

The Expertise Effect on Aesthetic Judgment of Chinese Paintings: An fNIRS Study

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Abstract

How artistic expertise influences aesthetic judgment represents an important research topic in experimental aesthetics. This study compared differences between experts and laypersons in aesthetic judgment of Chinese paintings, while simultaneously employing functional near-infrared spectroscopy (fNIRS) to examine differences in brain activity during Chinese painting appreciation. Behaviorally, no significant differences were observed between experts and laypersons in either aesthetic ratings or aesthetic consistency. However, fNIRS results revealed differences between experts and laypersons in Chinese painting aesthetics. First, by calculating inter-subject correlation (ISC) of neural activity between experts and laypersons, we found that experts exhibited significantly higher ISC than laypersons in the PFC (channel 14) and right TPJ (channel 24) when appreciating low-rated Chinese paintings; furthermore, experts' ISC in PFC channel 14 when appreciating high-rated Chinese paintings was significantly lower than when appreciating low-rated paintings, and showed a significant negative correlation with experts' beauty ratings. In contrast, laypersons showed no significant differences in ISC between high-rated and low-rated Chinese paintings, nor were any correlations with aesthetic ratings found. Second, intra-brain functional connectivity analysis revealed that experts exhibited significantly higher functional connectivity strength than laypersons during Chinese painting appreciation, with this effect primarily concentrated in the right TPJ. Integrating these findings, we reveal that the process of Chinese painting appreciation exhibits a clear expertise effect, which is closely associated with neural activity in the prefrontal cortex and temporoparietal junction. This study provides novel evidence from cognitive neuroscience for the field of aesthetics.

Full Text

The Expertise Effect in Aesthetic Judgment of Chinese Paintings: An fNIRS Study

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Abstract

How artistic expertise influences aesthetic judgment represents a crucial research topic in experimental aesthetics. This study compared differences between experts and laypersons in aesthetic judgment of Chinese paintings while employing functional near-infrared spectroscopy (fNIRS) to examine differential brain activity during Chinese painting appreciation. Behaviorally, no significant differences emerged between experts and laypersons in either aesthetic ratings or aesthetic consensus. However, fNIRS results revealed distinct differences between experts and laypersons during Chinese painting appreciation. First, through inter-subject correlation (ISC) analysis of neural activity, we found that experts exhibited significantly higher ISC than laypersons in the prefrontal cortex (Channel 14) and right TPJ (Channel 24) when viewing low-rated Chinese paintings. Moreover, experts showed significantly lower ISC in PFC Channel 14 when viewing high-rated paintings compared to low-rated paintings, which correlated negatively with beauty ratings. Conversely, laypersons showed no significant ISC differences between high- and low-rated paintings, nor any correlations with aesthetic ratings. Second, intra-brain functional connectivity analysis revealed significantly stronger connectivity in experts than laypersons during Chinese painting appreciation, primarily localized to the right TPJ. Taken together, these findings demonstrate a clear expertise effect in Chinese painting appreciation, closely related to neural activity in the prefrontal cortex and temporoparietal junction. This study provides new cognitive neuroscience evidence for the aesthetics field.

Keywords: Chinese painting; aesthetic judgment; experts and laypersons; inter-subject correlation analysis; functional connectivity analysis

Expertise constitutes a significant factor influencing aesthetic judgment. Compared to laypersons, experts possess specific, structured domain knowledge, resulting in different cognitive and comprehension levels within their knowledge systems that ultimately lead to divergent aesthetic judgments from laypersons (Jacobsen, 2010). The notion that experts and laypersons struggle to reach consensus in art appreciation seems self-evident. Numerous studies have confirmed that experts and laypersons differ in aesthetic judgment across various domains, including paintings, music, films, websites, and even software code (Hasse & Weber, 2012; Kozbelt, Dexter, Dolese, & Seidel, 2012; Silvia & Paul, 2013; Bölte, Hösker, Hirschfeld, & Thielsch, 2017).

