group preference plays an important role in individual survival and social adaptation. An interesting outcome of the present study was that the Tibetan participants responded faster to the negative traits in the in-group encoding task than to those in the out-group or the font encoding tasks. A possible explanation may be that the faster responses to negative traits by Tibetan participant means that they tend to avoid the in-group negative information as quickly as possible. This may further confirm the self-enhancement/self-protection effect.

CONCLUSION

In summary, the present study expanded the findings of the previous research by demonstrating that self-enhancement motivation moderates the GRE. That is, ethnic identity salience may not be necessary for GRE when self-enhancement is considered. Further research should verify the effect of self-enhancement motivation on GRE in different paradigms (explicit vs. implicit) and different contexts (dominant groups vs. non-dominant groups), and examine the different indicators (reaction time vs. memory performance) of GRE.

DATA AVAILABILITY

All datasets generated for this study are included in the manuscript and/or the Supplementary Files.

ETHICS STATEMENT

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PROTOCOL

(1) Introduction

Previous studies have documented that people tend to respond faster and memorize in-group traits better. This process of superiority is called the group-reference effect (GRE). It may be particularly manifest for ethnic minorities, due to their salient ethnic identity. However, few studies have explored how the valence of traits may modulate this in-group preference effect. According to self-enhancement motivation theory, individuals may only show preference for positive traits rather than negative traits.

(2) Ethical issues

1. In this study we will ask participants to watch the picture on computer screen and make a button response.
2. If participants agree to participate, they are free to withdraw at any time throughout the duration of the experiment without any penalty.
3. During the study if the participants feel uncomfortable, they may leave the laboratory and participants' information will be discarded.
4. All information participants provide will remain confidential and will not be associated with participants' name.
5. This study will last for approximately 30 min.
6. Participants were informed of their rights and were free to ask any questions concerning the research.
7. If participants can finish all the experiments, he or she may obtain financial compensation.
8. If participants have any further questions concerning this study please feel free to contact us.

(3) Objectives

We expected that the GRE effect would primarily occur in positive trait judgment and would be motivated by self-enhancement.

(4) Enrollment Procedures

By posting ads on campus, recruit the participant.

(5) What is collected?

(5.1) Behavioral results:

According to the button responses of subjects, record Reaction Times.

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AUTHOR CONTRIBUTIONS

AZ conceived the research. RX participated in writing the manuscript. WS participated in performing the research. FW participated in reviewing the literatures. DL participated in making the figures and tables. SL participated in modifying the manuscript.

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Cultural Orientation of Self-Bias in Perceptual Matching

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Previous research on cross-culture comparisons found that Western cultures tend to value independence and the self is construed as an autonomous individual, while Eastern cultures value interdependence and self-identity is perceived as embedded among friends and family members (Markus and Kitayama, 1991). The present experiment explored these cultural differences in the context of a paradigm developed by Sui et al. (2012), which found a bias toward the processing of self-relevant information using perceptual matching tasks. In this task, each neutral shape (i.e., triangle, circle, square) is associated with a person (i.e., self, friend, stranger), and faster and more accurate responses were found to formerly neutral stimuli tagged to the self compared to stimuli tagged to non-self. With this paradigm, the current study examined cross-cultural differences in the self-bias effect between participants from Hong Kong and the United Kingdom. Results demonstrated a reliable self-bias effect across groups consistent with previous studies. Importantly, a variation was identified in a larger self-bias toward stranger-associated stimuli in the United Kingdom participants than the Hong Kong participants. This suggested the cultural modulation of the self-bias effect in perceptual matching.

Keywords: cross-culture comparison, independent and interdependent, self-construal, perceptual matching, self-bias

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INTRODUCTION

The "self" is an important concept that has been the focus of different fields, from social psychology, cross-culture psychology to social cognitive neuroscience. Many have attempted to decode and explain what the self is in the mind and brain. In recent years, much literature has focused on cultural differences between the East (e.g., East Asia) and the West (e.g., North America and Western Europe). These differences have been referred to as individualism versus collectivism by Triandis (1989), or independence versus interdependence by Markus and Kitayama (1991), and the concept of the self in relation to others is one of the key distinctions between the East and the West (Gardner et al., 1999). This study investigates the impact of cultural experiences on the self-bias effect in British and Hong Kong participants.

Cultural experiences play a crucial part in forming the concept of the self. The self is developed through interactions with, not only other people, but also the social environment and cultural background (Markus and Kitayama, 2003; Kitayama et al., 2007). Markus and Kitayama (1991) stress the importance of independence and interdependence in self-identity. In particular, Western cultures tend to emphasize independence and perceive the self as distinct autonomous entities

unique from other people. This encourages one to discover and express one's unique attributes. In order to achieve independence from other people, one's self-identity is formed with reference to one's own internal thoughts, feelings, motivations, and actions irrespective of other people (see **Figure 1A**). Eastern cultures, however, place greater emphasis on interdependence, which refers to the interconnectedness of oneself to other people and group membership forms an important part of self-identity. This is reflected in the overlap of one's concept of the self to other people (see **Figure 1B**).

Typically, one's level of independence and interdependence is measured through self-reported questionnaires such as the Self-Construal Scale (Singelis, 1994) and the Individualism and Collectivism Scale (Singelis et al., 1995). The focus of these questionnaires is to measure one's relationship with others and the extent to which representations of the self are perceived as separated or connected with family and friends (Markus and Kitayama, 1991).

Cultural differences not only influence the concept of the self but also affect one's perception and cognition. East Asians tend to live in a highly interdependent society where attention is directed more to relationships with other people. Westerners, however, live in a more independent society where less attention is paid to the social context. This cultural difference impacts the way stimuli are perceived in the environment. Many have found that Westerners pay more attention to salient objects than contextual background and that Easterners detect contextual relations more than specific items (Nisbett and Miyamoto, 2005). For example, Masuda and Nisbett (2001) demonstrated this attention difference by asking the participants to view and describe a series of vignettes and pictures. In one study, American students tend to describe the most salient objects first (e.g., "I saw a trout") while Japanese students described the context first (e.g., "I saw a stream"). Results demonstrated that the Japanese students noticed 60% more details about the context than the American students (Masuda and Nisbett, 2001). In another study, American and East Asian participants viewed pictures and vignettes that have focal object or contextual information changes. Findings showed that American participants were more sensitive to changes in focal objects than to changes in the periphery or context. In contrast, East Asian participants were more sensitive to contextual changes than to focal object changes (Masuda and Nisbett, 2006). Similarly, Singelis and Brown (1995) reported that the context of the situation easily influences the behavior of interdependent individuals but not independent individuals. Kühnen et al. (2001) also found that stimulus processing is more affected by context in interdependent than independent self-construals. These findings confirm that culture guides the perception of the self, as well as the way we perceive our environment.

Similar results were also reported by Kitayama et al. (2003) through a framed-line test. Participants viewed a square with a line inside and were asked to reproduce the line in another square in either the same absolute length or in the same proportion to the square. The East Asian participants performed more accurately in the relative task than the absolute task. In contrast, the Western participants performed better in the absolute task than the relative task. The Westerners were also much better at the absolute task than the East Asians, while the East Asians outperformed the Westerners in the relative task.

Eye movement study also demonstrated culturally different viewing patterns. Objects placed into photographs of naturalistic scenes were presented to the participants for viewing. It was found that Americans fixated more on the object, whereas the Chinese spent more time looking at the background (Chua et al., 2005). Thus, the context of the situation heavily influences stimuli processes and the responses of the interdependent individuals (Singelis and Brown, 1995; Kühnen et al., 2001).

As a result of the focus on contextual information, people from interdependent cultures have adapted to perceive the self and close others very differently from independent cultures. Memory encoded in self-reference had been found to vary between cultures. Wagar and Cohen (2003) compared Euro-Canadians and Asian-Canadians using a paradigm that cued referential memory with three questions. Each of the questions corresponded to an encoding level – self-reference ("Does this word describe you?"), other-reference ("Does this word describe your best friend?"), and word structure ("Is the first letter a vowel?"). Each question was followed by the display of a word that was either a personal trait or a collective trait. The task was to decide whether the trait words applied to the cued questions. Later, a memory test on what words appeared in the previous phase was administered. Results showed that Euro-Canadian participants responded fastest to words encoded in self-reference regardless of trait type. Self-referenced words were also significantly quicker in response than words encoded in other-reference and vowel structure. The Asian Canadians, however, were only faster to recognize collective traits, but much slower with personal traits, when both were encoded in self-reference. This indicated a strong context-dependent description of the self in Asian Canadians.

Anecdotal memories were also different across the East and the West. Using a self-reported questionnaire, Wang (2001) asked participants to report their earliest childhood memory. American participants reported specific memories that were focused more on individual events (e.g., "when I was 4, I got stung by a bee") with elaborate and expressive descriptions of emotions and personal experiences. On the other hand, the Chinese memories were more about routine activities within the family or neighborhood (e.g., "my mum took me to school everyday"), with descriptions that focused on significant others or the relationship with others.

Cross-culture variations were also found in self-face recognition. Sui et al. (2009) conducted a study to examine self-face processing using event-related potentials (ERPs) in British and Chinese participants. During the study, participants were asked to make judgments about the orientation of target faces that was either self-face or a familiar face. Behaviorally, the British participants showed a larger self-advantage than Chinese participants, but performance was faster and more accurate to self-faces than to familiar faces in both British and Chinese participants. ERP analyses revealed larger activity at 280–340 ms in the anterior N2 component for self-faces than familiar faces in British participants, while the Chinese showed

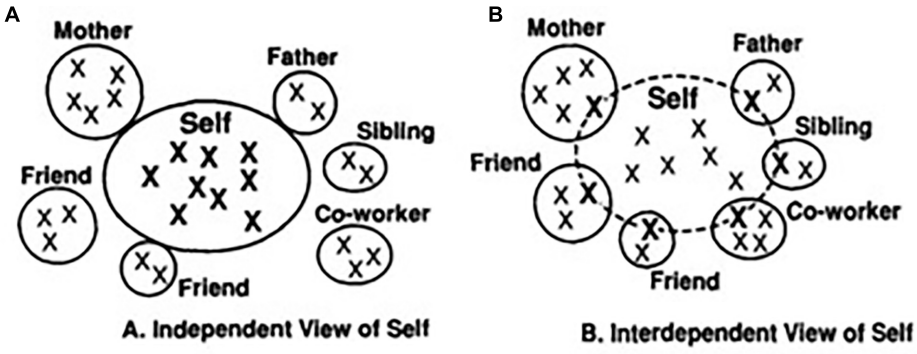

FIGURE 1 | Self-identity in relation to others, as described by Markus and Kitayama (1991). **(A)** Independent self. **(B)** Interdependent self. Xs indicates one's representations of the self.

reduced anterior N2 amplitudes to self-faces than familiar faces. This suggests that self-advantage is universal, but people from different cultural backgrounds develop different strategies to fit with the environment.

The neural representation of the self also differs across culture. Zhu et al. (2007) measured brain activity using fMRI as participants performed a trait judgment task. Similar to the memory test mentioned above, one of three questions was presented to cue the person to be judged – self, mother, and public figure (other). A null condition was presented between the judgment tasks where participants viewed rows of asterisks. Following the cue question, a trait adjective was presented and the participant decided whether the adjective described the cued person. Results illustrated that relative to the null condition, Western participants showed increased activations in the medial prefrontal cortex (MPFC) in response to self-judgments and reduced MPFC activities to mother-judgments. Unlike their Western counterparts, the Chinese showed enhanced MPFC activity in response to both self-judgments as well as mother-judgments when compared with other-judgments and null condition. These results indicated that while the MPFC is involved in self-representation in both cultures, MPFC also represented mother in Chinese participants.

In a similar study, Chiao et al. (2009) found different degrees of neural activation within the anterior rostral regions of MPFC due to cultural contrasts. Results found individualists, as revealed by the Self-Construal Scale, showed greater activation in the MPFC in response to general self-descriptions (traits that describe the participant in general) than contextual self-descriptions (traits that describe the participant only under certain conditions such as "when you are talking to your mother"), while collectivists demonstrated increased activation for contextual self-description than general self-description. These findings gave evidence that different cultural values have led to the neural unification or separation of the self in relation to close others.

Nevertheless, the self-bias effect has been consistently found in previous studies. Most results consistently showed a prioritization effect when processing self-relevant information. This bias toward self-stimuli was particularly robust in the perceptual matching task. Sui et al. (2012) designed a simple shape (i.e., triangle, square, or circle) and label (i.e., self, friend, or stranger) matching task. Participants were asked to learn to associate a shape with a label (e.g., triangle is you, square is your best friend, and circle is a stranger) and were tested by making judgments on whether the shape and label shown on screen matched the associations previously learnt. It was shown that responses were faster and more accurate to the self-associations than to friend and stranger associations.

In collaboration with the University of Hong Kong, the current study was conceived to test the cultural differences in self bias between participants from Hong Kong (HK) and the United Kingdom (UK). Though previous studies have examined the self-bias effect in cognitive processes such as memory and high-level decision-making (Cunningham et al., 2008; Turk et al., 2008), relatively few has examined low-level processes. Moreover, previous research often used stimuli that were highly familiar to the participant (e.g., one's own face or familiar faces). The current study focused on low-level processing in perceptual matching by using geometric shapes as stimuli. Geometric shapes such as triangle, circle, and square are commonly found in both Western and Eastern cultures. This means that confounds such as familiarity (in studies using familiar faces as stimuli) can be controlled by making associations with geometric shapes. Additionally, geometric shapes also control for any cultural predispositions or self-relevant information carried by the stimuli prior to learning the associations. Thus, the perceptual matching paradigm (Sui et al., 2012) improves the validity of studies that make comparisons between variables.

The aim of the current study was to examine the difference in the relationship between self and others in independent and interdependent cultures using the perceptual matching paradigm. In interdependent cultures, the self-identity is embedded among the identity of family and friends, and the idea of an individual self is less pronounced. As a result, it was expected that one's reaction time (RT) to self and friend stimuli should demonstrate a smaller difference because the friend-stimuli are a reflection of the self (see **Figure 1B**). In contrast, individualistic cultures promote an autonomous self, which should be reflected in a stronger sense of the individual, resulting in a faster response to

the self when compared to other associations (see **Figure 1A**). Based on these ideas, it was hypothesized that the self-bias effect relative to friend would be significantly smaller in HK than in UK participants in perceptual matching.

MATERIALS AND METHODS

Participants

Altogether 56[1] volunteers took part in this study. Of these, 32 healthy Caucasian volunteers (10 male, 18–35 years of age, mean age ± standard deviation = 22.22 ± 4.51) were recruited in the UK and tested at the University of Oxford; 24 healthy Chinese volunteers (five male, 18 to 24 years of age, mean age ± standard deviation = 19.92 ± 1.91) were recruited in Hong Kong and tested at the University of Hong Kong. Hong Kong participants were bilingual and had not previously studied overseas for more than 1 year. All participants were right-handed and had normal or corrected-to-normal vision. Informed consent was obtained from all participants prior to the experiment. The procedure used in this experiment was ethically approved by the University of Oxford Central University Research Ethics Committee and the University of Hong Kong Human Research Ethics Committee.

Stimuli and Materials

The computer task was displayed on different sized monitors, with different degrees of visual angle, in the UK and HK studies. In the UK, a white fixation cross was presented at the center of the screen at 0.8° × 0.8° of visual angle. Then, one of three geometric shapes (triangle, square, or circle) was presented above the fixation cross at 3.8° × 3.8° of visual angle, and one of three personal labels (you, friend, or stranger) was presented below the fixation cross at 3.1/3.6° × 1.6° of visual angle. The association of shapes with labels was counterbalanced across participants. The distance between the shape/label to the fixation cross was 3.5° of visual angle. All stimuli were presented in a gray background on a 23-in monitor (1920 × 1400 at 60 Hz). The program was run on a PC using E-prime software (version 2.0). All stimuli were consistent with those used in the Sui et al.'s (2012) study. In Hong Kong, the white fixation cross was presented at 0.4° × 0.4° of visual angle. The three geometric shapes were presented at 3.3° × 3.3° of visual angle, and the three labels were presented at 2.0/4.3° × 0.9° of visual angel. The distance between the shape and the fixation cross was 1.8°, and the distance between the label and the fixation cross was 1°. Stimuli were presented in a gray background on a 17-in monitor (1024 × 768 at 60 Hz). The program was run on a PC using E-prime software (version 2.0).

To determine the effects of testing using different parameters, 12 participants in the UK were tested using the HK specifications. However, I was unable to locate a 17-in monitor, so a 13-in monitor was used instead to determine whether the smaller screen affected the results. All stimuli presented were identical to the ones used in HK. A mixed design ANOVA was performed within the UK participants using the group with different parameters as a between-subject variable. No significant differences were found between the two groups, eliminating the parameters as a confounding variable. As a result, data from all participants were included in the final analyses.

