Psychology and Aging

The Nature of Positivity Effects in Emotional Memory in a Chinese Sample Both Valence and Arousal Matter

--Manuscript Draft--

Manuscript Number:	PAG-2020-0945R1
Full Title:	The Nature of Positivity Effects in Emotional Memory in a Chinese Sample Both Valence and Arousal Matter
Abstract:	The age-related positivity effect—a tendency in older adults to remember more positive than negative information, relative to young adults—has been extensively studied among Westerners. Much less is known regarding whether Chinese adults also exhibit the positivity effect. In the present work, we tested whether Chinese adults exhibit the positivity effect in memory for facial expressions of emotion. We also tested whether arousal could moderate the manifestation of the positivity effect in Chinese adults, given their preference for low-arousal positive emotions. Chinese younger and older adults were tested on their recognition memory for emotional facial expressions. An interaction between age group and valence and arousal was found, such that Chinese older adults underperformed their younger counterparts in recognizing high arousal positive pictures (i.e., excitement), as well as negative pictures regardless of arousal, but performed equally well (if not better) in recognizing low arousal positive pictures (i.e., smile), which confirmed our hypothesis. The present work confirms the cultural influences on older adults' memory performance and highlights the importance of arousal in modulating emotional memory in Chinese older adults.
Article Type:	Article
Keywords:	Positivity effect; Arousal; Chinese older adults; Emotional memory
Corresponding Author:	Xin Zhang, PhD Peking University, China Beijing, 100871, CHINA
Corresponding Author E-Mail:	zhang.x@pku.edu.cn
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Peking University, China
Other Authors:	Jennifer Stanley
	Jin Ke
	Xuan Song, Ph.D
	Jing Mu, MA
	Yuanqing Chang, BSS
	Hongmei Lin, BS
Author Comments:	July 7, 2021 Psychology and Aging Manuscript No. PAG-2020-0945 New Title: The Nature of Positivity Effects in Emotional Memory in a Chinese Sample: Both Valence and Arousal Matter Dear Dr. Ute Kunzmann: Thank you for the opportunity to revise our manuscript on the positivity effect and for granting the extension on our revision. To respond to your comments and the reviews, we collected new data. This was something of a challenge during the pandemic, so we appreciate the extra time allowed for this revision. We believe the manuscript is much improved and hope that you and the reviewers agree. Given the significant changes in the manuscript, we have a new title to better reflect the focus of the study, The Nature

	of Positivity Effects in Emotional Memory in a Chinese Sample: Both Valence and Arousal Matter. We sincerely thank you and the reviewers for your helpful comments and suggestions. They helped us to sharpen our conceptual framework and align the design to our specific research questions (please refer to our response letter for the detailed responses to each of these points). We again thank the associate editor and reviewers again for their time and helpful suggestions for improving this manuscript. We hope the changes have done so and that the manuscript is now suitable for publication in Psychology and Aging. Should you have further questions about the manuscript, please feel free to contact me at zhang.x@pku.edu.cn. Yours Sincerely, Xin Zhang, Ph.D Associate Professor School of Psychological and Cognitive Sciences Peking University Beijing, PR China
Corresponding Author's Secondary Institution:	
First Author:	Jennifer Stanley
Order of Authors Secondary Information:	
Suggested Reviewers:	Helene Fung, Ph.D Chinese University of Hong Kong hhlfung@psy.cuhk.edu.hk she is an expert in cross-cultural differences in positivity effect.
Opposed Reviewers:	
Order of Authors:	Jennifer Stanley
	Jin Ke
	Xuan Song, Ph.D
	Jing Mu, MA
	Yuanqing Chang, BSS
	Hongmei Lin, BS
	Xin Zhang, PhD
Manuscript Classifications:	culture; emotion; memory
Additional Information:	
Question	**Response**
Did your study receive research ethics committee, e.g., Institutional Review Board, approval? (Please note: you must include in your Methods* section a brief statement of your response to whichever one of the following questions applies for the research reported in your manuscript.)	Yes
If Yes, list the name of the ethics committee that approved the research, protocol number, and title of study. as follow-up to "Did your study receive research ethics committee, e.g., Institutional Review Board, approval?	Institutional Review Board of School of Psychological and Cognitive Sciences, Peking University. Protocol number #2014-03-04 title: positivity effect in China

(Please note: you must include in your Methods* section a brief statement of your response to whichever one of the following questions applies for the research reported in your manuscript.)"	
Submissions do not typically exceed 8,000 words. Please enter the number of words in your manuscript's text, not counting Title Page, Abstract, Keywords, References, Tables, Figures or Supplemental Material for Online Publication.	5473
Original color figures can be printed in color at the editor's and publisher's discretion provided the author agrees to pay a portion of the cost. A list of the color figure prices charged to the author is available here. Please indicate which statement applies to your manuscript:	Print figures in grayscale, display as color online only. There is no cost to the author for this option.

The Nature of Positivity Effects in Emotional Memory in a Chinese Sample: Both Valence and Arousal Matter

Jennifer Tehan Stanley[1], Jin Ke[2], Xuan Song[2,3], Jing Mu[2], Yuanqing Chang[2], Hongmei Lin[2], Xin Zhang[2]

[1]Department of Psychology, University of Akron, Ohio, U.S.

[2]School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China

[3]Center for Mental Health Education, China Institute of Industrial Relations, Beijing, China

Author Notes

Correspondence regarding this manuscript should be addressed to Dr. Xin Zhang, School of Psychological and Cognitive Sciences, Peking University, Beijing, China, 100871. Email: zhang.x@pku.edu.cn. The study received financial support from the National Natural Science Foundation of China (#31871121 to Dr. Xin Zhang).

Abstract

The age-related positivity effect—a tendency in older adults to remember more positive than negative information, relative to young adults—has been extensively studied among Westerners. Much less is known regarding whether Chinese adults also exhibit the positivity effect. In the present work, we tested whether Chinese adults exhibit the positivity effect in memory for facial expressions of emotion. We also tested whether arousal could moderate the manifestation of the positivity effect in Chinese adults, given their preference for low-arousal positive emotions. Chinese younger and older adults were tested on their recognition memory for emotional facial expressions. An interaction between age group and valence and arousal was found, such that Chinese older adults underperformed their younger counterparts in recognizing high arousal positive pictures (i.e., excitement), as well as negative pictures regardless of arousal, but performed equally well (if not better) in recognizing low arousal positive pictures (i.e., smile), which confirmed our hypothesis. The present work confirms the cultural influences on older adults' memory performance and highlights the importance of arousal in modulating emotional memory in Chinese older adults.

Keywords: *Positivity effect*, *Arousal*, *Chinese older adults*, *Emotional memory*

The Nature of Positivity Effects in Emotional Memory in a Chinese Sample: Both Valence and Arousal Matter

Numerous studies have documented that older people, in comparison with young adults, tend to pay more attention to and remember more positive than negative or neutral stimuli, which is termed *the positivity effect* (Carstensen, 2006). However, whether the positivity effect exists universally is still unknown, and there have been mixed findings regarding whether non-Western samples, especially Eastern Asians, also exhibit a positivity bias (Fung et al., 2008; Kwon et al., 2009). The present study aimed to fill this gap by testing for the positivity effect in a group of Chinese adults and also providing a potential explanation for the previous mixed findings.

The Positivity Effect and the Cross-Cultural Controversy

According to *Socioemotional Selectivity Theory* (SST; Carstensen, 2006), older adults hold a more limited future time perspective than young adults, and have a stronger desire to realize their emotional goals; whereas younger adults hold a more expansive future time perspective, and prioritize goals that could bank resources for the future, such as knowledge acquisition. It is posited that this shift in motivation leads to systematic age differences in selective attention and memory. Compared with younger adults, older adults attend more to positive stimuli than negative stimuli (English & Carstensen, 2015; Isaacowitz et al., 2006a; Isaacowitz et al., 2006b; Mather & Carstensen, 2003), and they also remember more positive stimuli than negative stimuli in both recall (Charles et al., 2003; Sava et al., 2017) and recognition tasks (Charles et al., 2003); in working memory (Mikels et al., 2005), short term memory (Mammarella et al., 2016), as well as autobiographical memory (Cuddy et al., 2017;

Kennedy et al., 2004). According to the definition of the positivity effect, the effect is present when either there is 1) greater attention or memory for positive than negative information among older compared to young adults, or 2) a reduction of a negativity bias among older relative to young adults, a pattern sometimes referred to as an age-related negativity suppression effect (Reed et al., 2014). Thus, the positivity effect is present when the ratio of positive to negative stimuli is greater for older adults than young adults. Evidence from cognitive neuroscience suggests that such differences are not primarily caused by cognitive declines (Mather & Knight, 2005; Petrican et al., 2008) or neural degradation (Mather et al., 2004; Mather, 2016), but rather by age-related motivational shifts as suggested by SST (Carstensen & DeLiema, 2018; Kalenzaga et al., 2016). Importantly, not all studies find support for the positivity effect in memory in Western samples (Grühn et al., 2005; Majerus & D'Argembeau, 2011; Wurm et al., 2004), suggesting important boundary conditions for the effect. A meta-analysis found that the positivity effect is larger when participants "freely view" the stimuli in the study phase rather than other instructions such as rating the stimuli during the study phase and in studies with wider age gaps between young and older adults (Reed et al., 2014).