As one of the most universal aesthetic art forms, painting has been widely employed in aesthetic research (Xenakis, Arnellos, Spyrou, & Darzentas, 2012; Seidel & Prinz, 2018). Research indicates that experts can extract higher-level visual information from paintings, reflected in differences in eye-scanning patterns between experts and laypersons. Untrained laypersons tend to focus on individual objects, whereas art-trained experts pay greater attention to relationships among pictorial elements (Koide, Kubo, Nishida, Shibata, & Ikeda, 2015). Even when paintings contain no representational objects (i.e., abstract art), artists' scanning path distributions differ from novices. Artists exhibit more global scanning and are less guided by local salient stimuli compared to laypersons. Furthermore, art history experts more efficiently locate creatively meaningful content when appreciating representational art (Renaissance portraits) and demonstrate more systematic observation strategies in verbal reports, including more attempts at professional terminology and symbolic interpretation (Bauer & Schwan, 2017). These studies support the view that artists perceive more information from paintings based on their experience and knowledge, achieving a higher-level "interpretation" of artworks.

Artistic expertise can also influence the neural activity underlying aesthetic judgment processes. When evaluating the aesthetic appeal of architectural images, architects show greater activation in the hippocampus, precuneus, and orbitofrontal cortex than laypersons (Kirk, Skov, Christensen, & Nygaard, 2009). Müller et al. (2010) similarly observed higher neuronal activation in experts than laypersons during painting appreciation. Additionally, possessing expertise strengthens neuronal connections in specific representational processes, leading to heightened understanding and accessibility of these artworks (Cheung & Bar, 2012; Harel, Gilaie-Dotan, Malach, & Bentin, 2010). However, Pang et al. (2013) found that during free viewing of paintings, experts elicited smaller ERP components P3b and bilateral posterior late positive component (LPC) than laypersons. They interpreted this reduced brain activation as potentially reflecting higher neural efficiency in expert aesthetic judgment. Although the neural basis of expertise effects on aesthetic judgment remains unclear, this ambiguity may relate to differences across studies in visual or auditory stimulus presentation, passive observation versus explicit judgment, and even reference electrode selection, all of which hinder definitive conclusions.

As an important component of painting art, is aesthetic appreciation of traditional Chinese paintings similarly influenced by expertise level? This constitutes the central question of our study. Compared to Western realistic painting, ancient Chinese painters expressed personal emotions and will through depictions of natural objects (Fong, 2003; Zhang, 2017). Many subjects in Chinese paintings are symbolic. For instance, Qi Baishi's work *Catfish* (1937) shares pronunciation with "nian yu" (abundant years), using metaphor to express blessings for longevity. Moreover, because Chinese painting creation typically reflects specific historical and folk characteristics, different people interpret works differently. The famous *Along the River During the Qingming Festival* from the Northern Song Dynasty has long been debated in meaning—some believe "Qingming" refers to a place name near Kaifeng, Henan; others think it indicates the traditional festival; still others consider it praise offered to the first collector, Emperor Huizong. These characteristics emphasize that understanding the essence of Chinese paintings requires adequate consideration within cultural and social contexts (Shu, 2014). Leder and Belke et al.'s (2004) model of aesthetic appreciation and aesthetic judgments posits that psychological processes in art appreciation involve two steps. First, aesthetic judgment reflects the degree to which the discussed art object meets aesthetic normative standards (i.e., beautiful or not beautiful). This level is typically achievable by both art experts and laypersons. Second, aesthetic emotional experience or evaluation characterizes the emotional features of the aesthetic process, usually only reached by art experts at higher stages such as emotional mastery. However, to date, research on differences in aesthetic judgment of Chinese paintings across expertise levels (experts versus laypersons) remains lacking. Current research should focus on strengthening investigation into the psychological mechanisms and neural foundations underlying aesthetic feelings evoked by "lyrical and expressive" art forms like Chinese paintings, which holds potential significance for understanding how to guide improvements in Chinese painting appreciation. Additionally, employing Chinese paintings as aesthetic materials further expands research objects in neuroaesthetics and provides further data and empirical support for existing conclusions about expertise effects on aesthetic judgment.