Each participant completed a word-search task at the beginning of the experiment, which consisted of two short texts with no pronouns that described trips to tourist destinations. The reason behind this was that this experiment was part of a larger project. The goal of the project was to examine the effects of culture on the modulation of self-bias. The current experiment focused on the default cultural framework and its effects on the self-bias effect, while a second part of the project investigated the effects of cultural priming on the modulation of the self-bias effect. Previous studies have shown that pronouns such as "I" or "we" can successfully prime independent and interdependent self-construals (e.g., Brewer and Gardner, 1996; Sui and Han, 2007). The other part of project with priming manipulations used texts that contain pronouns such as "I" or "we." For procedural consistency within the project, the word-search task in this particular experiment excluded the use of pronouns to make sure that the participants were tested at baseline where no cultural priming would occur as a result of pronoun words such as "I" or "we."

Self-reported questionnaires were implemented at the end of the experiment to measure the relationship between behavioral responses and trait characteristics. This included the Self-Construal Scale (Singelis, 1994) and the Individualism and Collectivism Scale (Singelis et al., 1995).

Procedure

Each participant conducted a word-search task and a computer-based matching task twice (see **Figure 2**). A questionnaire booklet was completed at the end of the study. The purpose of the word-search task was to ensure that each participant performed the computer task in their default cultural frame of mind – that is independence for UK participants and interdependence for HK participants. The word-search task consisted of two short texts with no pronouns that described a tourist destination (Sui and Han, 2007). This made sure that the participants were tested at baseline where no cultural priming would occur as a result of pronouns such as "I" or "we." Participants were instructed to read each text and circle target nouns in the text (such as *park, area, pyramid, giza, sphinx*). The number of target words was the same for both texts. Verbal instructions were given for participants to read each text three times to make sure all target words were found. After each text, participants subsequently performed a perceptual matching task on the computer.

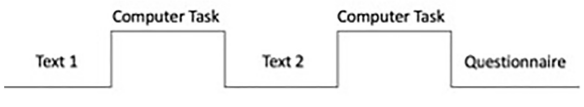

FIGURE 2 | Task procedure alternating between word-search task and computer task.

[1]Based on the effect size from previous research (e.g., Sui et al., 2012), a minimum of 26 subjects were required to achieve *power* = 0.80, *a* = 0.05.

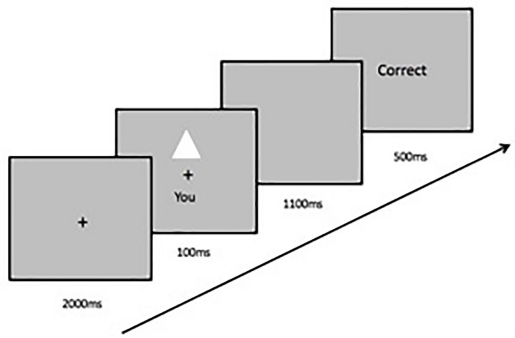

FIGURE 3 | The trial procedure and an example of the stimuli for the computer task.

For the computer task, participants first learned to associate a shape with a label. For example, the triangle represents you, the square represents your best friend, and the circle represents a stranger. Verbal and oral instructions were given as the participants learned the correct associations, though shape images were not presented at this stage. The learned associations remained the same throughout the two computer tasks for each participant. At the beginning of each trial, a fixation cross was presented at the center of the screen for 2000 ms, followed by a pair of a shape with a label above and below the fixation cross for 100 ms. The shape and label either matched the associations previously learned or was a recombination of a shape with a label randomly generated by the computer. Next, the screen remained blank for 1100 ms, during which time participants had to judge whether the shape-label pair matched or not by pressing one of the two buttons as quickly and accurately as possible with one of two index fingers (see **Figure 3**). Following each response, feedback (green "Correct" or red "Incorrect") was given on the screen for 500 ms at the end of each trial. If no response was given within the 1100 ms window, the feedback "Too Slow!" was displayed in yellow to prompt faster responses. Feedback on overall accuracy was provided at the end of each block. Participants performed nine practice trials and three blocks of 60 trials following each word-search task. This cycle of word-search task and computer task was repeated twice. After completing all the word-search tasks and the computer-based tasks, participants filled out the questionnaire booklet (see **Figure 2**).

Experimental Design and Data Analyses

Reaction times (based on the correct responses) from the UK and HK data were normalized by calculating the difference between two associations divided by the sum of the same two associations [i.e., (A−B)/(A+B)] to equate for possible group differences in the range of RTs. This method of normalizing the results makes comparisons between two associations, which is in line with the goal of this experiment. Results were reported in normalized RTs for both match trials and mismatch trials. The results of the ANOVAs on the normalized RTs between self and friend and the normalized RTs between self and stranger were reported. Finally, analyses of d-prime were also performed. Holm–Bonferroni corrections were applied to all multiple comparisons (Holm, 1979). See **Supplementary Table S1** for raw data.

RESULTS

RTs on Match Trials

Since this study mainly focused on examining the difference between self and others, mixed-design ANOVAs were performed on the normalized RTs between self and friend and between self and stranger. The type of normalized RTs (between self and friend or between self and stranger) was used as the within-subjects variable and culture group (HK vs. UK) as the between-subjects variable. A significant main effect of normalized RTs type was found, $F(1,54) = 6.28$, $p < 0.05$, $\eta^2 = 0.10$ (see **Table 2**). Pairwise comparison showed a larger difference in the normalized RTs between self and stranger than between self and friend ($p < 0.05$) regardless of culture group. No significant main effect of culture group was found, $F(1,54) = 2.15$, $p = 0.15$. A significant interaction between the type of normalized RTs and culture group was found, $F(1,54) = 4.48$, $p < 0.05$, $\eta^2 = 0.08$ (see **Table 1** for mean match RTs and **Table 2** for mean normalized match RTs).

Independent samples *t*-tests were performed to decompose the two-way interaction between the type of normalized RTs and culture group. A significant difference in the normalized RTs between self and stranger was found between the UK and the HK participants, $t(54) = 2.12$, $p = 0.039$, $dz = 0.75$ (see **Table 2** and **Figure 4**). The normalized RTs between self and friend, however, was not significantly different between the UK and HK participants, $t(54) = 0.50$, $p = 0.617$, $dz = 0.28$ (see **Table 2** and **Figure 4**). Though different from the initial hypothesis, a difference in self-bias (relative to stranger) was still identified between the two culture groups.

Additionally, one sample *t*-tests were performed on the normalized RTs to examine whether a significant self-bias effect was evident as previously demonstrated by Sui et al. (2012). Normalized RTs from both culture groups were compared against 0, which revealed significant effects of self-bias in both normalized scores between self and friend, UK: $t(31) = 6.49$,

TABLE 1 | Mean RTs (ms) and standard deviations (in brackets) for match trials as a function of association and culture group.

Associations	UK	HK
Self	632 (68)	649 (59)
Friend	695 (64)	706 (52)
Stranger	722 (56)	709 (62)

TABLE 2 | Mean normalized RTs (ms) and standard deviations (in brackets) for match trials as a function of bias and culture group.

Normalized RTs	UK	HK	Mean
Self and friend	0.05 (0.04)	0.04 (0.03)	0.05 (0.04)
Self and stranger	0.07 (0.04)	0.04 (0.04)	0.06 (0.04)

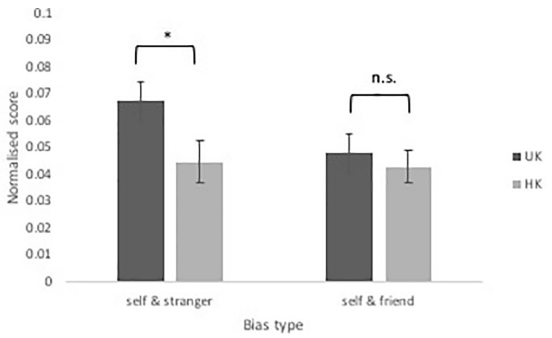

FIGURE 4 | Interaction between normalized RTs and culture group. Error bars represent one standard error. Significant differences are marked with "*."

TABLE 3 | Mean RTs (ms) and standard deviations (in brackets) for mismatch trials as a function of association and culture group.

Associations	UK	HK
Self	754 (63)	747 (57)
Friend	754 (61)	737 (67)
Stranger	746 (58)	735 (57)

$p < 0.001$, $d = 1.15$, HK: $t(23) = 7.19$, $p < 0.001$, $d = 1.47$, and between self and stranger, UK: $t(31) = 9.24$, $p < 0.001$, $d = 1.63$, HK: $t(23) = 5.69$, $p < 0.001$, $d = 1.16$. This means that a culturally independent self-bias effect was observed in both UK and HK participants.

RTs on Mismatch Trials

Data from shape-based mismatch trials were also analyzed. A mixed-design ANOVA was carried out with one within-subjects variable – type of normalized RTs (between self and friend or between self and stranger) – and one between-subjects variable – culture group (HK or UK). This revealed no significant main effect of normalized RT type, $F(1,54) = 0.72$, $p = 0.40$, nor culture group, $F(1,54) = 1.81$, $p = 0.18$. No significant interaction was found between the type of normalized RTs and culture group, $F(1,54) = 0.37$, $p = 0.55$ (see **Table 3** for mean mismatch RTs and **Table 4** for mean normalized mismatch RTs). This suggested that the responses were not significantly different between the shape-based mismatch associations across the two culture groups.

D-Prime

Using the Green and Swets (1966) formula, d-prime was calculated for each participant to determine their sensitivity to correct and incorrect associations across both match and mismatch shape-label associations. This sensitivity refers to how difficult it is for the participant to discriminate the target stimuli (i.e., match trials) from background noise (i.e., mismatch trials) and is calculated using the accuracy from the match and mismatch conditions.

A mixed-design ANOVA was performed on the d-prime values, using the shape-label association (self, friend, or stranger) as the within-subjects variable and culture group (HK or UK) as the between-subjects factor (see **Table 5**). The analysis

TABLE 4 | Mean normalized RTs and standard deviations (in brackets) for mismatch trials as a function of bias and culture group.

Biases	UK	HK	Mean
Self and friend	0.00 (0.02)	−0.01 (0.02)	−0.00 (0.02)
Self and stranger	−0.01 (0.02)	−0.01 (0.01)	−0.01 (0.02)

TABLE 5 | Mean d-prime and standard deviations (in brackets) for both match trials and mismatch trials as a function of association and culture group.

Associations	UK	HK	Mean
Self	2.76 (0.83)	2.12 (0.98)	2.48 (0.94)
Friend	2.19 (0.90)	1.77 (0.90)	2.01 (0.91)
Stranger	2.15 (1.10)	1.56 (1.02)	1.90 (1.10)
Mean	2.37 (0.10)	1.82 (0.06)	

TABLE 6 | Mean scores and standard deviations (in brackets) for the Individualism and Collectivism Scale and the Self-Construal Scale reported by UK and HK participants.

Questionnaire measure	UK	HK
Individualism	112.72 (6.76)	67.38 (9.43)
Collectivism	127.41 (7.75)	76.38 (8.09)
Independence	71.63 (10.27)	68.71 (8.13)
Interdependence	70.41 (12.46)	73.29 (8.40)

revealed a significant main effect of shape-label association, $F(2,108) = 16.71$, $p < 0.001$, $\eta^2 = 0.24$. Pairwise comparison of the shape-label associations indicated that d-prime for the self-association was significant higher than for friend ($p < 0.001$), and stranger associations ($p < 0.001$). Friend and stranger associations were not significantly different from each other ($p = 1.00$). There was also a significant main effect of culture group, $F(1,54) = 4.28$, $p < 0.05$, $\eta^2 = 0.07$. Larger d-prime was found in the UK participants than HK participants ($p = 0.05$) (see **Table 5**). The interaction between the shape-label association and culture group was not significant, $F(2,108) = 0.51$, $p = 0.60$.

Questionnaires Analyses

Correlation analyses were conducted to examine whether the self-bias effect (in normalized RT scores and d-prime) correlated with questionnaire measures for independent and interdependent self-construal. Data for the following questionnaires were collected – Individualism and Collectivism Scale (Singelis et al., 1995), Self-Construal Scale (Singelis, 1994). However, no significant results were found between the behavioral responses from the computer task and measures of independent and interdependent self from either questionnaires (please see **Table 6** for responses from the questionnaires). The lack of findings will be discussed in the following section.

DISCUSSION

This study explored the cultural influence on the self-bias effect in HK and UK participants through the perceptual matching paradigm. The aim of this study was to identify

the differences in cultural background as a modulating factor for the self-bias effect. The initial hypothesis was that due to cultural differences in the emphasis on independent and interdependent self, the self-bias effect relative to friend would be larger in the UK participants than HK participants. Though the results in RTs were slightly different from this hypothesis, a cultural variation was still identified between the two cultural groups: the UK participants demonstrated a larger self-bias effect relative to strangers than the HK participants. This difference in the self-bias effect relative to strangers was an indication that independent and interdependent cultural frameworks can modulate the magnitude of the self-bias effect in RTs. In contrast, d-prime results showed no cultural modulation on the self-bias effect. The d-prime results from both culture groups demonstrated the robustness of the self-bias effect – there was a significant advantage for the self-association than for friend and stranger associations in both HK and UK participants. This confirmed the prioritization in the processing of self-relevant information, consistent with previous research (e.g., Frings and Wentura, 2014; Mattan et al., 2015). However, no significant cultural differences in d-prime were observed between the two groups.

However, the UK participants were much more sensitive to all of the stimuli than HK participants, resulting in higher overall d-prime in the UK than in HK participants. The lower d-prime score may be due to the fact that the HK participants found the task more difficult. Previous research found that interdependent samples process objects with reference to the context or background more than Western samples (e.g., Masuda and Nisbett, 2001, 2006; Wang and Ross, 2005). It is possible that this strategy is not as well suited for the interdependent subjects of this particular task where the stimuli were presented on a blank background without context. In contrast, Western samples have an advantage over the Eastern samples as they process target objects individually.

Alternatively, the lower d-prime performance in the HK participants may have been a result of testing in a second language (English). One of the criteria for the HK participants was that they must not have studied more than 1 year abroad. Although this controls for the level of exposure to independent cultures, it also suggests that the participants may not be fluent in the English language. In which case, individuals may have more difficulty detecting the English stimuli. Future research should be conducted to test another group of non-native English speakers using English stimuli and use language as a between-subjects factor to see if there are any significant integration between English as a second language and task performance. Despite these limitations, the results of our experiment identified a difference in the self-bias effect between the two cultural groups.

Although no significant results were found between the questionnaire measures and the self-bias effect, it is important to keep in mind that the self is an ambiguous and abstract concept that is difficult to measure (Grace and Cramer, 2003). Many have questioned the reliability of questionnaire measures due to inconsistent results. For example, Harb and Smith (2008) criticize self-construal scales for not providing references to specific contexts in the interdependent measures when interdependent individuals are particularly sensitive to contextual cues. The environment is crucial to providing messages that elicit access to independent or interdependent self-construals (Sorensen and Oyserman, 2013). Large-scale studies across 30 nations also suggested that the Self-Construal Scale is unstable in structure within and across cultures (Levine et al., 2003; Georgas et al., 2006). Moreover, the number of questionnaire responses in this study may be too limited to produce enough statistical power to the correlation analyses. It is also important to note that western and eastern samples are not restricted to being only independent or interdependent. For example, although Americans were typically attributed to being more individualistic than people from other cultures, they are not less collectivistic than East Asians (Takano and Osaka, 1999; Oyserman et al., 2002). Independent and interdependent cultures are, in fact, two parallel dimensions that are not negatively correlated (Ng and Lai, 2011), which means that a higher measure of independence does not indicate a lower measure of interdependence, and vice versa. The results from the questionnaires in this study also confirmed this in that responses from both UK and HK participants showed similar values on independent and interdependent scores in the Self-Construal Scale and individualism and collectivism scores in the Individualism and Collectivism Scale. The self is a dynamic concept that can shift and evolve based on relations and contexts (Nisbett et al., 2001), and thus makes self-construal difficult to measure with fixed scales.

The findings of this experiment indicated that cultural variations play a role in the way humans process information about ourselves and unfamiliar others. Although previous studies have addressed cross cultural comparisons, the significance of this experiment lies in utilizing the shape-label paradigm, which included simple geometric shapes as stimuli (Sui et al., 2012). Previously, experiments have used stimuli such as faces (e.g., Keenan et al., 1999; Sui et al., 2009) and texts (e.g., Zhang and Mittal, 2007; Chiao et al., 2009) to study self-construal styles. These stimuli may introduce confounding variables because visual familiarity of faces, as well as complex language processes, are difficult to control. Geometric shapes, however, are universal in both Western and Eastern cultures, which makes it less susceptible to any cultural predispositions. The association of familiar and unfamiliar persons with geometric shapes eliminates the confounding effect of visual familiarity with faces, and removes translational and language problems produced in complex texts. The use of geometric shapes may also eliminate any self-relevant information carried by the stimuli prior to learning the association. Thus, this paradigm potentially improves the validity of the cross-cultural comparisons and provides more comparable data without the introduction of prior knowledge.