Furthermore, when Fung and colleagues (2008) tried to replicate the well-documented positivity effect in Hong Kong, they found the opposite of the positivity effect, such that older Hong Kong Chinese tended to look away from positive stimuli and gaze more at negative stimuli. However, Bi and Han (2015) found that in a recognition task for affective images from the International Affective Picture System (IAPS), Chinese older adults did not show a significant difference in memory for negative versus positive images, whereas

Chinese younger adults did show better memory for negative images than positive ones. This is consistent with one type of positivity effect that results from a reduced negativity bias in older compared to younger adults (Reed & Carstensen, 2012). In a cross-cultural comparison of the positivity effect, both Chinese and Americans exhibited the positivity effect in recall for pictures, driven by both an age-related positivity enhancement and negativity suppression (Chung & Lin, 2012). Another group of researchers found partial support for a positivity effect among Korean adults, such that compared with younger Koreans, older Koreans tended to remember more positive pictures from IAPS compared to negative ones (Kwon et al., 2009).

These inconsistencies likely suggest that certain boundary conditions are essential for the positivity effect to emerge (Reed & Carstensen, 2012). Like studies with Western samples, these moderators might include task instructions that constrain cognitive processing and sampling characteristics that narrow the age gap. However, given cultural differences in psychological constructs such as ideal affect valuation (Tsai et al., 2006) and interdependence (Markus & Kitayama, 1991), additional factors may influence positivity effects in Eastern cultures. Fung and colleagues (2010) examined whether interdependent self-construal, or the tendency to view the self as interconnected with others (Markus & Kitayama, 1991), moderates the positivity effect in recall for images among Chinese young, middle-aged, and older adults. Overall, older participants exhibited both a positive enhancement and negativity suppression effect in recall. However, older adults with higher levels of interdependence did not exhibit the negativity suppression effect, consistent with the view that individuals high in interdependence attend to all social cues, including negative cues, to maintain social harmony.

The Role of Arousal in the Positivity Effect

In previous studies, some indirect evidence suggests that arousal level might be a potential moderator of the positivity effect. For example, some studies suggested that the positivity effect in older adults may be restricted to low-arousal stimuli (Kensinger, 2008; Streubel & Kunzmann, 2011; Tomaszczyk & Fernandes, 2013). Evidence from cognitive neuroscience also suggests that low-arousal stimuli is associated with more controlled processing and emotional regulation, which rely on prefrontal functions (Scheibe & Carstensen, 2010), making the positivity effect more likely to emerge for low-arousal images than high-arousal images. In a norming study of affective images, age differences in valence and arousal ratings showed that older adults rated negative pictures as more negative and more arousing than did young adults, and older adults rated positive pictures more positive but less arousing than did young adults (Grühn & Scheibe, 2008), highlighting the importance of considering both valence and arousal in studies of the positivity effect.

However, studies directly examining whether manipulating arousal levels of the stimuli could affect the emergence of the positivity effect are rare. Therefore, the moderating role of arousal on the positivity effect still needs to be systematically tested. In addition, no study has examined whether the arousal level of facial expressions plays a potential moderating role of the positivity effects among Chinese adults. By manipulating the arousal level of emotional pictures, the present work systematically tested the role of arousal level on the emergence of the positivity effect among Chinese adults. The present work aims to contribute to the literature by providing a possible explanation for the discrepant findings in the positivity effect between Western and Eastern countries.

In terms of memories for emotional pictures, both arousal-biased competition theory (ABC; Mather & Sutherland, 2011) and affect valuation theory (Tsai et al., 2006) provide possible explanations for the observed inconsistency and further offer an answer to the question whether Chinese adults are likely to exhibit the positivity effect. According to arousal-biased competition (ABC) theory, people are surrounded by numerous external stimuli and internal thoughts, which posts challenges to people as which to remember and which to ignore. The theory postulates that our brain's ability to process information more efficiently is accomplished by prioritizing perceptually biased stimuli. Such bias occurs when the stimuli are perceptually conspicuous or goal-relevant (Mather & Sutherland, 2011). For example, Sakaki, Fryer, and Mather (2014) found that top-down stimuli priority influences memory for emotionally arousing pictures, such that when people prioritized those objects, emotionally arousing images (regardless of valence) could enhance memory for them, but impair memory for preceding objects if they were not prioritized. Similarly, Tomaszczyk and colleagues (2008) found that the positivity effect was eliminated for stimuli that were high in personal relevance (older adults recalled an equal number of positive and negative pictures that were personally relevant). The majority of studies on the positivity effect have examined pictures (scenes, images) and words. One study found that when pictures include social content, such as people, the positivity effect was attenuated (Hess et al., 2013), however, another study found that pictures with people (vs. without people) enhanced the positivity effect (Experiment 2; Mather & Knight, 2005). Further work that manipulated both the valence and arousal of social images, found that the positivity effect was only observed for high-arousal images, and this effect was driven by young adults' better recall for highly arousing negative social images (Hess et al., 2017).

The strength and vulnerability integration (SAVI) model (Charles, 2010) argues that older adults might have the desire to avoid high arousal emotions (regardless of valence) as they are more vulnerable to such affective states. High arousal content may be especially disruptive to older adults because of reduced cognitive resources (Labouvie-Vief et al., 2014). This idea is consistent with findings from an American sample where the positivity effect was observed for nonarousing words (e.g., serenity and sorrow) but was eliminated for high-arousing words (e.g., elation and slaughter; Kensinger, 2008). Meanwhile, from a cross-cultural perspective, the affect valuation theory (Tsai et al., 2006) argues that Eastern Asians and Westerners might have different *ideal* preferences for emotions in terms of arousal. For instance, in their empirical study, they found that Eastern Asians tended to prefer low arousal positive emotions (e.g., calm and peaceful; LAP) to high arousal positive emotions (e.g., excited and enthusiastic; HAP) *ideally*, while Westerners prefer LAP and HAP to a similar extent (Tsai, 2007). These cultural differences are hypothesized to be due to distinctions between individualistic cultures in which people aim to influence others versus collectivistic cultures in which people aim to adjust to others. This difference in ideal arousal might make Westerners more likely to exhibit the positivity effect regardless of arousal, while the positivity effect of Easterners would be more influenced by the arousal level of the stimuli. Moreover, such culture-specific preferences for low arousal positive emotions would become more complex when taking older adults into account (Tsai & Sims, 2016). For example, Tsai and Sims (2016) found that age-related differences in preference for LAP and HAP was not significant among European Americans, however, Hong Kong Chinese showed steady declines in preference for HAP across the lifespan, and an increase in preference for LAP from young to middle-age. This evidence jointly suggests that older Chinese adults might have a stronger preference for low-arousal positive emotions compared with both younger adults and older Westerners, which should lead to differences in the manifestation of the positivity effect.

Because there are cultural and individual differences in ideal affect, some studies have moved away from relying on normed ratings of valence and arousal to categorize stimuli (Fung et al., 2010; Kwon et al., 2009; Mather & Knight, 2005; St. Jacques et al., 2009). If the personal subjective evaluation of the valence and arousal of stimuli influences the cognitive processing devoted to encoding and recalling said stimuli, then individual ratings will be more predictive of later recall and should be even better indicators of the type of motivated cognitive processing hypothesized to drive positivity effects.

What has not been examined in previous work is whether these age by arousal by valence interactions extend to recognition memory for facial expressions in East Asian cultures. Facial expressions are particularly interesting stimuli because they are one of the most relevant social cues in the environment, which may enhance their relevance for older adults who are highly socially motivated (SST; Carstensen, 1992), and also may be especially prone to cross cultural effects given differences in the importance of maintaining social harmony between Western and East Asian cultures (Markus & Kitayama, 1991). Positivity effects in perception of emotional facial expressions (Kellough & Knight, 2012; Riediger et al., 2011), and recognition memory for facial expressions (Leigland et al., 2004; Spaniol et al., 2008) have been observed in Western samples, but neither of these studies systematically manipulated arousal.

The Present Study

Hence, in the present study, we tested whether Chinese adults exhibit the positivity effect in recognition memory for facial expression stimuli. Moreover, we also tested the effect of arousal on the positivity effect in Chinese adults. To do so, a set of facial expressions was created not only based on valence, but also on arousal. Thus, four different categories of facial expressions of Chinese adults were used with two types of emotion in each category. Specifically, participants viewed high arousal positive (happy, excited), low arousal positive (calm, content), high arousal negative (angry, afraid), and low arousal negative (bored, sad) facial expressions and were later asked to complete an old/new surprise recognition test. We expected an age × valence × arousal interaction, such that compared with younger Chinese adults, older Chinese adults should perform equally well (if not better) in recognizing low arousal positive pictures but underperform in recognizing high arousal positive pictures, as well as negative pictures regardless of arousal.

Method

Participants

Sample size was determined by conducting a power analysis in G*power using effect sizes from previous research that employed a similar experimental task (e.g., Zhang et al., 2019). This prior power analysis indicated that for an effect size of .15 to be detected with 80% power and significance at 5% level, a sample of 62 participants would be sufficient. In this study, 45 younger adults (25 females, M_{age} = 21.89, *SD* = 2.82), and 41 older adults (24 females, M_{age} = 65.76, *SD* = 4.13) were recruited. Older adults were screened for possible cognitive impairment with the Mini-Mental State Examination (MMSE; Folstein et al., 1975) before they could participate in the study. All older adults scored higher than 26 on the MMSE, with a mean score of 29.71, and standard deviation of .79. Participants received a ¥30 monetary reward for their participation. The present study was approved by the Institutional Review Board of School of Psychological and Cognitive Sciences, Peking University.