Although numerous studies have confirmed that aesthetic judgment ability varies across individuals, determining what criteria measure this ability remains challenging. Kant (1790) proposed that if aesthetic judgment is pure, consensus (or common subjectivity) should be expected. Some researchers have noted that regarding standards of beauty, whether appreciators exhibit aesthetic consensus—i.e., aesthetic consistency—constitutes an important indicator of aesthetic ability (Müller-Salo, 2018). In other words, experts' evaluations of artworks should be less influenced by subjective preferences and more likely to reach consensus. Conversely, laypersons' judgments are not necessarily based on aesthetics but rather on personal preferences (Bölte et al., 2017; Lundy, Smith, 2017). These characteristics predict that experts may exhibit higher internal consistency than laypersons when evaluating artworks (Müller, Höfel, Brattico, & Jacobsen, 2010). Some studies have confirmed that experts show

consistency when evaluating creative or artistic works. For example, in poetry creativity rating studies, experts demonstrated higher internal consistency than non-experts (Kaufman, Baer, Cole, & Sexton, 2008). Lundy and Smith (2017) found in a music aesthetic evaluation study that experts showed highly consistent ratings with overall score distributions closer to normal, whereas non-professionals showed greater rating variability and weaker intercorrelations. A recent study noted that experts' painting evaluations were more consistent, while laypersons' aesthetic judgment and emotional valence ratings were easily influenced by painting abstractness (Gartus & Leder, 2020). However, some researchers have found that non-experts' evaluations of beauty quality are consistent with experts (Wanderer, 2011). This consistency may primarily derive from social influence rather than consensus about the aesthetic object itself—people give higher ratings to socially acclaimed works (e.g., *Mona Lisa*), but when appreciating works with low social influence or unfamiliar works, laypersons and experts show significant differences in aesthetic evaluation (Lundy, 2010).

The above discussion reveals that aesthetic consistency can serve as an indicator of aesthetic judgment ability (Müller-Salo, 2018). Since aesthetic consistency involves consistent evaluation of artworks across individuals, traditional neuroimaging studies analyzing single-brain activation are insufficient to reveal the neural basis of aesthetic consistency (Lengger, Fischmeister, Leder, & Bauer, 2007; Kirk et al., 2009). Investigation of aesthetic consistency's neural mechanisms should address inter-subject similarity in neural activity among appreciators. Inter-subject correlation (ISC) analysis calculates BOLD signal temporal patterns across individuals during specific cognitive processing. Its fundamental assumption is that under naturalistic conditions, if multiple subjects share identical psychological processing when facing identical stimuli, corresponding functional brain regions should exhibit similar activity patterns (Nummenma et al., 2012; Nguyen, Vanderwal, & Hasson, 2019; Liu, Yang, & Wang, 2017). Simultaneously, subjects can freely interpret stimuli according to their understanding, enabling researchers to distinguish cognitive and emotional trait differences across populations based on neural activity similarity when receiving identical stimuli (Finn, Corlett, Chen, Bandettini, & Constable, 2018). More importantly, unlike traditional general linear model (GLM) analysis that assumes a canonical hemodynamic response function, ISC analysis makes no prior assumptions about specific timing of stimulus-evoked BOLD responses, monitoring spontaneous brain activity processes. Therefore, ISC is particularly suitable for investigating psychological processes such as natural semantic integration and emotional experience that are context-dependent and require sustained stimulus processing (Hasson, Ghazanfar, Galantucci, Garrod, & Keysers, 2012; Nastase, Gazzola, Hasson, & Keysers, 2019).

In summary, this study investigates how expertise level influences aesthetic judgment of Chinese paintings. Participants were asked to rate Chinese paintings on two dimensions: beauty ratings and preference ratings. These paintings were pre-classified as high-rated or low-rated Chinese paintings based on beauty