Some limitations of this experiment are as follows. First, HK participants are considered more bicultural than other East Asian cultures. Hong Kong has been the confluence of both Chinese

and Western cultures for nearly two centuries. The Hong Kong students recruited in this study may be more representative of a bicultural sub-group than the typical East Asian interdependent group. This may explain the lack of a decrease in self-bias relative to friend as was initially hypothesized, though further research is needed to fully explain this phenomenon.

Second, the experiment was administered in English in both the UK and the HK groups. Usually, experiments that use languages as stimuli are administered in the native tongue to avoid the effects of cultural priming. Participants who used an independent language (i.e., English) show decreased cognitive accessibility of the interdependent self compared to those who used a interdependent language (i.e., Chinese) (Trafimow et al., 1997; Wang et al., 2010). Ross et al. (2002) also reported that bicultural participants were more likely to report more favorable self-statements when writing in English than in Chinese. According to Kemmelmeier and Cheng (2004), language priming effects primarily occurred for self-construals that were not already salient in the respondents' culture. Despite this, the results of this experiment are still quite robust. Therefore, it is unclear to what extent the language cue has affected these results. Notably, the results showed the cultural effect even with these limitations.

Third, it is impossible to determine how much of the observed difference in this study could be attributed to cultural differences. For example, the reaction to strangers in HK participants could potentially be explained by the high-density population in Hong Kong. People may simply be more aware of others due to living in crowded spaces, as opposed to the British living in relative spacious environments. Other potential explanations could be living habits, genetics, etc. However, whether the significant findings were due to the study manipulations is a problem that is commonly faced by all researchers. Thus, it is important to keep in mind that we should be careful when drawing conclusions from study results. In the case of this study, interdependent culture should be considered a potential explanation for the results and not a definitive cause, especially when the questionnaire data do not support it.

This experiment provides some interesting future research questions. First, it would be interesting to explore the extent of the self-bias effect in relation to family members in cultures which possess different family values. Moreover, the strength of the self-bias against other members such as siblings, spouse, or children have yet to be examined. Interdependent cultures would suggest a stronger embeddedness of the self in one's family members than independent cultures. It would be interesting to examine whether the closeness of one's family member predicts the strength of the self-bias effect and how this effect changes due to cultural values.

Second, it is important to keep in mind that individual differences can exist within culture groups. Some people from independent cultures may be more interdependent and some from interdependent cultures may be more independent. The concept of the self, whether independent or interdependent, is a dynamic concept that can change depending on many factors such as social context (Markus and Kunda, 1986; Markus and Wurf, 1987; Oyserman et al., 2009; Colzato et al., 2012). Hence, future studies should take into consideration that cultural background is not the determining factor on the magnitude of the self-bias effect.

CONCLUSION

The present study investigated the impact of culture on self and other processing through a new paradigm. The results revealed that compared to their UK counterparts, HK participants showed reduced self-bias in relation to strangers. This supports the concept that interdependent self-construal style recognizes the self as an entity in relation to others while the individualist self is a single independent entity. Hence, cultural background can modulate the self-bias effect.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the University of Oxford Central University Research Ethics Committee and the University of Hong Kong Human Research Ethics Committee with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the University of Oxford Central University Research Ethics Committee and the University of Hong Kong Human Research Ethics Committee.

AUTHOR CONTRIBUTIONS

MJ, YS, JH, JS, and GH contributed conception and design of the study. MJ organized the database. MJ, SW, and HC performed the statistical analysis. MJ wrote the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01469/full#supplementary-material

TABLE S1 | Raw data in normalized RTs and d-prime.

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The Relationship Between Future Time Perspective and Self-Esteem: A Cross-Cultural Study of Chinese and American College Students

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The present study explored cross-cultural differences in future time perspective (FTP) and self-esteem and investigated whether the relationship between FTP and self-esteem differs between China and America. The FTP Scale and Rosenberg Self-Esteem Scale were administered to 460 Chinese and 340 American undergraduates. Results showed that American undergraduates scored higher on the future-negative, future-positive, future-confusion, future-perseverant, and future-perspicuity subscales than did Chinese undergraduates; American undergraduates also had higher self-esteem than did Chinese undergraduates. The dimensions of FTP (future-negative, future-positive, future-confusion, and future-perseverant) significantly predicted self-esteem in both the Chinese and American samples. These results broaden our understanding of cross-cultural differences in FTP and self-esteem. Implications and future directions are discussed.

Keywords: future time perspective, time perspective, self-esteem, cross-cultural differences, undergraduates

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INTRODUCTION

Time perspective is an individual-differences variable that influences behavior in various ways (Zimbardo and Boyd, 1999). In recent years, future time perspective (FTP) has acquired a prominent position within research on the psychology of time. FTP is a schema, or experience and conceptualization, of future time, and is operationalized as an individual's level of cognitive involvement in future life domains (Nuttin, 1985; Seginer and Lens, 2015). Follow-up studies found that FTP includes not only cognitive but also affective, behavioral, and motivational components (Peetsma, 2000; Lyu and Huang, 2016). Therefore, FTP can be defined as an individual's cognitive, affective, and behavioral tendencies toward the future that are manifested as relatively stable personality traits (Peetsma, 2000; Lyu and Huang, 2016). As a future-oriented personality trait, FTP embodies individual differences in future expectations and predictions; hence, FTP is an important predictor of the actual behaviors of individuals. Results of a meta-analysis revealed significant relationships between FTP and many outcomes (e.g., achievement, well-being, health behavior, risk behavior, retirement planning) (Kooij et al., 2018). However, are FTP scores consistent across different cultural contexts, and how does FTP relate to the self-concept (e.g., self-esteem)? The present study intends to explore these issues.

Future Time Perspective

The future involves uncertainty and ambiguity, in that risks and opportunities co-exist. Individuals might perceive the future with hope, but the future might also produce feelings of fear

(Morselli, 2013), which could be manifested as approach-avoidance conflict. Given the vast cultural differences in people's economic and social circumstances (Markus and Kitayama, 1991), will individuals with different cultural backgrounds have similar thoughts regarding their future? Mclnerney (2004) stated that researchers should maintain a cautious attitude toward the generalization of conclusions based on Western cultural backgrounds to non-Western cultures. Future consciousness is one concept that may be heavily influenced by culture. In traditional societies, the past and present are more important than the future, and this effect is more salient in cultures with an agricultural or nomadic-based economy (McInerney et al., 1997). For example, studies have shown that North Americans have a strong future orientation (Spears et al., 2001), whereas the Chinese are predominantly past-oriented (Brislin and Kim, 2003). However, such comparisons shed light on preferences for time orientations (e.g., past vs. future) within a single culture, but provide less information about how preferences differ between two or more cultures (Gao, 2016). For instance, although there is evidence showing that North Americans are relatively more focused on the future than on the past, there is no evidence indicating that North Americans are more concerned about the future than East Asians (Gao, 2016). Therefore, to determine whether the latter is actually the case, it is necessary to directly compare North American and East Asian participants' future orientations.

Morselli (2013) divided FTP into personal FTP and social FTP. Personal FTP refers to the personal achievements embedded within one's culture, which are not applicable to other cultures. In contrast, social FTP emphasizes the importance of social co-existence, with a focus on long-term goals and goals that transcend personal achievements, as well as the enhancement of intergroup and interpersonal relationships. Although future orientation has been examined in conjunction with other psychological constructs, there is currently insufficient research directly comparing FTP across cultures.

On the one hand, according to research in cultural psychology, American culture emphasizes individualism, freedom, and thinking about the future from one's own perspective. However, Chinese culture emphasizes collectivism, relationship orientation, and thinking about the future from the perspective of one's relationship network (Earley, 1989; Forbes et al., 2009; Jiang et al., 2016). Cultural differences may therefore affect the way that individuals think about the future. On the other hand, aspects of the immediate social environment, such as economic prosperity and recession, also affect the way people think about the future (Liebgold, 2014). In other words, people may think about the future according to their society's current social and economic conditions, and China and America are at different stages of development. Ecological system theory, as proposed by Bronfenbrenner (1979), emphasizes that individuals are embedded in a series of environmental systems (such as culture, society, and shared beliefs) that affect one another. That is, the system interacts with the individual and influences individual development. Investigating whether FTP scores are consistent among individuals with different cultural backgrounds can enhance understanding of the impact of the socio-cultural environment on future orientation generally and FTP specifically.

Self-Esteem

According to Baumeister et al. (1996), self-esteem is the evaluative component of the self-concept (i.e., the global evaluation of the self). Self-esteem is an important aspect of an individual's social and cognitive development (Berndt, 2002). Research has shown that self-esteem varies across cultures, such that individuals in Asian countries tend to report lower levels of self-esteem compared to individuals in North America and Western Europe (Farruggia et al., 2004; Cai et al., 2007; Li et al., 2015). These differences in self-esteem might be influenced by differences in individualism (which is more prevalent in Western cultures) and collectivism (which is more prevalent in non-Western cultures). Under individualism, individuals have a tendency toward the expression of autonomy and believe that they are unique within their surroundings. In contrast, under collectivism, individuals regard themselves as similar to others, emphasize social harmony and dependency, and pursue harmonious interpersonal relationships.

Future Time Perspective and Self-Esteem

We hypothesized that FTP would predict self-esteem. First, self-esteem has been used as an indicator of validity for the FTP scale in several studies (e.g., Zimbardo and Boyd, 1999; Worrell et al., 2015), and these past studies have revealed a positive relationship between FTP and self-esteem ($r = 0.19$, $p < 0.001$; $r = 0.13$, $p < 0.05$, respectively). Second, theoretically, Zaleski (1996) suggests that FTP is the basis for future anxiety, and that the nature of negative events expected and perceived by individuals determines their level of anxiety about the future. Intense anxiety experience triggers a threat to the self-concept and is directly associated with lower self-esteem (Sowislo and Orth, 2013; Zhang et al., 2016). Third, in our daily lives, positive future orientation can promote the improvement of individuals' self-esteem. For example, future-oriented students will set future goals according to their personal circumstances. If they strive to achieve future goals, they will evaluate themselves positively and hence exhibit higher self-esteem to the extent that they see themselves as meeting these goals. Finally, time balance (namely, remembering the past, grasping the current and planning the future) is conducive to maintenance of mental health, which, to some extent, helps to improve self-esteem.

Pursuing goals, planning, and forming future expectations are daily activities performed by individuals. These goals and expectations reflect self-worth, which requires high self-esteem (Crocker and Wolfe, 2001). We therefore argue that maintaining positive future thinking and high self-esteem are essential to psychological well-being in many societies. It is also possible that differences in sociocultural environments relate to discrepancies between FTP and self-esteem.

The Present Study

The aims of the current study are to investigate cultural differences in FTP and self-esteem and to test whether cross-cultural consistency exists in the relationship between FTP and self-esteem. We hypothesize that: (1) individuals from two different cultural backgrounds will show differences on FTP dimensions and self-esteem; and (2) within two cultural backgrounds, all FTP dimensions will be significantly correlated with self-esteem, but with differences in predictive power.

MATERIALS AND METHODS

Participants

A total of 819 undergraduates were recruited, of whom 19 participants provided incomplete information and were removed; thus, the final sample consisted of 800 participants. Four hundred and sixty participants were Chinese undergraduates (180 males, 280 females, ages ranged between 17 and 24, *M*age = 19.27, SD = 1.17), who were recruited from universities in Chongqing, China. Three hundred and forty participants were American undergraduates (108 males, 232 females, ages ranged between 18 and 28, *M*age = 20.09, SD = 3.44), who were recruited from the University of Chicago and Ohio University, United States.

Instruments

The Chinese version of the FTP scale (Lyu and Huang, 2016) was used, which comprises 28 items. Responses were collected via a five-point scale. To obtain an American English version of the FTP scale, the procedure for forward-backward translation recommended by Brislin (1970) was employed. Two psychology professors translated the 28 Chinese items into English, and two bilingual psychology teachers performed back-translation and comparative modifications. Exploratory structural equation modeling (ESEM) analysis, which takes into account the characteristics of exploratory factor analysis and confirmatory factor analysis (Asparouhov and Muthén, 2009), was performed by using Mplus 7.0 (Muthén and Muthén, 2012). The results showed that the model fit for the Chinese sample was good (χ^2/df = 1.78, RMSEA = 0.04, 90% confidence interval [0.03, 0.05], CFI = 0.95, TLI = 0.91, SRMR = 0.03). The American model fit index was also good (χ^2/df = 1.83, RMSEA = 0.07, 90% confidence interval [0.06, 0.08], CFI = 0.90, TLI = 0.86, SRMR = 0.05). In this study, Cronbach's αs for the subscales ranged from 0.66 to 0.87 among Chinese participants and from 0.65 to 0.80 among American participants (see **Table 1**).

Rosenberg (1965) initially developed the Self-Esteem Scale; Wang et al. (1999) generated the modified Chinese version. The scale measures general self-evaluation on a single dimension and consists of 10 items, which are administered on a four-point scale, where one indicates "strongly agree" and four indicates "strongly disagree." In this study, Cronbach's α for the Chinese participants was 0.78, and Cronbach's α for the American participants was 0.80.

Procedure

Permission was obtained from the parents and teachers of the Chinese participants before conducting the survey in class. A graduate student was trained to supervise participants' completion of the questionnaire. The American participants were students taking psychology classes, who participated in the survey online for course credit. All participants signed a consent form before the survey was conducted.

RESULTS

Descriptive Statistics and ANOVAs

Descriptive statistics for the American and Chinese undergraduates are presented in **Table 1**. Multivariate analysis of variance (ANOVAs) showed that FTP dimensions and self-esteem differed between American and Chinese undergraduates (Wilk's $\lambda = 0.73$, $F(7, 792) = 41.64$, $p < 0.001$, partial $\eta^2 = 0.27$). Univariate ANOVAs revealed that compared to Chinese undergraduates, American undergraduates were more negative [$F(1, 798) = 35.94$, $p < 0.001$, $\eta^2 = 0.08$] and more confused [$F(1, 798) = 20.14$, $p < 0.001$, $\eta^2 = 0.04$] about the future. American undergraduates were also more positive, perseverant and perspicuous about the future than Chinese undergraduates ($F_{all} > 7.67$, $p < 0.01$, $\eta^2_{all} > 0.02$). American undergraduates also have higher self-esteem than Chinese [$F(1, 798) = 3.78$, $p < 0.01$, $\eta^2 = 0.01$]. The difference between American and Chinese undergraduates was not significant for future-planning [$F(1, 798) = 0.04$, $p > 0.05$].

Correlations Analysis

Pearson product-moment correlation analyses of the relationship between FTP and self-esteem (see **Table 2**) showed that among Chinese undergraduates, the future-positive ($r = 0.45$, $p < 0.001$), future-perseverant ($r = 0.40$, $p < 0.001$), future-perspicuity ($r = 0.30$, $p < 0.05$), and future-planning ($r = 0.31$, $p < 0.001$) subscales were positively correlated with self-esteem; whereas future-negative ($r = -0.58$, $p < 0.001$) and future-confusion ($r = -0.48$, $p < 0.001$) subscales were negatively correlated with self-esteem. For American undergraduates, the future-positive ($r = 0.55$, $p < 0.001$), future-perseverant ($r = 0.41$, $p < 0.001$), future-perspicuity ($r = 0.51$, $p < 0.05$), and future-planning ($r = 0.19$, $p < 0.001$) subscales were positively correlated with self-esteem; whereas the future-negative ($r = -0.63$, $p < 0.001$) and future-confusion ($r = -0.35$, $p < 0.001$) subscales were negatively correlated with self-esteem. This indicates that the correlations between components of FTP and self-esteem were similar in both cultures.

Hierarchical Regression Analysis of Future Time Perspective on Self-Esteem

Hierarchical regression analyses of the relationship between FTP and self-esteem were performed separately for American and Chinese undergraduates (see **Table 3**). Among Chinese undergraduates, after controlling for age, gender, and family economic status [model $F(9, 450) = 53.65$, $p < 0.001$, $\Delta R = 0.41$], the significant predictors of self-esteem were family economic

TABLE 1 | Descriptive statistics and ANOVAs.

	China			America			*F* (1, 798)	η^2
	M	**SD**	**α**	***M***	**SD**	**α**		
Future-negative	**2.12**	0.64	0.87	**2.54**	0.84	0.86	35.94	0.08
Future-positive	**3.56**	0.61	0.84	**3.76**	0.78	0.85	7.67	0.02
Future-confusion	**2.68**	0.70	0.80	**3.00**	0.90	0.78	20.14	0.04
Future-perseverant	**3.58**	0.46	0.70	**3.84**	0.56	0.65	14.08	0.07
Future-perspicuity	**3.94**	0.59	0.77	**4.14**	0.64	0.72	7.97	0.03
Future-planning	3.45	0.53	0.66	3.47	0.75	0.70	0.15	0.00
Self-esteem	**3.47**	0.50	0.78	**3.61**	0.74	0.80	3.78	0.01

The bold fonts are significant difference.

TABLE 2 | Correlations between future time perspective and self-esteem.