Materials and Design

Stimuli for this study consisted of facial expressions of younger and older Chinese men and women selected from the International Affective Picture System (Lang, 2005) and the Tsinghua facial expression database (Yang et al., 2020), and self-created emotional pictures, displaying eight expressions: bored and sad (low arousal negative emotions), angry and fear (high arousal negative emotions), calm and content (low arousal positive emotions), and happy and excited (high arousal positive emotions). These stimuli were developed based on the categorization of affect valuation theory (AVT; Tsai et al., 2006), please refer to the Appendix for examples. Among these stimuli, happy, excited and angry pictures came from IAPS, while content, fear and sad came from Tsinghua facial expression database and calm as well as bored pictures were newly created by us.

In each emotion category, there were eight faces displaying the same expression, resulting in a total of 64 emotional facial expression pictures. These pictures were further randomly divided into halves (list A and list B, both of which included 32 pictures and comprised four pictures for each emotion category). For all 8 pictures in each emotion category, we balanced the numbers of pictures across gender and age group (i.e., there were four pictures of each gender and each age group in each category; 4 female, 4 male, 4 young, 4 old).

Valence and arousal ratings for each facial expression type were obtained in a pilot study using a different sample of participants (20 younger adults, and 20 older adults; see **Table 1**). Participants rated the facial expressions using a 9 × 9 grid, representing both valence and arousal (a larger value means more positive/aroused). A significant emotion type main effect was found ($F = 13.768$, $p < .001$), such that in terms of valence, participants rated excited ($M = 7.34$, $SD = 1.36$) > happy ($M = 6.41$, $SD = .99$) > content ($M = 5.86$, $SD = .90$) = calm ($M = 5.17$, $SD = 1.07$) > bored ($M = 4.14$, $SD = 1.19$) = fear ($M = 4.06$, $SD = 1.82$) = sad ($M = 3.77$, $SD = 1.40$) = angry ($M = 3.60$, $SD = 1.62$). We also found a significant age × emotion type interaction ($F = 6.765$, $p < .001$). In terms of arousal, a significant emotion type main effect was found ($F = 27.535$, $p < .001$), such that they rated excited ($M = 7.89$, $SD = 1.50$) > happy ($M = 7.21$, $SD = 1.48$) > content ($M = 6.57$, $SD = 1.65$) > fear ($M = 6.44$, $SD = 2.44$) > angry ($M = 6.04$, $SD = 2.26$) > calm ($M = 5.86$, $SD = 1.65$) > sad ($M = 5.01$, $SD = 2.53$) = bored ($M = 4.96$, $SD = 2.10$). We also found a significant age × emotion type interaction ($F = 4.031$, $p < .001$). These ratings partially confirmed the validity of the stimuli, which was in line with the categorization of Affect Valuation Theory.

Procedure

The study was divided into two phases: the study phase and the testing phase. In the study phase, participants were randomly assigned to study either list A or list B. Then they were instructed only to very carefully view each picture shown on the screen for five seconds.

After the study phase, several tests were administered including measures of digit span forward and backward, digit symbol substitution (Wechsler, 1997), verbal fluency (i.e., Category Naming Task; Spreen & Benton, 1977), as well as demographic information, including age, sex, and education. These measures later served as covariates, similar to previous research on the positivity effect (Fung et al., 2008; Fung et al., 2010). Next came the testing phase, during which a surprise recognition memory test was given. Participants were asked to go through a 64-trial recognition task, in which both list A and list B were shown on the screen (the pictures in list A & B were presented in a random intermixed order), and asked to indicate whether or not they had seen those pictures before (an old/new response) and to rate the valence and arousal of each picture. Finally, participants were debriefed about the study.

Results

Preliminary Analysis

Table 2 shows the descriptive statistics of all variables included in the study for each age group. As shown in the table, significant age differences were observed in Education level: F (1, 84) = 123.771, $p < .001$, $\eta^2_{partial} = .596$, digit symbol substitution test: F (1, 84) =230.092, $p < .001$, $\eta^2_{partial} = .73$, verbal fluency: F (1, 84) = 50.858, $p < .001$, $\eta^2_{partial} = .377$, digit span – forward: F (1, 84) = 38.721, $p < .001$, $\eta^2_{partial} = .316$ and digit span – backward: F (1, 84) = 122.414, $p < .001$, $\eta^2_{partial} = .593$. Variables that differed significantly by age group were included as covariates, and unless specifically mentioned, statistically controlling for these variables did not alter the results described below.

Hypothesis Testing

Table 4 shows the false alarms (proportion of faces reported as viewed but were actually novel) and hits (proportion of faces correctly identified) for different emotions across age groups. The dependent variable, d', was calculated as follows: d' = $Z_{\text{hit}} - Z_{\text{false alarm}}$ (Signal Detection Theory; Stanislaw & Todorov, 1999); a larger d' indicates better recognition memory. We firstly conducted an emotion type x age group x list mixed-design ANOVA on d', and found that list did not have a significant main effect nor any interactions with emotion type or age group, *F*s < 1.72, indicating that study list (i.e., study list A or list B) did not influence participants' memory performance. Thus, we merged the data from participants across both lists. A mixed-design ANOVA with valence and arousal as within-subjects factor, age group (younger adults and older adults) as a between-subjects factor, was conducted on d'. Significant valence (marginal), arousal and age group main effects were found, F (1, 84) = 3.294, p = .073, $\eta^2_{partial}$ = .038, F (1,84) = 17.487, p < .01, $\eta^2_{partial}$ = .172, and F (1,84) = 388.755, p < .01, $\eta^2_{partial}$ = .822, respectively, qualified by a significant valence × arousal × age group interaction, F (1, 84) = 6.417, p = .013, $\eta^2_{partial}$ = .071. To further explore the significant valence × arousal × age group interaction, we examined memory for different emotion types within each age group by conducting repeated-measures ANOVAs. The results indicated that younger adults exhibited a memory advantage for high arousal facial expressions, F(1, 44) =14.425, p < .01, $\eta^2_{partial}$ = .247. Neither the main effect of valence nor the valence × arousal interaction were significant. As for older adults, significant valence and arousal main effects were found, F(1, 40) = 10.353, p = .003, $\eta^2_{partial}$ = .206, F(1, 40) = 5.026, p = .031, $\eta^2_{partial}$ = .112, respectively. We also found a significant valence × arousal interaction (F(1, 40) = 9.227, p = .004, $\eta^2_{partial}$ = .187). However, by further exploring this valence × arousal interaction, we found that older adults exhibited a HAP advantage in memory (but not LAP, please also refer to Figure 1). Taking these results together, the evidence suggests that older Chinese adults did exhibit a positivity effect in memory, but only for the high arousal positive emotions, not for the low arousal positive emotions. However, one caveat should be noted, i.e., in the present study, the valence and arousal of facial expressions were inferred from preassigned categories based on affect valuation theory, and we did not know whether participants subjectively agreed with the assigned emotion when viewing the stimulus. Hence, in the present study, we explicitly asked participants to rate the valence and arousal of different stimuli, to further strengthen our findings by using these self-rated valence and arousal to 1) re-categorize emotions into HAP, LAP, neutral, HAN and LAN and then conduct repeated measure ANOVA to see differences in memory performance in 5 emotion types; 2) conduct hierarchical Linear Modeling (HLM, Raudenbush & Bryk, 2002) to test whether their subjective ratings of valence and arousal could influence memory.

Ratings of Valence and Arousal on Memory Accuracy

Table 3 shows the average valence and arousal ratings for each emotion type by age group. We used subjective ratings of valence and arousal of different emotion pictures to re-categorize them into 5 emotion types, namely, HAP, LAP, neutral, HAN and LAN[1], the results of which are presented in **Table 5**. A mixed-design ANOVA on *d'* with emotion type (HAP, LAP, HAN, LAN, vs. Neutral) as the within-subject factors and age group (YA vs. OA) as the between-subjects factors was conducted. Only a significant age main effect was

[1] The criteria of categorizing an emotional picture as a neutral one is as follows: we ranked each participants' evaluated valence and arousal from largest to smallest, then we categorized those pictures whose both valence and arousal lied in 27.64% to 72.36% as neutral, to make their number close to 1/5 in all, see **Figure 2**).

found, $F(1, 84) = 267.297$, $p < .001$, $\eta^2_{partial} = .761$. Neither the main effect of emotion type nor the age group × emotion type interaction were significant. These results suggest that when compared with older adults, Chinese younger adults have an advantage in remembering emotional pictures regardless of emotion type (Figure 3).

To further test whether the results differed when subjective ratings of valence and arousal were used, we conducted a hierarchical linear model in Mplus. We used the approach very similar to Mickley Steinmetz and colleagues (Mickley Steinmetz, Sturkie, Rochester, Liu, & Gutchess, 2018), except that we used multilevel logistic modeling. The dependent variable was memory for each picture (dichotomous variable, 1 = correctly recognized, 0 = did not recognize). The within-person predictors were valence and arousal ratings of each picture, as well as the interaction between them, which was created by multiplying these centered predictors following recommendations of Aiken and West (1991). The between-person predictors included age group (1 = younger adults, and 2 = older adults), sex (1 = males, 2 = females), cognitive abilities, and other demographics. The final equation for the model is shown below.