ratings (half more beautiful, half less beautiful). Additionally, this study combined functional near-infrared spectroscopy (fNIRS) to provide neurodynamic evidence for Chinese painting aesthetic judgment. Compared to other brain imaging techniques (fMRI, MEG, EEG), fNIRS offers advantages in ease of use, tolerance for head movement, and ecological validity (Cui, Bryant, & Reiss, 2012; Tak & Ye, 2014), making it an important future direction for neuroaesthetics. This study focused on the prefrontal cortex (PFC) and right temporoparietal junction (TPJ) as primary brain regions. The PFC has been implicated in top-down cognitive control (Cupchik, Vartanian, Crawley, & Mikulis, 2009) and aesthetic pleasure experience (Cela-Conde et al., 2004) in previous aesthetic research. The TPJ, particularly the right TPJ, relates to attention to aesthetic stimuli and meaning recognition processes (Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011). Based on the aesthetic judgment model, we hypothesized that both experts and laypersons should possess basic aesthetic judgment ability, i.e., higher aesthetic evaluation for high-rated than low-rated Chinese paintings. Regarding neural activity, this study first employed inter-subject correlation (ISC) analysis to examine within-group neural activity similarity when experts and laypersons appreciated Chinese paintings, providing neural-level evidence for aesthetic consistency. Second, the study analyzed differences in intra-brain functional connectivity (FC) strength between experts and laypersons during Chinese painting appreciation. Compared to ISC analysis, intra-brain functional connectivity provides information about inter-regional correlations during specific cognitive and emotional task execution (Yoshino, Oka, Yamamoto, Takahashi, & Kato, 2013). Some studies have confirmed that domain-specific expertise affects individuals' functional connectivity strength; for example, musicians show stronger functional connectivity than non-musicians in motor, visual, and language expression areas during music creation (Herholz & Zatorre, 2012). Therefore, functional connectivity analysis can further test whether specific brain functional networks participate in Chinese painting aesthetic evaluation and attempt to explain key brain regions' roles in the neural basis of expertise effects on aesthetic judgment.

2.1 Participants

Thirty-six undergraduate and graduate students were recruited ($M = 22.3$, $SD = 2.46$). This study focused on domain-specific expertise (presence or absence of painting art knowledge background). Expert participants were undergraduates or graduates who had received three or more years of painting art training (composition, painting techniques, color usage, etc.), with painting appreciation and evaluation forming an important component of their training ($n = 17$, 13 females). Layperson participants were undergraduates or graduates from non-art departments without relevant art training ($n = 19$, 11 females). All participants were right-handed, had normal or corrected-to-normal vision, no psychiatric or neurological history, and were matched in age and education. All participants signed informed consent before the experiment and received compensation afterward. This study was approved by the East China Normal University Ethics

Committee (Approval No.: HR080-2018).

2.2 Experimental Materials

Before the formal experiment, five participants were recruited voluntarily (who did not participate in the formal experiment) to rate 59 Chinese paintings on a 9-point scale. Paintings with scores greater than one standard deviation above the mean were defined as high-rated Chinese paintings, and those less than one standard deviation below the mean as low-rated Chinese paintings. High- and low-rated paintings were matched based on color, layout, and content. Ultimately, 12 high-rated and 12 low-rated Chinese paintings were obtained (2 for practice, 10 for formal experiment). To exclude familiarity effects on aesthetic judgment, well-known works by famous masters (e.g., Qi Baishi's *Peony*) were not selected. None of the five participants reported having seen any of the paintings before. Familiarity was also assessed in the formal experiment. All Chinese paintings were selected from “Chinese Digital Library—Image Database—National Art Museum of China—Flower-and-Bird Paintings” (http://www.apabi.com/hdsf/?pid=usp.catsearch&db=picture&cult=CN&dt=Apabi_{ArtPic}&dbtype=1&c). Width was fixed at 476 pixels, with height changing proportionally according to original images, maintaining aspect ratios around 4:3. Average brightness relative to white (white value = 1, black value = 0) did not differ across all Chinese paintings. Examples of high- and low-rated Chinese paintings are shown in [FIGURE:N].