	1	2	3	4	5	6	7
1. Future-negative	–	−0.64***	0.65***	−0.36**	−0.55***	−0.23*	−0.63***
2. Future-positive	−0.35***	–	−0.50**	0.48***	0.72***	0.24**	0.55***
3. Future-confusion	0.61**	−0.31***	–	−0.30***	−0.42***	−0.27*	−0.35***
4. Future-perseverant	−0.33***	0.40***	−0.22***	–	0.55***	0.42***	0.41***
5. Future-perspicuity	−0.42***	0.39***	−0.28***	0.43***	–	0.23***	0.51***
6. Future-planning	−0.31***	0.35***	−0.28***	0.47***	0.38***	–	0.19***
7. Self-esteem	−0.58***	0.45***	−0.48***	0.40***	0.30***	0.31***	–

*Correlations for Chinese undergraduates are shown below the diagonal line and those for American undergraduates above the diagonal line. *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.*

status (β = 0.08, $t = 2.13$, $p < 0.05$), the future-negative subscale (β = −0.35, $t = -7.70$, $p < 0.001$), the future-positive subscale (β = 0.22, $t = 5.37$, $p < 0.001$), the future-confusion subscale (β = −0.16, $t = -3.53$, $p < 0.001$), and the future-perseverant subscale (β = 0.16, $t = 4.06$, $p < 0.001$). Among American undergraduates, after controlling for age, gender and family economic status [model F (9, 330) = 74.92, $p < 0.001$, $\Delta R = 0.43$], the significant predictors of self-esteem were the future-negative subscale (β = −0.53, $t = -9.27$, $p < 0.001$), the future-positive subscale (β = 0.15, $t = 3.69$, $p < 0.05$), the future-confusion subscale (β = −0.16, $t = -3.18$, $p < 0.01$), the future-perseverant subscale (β = 0.17, $t = 3.75$, $p < 0.001$), and (marginally) the future-perspicuity subscale (β = 0.11, $t = 1.60$, $p < 0.1$).

DISCUSSION

This study revealed that scores on the different dimensions of FTP varied by cultural background. Specifically, American undergraduates were more negative and confused about the future, but also more positive, perseverant, and perspicuous about the future than Chinese undergraduates. These findings are somewhat similar to one study (Gao, 2016), which showed that Chinese individuals regarded positive aspects of one's future (expectations) as more important than Americans, whereas Americans regarded negative aspects of one's future (fear) as more important than Chinese. Below, we elaborate on possible reasons for these differences.

First, since the financial crisis of 2008, the economic outlook in America has not been favorable (in 2018, the growth rate of the American GDP was only 2.9%; U.S. Department of Commerce, 2019). Hence, American undergraduates might have adopted a pessimistic attitude toward the future when considering their career and economic prospects. In contrast, China is a developing nation, with good developmental trends in recent years (in 2018,

TABLE 3 | Hierarchical regression analysis of future time perspective on self-esteem.

	China		America	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Step1				
Gender	−0.10	−0.03	−0.03	−0.01
Age	−0.01	0.02	−0.09	−0.01
Family economic status	0.18***	0.08*	0.16*	0.05
Step2				
Future-negative		**−0.35*** **		**−0.53*** **
Future-positive		**0.22*** **		**0.15*** **
Future-confusion		**−0.16*** **		**−0.16****
Future-perseverant		**0.16*** **		**0.17*** **
Future-perspicuity		0.06		**0.11**†
Future-planning		0.01		0.01
R^2	0.04	0.45	0.04	0.47
F	6.64	53.65***	2.60†	74.92***
df	(3, 456)	(9, 450)	(3, 330)	(9, 330)
ΔR		0.41		0.43

*Marginal significance †$p < 0.1$. The bold fonts are significant predictive effect. *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.*

the growth rate of the Chinese GDP was 6.6% and the registered urban unemployment rate was 3.8%; National Bureau of Statistics of China, 2019). Therefore, Chinese undergraduates' lower levels of pessimism about the future might be related to national socio-economic factors (Seginer and Schlesinger, 1998; So et al., 2016). However, American undergraduates also believe that the future can be predicted based on previous national trends in economic development, which could explain why they demonstrated more optimism about the future.

Second, American culture emphasizes individualism (Earley, 1989; Forbes et al., 2009; Jiang et al., 2016), which focuses on the autonomy of individuals. Undergraduates need to face the issue of employment after graduation. Thus, in addition to the aforementioned economic problems, they will also have to strive for their future in relative isolation, which might cause them to feel that the future is uncertain (Lee, 2012). However, members of individualistic cultures also tend to believe that their own efforts can make a difference. In contrast, Chinese culture emphasizes collectivism (Earley, 1989; Forbes et al., 2009; Jiang et al., 2016), which focuses on social harmony and dependency. Thus, Chinese undergraduates think about their future not only from their own perspective, but also from the perspective of important people around them (e.g., their parents, teachers, relatives, and friends) (Zhang et al., 2015). The various elements of "me" are interwoven, thus presenting a more complex view of the future.

Third, Eastern cultures often emphasize Confucianism, which advocates that "happiness lies in contentment." Thus, past and present contentment is used as a basis for increasing the frequency and expectations of future thinking (Fingerman and Perlmutter, 1995). Our study discovered that American undergraduates exhibited greater perseverance regarding the future, and persistence implies the ability to resist current temptations. Bembenutty and Karabenick (2004) proposed that individuals delay gratification based on two aspects of information: the value of the delayed option and motivation to achieve the final goal. Individualism stresses individual freedom and realization of self-worth, which are complementary to the experience of achieving one's ultimate goals. In particular, the one-child policy in China has created a large number of one-child families, and a superior childhood growth environment can lead to greater persistence. Moreover, influenced by the Confucian culture, Chinese students are more accustomed to the *Zhongyong* (The Doctrine of the Mean). Therefore, they show a tendency to be "not pleased by external gains, not saddened by personal losses." In addition, the development of self-esteem also reflects the development of self-consciousness, which has also been demonstrated in our study, as American undergraduates scored higher in self-esteem than Chinese undergraduates (Farruggia et al., 2004; Cai et al., 2007). Accordingly, Americans undergraduates were more persistent about the future than Chinese undergraduates.

This study also showed that the relationship between FTP and self-esteem was consistent within two cultural environments. In both China and America, age and gender were not significant predictors of self-esteem. Future-negative subscale scores negatively predicted self-esteem, while future-positive subscale scores positively predicted self-esteem. This indicates that affect with respect to the future predicted self-esteem. Studies have shown that emotions are correlated with self-esteem (Zhang et al., 2016); individuals with past experiences of positive emotions tend toward high self-esteem, whereas those with past experiences of negative emotions tend toward low self-esteem (Lyu and Huang, 2008). Similar to the present study, Kang et al. (2003) found that the impact of emotional status on self-esteem was consistent across cultures, which suggests that an individual's positive self-perception is affected to a certain extent by temperament rooted in biological underpinnings (Schimmack et al., 2002). Future-perseverance subscale scores were also a significant predictor of self-esteem. Future-perseverance primarily involves behavioral persistence and manifests as an individual's ability to delay gratification (Lyu and Huang, 2016). When individuals perform a comprehensive evaluation of their surrounding environment and engage in long-term planning, the process of choosing between delayed and immediate gratification cannot be separated from self-evaluation and regulation (Bembenutty and Karabenick, 2004). Selecting delayed gratification implies self-regulation and positive self-evaluation.

It should be noted that future confusion negatively predicted self-esteem, whereas future-perspicuity positively predicted self-esteem, among American undergraduates, which reflects different effects of different types of awareness about one's future. From the perspective of the self, future-confusion stems from present uncertainty. Given that most of the undergraduate participants in the current study had just transitioned from high school into a university setting, they were faced with uncertainty in an unfamiliar environment, thereby engendering an unstable cognitive evaluation of the self (Ross, 1995). However, independence is fostered among Americans from early childhood; hence, American undergraduates may been better able to cognitively cope with changes in their surrounding environment, and being certain about oneself and one's surroundings is positively correlated with self-evaluations (Orr and Moscovitch, 2015). Therefore, Chinese undergraduates possibly tended to change their self-concept to adapt to their environment, whereas American undergraduates possibly tended to change their environment to adapt to their self-concept (Jiang et al., 2016).

Furthermore, family economic status was positively predictive of self-esteem, whereby better economic status was associated with higher levels of self-esteem. This finding is consistent with previous studies. For example, studies have shown that self-esteem and socio-economic status (including family economic status) are positively correlated (Zhang and Postiglione, 2001; Twenge and Campbell, 2002). Undergraduates with better family economic status will experience greater social support and encounter different social challenges, thus continuously improving their self-evaluation during this process. As China is still in the developmental stage, there is still a significant difference in family economic status caused by the wealth gap. A meta-analysis by Twenge and Campbell (2002) showed that members of Asian cultures believed that socio-economic status was particularly important to self-esteem, which reflects

the self-protection mechanism that exists in those with collectivistic backgrounds.

It should be noted that future-planning subscale scores did not significantly differ according to cultural background. This indicates that regardless of the environment, future-planning is indispensable. When undergraduates break away from the constraints of their families, they will require clear understanding so as to plan for the future and better adapt to society. This is a manifestation of universal psychological adaptability in humans (Londono and McMillan, 2015).

Of course, there were a few limitations in this study. First, the sample's representativeness was limited, as only three cities (Chongqing in China and Chicago, Illinois and Athens, Ohio in America) were selected for this study. The sample size should also be increased in future studies. Furthermore, sample homogeneity within the two cultures could not be ensured, with relatively large influences from external factors. Thus, caution is needed when generalizing the research conclusions. Future studies should include more countries (e.g., Japan, Korea, Britain, France) to increase generalizability. Second, FTP and self-esteem are two relatively stable traits, and there were no differences across cultures in their relationship to one another, possibly because the scale wording was not culture-specific. It is necessary to examine implicit as well as implicit measures of these constructs (e.g., future fluency task, implicit self-esteem) in further research. Finally, the FTP scale may have been limited by potential differences in comprehension of language across cultures. That is, errors might have occurred during the translation process, and hence, better measurement tools should be developed in subsequent studies.

In conclusion, compared to Chinese students, American students were more negative and more confused about the future, but were also more positive, persistent and perspicuous about the future than Chinese students. In both the American and Chinese samples, the future-negative, future-positive, future-confusion, and future-perseverant subscales of FTP significantly predicted self-esteem.

ETHICS STATEMENT

This study was approved by the ethics committee of Faculty of Psychology at Southwest University. The participants signed an informed consent form stating the aim of the study and explaining that they could withdraw from the study, and the data would be anonymous.

AUTHOR CONTRIBUTIONS

HL designed the study idea and research framework. GD contributed to the data analysis and writing. KR contributed to the data collection and manuscript modification.

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Self-Deception Reduces Cognitive Load: The Role of Involuntary Conscious Memory Impairment

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People often hear classic allusions such as plugging one's ears while stealing a bell, drawing cakes to satisfy one's hunger, and the emperor's new clothes. These allusions reflect a principle that people believe in nonexistent phenomena to satisfy their desires, also called self-deception. The current research used three experiments to examine the impact of social status and cognitive load on self-deception, and further to explore the inner connection about cognitive load and self-deception. The results found that deceiving individuals of high social status can play a role through the intrinsic mechanism of involuntary conscious memory (ICM). The higher the cognitive load of the deceiver, the greater the possibility of deception. The study demonstrated that involuntary conscious memory is the internal mechanism of self-deception, further explore the origin of self-deception, and enrich the self-deception theory.

Keywords: self-deception, deception, cognitive load, involuntary conscious memory, forward-looking paradigm

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INTRODUCTION

People often hear classic allusions such as plugging one's ears while stealing a bell, pointing to a deer and calling it a horse, drawing cakes to satisfy one's hunger, and the emperor's new clothes. These allusions reflect the principle that people believe in nonexistent phenomena to satisfy their desires. This is called "self-deception." Self-deception is a personality trait and an independent mental state, it involves a combination of a conscious motivational false belief and a contradictory unconscious real belief (von Hippel and Trivers, 2011). The forward-looking paradigm is widely used in self-deception research field to examine how self-deception influences predictions of the future (Chance et al., 2011; Yang, 2017; Ren et al., 2018; Liu et al., 2019). Participants take tests that assess their general knowledge and IQ. The paradigm includes three phases. In the first phase, participants are given the opportunity to view an answer key while taking an initial test; in the second phase, participants are asked to predict their future performance on a similar second test that lacks an answer key; in the third phase, participants take the second test, and the actual test score is recorded (Chance et al., 2011). Chance's study found that compared with the control group, the self-deception group predicted significantly higher scores on the second test that were much higher than their actual test scores (the self-deception group had the opportunity to view an answer key while taking the

initial test, whereas those in the control group did not have this opportunity). And a new study that used the forward-looking paradigm found that this paradigm can effectively indicate the existence of deception and that individuals of high social status are better able to control themselves and reduce self-deception (Ren et al., 2018).

With regard to the theoretical difference between deception and self-deception, previous studies have provided some explanations. Lu (2012) suggested that self-deception functions as a strategy in interpersonal communication to deceive others from the perspective of evolutionary theory. Because it is possible to deceive others directly, individuals can deceive themselves and then "honestly" send an incorrect message to the other party, such as withholding fitness-enhancing information from both oneself and others. Self-deception as an adaptation must cease to operate in most instances once the goal of deception has been achieved. Truthful information that has been kept from both oneself and others will then be retrieved to benefit the self. It is likely that this information manipulation co-opts memory to execute self-deception.

In human deception, cognitive load is an important indicator in recognizing deception (Trivers, 2011). Previous studies have shown that cognitive load reveals deception, but there are additional costs: the requirements of working memory reduce performance in challenging areas (Schmader and Johns, 2003) and damage social function (Hippel and Gonsalkorale, 2010). According to the theory of limited cognitive resources (Sweller, 1988), individual cognitive resources are generally limited. If too many cognitive resources are consumed, the cognitive load will be larger (Barrett et al., 2007; Van Dillen and Koole, 2007). While most people need to distinguish fact and lie, the deceiver needs to make sure that fact can be hidden and that lie can be supported. Two conflicting messages must exist at the same time, so a high cognitive burden is required. Based on the related research on self-deception and cognitive load, the current study proposed that, while self-deception provides a way to avoid this cognitive load, deceivers can convince themselves that their deception is indeed true, and they no longer need to maintain the truth of the event while highlighting the lie. On the contrary, by believing the lies they tell others, they can relax and focus on other things. Based on the theory of limited cognitive resources, can people reduce their cognitive load by deceiving themselves to avoid the cognitive cost of deceiving? This is the first question to be explored in our study.

Self-deception to some extent involves interpersonal self-deception. This process is achieved by relegating real information to the unconscious while consciously providing false information to others and to self (Trivers, 2000; von Hippel and Trivers, 2011). Some studies have found that when individuals use self-deception strategies to lie in interpersonal relationships, their situational pressures have considerable bearing on whether they use self-deception strategies. When the situation is more stressful, individuals are more likely to deceive themselves. Furthermore, high and low status relate to the level of one's ability to detect lies (Lu and Chang, 2014; Ren et al., 2018). Previous studies on social status have shown that because low-status individuals lack power, if they wish to gain additional resources, they can only do so in a surreptitious way, such as hiding food, distracting others' attention, or covering up their transgressions (Bugnyar and Kotrschal, 2004; Bräuer et al., 2007).

Previous studies have found that self-deception is related to memory. Roediger (1990) proposed that the memory structure consists of explicit/conscious and implicit/unconscious memory. Trivers (2000) proposed an information placement system of self-deception that supported Schacter and Roediger's arguments. Conscious memory involves subjective awareness in the recollection of experience, whereas unconscious memory involves retrieval without awareness, which affects behavior. In interpersonal self-deception (Trivers, 2000), false information is in the conscious, whereas true information is in the unconscious. When the motivation for deception ceases, true information can return to the conscious.

Lu and Chang (2014) used Trivers' theory to conduct empirical research using voluntary conscious memory (VCM) and involuntary conscious memory (ICM) to explore the relationship between social status and self-deception. VCM involves intentional and effortful recollections of experiences. By contrast, ICM involves unintentional and spontaneous recollections that are self-reported without effortful recall (Baddeley and Della Sala, 1996; Tulving, 2002). In widely adopted tasks of conscious memory, such as free recall and recognition, both VCM and ICM are assumed to be involved (Mandler, 1980; Schacter et al., 1989; Kvavilashvili and Mandler, 2004). An increasing number of studies of ICM have shown that spontaneous recollections in self-reports occur in various contexts, including semantic (Richardson-Klavehn and Gardiner, 1996; Kvavilashvili and Mandler, 2004) and episodic memory tasks (Berntsen and Jacobsen, 2008; Rasmussen et al., 2014). VCM and ICM may help to explain how conscious memory is temporarily impaired in self-deception. Self-deceivers make an effort to subjectively and voluntarily collect true information to convey to the deceived because self-deceivers are honest both to themselves and to the deceived. However, they unconsciously and involuntarily withhold true information from the deceived. Thus, the VCM of self-deceivers should be similar to that of nondeceivers, whereas ICM, which automatically emerges in the conscious without effortful recall, may be reduced to help achieve self-deception.