Within-person:

Prob(Memory = 1| B) = P

$$\log\frac{P}{1-P} = \beta_0 + \beta_1 Valence + \beta_2 Arousal + \beta_3 Valence \times Arousal + r_{ij}$$

Between-person:

$$\beta_0 = \gamma_{00} + \gamma_{01} Age\ Group + \gamma_{02} Sex + \gamma_{03} Education + \gamma_{04} DSF + \gamma_{05} DSB + \gamma_{06} DSST + \gamma_{07} VF + u_{0j}$$

$$\beta_1 = \gamma_{10} + \gamma_{11} Age\ Group + u_{1j}$$

$$\beta_2 = \gamma_{20} + \gamma_{21} Age\ Group + u_{2j}$$

$$\beta_3 = \gamma_{30} + \gamma_{31} Age\ Group + u_{3j}$$

Notes: DSF = Digit span forward; DSB = Digit span backward; DSST = Digit symbol substitution task; and VB = Verbal fluency.

The results are shown in Table 7. Only the effect of digit span backward was found to be significant, *b* = .148, *SE* = .06, *odds* =2.616, suggesting both younger and older adults could remember high arousal emotions. Further exploration by separating memory on pictures that participants have seen (hit model) and pictures unseen (correct rejection model) revealed something new (results shown in Table 8 & 9). In the *hit* model, other than the same significant effect of digit span backward as detected in the overall model (*b* = .228, *SE* = .09, *odds* =2.495), a significant arousal main effect was found (*b* = .087, *SE* = .03, *odds* =3.043). Meanwhile, a significant arousal × valence interaction was found, *b* = .087, *SE* = .04, *odds* =2.230. These results indicate that while emotions with high arousal were better remembered, more specifically, HAP emotions were better recognized. In the *correct rejection* model, a significant valence main effect as well as a significant valence × age group interaction were found, *b* = -.056, *SE* = .02, *odds* =-3.304; *b* = .079, *SE* = .03, *odds* =2.333, respectively. Also, we found a significant arousal × age group interaction, *b* = -.117, *SE* = .04, *odds* =-2.831. Simple slope analysis of these results indicated that while generally negative valenced emotions stimuli were better distinguished, more speficically, older adults are better at correctly rejecting high arousal and positively valenced new items, which was in concordance with the ANOVA reported above.

Discussion

In the present study, we found that older Chinese adults indeed show the positivity effect such that older adults tended to recognize positive facial expressions better than negative expressions (regardless of arousal), while younger adults did not exhibit an effect of valence. This age by valence interaction was qualified by the hypothesized age by valence by arousal interaction for recognition memory of facial expressions. However, the 3-way interaction was in the opposite direction from our hypothesis: there was no LAP advantage for older adults; instead HAP faces were better recognized by older adults than LAP faces. When we further examined the data using HLM to control for participants' own subjective ratings of valence and arousal, the age by image type interaction was not significant for d'. Instead, we found a valence by arousal interaction for hits (memory for older items), with HAP items being better recognized, and two interactions with age for correct rejections (memory for new items), showing that older adults were better than young adults at rejecting high arousal and positively-valenced items. Findings across these two analytic approaches (i.e., ANOVA using pre-assigned categories of arousal and valence vs. HLM using subjective ratings of arousal and valence), yield similar conclusions. Chinese older adults exhibited a positivity effect, with better memory for *high arousal* positive emotions.

What might account for these unexpected results? In contrast with previous work that used affective images such as scenes to investigate cultural differences in ideal affect (Tsai, 2006), our study varied facial expressions of emotion on arousal and valence. Faces and places are processed in different brain regions by both younger and older adults (Grady et al., 1994), suggesting some potential explanations for discrepant findings regarding arousal effects for affective images versus faces. It may be that positivity effects in memory for facial expressions is not modulated by arousal, but positivity effects for images do differ according to arousal.

The theory of arousal biased competition (Mather & Sutherland, 2011) argues that information that has priority due to personal relevance, emotional relevance, surprise, or social relevance will receive both enhanced processing and superior memory. In our study, we found that Chinese older adults were particularly sensitive to HAP facial expressions (happy, excited). Using the reasoning from the arousal biased competition perspective, these results suggest that older adults were prioritizing HAP more so than young adults. This interpretation appears to contradict predictions based on the SAVI model (Charles, 2010) and work by Labouvie-Vief and colleagues (2014) that older adults should avoid high arousal stimuli because it is too disruptive to their system.

Although we did not expect a HAP advantage for older adults, one possible explanation is that our HAP facial expressions were not so arousing as to be disruptive to older adults. Indeed, facial expressions of excitement and happiness, while more highly arousing than calm and content facial expressions, may not reach the level of arousal that older adults avoid or have trouble processing. We selected the facial expressions to be common facial expressions encountered in various social settings. Of those common expressions, we selected the lower and higher arousal expressions within each valence. Perhaps positive, but extremely high arousal expressions, such as ecstasy, would be too arousing for older adults and result in the predicted preference for LAP among older adults. Future research may want to investigate additional facial expressions to test this possibility. It is also possible that facial expressions do not have the range of arousal to tax older adults’ resources, suggesting a potential important methodological limitation of using facial expressions as stimuli when studying arousal.

An opposite argument might also be made that the extreme social and personal relevance of facial expressions might have washed out other effects for older adults. One reason we wanted to investigate facial expressions is because older adults prioritize social and emotional goals to a greater extent than young adults (Carstensen, 2006) and East Asian cultures value social harmony more than Western cultures (Markus & Kitayama, 1991). It is possible, then, that the social relevance of the facial expressions was strong enough for older adults to override the other psychological factors at play, leading them to prioritize high-arousing positive stimuli as the most relevant to their social goals. In a social situation, it could be argued that a friendship is more likely to develop from a person who is smiling (happy or excited) than a person who is expressing low arousal positive emotions (calm and content). We did not measure participants' social goals in this study, so we cannot address this possibility in the present study. However, this interpretation would be consistent with a study that eliminated the positivity effect in memory for pictures high in personal relevance; older adults recalled just as many negative as positive pictures that were high in personal relevance (Tomaszczyk et al., 2008). The logit hierarchical linear modeling results further strengthen this argument by showing that participants' subjective ratings of arousal play an important role in affecting their memory for emotional pictures.

From a cross-cultural perspective, affect valuation theory (Tsai et al., 2006) suggests that Eastern Asian participants tend to prefer low arousal positive emotions (e.g., calm and peaceful; LAP) to high arousal positive emotions (e.g., excited and enthusiastic; HAP) *ideally*, while Westerners prefer LAP and HAP to a similar extent (Tsai, 2007). The same argument for the absolute level of arousal of our high-arousal positive facial expressions could be made here. Perhaps the HAP faces were not considered so highly arousing as to be outside of ideal affect for our Chinese participants. In both Mandarin and English languages, the word for “happy” is very common and even serves as the exemplar for positive emotions. Perhaps happy facial expressions are so mundane as to lose some of the aversive aspects of high arousal for Chinese participants.

Limitation and Future Directions

One limitation should be acknowledged before we can make any meaningful conclusion, such that the present study used a cross-sectional design to test age-related differences in memory, and cohort effects might potentially affect the results obtained. In order to reach a comprehensive understanding of age-related changes in memory for pictures of different valence and arousal, longitudinal studies are needed. Especially for Chinese older adults, as values in the Chinese society are changing rapidly, whether older adults will always prioritize group harmony is questionable. In addition, there has been suggestions that individuals tended to have a preference for own age group when asked to remember emotional stimuli (i.e., own-age bias, e.g., Wright & Stroud, 2002) while the current investigation was not designed (and therefore not powered) to detect a 4-way interaction (i.e., age group x valence x arousal x target age), making the test for potential own-age bias in this study impossible (although we have carefully designed our stimuli to make sure equalvalence of target age and gender). Nevertheless, future studies should consider such possiblility and eventually tested it.

Despite these limitations, the present study demonstrated a potential explanation for previous inconsistencies regarding the generalizability of the positivity effect in different cultures by showing that not only valence but also arousal could affect the *(non)existence* of the positivity effect, and such effect holds for both preassigned and subjective ratings of valence and arousal. Furthermore the relative priority of low versus high arousal stimuli may vary depending on the stimulus type: high arousal positive facial expressions may receive priority processing by older adults.

References

Bi, D., & Han, B. (2015). Age-related differences in attention and memory toward emotional stimuli. *PsyCh Journal*, *4*(3), 155–159. https://doi.org/10.1002/pchj.99

Carstensen, L. L. (1992). Social and emotional patterns in adulthood: Support for socioemotional selectivity theory. *Psychology and Aging*, *7*(3), 331–338.