2.3 Experimental Procedure

Participants sat in front of a computer screen in a softly lit laboratory, with eyes level with the screen center. A 22-inch Dell LCD monitor presented experimental materials at 60 Hz refresh rate. Participants were informed they would complete a series of traditional Chinese ink painting appreciation tasks and rate each painting on two dimensions: liking and beauty. The experiment consisted of practice and formal phases. Each trial began with a 500 ms fixation point, followed by a Chinese painting presented for 8–12 s (presentation duration pseudorandomized across trials). Two questions then appeared sequentially: “How beautiful do you think this painting is?” and “How much do you like this painting?” Participants rated all Chinese paintings on a 5-point scale for both questions (1 = very unbeautiful/very dislike, 5 = very beautiful/very like, 3 = uncertain). The rating interface initially displayed “3”; participants switched ratings using “←” and “→” keys (no switch needed for 3) and confirmed with “Enter.” Response time was limited to 2 s to encourage ratings based on immediate feelings during picture appreciation and avoid interference from excessive deliberation. After an inter-trial blank screen (4–6 s), the next trial began. Participants were told to base ratings on personal feelings without right or wrong answers. A complete trial is illustrated in [Figure 1: see original paper]A. After the experiment, participants were asked whether they had seen the images before. Finally, they were thanked and dismissed.

[Figure 1: see original paper] shows the experimental procedure and Chinese painting examples. (A) Schematic diagram of stimulus presentation in a complete trial; (B) Examples of high-rated and low-rated Chinese paintings. The practice phase included 4 trials (2 high-rated and 2 low-rated paintings). The formal experiment comprised 20 trials, with 10 trials per block and 3-minute rest between blocks. High- and low-rated Chinese paintings were presented pseudorandomly (random order within each task but consistent presentation order across all participants).

2.4 Data Collection

E-prime 2.0 software presented experimental stimuli and collected behavioral data. A Hitachi (Japan) ETG-7100 system recorded changes in oxy-hemoglobin (Hbo) and deoxy-hemoglobin (Hbr) concentrations during the task at 10 Hz sampling frequency. Upon entering the laboratory, participants wore a pre-prepared fNIRS cap containing one 3×5 probe patch (8 emitters and 7 detectors, 22 channels) and one 4×4 probe patch (8 emitters and 8 detectors, 24 channels) (see original paper). Probe patches were positioned according to the international 10–20 system: the 3×5 patch was placed over the prefrontal cortex, with the middle emitter of the bottom row positioned at FPz (yellow circle in Figure 2(b)), the 4×4 patch was placed over the right temporoparietal junction, with the probe in the second row from bottom and second column from back positioned at P6 (yellow circle in Figure 2(b)), ensuring patch rows aligned with the sagittal reference curve. All probes were spaced approximately 3 cm apart. Signal quality was checked and adjusted before recording (including hair displacement near probes) to ensure acceptable signal-to-noise ratios. After fNIRS recording, a 3D digitizer (EZT-DM401) determined channel and probe locations, and virtual registration methods co-registered fNIRS channel positions with MNI space coordinates (Reindl, Gerloff, Scharke, & Konrad, 2018) to obtain correspondence between all channels and Brodmann areas (see).

[Figure 2: see original paper] shows fNIRS probe and channel scalp spatial layout: (a) Prefrontal cortex 3×5 probe patch; (b) Right temporoparietal junction 4×4 probe patch.

shows correspondence between channel layout and Brodmann areas: - Left prefrontal cortex (L-PFC): CH4, CH8, CH9, CH13, CH17, CH18, CH22 - Middle prefrontal cortex (m-PFC): CH2, CH3, CH7, CH11, CH12, CH16, CH20, CH21 - Right prefrontal cortex (R-PFC): CH1, CH5, CH6, CH10, CH14, CH15, CH19 - Superior parietal gyrus (SPG): CH17, CH20, CH21, CH24 - Precentral gyrus (pre-CG): CH18, CH19, CH22, CH23 - Postcentral gyrus (post-CG): CH4, CH8, CH11, CH15 - r-TPJ angular gyrus (AG): CH10, CH13, CH14 - Supramarginal gyrus (SMG): CH12, CH16, CH19 - Superior temporal gyrus (STG): CH1, CH5, CH6 - Middle temporal gyrus (MTG): CH2, CH3, CH7