Based on the above research, we hypothesized that VCM and ICM may help to explain how conscious memory is temporarily impaired in self-deception. Lu and Chang (2014) found that during a task, in individuals with high social status, VCM will produce more memory error messages, while ICM can correct memory; that is, the high social status of individual participants is involved in self-deception. Therefore, the role of ICM between social status and self-deception remains to be verified.

Social status and cognitive load presumably have direct and indirect impacts on self-deception. What are the reasons and mechanisms that affect self-deception? This is the second question that this study aims to explore. Previous research showed that the impairment of ICM can reduce cognitive load,

and self-deception can reduce cognitive load (Lu and Chang, 2014). The current study continues to explore this question: can this intrinsic mechanism reduce self-deception? Apart from the intrinsic mechanism, individual self-deception also affects cognitive load (Lu and Chang, 2014), which is an external factor that influences ICM. This study also aims to answer these questions. Based on Lu and Chang's (2014) research, the purpose of the present study was to provide a more empirical test of Trivers' theory by addressing the aforementioned issues.

From the above, the current study proposed three questions to explore the relationship between self-deception and cognitive load. First, people use self-deception to deceive others, whether self-deception can reduce cognitive load compared to direct deception? Second, if the results of Experiment 1 suggested that self-deception reduces an individual's cognitive load, what is the inner mechanism? Previous studies have shown that interpersonal self-deception is that people will put real information into unconscious, while consciously providing false information to others and self (Trivers, 2000; von Hippel and Trivers, 2011), and previous study has shown that ICM can reduce the cognitive load (Lu and Chang, 2014). So, can memory impairment can achieve interpersonal self-deception? Third, according to the theory of limited cognitive resources, do individuals with high cognitive load experience self-deception due to excessive cognitive load? In other words, does cognitive load of an individual have an effect on the individual's self-deception? In order to resolve the three questions, we designed three experiments.

EXPERIMENT 1

In Experiment 1, the forward-looking paradigm was used to induce self-deception and deception to determine whether self-deception can eliminate the costly cognitive load associated with deception. We hypothesized that participants in the self-deception group and the deception group would have higher cognitive load scores compared to the control group. When comparing the two groups with high cognitive load scores, the self-deception group would have lower cognitive load scores than the deception group.

Methods

Participants

The experimental procedure was approved by the IRB of the Institute of Psychology, Hunan Normal University. Ninety non-psychology-major students participated in the experiment. All participants provided verbal informed consent. Prior to this experiment, they had not taken civil service examinations or similar tests, and they signed informed consent for the experiment. Participants were randomly assigned to the self-deception group, the deception group, or the control group, with 30 people in each group (seven participants failed to understand the task's rules and did not complete the task, so 83 participants with valid data were selected). We used G*Power Version 3.1.9.2 software (Faul et al., 2009) to acquire a *post hoc* calculation of the power of the sample size. According to the effect size of Experiment 1 (effect size $f = 0.717$), using the parameters $\alpha = 0.05$, total sample size = 83, number of groups = 3, the analysis estimated a power of 0.99.

Measures for General Knowledge and Cognitive Load

The study used the forward-looking paradigm (Chance et al., 2011) and 20 general knowledge questions (Yang, 2017) for the experiment. An example of a general knowledge question was "When did the first world war break out? A.1910, B.1914, C.1939, D.1940."

This experiment used the NASA-Task Load Index (NASA-TLX) scale developed by NASA, as translated and revised by Xiao et al. (2005), to measure the cognitive load after completion of the task. The NASA-TLX is a multidimensional instrument that consists of six subscales: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Frustration (FR), Effort (EF), and Performance (PE). Twenty-step bipolar scales are used to obtain ratings on these dimensions, resulting in a score between 0 and 100. The underlying assumption of the instrument is that the combination of these six dimensions is likely to represent the "workload" experienced by operators (Hart, 2006; Hoonakker et al., 2011).

Procedure

In this study, a single factor (self-deception, deception, and control group) was used in the design. The dependent variable was the cognitive load after the task was completed.

Prior to the experiment, the participants were told that the task was a general knowledge question in which a higher score indicated a higher level of intelligence. They were told that if their scores were in the top 20%, they would receive a bonus.

After the experiment began, the self-deception group completed five moderately difficult common-sense questions within 5 min. Each participant could see the answers, which were at the bottom of the test. After the first test, the participants were asked to complete 15 similar unanswerable common-sense questions. Prior to the second test, the participants were asked to make a prediction score and report it to the researcher. The participants then completed the second test.

The deception group was also able to see the answers at the bottom of the test. However, unlike the self-deception group, after completing all the tests, the participants checked their own answers and collated the scores of the second test. The researcher stressed that their answers would not be checked.

The control group could not see the answers. The control group also took the prediction test before the formal test, and the participants were required to make score predictions and report them to the researcher before completing the second test.

When the self-deception, deception, and control groups had completed the two tests, all participants were measured for the degree of cognitive load using the NASA scale. Because these tests did not involve physical exercise or performance in the experiment, these two sections of the NASA scale were eliminated (**Figure 1**).

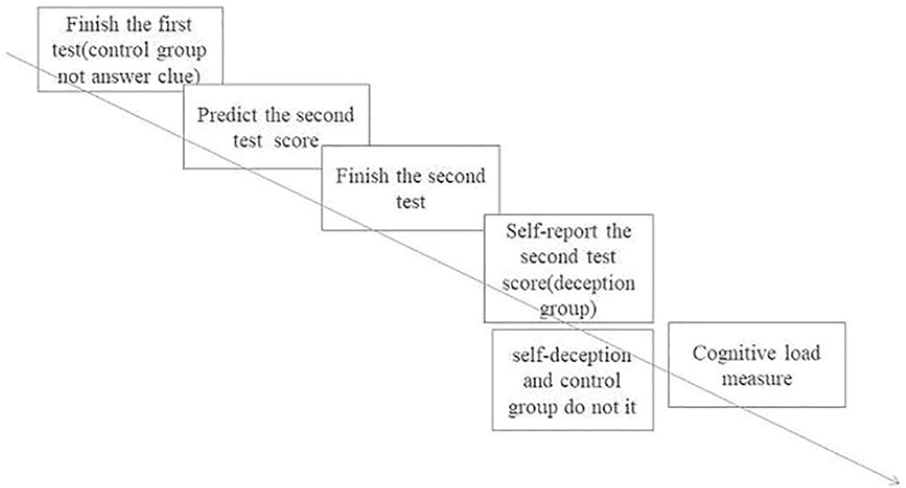

FIGURE 1 | Trials of Experiment 1.

Results

Manipulation Check

There were significant differences in the prediction of the scores between the self-deception group and the control group on the second test, $F(2,81) = 33.22$, $p < 0.001$, $\eta_p^2 = 0.45$. Compared with the control group ($M = 74.64$, SD = 15.51) and the deception group ($M = 84.04$, SD = 10.20), the self-deception group ($M = 102.76$, SD = 13.34) reported higher predicted scores.

Cognitive Load Results

Next, the results of the NASA cognitive load scale of the self-deception group, the deception group, and the control group were calculated. The weight of the four questions in the NASA scale was 25% each, and the total score of the cognitive load was the sum of the weighted scores of each question multiplied by 10. The total scores of the cognitive load in the self-deception, deception, and control groups were analyzed by single-factor analysis of variance. The results showed that there were significant differences in the total score of the cognitive load among the three groups, $F(2,80) = 11.29$, $p < 0.01$, $\eta_p^2 = 0.12$. Multiple comparisons showed that the total cognitive load score ($M = 62.02$, SD = 9.51) of the deception group was significantly higher than that of the self-deception group ($M = 33.79$, SD = 9.22; $p < 0.01$) and of the control group ($M = 28.571$, SD = 8.99; $p < 0.01$). In addition, the self-deception group's score was significantly higher than that of the control group ($p < 0.05$) (**Figure 2**).

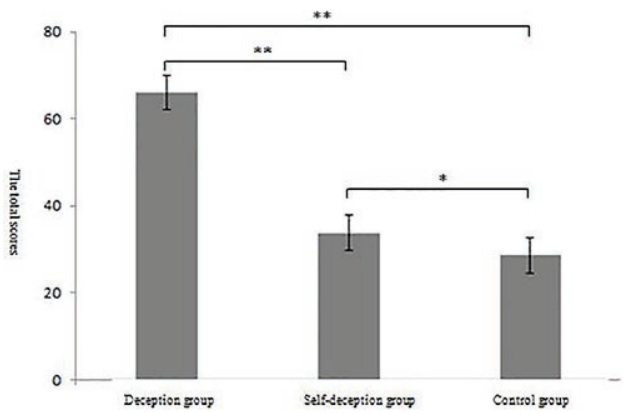

FIGURE 2 | Results of Experiment 1: total scores of the deception, self-deception, and control groups (*$p < 0.05$, **$p < 0.01$).

Discussion

The results of Experiment 1 showed that the predicted results for the second test in the self-deception group were significantly higher than the predicted results for the second test in the control group, indicating that self-deceptive behavior of the participants was successfully induced under the forward-looking paradigm. This result is consistent with previous conclusions (Yang, 2017; Ren et al., 2018) and indicates that both the forward-looking paradigm and the experimental materials could induce self-deception in the participants. In terms of the cognitive load results, the self-deception group experienced a greater cognitive load than the control group, indicating that the self-deception behavior itself, like all other ordinary behaviors, caused the participants to experience a certain cognitive load. However, compared with the self-deception group, the deception group had a greater cognitive load. This result is also in line with previous studies to some extent (Vrij and Barton, 2004; Atoum, 2006): under the same conditions of high cognitive load, the cognitive load of self-deception behavior is lower than that of deception. As evidence of the existence of interpersonal deception, self-deception has the advantage of saving cognitive resources and reducing cognitive load, as demonstrated by Experiment 1.

Experiment 1 showed that compared with the non-deception group, the deception and self-deception groups both experienced

cognitive loads, but the cognitive load of the self-deception group was lower than that of the deception group. Previous studies have shown that when people of high social status are deceived, the memory adaptation of individual self-deception results in the impairment of ICM. We hypothesized that the memory of ICM is weakened by the self-adaptation of memory, thereby reducing the cognitive load of participants in the process of deception.

EXPERIMENT 2

In Experiment 2, we hypothesized that compared with participants who deceived a low-status person, those who deceived a high-status person would temporarily be impaired in self-deception. Specifically, ICM would temporarily be impaired, but VCM would not be significantly different because the participants would consciously impair their memory to lie to others. We further hypothesized that both VCM and ICM would not be significantly different in the non-deception condition because the participants would not consciously impair their memory to lie to others.

Method

Participants

The experimental procedure was approved by the IRB of the Institute of Psychology, Hunan Normal University. All participants provided verbal informed consent. One hundred non-psychology-major college students were recruited to participate in the experiment (M_{age} = 19.8 ± 0.75 years). They were paid 20 Yuan (approximately US$3) after the experiment, which lasted approximately 25 min. Participants were randomly assigned to four conditions: deception high status, deception low status, non-deception high status, and non-deception low status. We used G*Power Version 3.1.9.2 software (Faul et al., 2009) to acquire an *a priori* estimate of the required sample size. Using the parameters power = 0.8, effect size f = 0.25, α = 0.05 and given the current experimental design, the analysis estimated a sample size of 82. We ultimately recruited a total of 100 undergraduates. The actual power for this sample size was 0.88.

Experimental Material

The word materials were selected from 60 double-character Chinese words in the Chinese word library and edited by e-prime software. Each word was displayed on a computer screen for 7 s, followed by an instruction indicating whether the participant should cheat. The instructions for deception and non-deception were presented randomly, with half of the words being deceptive (including a deception instruction) and half being non-deceptive (not including a deception instruction). Participants who were assigned to deceive high-status individuals were told that they were going to deceive the teacher and were told to hide the words that had the "deceive the teacher" instruction in a later task. In contrast, the participants who were assigned to deceive low-status individuals were told that they would deceive students in later cheating tasks, which involved concealing words with the "cheat the student" instruction. Non-deceptive words had the instruction "not cheating" for the conditions of both high and low status.

The VCM and ICM measurements were based on the measurement method used in the research of Lu and Chang (2014). The cognitive load scale was the same as in Experiment 1.

Procedure

Experiment 2 used a 2 (Social status: High vs. Low) × 2 (Attribute of words: Deception vs. Non-deception) between-subjects design. The dependent variables were the number of test words of the first VCM/ICM test, the number of words in the second VCM/ICM test, and the difference in the number of words in the two VCM/ICM tests.

Before the experiment began, the participants were informed that they had been asked to participate in a deception task. Next, the participants were asked to remember 60 Chinese-language words (word memory tables) with medium frequency of use. They were told that the researcher would later ask them which words they had learned.

In the word memory table, half of the words included deception instructions, while the other half of the words did not. The deceptive words required participants to conceal the target words in the subsequent deception task, while the non-deceptive words required them to report the words honestly in the subsequent deception task. Participants who deceived high-social status individuals were told that their task was to deceive teachers in subsequent deception tasks. Those who deceived low-social status individuals were told that their task was to deceive students in subsequent deception tasks. At the end of the learning stage, to avoid rehearsal and recency effects, the participants completed a shape recognition filler task on the computer for 5 min.

After the filler task, the participants were told that they needed to complete a test before participating in the deception task. The VCM group completed the first VCM material test. The test content was a test paper containing 30 Chinese characters, with two spaces next to each of them. These Chinese characters were the first characters of the two-character words that the participants studied in the word memory table during the learning stage. The participants were asked to use the first character as a reminder to recall the words they had learned in the glossary and write them in the first space; using the first character to remember the second one is a "cued recall task." If they could not remember the word they had learned, in the second space they were asked to write a word based on the two characters associated with the given first character. If the participant was able to actively and explicitly recall the word in the first space, the word that was written in the first space was considered to be recalled using VCM.

The ICM group completed the first ICM material test with the same test content as the VCM group. Unlike the VCM group, in the first space, the participants were asked to write the two-character words as quickly as possible. The participants were asked to do this quickly to avoid intentional recall. After completing the task, the participants were asked to check

whether they had learned these words during the learning stage. If they confirmed learning a word, they were asked to write another two-character word beginning with the given character in the second space. The words written in the first blank and later identified as learning words were considered to be recalled using ICM because these words automatically reached the participant's mind without deliberate recall. All participants completed the test and the cognitive load self-report scale.

To test the participants' actual memory of words, the participants were told that they would not have to cheat on the next task and should actually report the words they remembered. Finally, the participants were asked to take the VCM and ICM tests again. The content of the test was the remaining 30 words, excluding the words in the first test. At this time, the subjects were no longer in a situation of deception and self-deception and did not have a motivation to cheat (**Figure 3**).

Results

Cognitive Load Check

A t test was conducted on the self-reported cognitive load scores of the high-social status and low-social status groups. The cognitive load scores of the high-social status group (M = 33.80, SD = 10.317) were significantly lower than those of the low-social status group (M = 57.54, SD = 13.459), $t(98) = -9.899$, $p < 0.01$, $d = 0.50$. These results suggest that people who cheat on high social status have a greater cognitive load.

Number of Words in the First Voluntary Conscious Memory/Involuntary Conscious Memory Test

A two-factor analysis of variance for VCM found that the main effect of social status and the attributes of words showed no significant difference.

A two-factor analysis of variance for ICM found that the main effect of the attributes of words was significant, $F(1,49) = 12.57$, $p < 0.01$, $\eta_p^2 = 0.17$, and the number of ICM deceptive words was significantly lower than the number of ICM non-deceptive words. More importantly, there was an interaction between social status and the attributes of words, $F(1,49) = 11.28$, $p < 0.01$, $\eta_p^2 = 0.11$. Furthermore, a simple effect analysis showed that for the number of deceptive words, individuals who deceived people of high social status (M = 5.36, SD = 1.32) had significantly lower ICM recall than those who deceived people of low social status (M = 7.40, SD = 2.35) (**Figure 4**).

Difference in the Number of Words in the Second Voluntary Conscious Memory/Involuntary Conscious Memory Test

A two-factor analysis of variance for VCM found that the main effect of social status and the attributes of words showed no significant difference.

A two-factor analysis of variance for ICM found that the main effect of word attributes was significant, $F(1,49) = 13.85$, $p < 0.01$, $\eta_p^2 = 0.12$. ICM deception word memory test (M = 3.08, SD = 0.33) was significantly higher than that of the non-deception test (M = 0.5, SD = 0.15); and the main effect of social status was significant, $F(1,49) = 37.41$, $p < 0.01$, $\eta_p^2 = 0.28$. Compared with the low social status deception (M = 0.41, SD = 0.13), the high social status deception had more ICM recall (M = 2.98, SD = 0.29) (**Figure 5**). More importantly, there was an interaction between the attributes of words and social status, $F(1,49) = 21.68$, $p < 0.01$, $\eta_p^2 = 0.19$. Comparing with non-deception words, Individuals who had cheated on high social status had more ICM recall (M = 2.67, SD = 0.23) than those who had cheated on low social status (M = 0.40, SD = 0.16) (**Figure 5**).