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science*, *312*(5782), 1913–1915. https://doi.org/10.1126/science.1127488

Carstensen, L. L., & DeLiema, M. (2018). The positivity effect: A negativity bias in youth fades with age. *Current Opinion in Behavioral Sciences*, *19*, 7–12. https://doi.org/10.1016/j.cobeha.2017.07.009

Charles, S. T. (2010). Strength and vulnerability integration: A model of emotional well-being across adulthood. *Psychological Bulletin*, *136*(6), 1068–1091. https://doi.org/10.1037/a0021232

Charles, S. T., Mather, M., & Carstensen, L. L. (2003). Aging and emotional memory: The forgettable nature of negative images for older adults. *Journal of Experimental Psychology: General*, *132*(2), 310–324. https://doi.org/10.1037/0096-3445.132.2.310

Chung, C., & Lin, Z. (2012). A cross-cultural examination of the positivity effect in memory: United States vs. China. *The International Journal of Aging and Human Development*, *75*(1), 31–44. https://doi.org/10.2190/AG.75.1.d

Cuddy, L. L., Sikka, R., Silveira, K., Bai, S., & Vanstone, A. (2017). Music-evoked autobiographical memories (MEAMs) in Alzheimer disease: Evidence for a positivity effect. *Cogent Psychology*, *4*(1), 1277578.

https://doi.org/10.1080/23311908.2016.1277578

Dolcos, F., LaBar, K. S., & Cabeza, R. (2004). Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. *Neuron*, *42*(5), 855–863. https://doi.org/10.1016/S0896-6273(04)00289-2

English, T., & Carstensen, L. L. (2015). Does positivity operate when the stakes are high? Health status and decision making among older adults. *Psychology and Aging*, *30*(2), 348–355. https://doi.org/10.1037/a0039121

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive states of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Fung, H. H., Lu, A. Y., Goren, D., Isaacowitz, D. M., Wadlinger, H. A., & Wilson, H. R. (2008). Age-related positivity enhancement is not universal: Older Chinese look away from positive stimuli. *Psychology and Aging*, *23*(2), 440–446. https://doi.org/10.1037/0882-7974.23.2.440

Fung, H. H., Isaacowitz, D. M., Lu, A. Y., & Li, T. (2010). Interdependent self-construal moderates the age-related negativity reduction effect in memory and visual attention. *Psychology and Aging*, *25*(2), 321–329. https://doi.org/10.1037/a0019079

Grühn, D., & Scheibe, S. (2008). Age-related differences in valence and arousal ratings of pictures from the International Affective Picture System (IAPS): Do ratings become more extreme with age? *Behavior Research Methods*, *40*(2), 512–521. https://doi.org/10.3758/BRM.40.2.512

Grühn, D., Smith, J., & Baltes, P. B. (2005). No aging bias favoring memory for positive material: Evidence from a heterogeneity-homogeneity list paradigm using emotionally toned words. *Psychology and Aging*, *20*(4), 579–588. https://doi.org/10.1037/0882-7974.20.4.579

Gutchess, A. H., Kensinger, E. A., Yoon, C., & Schacter, D. L. (2007). Ageing and the self-reference effect in memory. *Memory*, *15*(8), 822–837. https://doi.org/10.1080/09658210701701394

Hess, T. M., Popham, L. E., Dennis, P. A., & Emery, L. (2013). Information content moderates positivity and negativity biases in memory. *Psychology and Aging*, *28*(3), 853–863. https://doi.org/10.1037/a0031440

Hess, T. M., Popham, L. E., & Growney, C. M. (2017). Age-related effects on memory for social stimuli: The role of valence, arousal, and emotional responses. *Experimental Aging Research*, *43*(2), 105–123. https://doi.org/10.1080/0361073X.2017.1276374

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006a). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and Aging*, *21*(1), 40–48. https://doi.org/10.1037/0882-7974.21.1.40

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006b). Is there an age-related positivity effect in visual attention? A comparison of two methodologies. *Emotion*, *6*(3), 511–516. https://doi.org/10.1037/1528-3542.6.3.511

Kalenzaga, S., Lamidey, V., Ergis, A.-M., Clarys, D., & Piolino, P. (2016). The positivity bias in aging: Motivation or degradation? *Emotion*, *16*(5), 602–610. https://doi.org/10.1037/emo0000170

Kellough, J. L., & Knight, B. G. (2012). Positivity effects in older adults' perception of facial emotion: The role of future time perspective. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 67B*(2), 150–158. https://doi.org/10.1093/geronb/gbr079

Kennedy, Q., Mather, M., & Carstensen, L. L. (2004). The role of motivation in the age-related positivity effect in autobiographical memory. *Psychological Science*, *15*(3), 208–214. https://doi.org/10.1111/j.0956-7976.2004.01503011.x

Kensinger, E. A. (2008). Age differences in memory for arousing and nonarousing emotional words. *Journals of Gerontology: Psychological Sciences*, *63B*(1), 13–18. https://doi.org/10.1093/geronb/63.1.P13

Kensinger, E. A., & Corkin, S. (2004). The effects of emotional content and aging on false memories. *Cognitive, Affective, & Behavioral Neuroscience*, *4*(1), 1–9. https://doi.org/10.3758/CABN.4.1.1

Kwon, Y., Scheibe, S., Samanez-Larkin, G. R., Tsai, J. L., & Carstensen, L. L. (2009). Replicating the positivity effect in picture memory in Koreans: Evidence for cross-cultural generalizability. *Psychology and Aging*, *24*(3), 748–754. https://doi.org/10.1037/a0016054

Labouvie-Vief, G., Gilet, A.-L., & Mella, N. (2014). The dynamics of cognitive-emotional integration: Complexity and hedonics in emotional development. *The Oxford Handbook of Emotion, Social Cognition, and Problem Solving in Adulthood*, 83–98.

Lang, P. J. (2005). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* (p. A-8). University of Florida.

Leigland, L. A., Schulz, L. E., & Janowsky, J. S. (2004). Age related changes in emotional memory. *Neurobiology of Aging*, *25*(8), 1117–1124. https://doi.org/10.1016/j.neurobiolaging.2003.10.015

Majerus, S., & D'Argembeau, A. (2011). Verbal short-term memory reflects the organization of long-term memory: Further evidence from short-term memory for emotional words. *Journal of Memory and Language*, *64*(2), 181–197. https://doi.org/10.1016/j.jml.2010.10.003

Mammarella, N., Di Domenico, A., Palumbo, R., & Fairfield, B. (2016). When green is positive and red is negative: Aging and the influence of color on emotional memories. *Psychology and Aging*, *31*(8), 914–926. https://doi.org/10.1037/pag0000122

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review*, *98*(2), 224–253. https://doi.org/10.1037/0033-295X.98.2.224

Mather, M. (2016). The affective neuroscience of aging. *Annual Review of Psychology*, *67*, 213–238. https://doi.org/10.1146/annurev-psych-122414-033540

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Ochsner, K., Gabrieli, J. D. E., & Carstensen, L. L. (2004). Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychological Science*, *15*(4), 259–263. https://doi.org/10.1111/j.0956-7976.2004.00662.x

Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological Science*, *14*(5), 409–415. https://doi.org/10.1111/1467-9280.01455

Mather, M., & Knight, M. (2005). Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging*, *20*(4), 554–570. https://doi.org/10.1037/0882-7974.20.4.554

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science*, *6*(2), 114–133. https://doi.org/10.1177/1745691611400234

Mickley Steinmetz, K. R., Sturkie, C. M., Rochester, N. M., Liu, X., & Gutchess, A. H. (2018). Cross-cultural differences in item and background memory: Examining the influence of emotional intensity and scene congruency. *Memory*, 26(6), 751-758. https://doi.org/10.1080/09658211.2017.1406119

Mikels, J. A., Larkin, G. R., Reuter-Lorenz, P. A., & Carstensen, L. L. (2005). Divergent trajectories in the aging mind: Changes in working memory for affective versus visual information with age. *Psychology and Aging*, *20*(4), 542–553. https://doi.org/10.1037/0882-7974.20.4.542

Petrican, R., Moscovitch, M., & Schimmack, U. (2008). Cognitive resources, valence, and memory retrieval of emotional events in older adults. *Psychology and Aging*, *23*(3), 585–594. https://doi.org/10.1037/a0013176

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*, 1–9. https://doi.org/10.3389/fpsyg.2012.00339

Reed, A. E., Chan, L., & Mikels, J. A. (2014). Meta-analysis of the age-related positivity effect: Age differences in preferences for positive over negative information. *Psychology and Aging*, *29*(1), 1–15. https://doi.org/10.1037/a0035194

Riediger, M., Voelkle, M. C., Ebner, N. C., & Lindenberger, U. (2011). Beyond "Happy, Angry, or Sad?” Age-of-poser and age-of-rater effects on multi-dimensional emotion perception. *Cognition & Emotion*, *25*(6), [Special Section] 968-982. https://doi.org/10.1080/02699931.2010.540812

Sakaki, M., Fryer, K., & Mather, M. (2014). Emotion strengthens high-priority memory traces but weakens low-priority memory traces. *Psychological Science*, *25*(2), 387–395. https://doi.org/10.1177%2F0956797613504784

Sander, D., Grafman, J., & Zalla, T. (2003). The human amygdala: An evolved system for relevance detection. *Reviews in the Neurosciences*, *14*(4), 303–316. https://doi.org/10.1515/REVNEURO.2003.14.4.303

Sava, A.-A., Krolak-Salmon, P., Delphin-Combe, F., Cloarec, M., & Chainay, H. (2017). Memory for faces with emotional expressions in Alzheimer’s disease and healthy older participants: Positivity effect is not only due to familiarity. *Aging, Neuropsychology, and Cognition*, *24*(1), 1–28. https://doi.org/10.1080/13825585.2016.1143444

Scheibe, S., & Carstensen, L. L. (2010). Emotional aging: Recent findings and future trends. *Journal of Gerontology: Psychological Sciences, 65*(2), 135–144. https://doi.org/10.1093/geronb/gbp132

Spaniol, J., Voss, A., & Grady, C. L. (2008). Aging and emotional memory: Cognitive mechanisms underlying the positivity effect. *Psychology and Aging*, *23*(4), 859–872. https://doi.org/10.1037/a0014218

Spreen, O., & Benton, A. L. (1977). Category Naming Task. In *Neurosensory Center Comprehensive Examination for Aphasia*. Neuropsychology Laboratory, University of

Victoria.