2.5 Data Analysis

2.5.1 Behavioral Data We first conducted 2 (expertise: layperson vs. expert) \times 2 (Chinese painting type: high-rated vs. low-rated) mixed-effects ANOVAs on beauty and liking ratings separately. Second, we were particularly interested in whether expertise groups differed in aesthetic consensus. Therefore, we calculated rating consistency for expert and layperson groups when viewing high-rated and low-rated Chinese paintings. Specifically, we performed Pearson correlation analyses between each individual' s ratings and the ratings of all remaining participants (correlation values r range from -1 to 1; values closer to 1 indicate greater inter-individual aesthetic judgment consistency). The obtained Pearson correlation coefficients r were standardized (Fisher-Z transformation: Fisher-Z = $0.5 \times \ln((1+r)/(1-r))$). The mean of this participant' s r values (Fisher-Z) with all other participants represented the degree of consistency between this participant and all other participants in the group. Finally, standardized correlation coefficients were subjected to group-level mixed-effects ANOVA, with simple effects analysis conducted on significant interactions and statistical p -values Bonferroni-corrected.

2.5.2 fNIRS Data fNIRS data analysis used Matlab R2018a (MathWorks, Natick, MA) with BrainNet Viewer toolbox (<http://www.nitrc.org/projects/bnv/>) (Xia, Wang, & He, 2013) for fNIRS result visualization. Signals were preprocessed as follows: (1) Exclude channels with poor scalp contact. Specifically, if heartbeat could not be identified in corresponding wavelet transform plots or if channels showed excessive noise with too many spikes during visual inspection, the channel was deemed noisy. Participants with noisy channels exceeding 50% of total channels (>23) were excluded from subsequent analysis. (2) Remove motion artifacts using wavelet-based motion artifact removal with probability threshold $\alpha = 0.4$ (same as Molavi & Dumont, 2012). (3) Apply 0.01-0.5 Hz bandpass filtering to eliminate physiological noise from respiration and heartbeat, low-frequency drift, and instrument noise. Next, oxy-hemoglobin (oxy-Hb), deoxy-hemoglobin (deoxy-Hb), and total hemoglobin (THb) concentration changes (ΔH_{bo} , ΔH_{br} , and $\Delta TotalHb$) were calculated from optical density signals based on the modified Beer-Lambert law. Since H_{bo} is sensitive to local cerebral blood flow changes (Hoshi, 2007; Cui et al., 2012) and has higher signal-to-noise ratio (Ding, Fu, & Lee, 2014; Sasai, Homae, Watanabe, & Taga, 2011), only ΔH_{bo} was included in subsequent data analysis. To exclude button-press effects on neural activity, fNIRS analysis was limited to Chinese painting appreciation periods, excluding button-press judgment periods.

Chinese painting aesthetic brain activity analysis primarily included inter-subject neural activity similarity analysis and intra-brain functional connectivity strength analysis, as illustrated in [Figure 3: see original paper].

Neural Activity Similarity Analysis. We employed inter-subject correlation (ISC) analysis to calculate Pearson correlations of time series between subjects during Chinese painting appreciation for each channel (Nastase et al., 2019;

Jimenez et al., 2020). Specifically, each participant's time series in each channel was correlated with every other participant's time series in the same channel to obtain correlation coefficient r , which was standardized (Fisher-Z) and averaged at the participant level. This yielded the average neural activity signal similarity between this participant and all other participants for that channel. Standardized correlation coefficients were then subjected to group-level 2 (expertise: expert vs. layperson) \times 2 (Chinese painting type: high-rated vs. low-rated) statistical tests, with simple effects analysis on channels showing significant interactions. All channel statistical test p-values were FDR-corrected to avoid Type I errors (Benjamini & Yekutieli, 2001; Genovese, Lazar, & Nichols, 2002).

Selection of Significant Channels for Aesthetic Consistency. Due to long-term autocorrelation in fNIRS time series causing spurious correlations (Zarahn, Aguirre, & D'Esposito, 1997), this study employed permutation testing (random permutation test) to identify channels significantly above random levels by constructing ISC distributions from randomly permuted ΔH_{bo} sequences, thereby excluding potential confounding effects and reducing false discovery risk (Hasson, Furman, Clark, Dudai, & Davachi, 2008; Nastase et al., 2019). For each channel, we scrambled painting-internal time sequences (in fixed clusters of 10 time points/1 s) while keeping paintings unscrambled relative to each other, then recombined scrambled sequences with other participants' original time series to recalculate Pearson correlations. This procedure was performed 2000 times to obtain ISC null distribution intervals for each channel, then calculated significance levels of real-condition ISC within this random distribution ($p < 0.05$, one-tailed). Specifically, significance p-values were calculated as the number n of random distribution values exceeding the real ISC value divided by 2000 ($p = n/2000$). If all values were smaller than the real value, n was set to 1 ($p = 1/2000 = 5 \times 10^{-4}$).