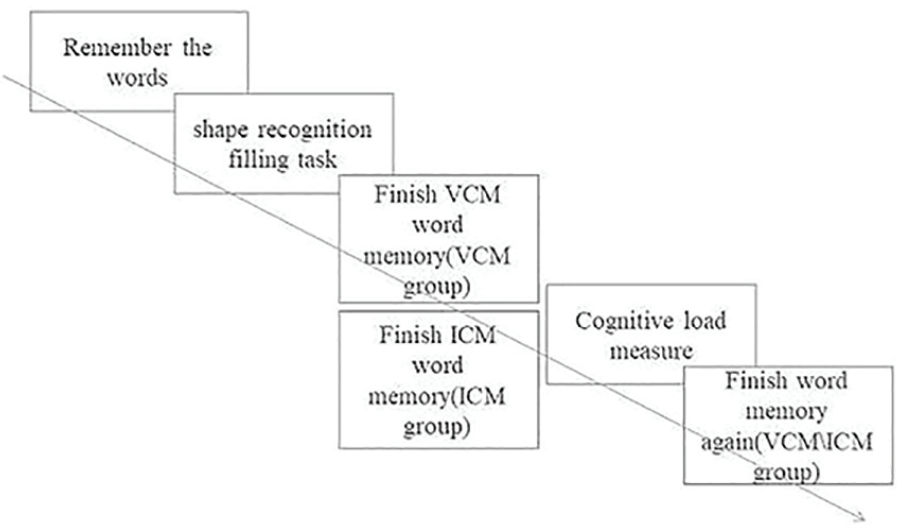

FIGURE 3 | Trial of Experiment 2.

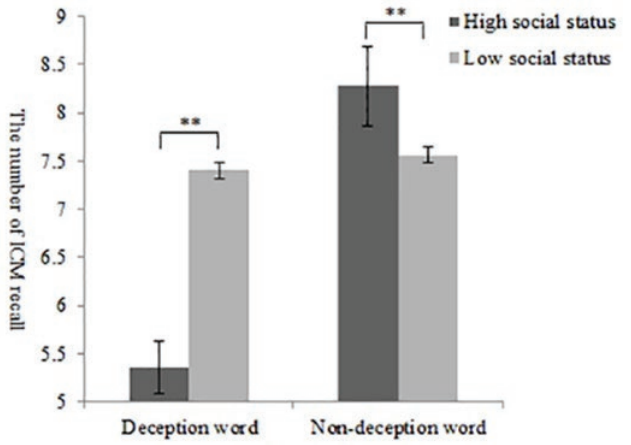

FIGURE 4 | Results of Experiment 2: number of recall words in the first ICM test between the high- and low-social status group and the deception or non-deception word group (**$p < 0.01$).

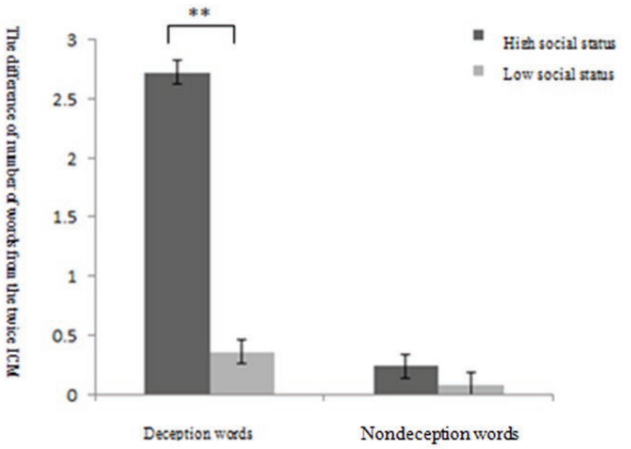

FIGURE 5 | Results of Experiment 2: difference in the numbers of words between the two ICM tests between the high- and low-social status groups and the deception or non-deception words groups (**$p < 0.01$).

Discussion

Experiment 2 found that in the first memory test, the number of deceptive words recalled by participants who deceived people of high social status was significantly lower than the number of words recalled by participants who deceived people of low social status. For the number of non-deceptive words, there was no significant difference between participants who deceived high- and low-social status individuals. The result is consistent with previous study, which showed that if individuals were confronted with deception targets who whose social status was higher than their own. High social status can induce self-deception, because of high social status represent authority and status, it was easier to evade the punishment of high-status individuals by using self-deception (Lu, 2012), it was easier to evade the punishment of high social status by using self-deception. Thus, individuals who were prone to more self-deception were of lower social status (Cummins, 1999; Lu and Chang, 2014). These results suggested that people used a self-deception strategy that is the impairment of ICM to achieve self-deception, and to better deceive others. Participants who deceived high-social status individuals with ICM in the task had more memory error messages than those with VCM in the task, who were able to correct their memory. This finding suggests that participants who deceived high-social status individuals engaged in self-deception.

In previous studies (Chance et al., 2011; Lu and Chang, 2014), a forward-looking paradigm was used to compare the ICM and VCM of self-deceiving individuals and deceiving individuals. Only self-deception ICMs were depleted. Thus, self-deception reduces the generation of cognitive load through the adaptiveness of memory compared to deceptive behavior. According to the theory of limited cognitive resources, there were limited effects accompanied by cognitive load consumption. Thus, individuals with a high cognitive load engage in self-deception because of the high cognitive load to alleviate this cognitive burden. To address this issue, Experiment 3 was designed to investigate how cognitive load affects an individual's self-deception when an answer is provided.

EXPERIMENT 3

Experiment 1 and Experiment 2 suggested that self-deception reduces cognitive load, which is caused by ICM impairment of self-deception. Because that we know that self-deception reduce cognitive load through ICM this intrinsic mechanism, what effect, in turn, does the level of an cognitive load have on self-deception? Therefore, Experiment 3 aimed to examine the effect of cognitive load on self-deception. We hypothesized that the difference between the second predicted score and the actual score of high cognitive load was greater than low cognitive load.

Method

Participants

The experimental procedure was approved by the IRB of the Institute of Psychology, Hunan Normal University. All participants provided verbal informed consent. A total of 120 non-psychology-major college students were recruited to participate in the experiment (M_{age} = 19.68 ± 0.72 years). Prior to this, they had not participated in civil service examinations or similar tests, and they signed informed consent for the experiment. They were paid 20 Yuan (approximately US$3) after the experiment. We used G*Power Version 3.1.9.2 software (Faul et al., 2009) to acquire an *a priori* estimate of the required sample size. Using the parameters power = 0.8, effect size f = 0.25, α = 0.05 and given the current experimental design, the analysis estimated a sample size of 82. We ultimately recruited a total of 120 undergraduates, and the actual power for this sample size was 0.93.

Cognitive Load Task

The cognitive load task adopted the cognitive load scale (Greene et al., 2008). Based on the results of the preliminary experiment, we asked participants to memorize 12 numbers to distinguish between high and low cognitive load. The high cognitive load group memorized 12 different numbers, and the low cognitive load group memorized the same 12 numbers. The common-sense judgment material was the same as in Experiment 1.

Procedure

Experiment 3 used a 2 (cognitive load: High vs. Low) × 2 (Answer clue: Yes vs. No) between-subjects design. The dependent variables were second predicted score and difference between predicted and actual scores.

Prior to the start of the experiment, all participants were randomized into a high cognitive load group and a low cognitive load group. Participants in the high cognitive load group were assigned high cognitive load tasks, and participants in the low cognitive load group were assigned low cognitive load group tasks.

Next, the participants were asked to complete the initial five items of the general knowledge questions in 5 min. In the first test, participants were randomly divided into a group that received answer clues and a group that did not receive answer clues. Each group had 30 participants. The experimental group had the opportunity to see the answer clues on the bottom of the test paper on each page, but there were no answers at the bottom of the test for the control group. After completing the first test, all subjects answered a second test question without an answer prompt and then predicted the score of the second test (15 similar questions), wrote their predicted score on the test paper, and then finished the second test (**Figure 6**).

Results

Second Predicted Score

The results showed that for the second predicted score, the main effect of the answer clues was significant, $F(1,119) = 30.89$, $p < 0.01$, $\eta_p^2 = 0.24$. The second predicted score was significantly higher for participants with answer clues ($M = 107.25$, SD = 17.09) than for those who did not have answer clues ($M = 85.50$, SD = 20.99). The main effect of cognitive load was significant, $F(1,119) = 17.25$, $p < 0.01$, $\eta_p^2 = 0.29$. The second test score for the high cognitive load group ($M = 104.50$, SD = 21.71) was significantly higher than that of the low cognitive load group ($M = 88.25$, SD = 19.20). The interaction between answer clues and cognitive load was not significant, $F(1,117) = 0.10$, $p > 0.05$, $\eta_p^2 = 0.01$.

Difference Between the Predicted and Actual Scores

The results showed that for the second predicted score (the degree of self-deception), the main effect of the answer clues was significant, $F(1,119) = 102.67$, $p < 0.01$, $\eta_p^2 = 0.47$. Compared with the group that did not receive answer clues ($M = 10.67$, SD = 11.33), the answer clues group ($M = 39.17$, SD = 20.77) had significantly higher predicted scores than actual scores. The main effect of cognitive load was significant, $F(1,119) = 18.03$, $p < 0.01$, $\eta_p^2 = 0.14$. Compared with the low cognitive load group ($M = 18.33$, SD = 20.27), the high cognitive load group ($M = 31.50$, SD = 21.77) predicted scores were significantly higher than actual scores. The interaction between answer clues and cognitive load was significant, $F(2,117) = 12.61$, $p < 0.01$, $\eta_p^2 = 0.11$. Simple effect analysis showed that for the predicted and actual scores, comparing with non-answer clues, when answer clues, high cognitive load ($M = 47.36$, SD = 20.42) had significantly higher than low cognitive load ($M = 30.98$, SD = 2.35) (**Figure 7**).

Discussion

Experiment 3 found that under the forward-looking paradigm of self-deception, individuals who received answer clues had significantly higher second test prediction scores than individuals who did not receive answer clues. Thus, the participants' self-deception behavior was successfully induced under the forward-looking paradigm, a result consistent with previous research (Chance et al., 2011; Yang, 2017). Compared with the low cognitive load group, the second test prediction scores of the

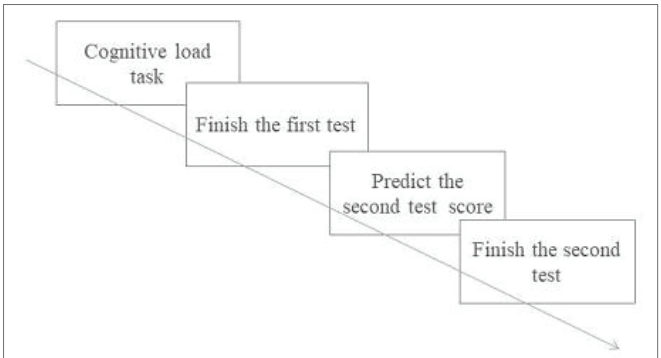

FIGURE 6 | Trials of Experiment 3.

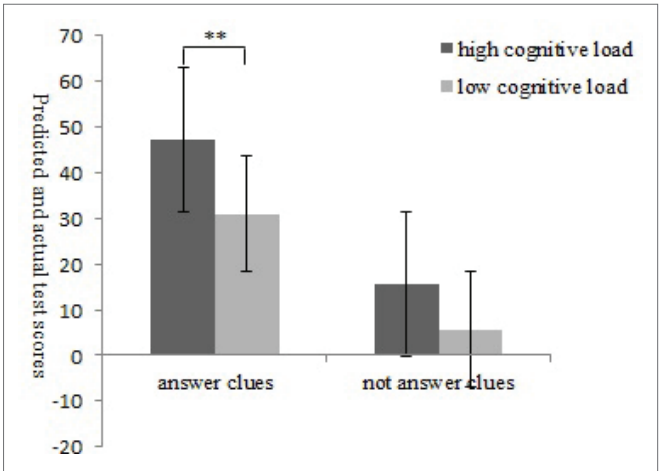

FIGURE 7 | Results of Experiment 3: difference between predicted and actual scores for high versus low cognitive load and answer versus no answer clues (**$p < 0.01$).

high cognitive load group were significantly higher, which showed that the high cognitive load group was more likely to experience an effect on cognitive load than the low cognitive load group. For the difference between the predicted score and the actual score on the second test, in the group with the answer clues, individuals with a high cognitive load had a greater difference in performance than those with a low cognitive load. Thus, individuals with a high cognitive load were more likely to engage in self-deception, which is consistent with our hypothesis.

The results of Experiment 3 also showed that individuals with a high cognitive load not only did not inhibit self-deception but also promoted self-deception. The reason may be that individuals with a high cognitive load were overburdened, and in cases where additional cognitive load consumption has been identified, they may have used the self-adaptability of memory and unconscious impairment to save cognitive resource consumption (Nairne and Pandeirada, 2010). ICM is the part of memory that is forgotten unconsciously. Forgetting part of the ICM produces less cognitive load. At the same time, people cannot recall the content of ICM; they can only lie to themselves, which promotes the behavior of self-deception. Therefore, cognitive load is not only an important indicator for distinguishing between self-deception and deceptive behavior but also an important external mechanism for self-deception behavior.

GENERAL DISCUSSION

Self-Deception Saves Cognitive Resources More Than Deception

Experiment 1 showed that self-deception saves cognitive resources more than deception; it is consistent with previous research, the deceiver can be detected by clues associated with the cognitive load (Vrij and Barton, 2004; Atoum, 2006). Thus, self-deception is a strategy in interactions between individuals rather than an independent strategy. Because that interpersonal deception saving cognitive resources and reducing the production of cognitive load. In this study, the task of cognitive resource consumption was strictly controlled by direct laboratory operation. The intention was to induce self-deception and deception in groups under the same experimental conditions. Through subjective reporting of cognitive load, the cognitive load differences between the two behaviors were directly compared. This study found that under the same experimental conditions, the cognitive load generated by self-deception behavior was lower than that generated by deception behavior, which demonstrates that self-deception behavior, as a form of interpersonal deception, has the advantage of saving cognitive resources and reducing cognitive load.

Memory Impairment May Be Internal Mechanism of Self-Deception to Save Cognitive Resources

Experiment 2 found that self-deception saved cognitive resources compared with deception, and it is necessary to discuss its internal mechanism. Experiment 2 found that the impairment of ICM deceived the individual memory system to save the internal mechanism of cognitive resources. Using the paradigm of the memory of self-deception behavior, the high or low social status of the target of deception induced different memory encoding processes in participants. This process can reveal the purposes of participants' self-deception and deception behavior. Individuals who received a higher status target were exposed to higher potential lie detection rates and greater situational pressures, so they were more inclined to self-deception. In ICM measurements, fewer deceptive words were reported than non-deceptive words, demonstrating that self-deceiving individuals' ICM was impaired. When instructed to deceive an individual of high social status, self-deceptive individuals also reported lower cognitive loads. These results were consistent with the hypothesis, showing that self-deception behavior as a means of interpersonal deception saves cognitive resources and reduces cognitive load. Thus, its internal mechanism seems to be the conscious memory impairment of the memory system. The impairment pattern of this memory component occurs during the individual's encoding or retention of memory and is a silent and unheralded process of generation. This is what occurred in Experiment 2: individuals are often unaware of this deep change in memory, but this partial impairment of memory causes individuals to unconsciously "lie" to themselves because the memories that should have been kept are no longer there. This form of self-deception becomes a perfect pattern of deception.

Cognitive Load Promotes Self-Deception

Experiment 3 showed that individuals with a high cognitive load did not inhibit self-deception but rather promoted it. This may be because individuals with a high cognitive load are overwhelmed by the burden of cognitive resource consumption. Research by Sweller (1988) suggests that the processing of information received by individuals produces a corresponding "level of mental energy" (Milton et al., 2008). ICM is a component of memory that is unconsciously impaired. When individuals lose part of their ICM, they have a lower cognitive load. At the same time, people cannot recall the content of nonrandom conscious memory; they can only lie to themselves, which promotes the formation of self-deception.

Experiment 3 addressed the problem of cognitive load as the external mechanism of self-deception behavior. Due to the limited amount of cognitive resources, individuals with a high cognitive load attempt to reduce it. One shortcut to achieve the goal of reducing cognitive load is to adapt to this conscious impairment. As a result, the scores predicted in the forward paradigm of self-deception were more daring and inaccurate and thus more prone to self-deception.

STRENGTHS AND LIMITATIONS

The current studies explored the cognitive mechanism by which self-deception could reduce cognitive load and found

that it was caused by impairing of involuntary conscious memory (ICM). The studies also found that self-deception would increase when individuals were under a high cognitive load. These results enrich previous research on self-deception field.

Even so, the current studies still have some limitations. First, because self-deception is very sensitive to the detection probability of presentation, it is difficult to verify self-deception through self-reports or other people's observations (Lu and Chang, 2011). In our studies, it was inevitable to adopt a self-report's method.