St. Jacques, P. L., Dolcos, F., & Cabeza, R. (2009). Effects of aging on functional connectivity of the amygdala for subsequent memory of negative pictures: A network analysis of functional magnetic resonance imaging data. *Psychological Science*, *20*(1), in press.

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments & Computers*, *31*(1), 137–149. https://doi.org/10.3758/BF03207704

Streubel, B., & Kunzmann, U. (2011). Age differences in emotional reactions: Arousal and age-relevance count. *Psychology and Aging*, *26*(4), 966. https://doi.org/10.1037/a0023424

Symons, C. S., & Johnson, B. T. (1997). The self-reference effect in memory: A meta-analysis. *Psychological Bulletin*, *121*(3), 371–394. https://doi.org/10.1037/0033-2909.121.3.371

Tomaszczyk, J. C., & Fernandes, M. A. (2013). A positivity effect in older adults' memorability judgments of pictures. *Experimental Aging Research*, *39*(3), 254–274. https://doi.org/10.1080/0361073X.2013.779178

Tomaszczyk, J. C., Fernandes, M. A., & MacLeod, C. M. (2008). Personal relevance modulates the positivity bias in recall of emotional pictures in older adults. *Psychonomic Bulletin & Review*, *15*(1), 191–196. https://doi.org/10.3758/PBR.15.1.191

Tsai, J. L. (2007). Ideal affect: Cultural causes and behavioral consequences. *Perspectives on*

Psychological Science, *2*(3), 242–259. https://doi.org/10.1111%2Fj.1745-6916.2007.00043.x

Tsai, J. L., Knutson, B., & Fung, H. H. (2006). Cultural variation in affect valuation. *Journal of Personality and Social Psychology*, *90*(2), 288–307. https://doi.org/10.1037/0022-3514.90.2.288

Tsai, J. L., & Sims, T. (2016). Emotional aging in different cultures: Implications of affect valuation theory. In A. D. Ong & C. E. Löckenhoff (Eds.), *Emotion, aging, and health.* (2015-40808-007; pp. 119–143). American Psychological Association. https://doi.org/10.1037/14857-007

Wang, Y., & Yang, J. (2017). Effects of arousal and context on recognition memory for emotional pictures in younger and older adults. *Experimental Aging Research*, *43*(2), 124–148. https://doi.org/10.1080/0361073X.2017.1276375

Wechsler, D. (1997). *WAIS-III: Administration and scoring manual*. Psychological Corporation.

Wright, D. B., & Stroud, J. N. (2002). Age differences in lineup identification accuracy: People are better with their own age. *Law & Human Behavior*, 26, 641-654. https://doi.org/10.1023/A:1020981501383

Wurm, L. H., Labouvie-Vief, G., Aycock, J., Rebucal, K. A., & Koch, H. E. (2004). Performance in auditory and visual emotional stroop tasks: A comparison of older and younger adults. *Psychology and Aging*, *19*(3), 523–535. https://doi.org/10.1037/0882-7974.19.3.523

Yang, T., Yang, Z., Xu, G., Gao, D., Zhang, Z., Wang, H., Liu, S., Han, L., Zhu, Z., & Tian, Y.

(2020). Tsinghua facial expression database–A database of facial expressions in Chinese young and older women and men: Development and validation. *PloS One*, *15*(4), e0231304. https://doi.org/10.1371/journal.pone.0231304

Zhang, W., Gross, J., & Hayne, H. (2019). An age-related positivity effect in semantic true memory but not false memory. *Emotion*, *21*(3), 526–535. https://doi-org.ezproxy.uakron.edu:2443/10.1037/emo0000715

Table 1. Evaluation of valence, arousal and *d*’ in 8 emotion categories (YA vs OA) in pilot study

		Arousal	Valence
Happy	OA	7.60 (1.49)	6.72 (1.21)
	YA	6.84 (1.63)	6.10 (.90)
	Average	7.21 (1.48)	6.41 (.99)
Excited	OA	7.97 (1.51)	7.41 (1.38)
	YA	7.81 (1.59)	7.27 (1.44)
	Average	7.89 (1.50)	7.34 (1.36)
Calm	OA	5.60 (1.87)	5.06 (1.24)
	YA	6.11 (1.52)	5.27 (1.04)
	Average	5.86 (1.65)	5.17 (1.07)
Content	OA	6.14 (1.52)	5.54 (.92)
	YA	7.00 (1.28)	6.17 (1.19)
	Average	6.57 (1.29)	5.86 (.90)
Angry	OA	6.40 (2.35)	3.79 (1.95)
	YA	5.68 (2.28)	3.41 (1.48)
	Average	6.04 (2.26)	3.60 (1.62)
Fear	OA	6.20 (2.56)	3.76 (1.76)
	YA	6.68 (2.42)	4.35 (1.99)
	Average	6.44 (2.44)	4.06 (1.82)
Bored	OA	5.01 (2.36)	4.02 (1.24)
	YA	4.91 (1.86)	4.26 (1.40)
	Average	4.96 (2.06)	4.14 (1.19)
Sad	OA	5.05 (2.69)	3.65 (1.51)
	YA	4.97 (2.44)	3.89 (1.36)
	Average	5.01 (2.53)	3.77 (1.40)

Table 2

Participant Characteristics

	Younger Adults (N = 45)	Older Adults (N = 41)
Sex	55.56% Female	58.54% Female
Age	21.89 (2.82)	65.76 (4.13)
Education*	3.96 (.21)	2.63 (.77)
Digit symbol substitution test*	51.18 (8.42)	24.61 (7.76)
Verbal Fluency*	17.60 (2.95)	12.41 (7.76)
Digit span – Forward*	8.84(.52)	7.68 (1.13)
Digit span – backward*	7.47 (1.01)	4.68(1.31)

Note. * indicates significant age differences.

Table 3. Self-rated valence and arousal in 4 emotion types (YA vs OA)

	Valence		Arousal	
	Younger Adults (N = 45)	Older Adults (N = 41)	Younger Adults (N = 45)	Older Adults (N = 27)
HAP	7.50 (1.06)	7.56 (1.06)	7.64 (1.04)	7.44 (1.01)
HAN	3.06 (1.32)	3.82 (1.90)	6.33 (1.48)	4.84 (1.76)
LAN	3.59 (1.10)	4.03 (1.70)	7.16 (1.12)	6.33 (1.13)
LAP	6.12 (.93)	6.27 (1.10)	6.48 (1.39)	6.18 (1.09)

Table 4

Hits, False Alarms, and d' for 4 Different Emotion Types Across Age Group

	Hit		False Alarm		d'	
	YA (*N* = 45)	OA (*N* = 41)	YA (*N* = 45)	OA (*N* = 41)	YA (*N* = 45)	OA (*N* = 41)
LAP*	.78 (.16)	.73 (.29)	.22 (.20)	.39 (.26)	2.02 (1.08)	1.20 (1.38)
HAP*	.77 (.17)	.68 (.27)	.09 (.08)	.13 (.09)	2.49 (.87)	2.06 (1.21)
LAN*	.76 (.21)	.69 (.30)	.17 (.14)	.38 (.28)	2.10 (1.01)	1.19 (1.60)
HAN*	.75 (.21)	.67 (.31)	.09 (.13)	.39 (.28)	2.67 (1.04)	1.06 (1.41)

Notes. YA = Younger Adults; OA = Older Adults. HAP = high arousal positive; LAP = low arousal positive; HAN = high arousal negative; LAN = low arousal negative. * indicated significant age-related differences in d'.

Table 5. Self-rated valence and arousal in 5 emotion types (After re-categorization)

	Valence	Arousal
HAP	7.83 (1.30)	8.06 (1.14)
HAN	2.52 (1.38)	7.96 (1.13)
Neutral	5.07 (1.77)	6.21 (1.77)
LAN	3.33 (1.57)	4.21 (1.57)
LAP	6.49 (1.38)	5.73 (2.08)

Table 6

Hits, False Alarms, and d' for 5 Different Emotion Types Across Age Group

	Hit		False Alarm		d'	
	YA (*N* = 45)	OA (*N* = 41)	YA (*N* = 45)	OA (*N* = 41)	YA (*N* = 45)	OA (*N* = 41)
LAP*	.71 (.26)	.64 (.31)	.15 (.21)	.27 (.27)	2.22 (1.93)	1.32 (2.22)
HAP*	.80 (.20)	.75 (.27)	.21 (.19)	.43 (.28)	2.28 (1.11)	1.18 (1.33)
Neutral*	.77 (.21)	.69 (.32)	.18 (.19)	.38 (.27)	2.29 (1.16)	1.23 (1.53)
LAN*	.71 (.27)	.65 (.31)	.16 (.19)	.36 (.29)	2.27 (1.47)	1.16 (1.54)
HAN*	.77 (.19)	.67 (.34)	.09 (.12)	.30 (.30)	2.78 (1.10)	1.39 (2.01)

Notes. YA = Younger Adults; OA = Older Adults. HAP = high arousal positive; LAP = low arousal positive; HAN = high arousal negative; LAN = low arousal negative; * indicates significant age-related differences in d'.