Functional Connectivity Analysis. Pearson correlation coefficient r was calculated between one channel's time course and all other channels' time courses within each individual. This constructed a 46×46 functional connectivity matrix for each participant, where each row or column represented correlations between one channel and all 46 channels (including itself). This yielded connectivity matrices for four conditions (expert high-rated, expert low-rated, layperson high-rated, layperson low-rated). Next, r -values were thresholded to obtain significant channel pairs (this study used median r -value as threshold). Fisher-Z transformation of r -values yielded functional connectivity strength statistics, with inverse Fisher transformation used to present functional connectivity matrix heatmaps. Finally, similar to above analyses, standardized correlation coefficients r (Fisher-Z) were subjected to group-level statistical tests (calculated only for channel pairs above threshold in the upper triangular matrix), with simple effects analysis on channels showing significant interactions. All statistical test p-values were FDR-corrected.

[Figure 3: see original paper] shows fNIRS data analysis schematic: (A1) ISC analysis schematic—Pearson correlation of time courses between Subject X and

Subject Y across all channels; (A2) Average ISC degree across all channels; (B1) Intra-brain functional connectivity schematic for Subject X; (B2) 46 \times 46 channel functional connectivity matrix schematic for Subject X.

Participants with fewer than 30% valid responses (i.e., no rating response within the 2 s limit; 3 laypersons) and those with poor fNIRS signal quality (1 layperson, 2 experts) were excluded. Final analysis included 15 experts (8 females) and 15 laypersons (10 females). Post-experiment inquiry revealed that only 1 participant (an expert) reported having seen 2 of the paintings, so these two paintings (trials) were removed from subsequent analysis.

3.1 Behavioral Results

All participants' ratings for high- and low-rated Chinese paintings are shown in [Figure 4: see original paper] A&B. Although some individuals rated low-rated paintings higher than high-rated ones, overall both layperson and expert groups gave significantly higher ratings to high-rated than low-rated Chinese paintings on both beauty and liking dimensions—i.e., they found high-rated paintings more beautiful and more likable. Subsequent mixed-effects ANOVAs on liking and beauty ratings revealed main effects of Chinese painting type. For beauty ratings, high-rated paintings received significantly higher scores than low-rated paintings (beauty: $M(\text{high}) = 3.55$, $SEM = 0.10$; $M(\text{low}) = 2.9$, $SEM = 0.11$, $F(1, 28) = 47.55$, $p < 0.001$, $\eta^2_p = 0.63$, 95% CI = [0.416, 0.733]). For liking ratings, participants also showed significantly greater liking for high-rated than low-rated paintings (liking: $M(\text{high}) = 3.44$, $SEM = 0.11$; $M(\text{low}) = 2.93$, $SEM = 0.09$, $F(1, 28) = 25.13$, $p < 0.001$, $\eta^2_p = 0.47$, 95% CI = [0.231, 0.617]). Additionally, correlations between beauty and liking ratings across conditions were calculated, revealing high correlations ($r(\text{layperson low}) = 0.88$, $p < 0.001$, 95% CI = [0.66, 0.97]; $r(\text{layperson high}) = 0.86$, $p < 0.001$, 95% CI = [0.67, 0.97]; $r(\text{expert low}) = 0.90$, $p < 0.001$, 95% CI = [0.82, 0.97]; $r(\text{expert high}) = 0.87$, $p < 0.001$, 95% CI = [0.56, 0.98]). Pairwise comparisons of these correlation coefficients using the *cocor* R package revealed no significant differences (all $ps > 0.1$). These results demonstrate the validity of our Chinese painting material classification and, consistent with previous research, reveal high correlation between beauty and liking aesthetic dimensions (Lüdtke, Meyer-Sickendieck, & Jacobs, 2014). However, behavioral results showed no main effect of expertise level on aesthetic ratings, nor significant interaction effects (all $F_s < 1$, $ps > 0.05$).