Second, in the process of Experiment 1, the experimenter found that when comparing the deception group with the self-deception and control group participants, there were larger mood swings and reactions in the deception group. Previous studies also found that emotion has a large influence on immoral behavior (Hess et al., 2018; Jahnke, 2018). Our study not involve other variables other than those discussed in the experiments. Future study could explore the influence of emotion.

Third, only the ways in which participants deceive themselves and hide information were studied. Deception and self-deception may also occur by means of distortion and forgery (Moomal and Henzi, 2000). Future research could study the multiple functions of deception.

CONCLUSION

Self-deception reduces cognitive load. In terms of internal mechanisms, self-deceiving individuals use the self-adaptability of memory to achieve self-deception through the impairment of nonrandom conscious memory to reduce their cognitive load. In terms of external mechanisms, a higher cognitive load leads to more self-deception.

DATA AVAILABILITY

The datasets for this manuscript are not publicly available because we propose to submit the dataset when the paper is accepted. Requests to access the datasets should be directed to fanwei@hunnu.edu.cn.

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

All authors were involved in all parts of the research. ZJ analyzed the data and wrote the manuscript. WZ designed studies and collected the data. LT performed the experimental procedures and examined the experimental material. WF and YZ guided experimental design and modified the manuscript.

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The Effects of Working Memory and Probability Format on Bayesian Reasoning

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Bayesian reasoning is common and critical in everyday life while the performance on Bayesian reasoning is rather poor. Previous studies showed that people could enhance their performance by applying cognitive resources under the natural frequency format condition. Working memory is one of the crucial cognitive resources in the reasoning process. However, the role of working memory on Bayesian reasoning remains unclear. In our study, we verified the effect of working memory on Bayesian reasoning by evaluating the performance of participants with high and low working memory span (WMS); we also investigated if working memory as a kind of cognitive resource can affect Bayesian reasoning performance by manipulating the cognitive load in a dual-task paradigm among participants with no-, low-, and high-loads. We found the following: (1) The Bayesian reasoning performance of high WMS participants was significantly higher than that of low WMS participants. (2) Performance under natural frequency condition was noticeably higher than that in standard probability condition. (3) Interaction between working memory and probability format was significant, and the performance of participants with high-load in natural frequency condition was higher when compared to those of participants with no- and low-load. Therefore, we can conclude that: (1) Working memory resource is a major factor in Bayesian reasoning. The performance of Bayesian reasoning is influenced by working memory span and working memory load. (2) A Bayesian facilitation effect exists, and replacing the standard probability format with a natural frequency format can significantly improve Bayesian performance. (3) Bayesian facilitation occurs only in participants with sufficient working memory resources.

Keywords: working memory, probability format, Bayesian reasoning, dual-process, cognitive resource

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INTRODUCTION

In daily life, people often make critical decisions based on conditional probabilities, such as in courts, hospitals and war rooms (Shi et al., 2019). Although decisions and judgments based on uncertainty are of great importance, reasoning performance based on probabilistic information is not satisfactory (Kahneman and Tversky, 1972). A good example of this is Bayesian reasoning. Bayesian reasoning is when people adjust their existing opinions based on new information or evidence to arrive at conclusions and make decisions. For example, the probability of breast cancer in the population is 1% for a woman who participates in routine screening. If a woman has breast

cancer, the probability that she will have positive mammography is 80%. If a woman does not have breast cancer, the probability that she will also have positive mammography is 9.5%. If a woman in this group had positive mammography, what's the probability that she has breast cancer? (Gigerenzer and Hoffrage, 1995).

Then we can calculate it as Bayes' rules:

$$P(h|d) = \frac{P(h)P(d|h)}{P(h)\ P(d|h)\ +\ P(-h)P(d|-h)}$$

Where, P(h) represents the base rate of 1%, P(d| h) represents the hit rate of 80%, P(d|−h) represents the false alarm rate of 9.5%, and P(h| d) represents the posterior probability.

Since Edwards (1968) carried out his research on Bayesian reasoning, studies have consistently shown that people are not good decision-makers and their reasoning abilities on Bayesian problems are quite poor (Kahneman and Tversky, 1972; Gigerenzer and Hoffrage, 1995). However, Bayesian reasoning is common and deadly in People's Daily life (Shi et al., 2019). Many researchers are trying to find ways to improve the reasoning performance. As for the influencing factors, previous studies mainly discussed the content (context) effect (Gavanski and Hui, 1992; Girotto and Gonzalez, 2002), the ways to obtaining probabilistic information (Lovett and Schunn, 1999) and factors of individual differences, such as knowledge background (Shi et al., 2006; Siegrist and Keller, 2011), cognitive style, cognitive responsiveness, numerical skills, emotional states and cognitive strategies (Sirota and Juanchich, 2011; Sirota et al., 2014; Reani et al., 2019).

Gigerenzer and Hoffrage (1995), Zhu and Gigerenzer (2006) found that when the natural frequency was used to represent probabilistic information, people and even children could perform Bayesian reasoning (Gigerenzer and Hoffrage, 1995; Zhu and Gigerenzer, 2006). This improvement has been confirmed by many studies (Cosmides and Tooby, 1996; Sloman et al., 2003; Barbey and Sloman, 2007; Sirota et al., 2014; Artur et al., 2015; McDowell and Jacobs, 2017; Weber et al., 2018).

There are two influential theories about the natural frequency promotion of Bayesian reasoning. One is the framework of ecological rationality, the other is nested set theory (Lesage et al., 2013). The ecologically rational framework argues that people perform better at natural numbers because people process natural frequencies better than probability. Some researchers found child couldn't solve Bayesian problems when it was in probability format but they can solve Bayesian problems in natural frequencies. However, their performance was still not very high (Zhu and Gigerenzer, 2006) and for different individuals, the facilitation in natural frequency representation is not always working in every situation (Gigerenzer and Hoffrage, 1995; Cosmides and Tooby, 1996; Lovett and Schunn, 1999; Sloman et al., 2003; Barbey and Sloman, 2007; Miroslav and Marie, 2011). The nested set theory holds that under natural frequency conditions, the performance of the reasoning task could be promoted by making a collection of "nested" relationship visualization (De Neys and Schaeken, 2007; Barbet and Guillaume, 2016). However, many theories and research studies show that working memory plays a major role in solving reasoning problems (Johnson-Laird and Savary, 1999; Oberauer et al., 2005; Baddeley, 2007, 2010; Sejunaite et al., 2019). As the core of cognitive processing, working memory is closely related to the reasoning process, such as analogical reasoning and syllogism reasoning, and propositional reasoning (Meiser et al., 2001; Morrison et al., 2001; Markovits et al., 2002; Capon et al., 2003; Copeland and Radvansky, 2004; Sejunaite et al., 2019).

Their study showed that both working memory span and working memory resources were highly positively correlated with reasoning tasks (Meiser et al., 2001; Morrison et al., 2001; Markovits et al., 2002; Capon et al., 2003; Copeland and Radvansky, 2004). The theoretical model of the relationship between reasoning and working memory, such as the dual-process model, also holds that all kinds of cognitive processing activities are restricted by the working memory ability during reasoning (Johnson-Laird and Savary, 1999; Meiser et al., 2001). Bayesian reasoning is a type of probability reasoning, which originates from the process of making decisions and judgments based on the obtained information. The discussion of this problem can be active in improving the research field of working memory and reasoning.

Researchers have explored cognitive processing, such as cognitive reaction ability, to investigate the facilitation effect (Gigerenzer and Hoffrage, 1999; Süß et al., 2002; Miroslav and Marie, 2011; Lesage et al., 2013; Sirota et al., 2014). Even children could do Bayesian reasoning by natural frequency format representation (Zhu and Gigerenzer, 2006; Artur et al., 2015; McDowell and Jacobs, 2017). In other studies, researchers examined the relationship between Bayesian reasoning performance, cognitive reflective ability and individual development under different problem formats, and conducted experimental operations on cognitive resources under the dual-task paradigm. Results showed that the performance of Bayesian reasoning tasks depends on the participants' general cognitive abilities (Lesage et al., 2013).

To further research the relationship between working memory and Bayesian reasoning, we expand upon the study of Lesage et al. (2013) in two aspects. To investigate the cognition process and rules of Bayesian reasoning and guide people in making effective decisions and judgments, we discuss both working memory and the probability format in this study. We assume that (1) working memory is closely related to Bayesian reasoning performance and that (2) there is a facilitation effect of natural frequency representation, but that the effect requires working memory resources. Two experiments were designed in this study. Experiment 1 is meant to study the influence of working memory span and probability format on Bayesian reasoning. The causal relationship of the working memory resource in the Bayesian inference task is not inferred from experiment 1 only. The dual-task can well study the central executive components involved in cognitive activities (Logie et al., 1994) and the introduction of an auxiliary task is an effective way to examine whether a process is dependent on the cognitive resource (De Neys, 2006; De Neys and Verschueren, 2006; De Neys and Schaeken, 2007; Khemlani et al., 2018; Kimura and Matsuura, 2019). Therefore, experiment 2 intends to design a dual-task experiment to further explore the mechanism

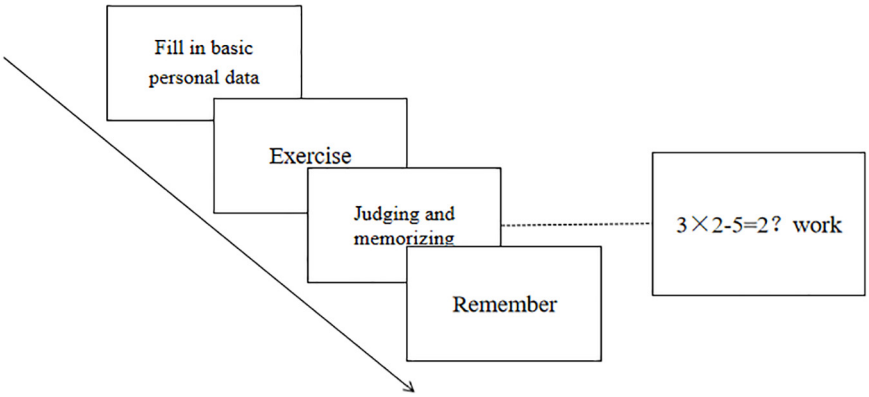

FIGURE 1 | Flow chart of Operation Span Task.

of working memory in the reasoning process by giving a working memory load to manipulate the available working memory resource.

EXPERIMENT 1: EFFECTS OF WORKING MEMORY SPAN ON BAYESIAN REASONING

Purpose and Hypothesis

This experiment is aiming to investigate the effect of WMS on Bayesian reasoning and Bayesian facilitation. Based on previous studies, the hypotheses are as follows: (1) working memory span is highly correlated with Bayesian reasoning score, the performance of high WMS group was better than those of low WMS group; (2) there is a natural frequency facilitation effect.

Methods

Participants

This experiment was approved by the Ethics Committee of Hunan Normal University, and written informed consent was obtained from all participants before the experiment was started. The sample size was calculated with a power of 0.8 and the minimum requirement of sample size was 36. 120 college students (male = 37, female = 83) participated in this experiment, with ages ranged from 18 to 25 years (mean ages = 20.5, SD = 3.45). All of the subjects volunteered to participate in the experiment and did not learn or understand Bayesian reasoning.

This experiment used Operation Span Task designed by Turner and Engle (1989), and revised by Song et al. (2011) (see **Figure 1**). It's made up of 75 mathematical equations with words chosen from the Dictionary of Modern Chinese Frequencies (1986 revised edition), double word noun, neutral. The word frequency is 0.0100–0.1429. The equations are all mixed operation of the multiplication (division) and the addition (subtraction), and the results are also in the single digits.

The WMS index was represented by the total number of double-character words correctly recalled in the group, with a range from 0 to 60. To ensure the validity of the subjects' participation in the dual-task, the correct rate of the secondary task (equality judgment) was required to be more than 85% (Ikeda and Kitagami, 2013). In the end, the data from 48 subjects were eliminated because the experiment was interrupted or the correct rate of equality judgment was less than 85% and 72 subjects were selected and divided into high WMS and low WMS groups to participate in the formal experiment. The average and standard deviation for each group are shown in **Table 1**.

TABLE 1 | Descriptive statistics of working memory span in high and low WMS groups.

Group	*N*	*M*	*SD*
High-WMS	36	54.47	3.19
Low-WMS	36	44.08	3.61

In the independent sample t-test, $t(70) = -12.93$, $p < 0.001$, and $d = 0.36$. This indicates that the difference between the high and low WMS groups is significant and the classification is effective in this experiment.

Materials and Instruments

A total of 5 of the 10 Bayesian problems (all problems are homogeneous) were extracted from materials developed by Zhu and Gigerenzer (2006) as the reasoning material. The problems were converted to an 800 × 600 pixel picture with black numbers on a white background. The text was in 21 Song style and 1.5 line spacing, and it was placed in the center of the picture. The procedure was run by E-prime 2.0 and rendered on a 19-inch DELL screen with a refresh frequency of 150 Hz and a resolution of 1024 × 768.

Here are two versions of the same Bayesian reasoning question (the Red Nose problem) (see **Figure 2**):

Procedure

The procedure consisted of an exercise part and a test part. When the subjects familiarized themselves with the probabilistic question of the exercise part, they could start the second part of the formal experiment. The instructions were presented first and then entered the reasoning task. After the reasoning questions were presented, they analyzed and calculated on the paper and input the results into the answer box when they were completed

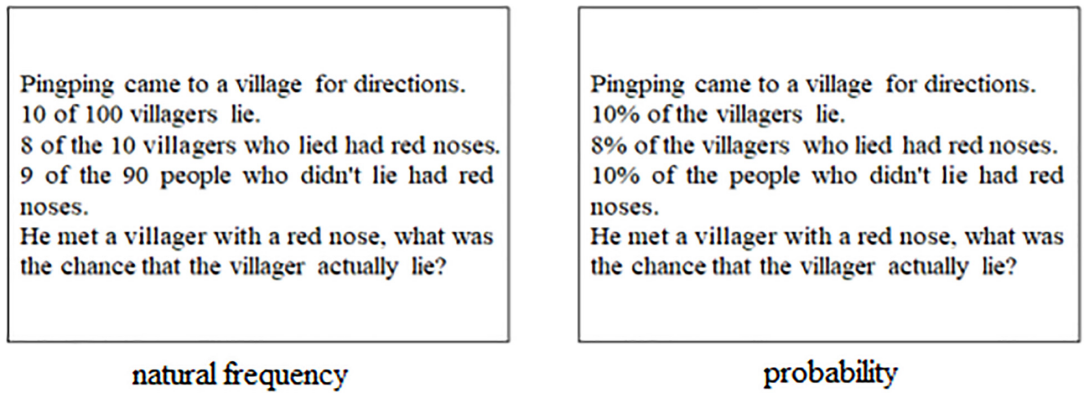

FIGURE 2 | Frequency and possibility version of the same Bayesian reasoning problem.

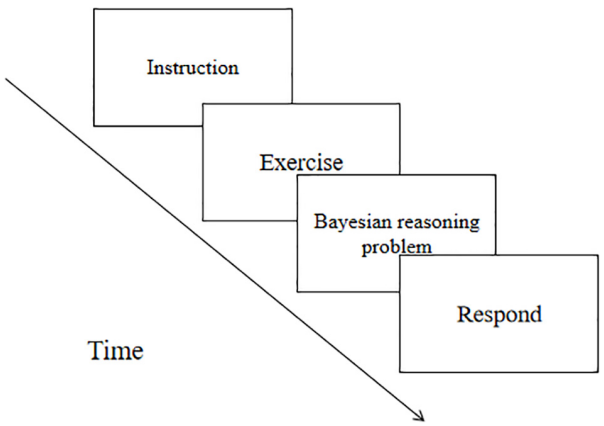

FIGURE 3 | Flow chart of Experiment 1.

(see **Figure 3**). At the end of the experiment, a small gift was given to the subjects.

Results and Analysis

The results of reasoning score of the 72 subjects were regarded as "correct" when the difference from standard answers was less than 1%; otherwise, they were regarded as "wrong." Correct answer was scored as 1 while incorrect answer was scored as 0, and the total score was between 0 and 5 points. The SPSS19.0 software was used to analyze the data. The analysis and results are shown in **Figure 4**.

Two-factor ANOVA showed that the main effect of WMS was significant [$F(1,68) = 6.967$, $p < 0.05$, $\eta^2 = 0.10$], that is, the Bayesian reasoning performance of high WMS subjects was significantly higher than that of low WMS subjects. The main effect of data format was significant [$F(1,68) = 22.574$, $p < 0.05$, $\eta^2 = 0.25$], indicating that the results of reasoning by means of natural frequencies were significantly better than those of reasoning by means of standard probability. Interaction between WMS and data format was significant [$F(1,68) = 4.783$, $p < 0.05$, $\eta^2 = 0.07$].

A further simple effect analysis showed the following:

At the high WMS level, the probability format effect was significant ($F = 22.15$, $p < 0.05$), meaning that the results of the high WMS subjects who used natural frequencies reasoning were significantly higher than the results of the subjects in the standard probability.