Table 7

Multi-level Analysis of the Influence of Valence and Arousal on Recognition Memory for Chinese (with unstandardized coefficients) in ALL pictures

	Coefficient (SE)	Odds	Odds 95% CI
Intercept			
Age Group (γ_{01})	-.404 (.27)	0.668	[.391, 1.140]
Sex (γ_{02})	.049(.13)	1.05	[.806, 1.370]
Education (γ_{03})	-.138 (.09)	0.871	[.718, 1.057]
Digit span forward (γ_{04})	.053 (.10)	1.054	[.861, 1.292]
Digit span backward (γ_{05})	.147 (.06)*	1.158	[1.036, 1.297]
Digit symbol substitution (γ_{06})	.001 (.01)	1.001	[.988, 1.014]
Verbal fluency (γ_{07})	.012 (.01)	1.012	[.986, 1.040]
Valence (γ_{10})	-.017 (.01)	0.983	[.956, 1.011]
Age Group (γ_{11})	.02 (.03)	1.02	[.969, 1.086]
Arousal (γ_{20})	.047 (.02)*	1.048	[1.006, 1.092]
Age Group (γ_{21})	-.046 (.04)	0.955	[.879, 1.038]
Valence × Arousal (γ_{30})	.006 (.03)	1.006	[.950,1.066]
Age Group (γ_{31})	-.003 (.06)	0.997	[.891, 1.117]
ICC		.121	

Notes. ** $p < .01$, * $p < .05$

Table 8

Multi-level Analysis of the Influence of Valence and Arousal on Recognition Memory (hit) for Chinese (with unstandardized coefficients) in pictures SEEN

	Coefficient (SE)	Odds	Odds 95% CI
Intercept			
Age Group (γ_{01})	.213 (.09)	1.237	[.546, 2.804]
Sex (γ_{02})	.038(.21)	1.039	[.688, 1.568]
Education (γ_{03})	-.171 (.22)	0.843	[.543, 1.308]
Digit span forward (γ_{04})	.027 (.16)	1.027	[748, 1.412]
Digit span backward (γ_{05})	.228 (.09)*	1.256	[1.047, 1.505]
Digit symbol substitution (γ_{06})	-.003 (.01)	0.997	[.972, 1.023]
Verbal fluency (γ_{07})	.003 (.03)	1.003	[.976, 1.095]
Valence (γ_{10})	.011 (.02)	1.011	[.974, 1.049]
Age Group (γ_{11})	-.018 (.04)	0.982	[.944, 1.098]
Arousal (γ_{20})	.087 (.03)**	1.091	[1.031, 1.155]
Age Group (γ_{21})	-.003 (.06)	0.997	[.864, 1.088]
Valence × Arousal (γ_{30})	.087 (.04)*	1.091	[1.010,1.178]
Age Group (γ_{31})	-.077 (.08)	0.926	[.794, 1.080]
ICC		.205	

Notes. ** $p < .01$, * $p < .05$; ICC = intra-class correlation, represents the ratio of the between-person variance to total variance.

Table 9

Multi-level Analysis of the Influence of Valence and Arousal on Recognition Memory (correct rejection) for Chinese (with unstandardized coefficients) in pictures UNSEEN

	Coefficient (SE)	Odds	Odds 95% CI
Intercept			
Age Group (γ_{01})	-.955 (.46)*	0.385	[.155, .953]
Sex (γ_{02})	.071(.18)	1.074	[.740, 1.556]
Education (γ_{03})	-.132 (.21)	0.876	[.578, 1.329]
Digit span forward (γ_{04})	.057 (.11)	1.059	[.858, 1.308]
Digit span backward (γ_{05})	.076 (.08)	1.079	[.923, 1.261]
Digit symbol substitution (γ_{06})	.001 (.01)	1.001	[.984, 1.030]
Verbal fluency (γ_{07})	-.017 (.03)	0.983	[.926, 1.043]
Valence (γ_{10})	-.056 (.02)**	0.946	[.914, .978]
Age Group (γ_{11})	.079 (.03)*	1.082	[1.012, 1.159]
Arousal (γ_{20})	-.007 (.02)	0.993	[.953, 1.034]
Age Group (γ_{21})	-.117 (.04)**	0.890	[.819, .966]
Valence × Arousal (γ_{30})	-.057 (.04)	0.945	[.880,1.013]
Age Group (γ_{31})	.034 (.07)	1.035	[.901, 1.188]
ICC		.205	

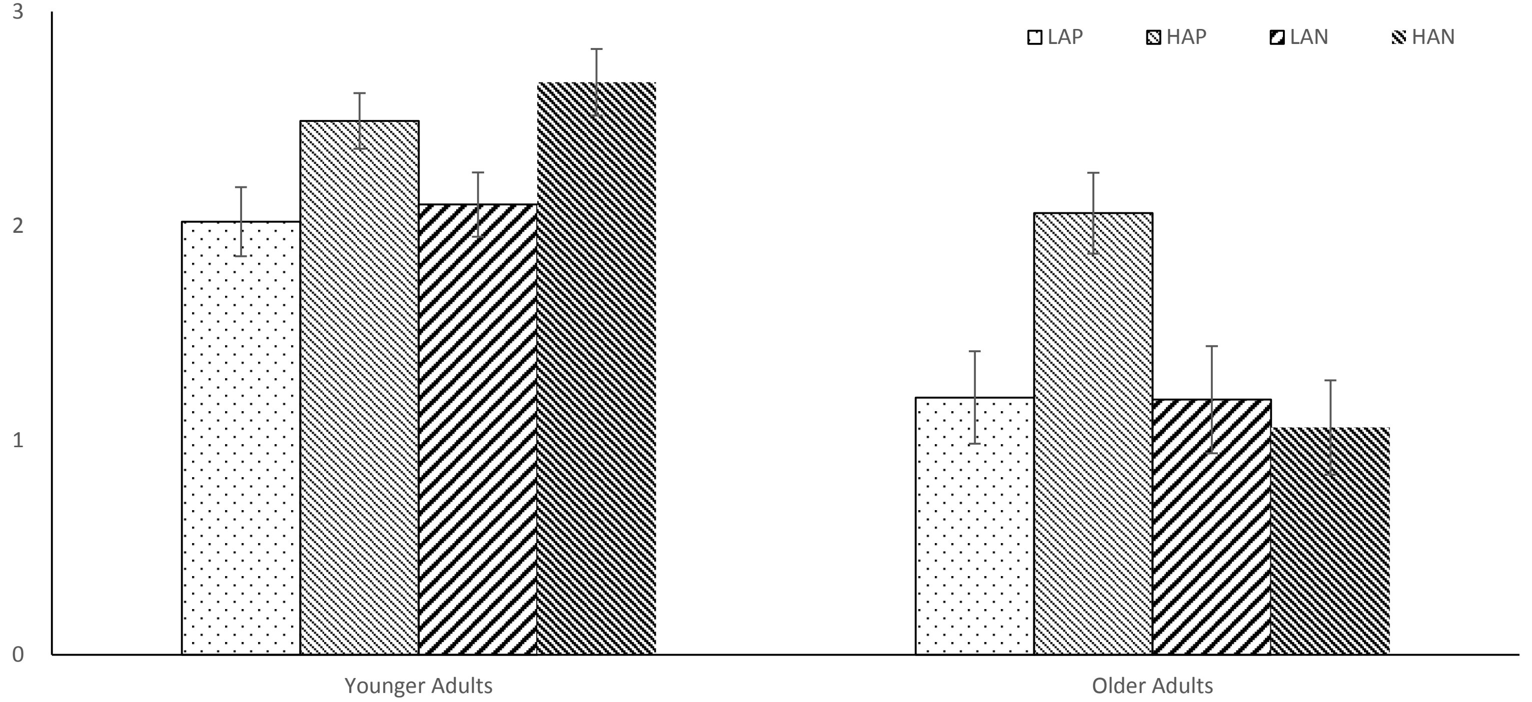
Notes. ** $p < .01$, * $p < .05$; ICC = intra-class correlation, represents the ratio of the between-person variance to total variance.