At the low WMS level, the probability format effect was not significant ($F = 3.03$, $p > 0.05$), that is to say, there was no significant difference between the results of low WMS subjects who used standard probability reasoning and the results of low WMS subjects who used natural frequencies.

The results showed that the working memory span is highly related to Bayesian reasoning, that the performance of the high WMS group was higher than low WMS, and the facilitation is more significant.

Although the results of experiment 1 showed that WMS is closely related to Bayesian reasoning, it was not sufficient for inferring the causality of working memory resources in the Bayesian reasoning task. Some studies have shown that

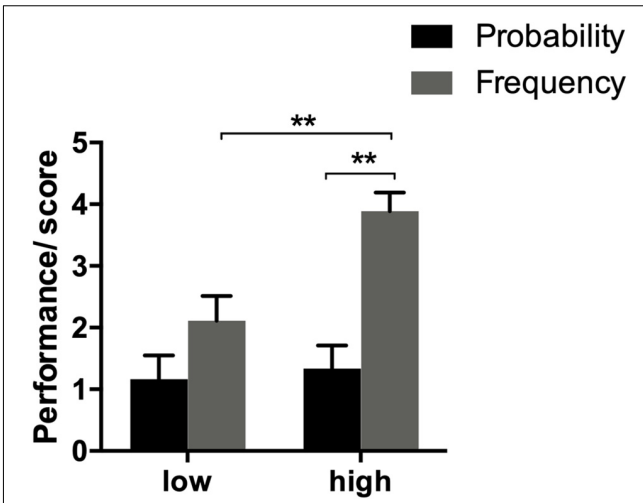

FIGURE 4 | Results of different WMS subjects. *$p < 0.05$ and **$p < 0.01$.

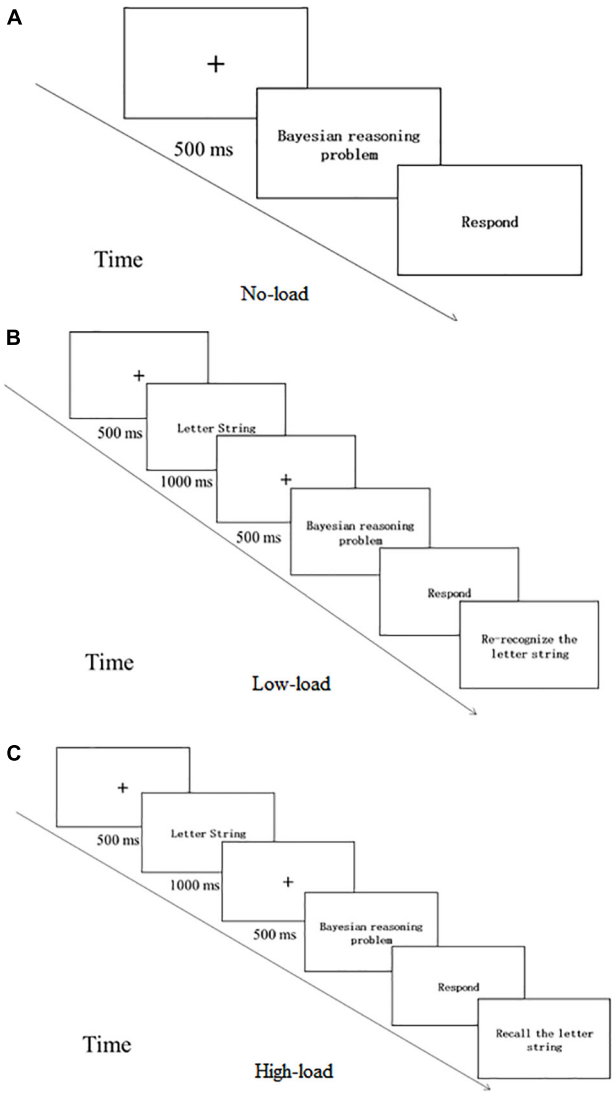

FIGURE 5 | Flow chart of Experiment 2. **(A)** is for No-load condition, **(B)** is for the Low-load condition and **(C)** is for the High-load condition.

the dual-task experiment can also explore the central executive components involved in cognitive activities and that the introduction of auxiliary tasks is also an effective way to examine whether a reasoning process depends on cognitive resources.

EXPERIMENT 2: THE INFLUENCE OF WORKING MEMORY LOAD ON BAYESIAN REASONING

Purpose and Hypothesis

Based on the dual-task paradigm (Logie et al., 1994; Khemlani et al., 2018; Kimura and Matsuura, 2019), the mechanism of working memory in the reasoning process is further explored by directly placing a load on the individual's working memory (De Neys and Verschueren, 2006; De Neys and Schaeken, 2007). The experimental assumptions are as follows: (1) working memory load affects the reasoning performance of subjects; and (2) there is a Bayesian facilitation effect, but it does not exist in all load conditions.

Methods

Participants

This experiment was approved by the Ethics Committee of Hunan Normal University in China, and written informed consent was obtained from all participants prior to the experiment. A necessary sample size of 42 was calculated by G-Power 3.1 with power = 0.8 (Iachini et al., 2005). 136 paid college students (male = 42, female = 96) aged 18–25 years (mean ages = 23.3, SD = 3.24) participated in this experiment.

Materials and Instruments

The secondary task designed by Si et al. (2012) was used as an alphabetical order task (high-load) and a letter recognition task (low-load). The main task selected two of 10 Bayesian problems (all of which are homogeneous) from Zhu and Gigerenzer (2006) (different from the five reasoning questions in experiment 1). The reasoning questions were converted to 800 × 600 pixel pictures with black characters on a white background. The characters were presented in 21 Song style (34 letters), 1.5 line spacing and the text was in the center of the picture. Programmed and run by E-Prime 2.0, the picture was presented on a 19-inch dell computer screen with a display refresh frequency of 150 Hz. The resolution was 1024 × 768. The same reasoning question was presented in two versions: standard probability and natural frequency.

Design

The subjects completed Bayesian reasoning problems in probability format and natural frequency format. The working memory resources were manipulated by the secondary task of the dual-task paradigm. The factor working memory load distinguished between the high-load, low-load and the control condition. In the dual-task condition, participants were presented with a letter string (i.e., AGRCWO) which they were instructed to keep in mind while solving the Bayesian reasoning problems. Subjects in the high-load condition need to recall the letter string while in the low-load condition only need to re-recognize the letter string (Si et al., 2012). No letter string was presented in the no-load condition (see **Figure 5**). The dependent variables were the subjects' score on 2 Bayesian reasoning questions (1 for a correct answer, 0 for an incorrect answer, the total score was 0∼2).

Procedure

Results and Analysis

Based on the finding of experiment 1, to further explore the working memory and if the working memory resources affect the Bayesian reasoning. Four subjects did not complete the reasoning questions or interrupted the experiment. The average score of the two alphabetical tasks (1 for a letter) and the two-letter recognition tasks (the correct answer score

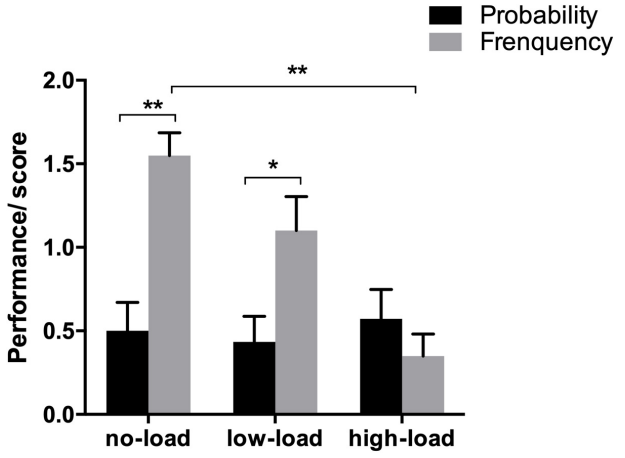

FIGURE 6 | Results of different WM loads and data formats. *$p < 0.05$ and **$p < 0.01$.

was 1 point while the incorrect answer was 0 points) were calculated and the data from eight subjects were excluded because their score of the secondary task was below the average three standard deviations. And the data of the remaining 124 subjects can be retained.

If the difference between the results of the reasoning and the standard answer was less than 1%, the answer was regarded as "correct," whereas regarded as "wrong," a correct answer scored as 1, and the total score was 0∼2. The results are shown in **Figure 6**.

Two-factor ANOVA showed that the main effect of the working memory load was significant [$F(2,118) = 5.861$, $p < 0.05$, $\eta^2 = 0.09$]. The results of reasoning in the three working memory load conditions were as follows: the best results were in the no-load condition, the second was in the low-load condition, and the worst was in the high-load condition. The main effect of the data format was significant [$F(1,118) = 13.896$, $p < 0.05$, $\eta^2 = 0.11$]. The reasoning results of subjects in the natural frequency scenario were significantly better than those of subjects who were in the standard probability scenario. Interaction between working memory load and data format was significant [$F(2,118) = 7.838$, $p < 0.05$, $\eta^2 = 0.12$].

A further simple effect analysis showed the following:

At the no-load level, the data format effect was significant ($F = 18.49$, $p < 0.05$), which showed that the reasoning results of the subjects in the natural frequency scenario were significantly better than those of subjects in the standard probability scenario.

At the low-load level, the data format effect was significant ($F = 7.90$, $p < 0.05$), that is, at the low working memory load level, the reasoning score of the subjects in the natural frequency scenario were significantly better than those of subjects in the standard probability scenario.

At the high-load level, the data format effect was not significant ($F = 0.74$, $p > 0.05$). At the high-load level, there was no significant difference in reasoning performance between the two data formats.

GENERAL DISCUSSION

Impact of Working Memory on Bayesian Reasoning Performance

The results of experiment 1 showed that the performance of Bayesian reasoning was influenced by the working memory span (WMS). This is consistent with the researches of Capon et al. (2003), Copeland and Radvansky (2004), and Bai et al. (2004) of other types of reasoning.

Bayesian reasoning is a kind of complicated probabilistic reasoning that involves a series of probability information and rules. Individuals with high WMS have more ability and resources to use probability rules, so they could integrate all kinds of explicit information relationships and operate on numbers, and can result in the answer smoothly. However, for individuals with low WMS, it is impossible to integrate and calculate the probability information effectively because the complex cognitive process is far beyond their own WM ability. Therefore, the reason why individuals cannot obtain the correct answer when completing the experimental task is that they guess or input an answer randomly according to their own intuitive judgments, which lead to a reasoning error (Lesage et al., 2013).

The results of experiment 2 showed that WM load can affect Bayesian reasoning. Specifically, the degree of influence increases with WM load. The reasoning performance was best in the no-load condition, second in the low-load condition and the worst in the high-load condition.

For each individual, the WM resource remains relatively stable and limited. When a secondary task occupies more WM resources, they have fewer resources to solve the main task (Robbie et al., 1982). Of the three conditions, the alphabetical recall was the one that takes up most of the WM resources; thus, under a condition of high-load, subjects had the least resources to address the Bayesian reasoning problem, so this result was the worst. The task of alphabetical recognition was simpler than the task of alphabetical sorting and takes up fewer resources. Therefore, there were more WM resources used to solve the problem, thus the performance under low-load condition was significantly improved. In the no-load condition, there were the only tasks competing for the limited WM resources, so the subjects showed the best performance.

Bayesian Facilitation Effects

Sloman et al. (2003) called the improvement of Bayesian reasoning performance under natural frequency conditions Bayesian facilitation. Both experiments 1 and 2 showed an obvious Bayesian facilitation effect: the subjects' results in natural frequency scenario were significantly higher than those in the standard probability scenario. This was consistent with the results of Gigerenzer and Hoffrage (1995), Cosmides and Tooby (1996), Brase et al. (1998), Artur et al. (2015), and McDowell and Jacobs (2017).

Therefore, two experiments verified the Bayesian facilitation in natural frequency representation. However, the Bayesian facilitation effect did not appear under all conditions, that is,

the occurrence of the Bayesian facilitation effect requires certain conditions. The results of experiment 2 verified the facilitation effect. The results showed that the performance in natural frequency format was significantly better than in the standard probability format under low-load and no-load conditions, but the difference between them was not significant under a high-load condition. This indicated that the Bayesian facilitation effect was only reflected in the low-load and no-load conditions, but it was not found in the high-load condition.

Working memory resource is a kind of important cognitive resource for reasoning (Meiser et al., 2001; Morrison et al., 2001; Markovits et al., 2002; Capon et al., 2003; Copeland and Radvansky, 2004; Baddeley, 2007, 2010; Sejunaite et al., 2019). Under high-load conditions, secondary tasks (alphabetical recall) occupied more WM resources, and few WM resources are used to complete the main task. As a result, the subjects in the two versions of the reasoning problem had poor scores. However, in the low-load or no-load conditions, the results were the opposite. Most of the WM resources were utilized for processing reasoning tasks. Although they performed poorly on reasoning problems with the standard probability format, they were able to accomplish relatively simple reasoning problems presented in natural frequency format (Johnson-Laird and Savary, 1999; Lesage et al., 2013).

The Explanation for the Effect of Working Memory on the Bayesian Facilitation

Experiment 1 found that under the natural frequency condition, the score of the high WMS group was significantly higher than those of low WMS. Experiment 2 also found that under the natural frequency condition, the reasoning results of subjects in low-load and no-load conditions were significantly higher than those under the condition of probability (Miroslav and Marie, 2011; Lesage et al., 2013; Sirota et al., 2014).

The ecologically rational framework argues that people perform better at natural numbers because people process natural frequencies better than probability. And the computational requirements for natural frequencies are much simpler than for probabilities. However, the participants couldn't complete the problems well in high-load conditions. The nested sets theory holds that there is a positive relationship between working memory resources and reasoning performance, especially under the natural frequency condition that nest-set is clear (De Neys and Schaeken, 2007; Barbet and Guillaume, 2016). The results of experiment 1 showed that the working memory span was highly related to the inference performance. Moreover, the reasoning score of individuals with a high working memory span is significantly better than those with low working memory span under the natural frequency condition. The results of experiment 2 also show that the result of reasoning depends on available working memory resources and the same as the facilitation under natural frequency condition.

The nested sets theory is proposed on the basis of the dual-process model, which makes the structure of the problem set clear and triggers the analysis system. The system uses executive cognitive resources to calculate the correct answer. Therefore, the reason why people perform better with natural frequency is that the nest-set is clear by making a collection of "nested" relationship (the larger subset embedded collection) visualization (Shi et al., 2006; Barbey and Sloman, 2007). That is, under the condition of arousing a clear nested sets representation, the reasoning performance of the subjects should be related to the general cognitive ability of the individual: the more cognitive resources there are the more likely it is that the individual obtains the correct answer. In contrast, under the condition of a fuzzy representation of the problem, they are unable to successfully complete reasoning tasks (De Neys and Schaeken, 2007; Artur et al., 2015; Barbet and Guillaume, 2016).

The results support the effect of working memory on reasoning. If the cognitive process is too complex that it exceeded people's working memory ability, their reasoning will be wrong. Bayesian reasoning is a very difficult probability reasoning that involves a series of probability rules such as addition, multiplication, division, and a complex cognitive process. The use and storage of the information, rules, and the calculation of the premise and new information are all restricted by working memory capacity (Johnson-Laird and Savary, 1999; Meiser et al., 2001; Khemlani et al., 2018; Kimura and Matsuura, 2019). For individuals with high working memory resources, because they have a strong ability to calculate numbers, use probability rules and integrate all kinds of explicit information relations, so they could calculate the answers more smoothly. But for individuals with low working memory resources, this complex cognitive process far exceeds their working memory ability, so they cannot effectively integrate and calculate the probability information and draw the correct conclusion. This means, that they only complete the task of random speculation or according to their own intuitive judgment arbitrary to input an answer, resulting in reasoning errors (Capon et al., 2003; Copeland and Radvansky, 2004; Khemlani et al., 2018).

CONCLUSION

Working memory resource is an important factor that influences Bayesian reasoning performance; that is, the quality of Bayesian reasoning results depends on working memory resources. Individuals with high WMS or sufficient resources exhibit better cognitive processing than those with low WMS or insufficient resources. However, this advantage is not always true, and it may not exist when the cognitive task is too hard. A Bayesian facilitation effect exists and replacing standard probabilities with natural frequency can greatly improve Bayesian performance. However, only in individuals with high working memory span or sufficient cognitive resources does this effect occur. The experimental results provide experimental evidence for the effect of working memory on Bayesian reasoning.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are publicly available. This data can be found here: https://figshare.com/articles/data/11827053.

ETHICS STATEMENT

This experiment was approved by the Ethics Committee of Hunan Normal University in China, and written informed consent was obtained from all participants prior to the experiment.

AUTHOR CONTRIBUTIONS

ZS, LY, and ZL conceived and designed the study. LY and ZL performed the experiments and wrote the manuscript. LY, ZL, and SP analyzed the data. ZS, LY, TT, and YX the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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