Figure Captions

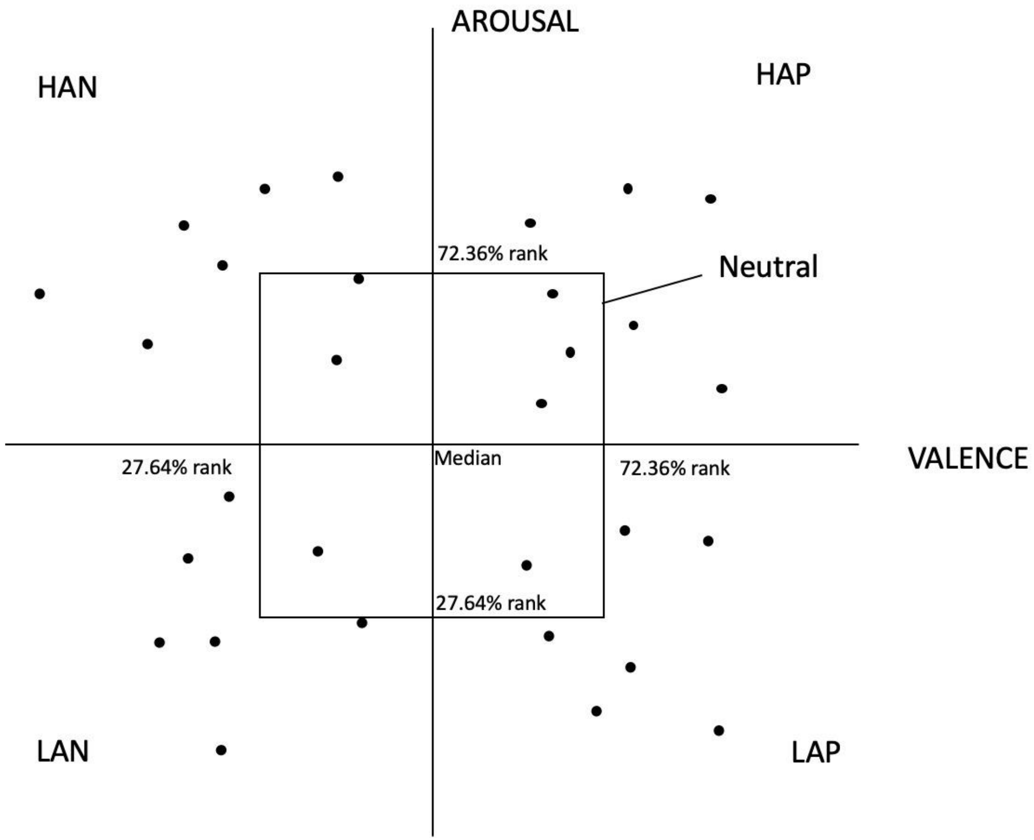
Figure 1. *d'* as a Function of valence, arousal and Age Group (4 emotion types)

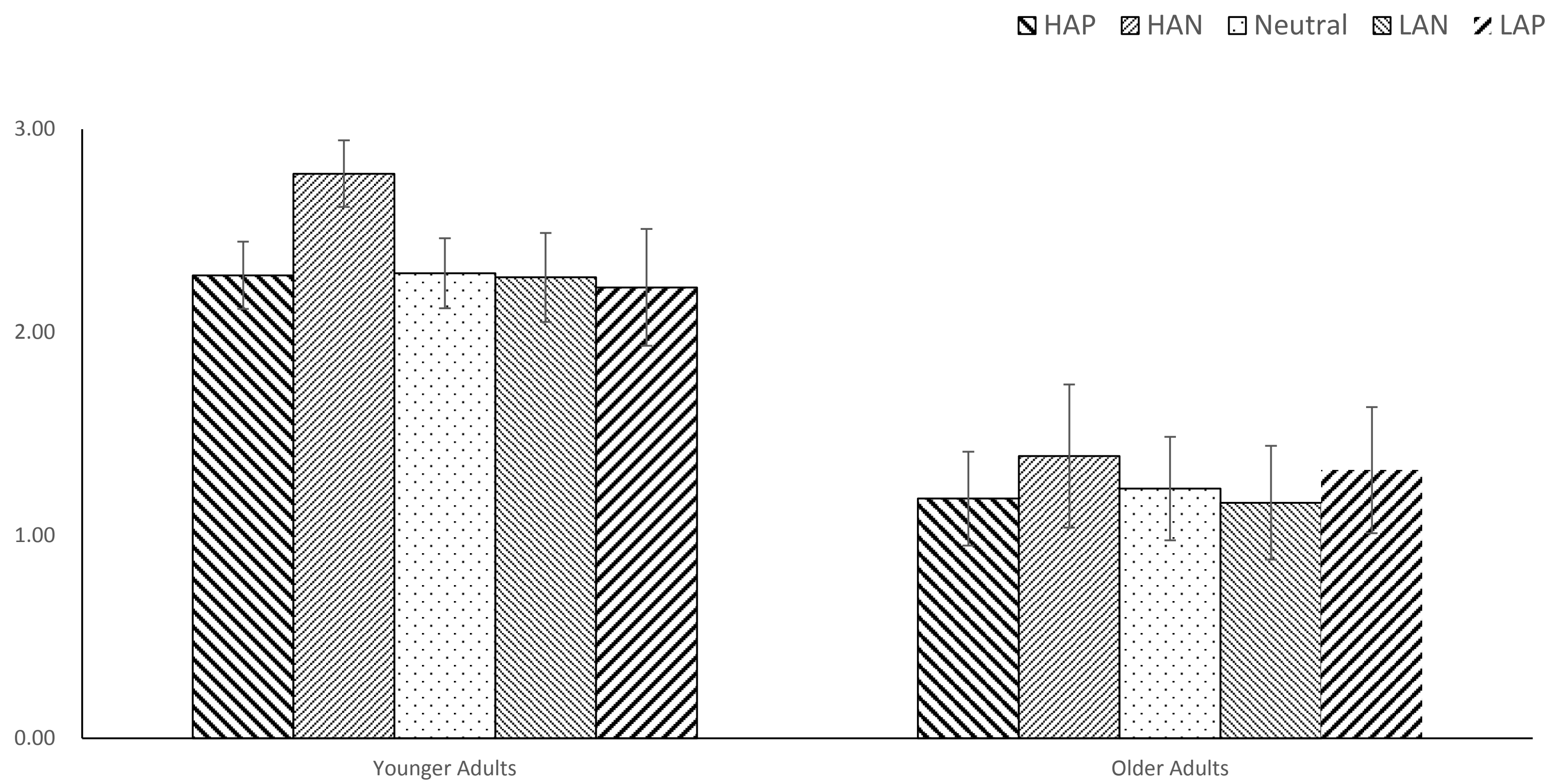
Figure 2. Classification of Facial Expressions

Figure 3. *d'* as a Function of emotion type and Age Group (5 emotion types)



Note. HAP = high arousal positive; LAP = low arousal positive; HAN = high arousal negative; LAN = low arousal negative


AROUSAL
HAN
HAP
72.36% rank
Neutral
VALENCE
27.64% rank
Median
72.36% rank
27.64% rank
LAN
LAP



Note. HAP = high arousal positive; LAP = low arousal positive; HAN = high arousal negative; LAN = low arousal negative

Appendix

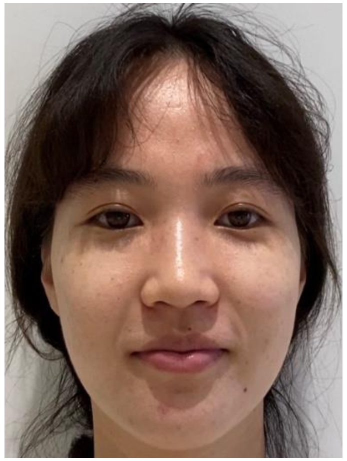
happy

happy

excited

excited

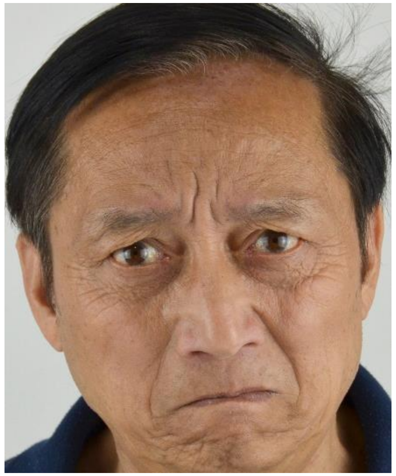
calm



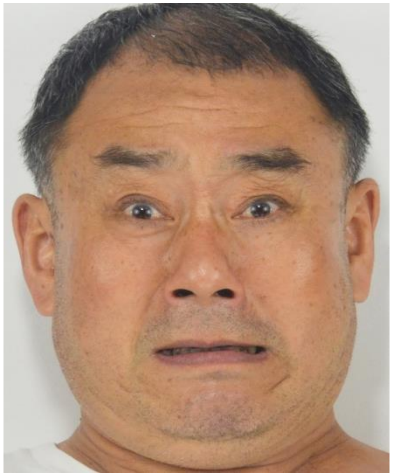
calm

content

content


angry

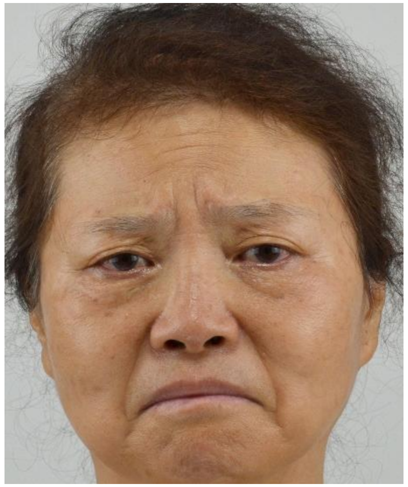

angry

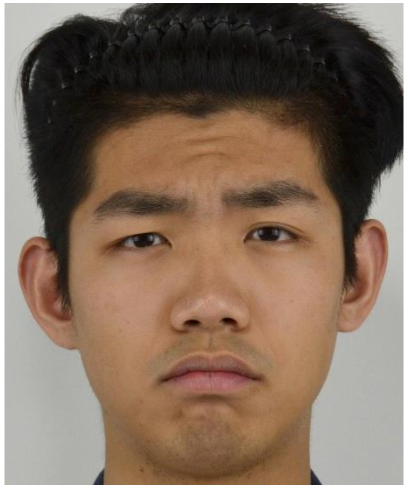

fear


fear


bored


bored


sad


sad