Separate mixed-effects ANOVAs on rating consistency for experts and laypersons on liking and beauty dimensions revealed significant main effects of Chinese painting type: consistency for high-rated paintings was significantly higher than for low-rated paintings on both beauty and liking dimensions (beauty: $M(\text{high}) = 0.18$, $SEM = 0.02$; $M(\text{low}) = 0.09$, $SEM = 0.03$, $F(1, 28) = 6.22$, $p = 0.019$, $\eta^2_p = 0.38$, 95% CI = [0.017, 0.371], as shown in Figure C; liking: $M(\text{high}) = 0.18$, $SEM = 0.03$; $M(\text{low}) = 0.09$, $SEM = 0.02$, $F(1, 28) = 6.76$, $p = 0.015$, $\eta^2_p = 0.47$, 95% CI = [0.023, 0.383], as shown in Figure E). Similar to aesthetic rat-

ing results, no expertise effects were found for rating consistency, nor significant interactions between expertise and Chinese painting type (all $F_s < 1$, $p_s > 0.05$). Given the small sample size limitation, we further validated rating consistency results using nonparametric bootstrap tests, which yielded consistent results—only main effects of Chinese painting type were significant (see Figures D & F).

[Figure 4: see original paper] shows behavioral aesthetic judgment results: (A&B) Differences between high- and low-rated Chinese paintings on liking (A) and beauty (B) ratings; (C&D) Between-group differences in rating consistency between expert and layperson groups for high- and low-rated Chinese paintings; C' and D' show nonparametric test results for main effects of Chinese painting type. Error bars represent standard error of the mean (** $p < .001$, ** $p < .01$, * $p < .05$).

3.2 fNIRS Results

3.2.1 Inter-Subject Neural Activity Similarity Results During Chinese Painting Appreciation

By comparing real-task ISC with ISC null distributions from randomly scrambled sequences to identify task-significant channels, 12 channels were retained (PFC: CH01, CH05, CH12, CH14, CH17, CH22; r-TPJ: CH07, CH14, CH16, CH19, CH20, CH24), outlined by black boxes in [Figure 5: see original paper]A. Mixed-effects ANOVAs (2 [expertise: layperson vs. expert] \times 2 [Chinese painting type: high-rated vs. low-rated]) on retained channels revealed significant interaction effects in prefrontal CH14 (approximately left middle frontal gyrus) and right TPJ CH24 (right superior parietal gyrus), as shown in [Figure 5: see original paper]B. CH14: $F(1, 28) = 9.42$, $p = 0.031$, $p = 0.045$ (after FDR), $^2p = 0.54$; CH46: $F(1, 28) = 6.14$, $p = 0.019$, $p = 0.035$ (after FDR), $^2p = 0.36$. Simple effects analysis revealed that in left prefrontal CH14, experts showed significantly higher neural activity similarity than laypersons when viewing low-rated paintings, $t(14) = 2.59$, $p = 0.023$, Cohen' s $d = 1.38$, 95% CI: [0.01-0.13]. Additionally, experts showed differences in neural activity similarity between painting qualities, with significantly lower similarity when viewing high-rated than low-rated paintings ($t(14) = -3.44$, $p < 0.01$, Cohen' s $d = 1.84$, 95% CI: [0.04-0.18]). For laypersons, no differences were found between high- and low-rated paintings ($p > 0.05$). In right TPJ CH24, the interaction effect only manifested as experts showing significantly higher neural activity similarity than laypersons when viewing low-rated paintings ($t(14) = 3.62$, $p < 0.01$, Cohen' s $d = 1.93$, 95% CI: [0.04, 0.15]). Additionally, a main effect of expertise was found in right TPJ CH16 (supramarginal gyrus), showing higher neural activity similarity in experts than laypersons ($F(1, 28) = 6.89$, $p = 0.014$), though only marginally significant after FDR correction ($p = 0.063$). No main effects of Chinese painting type were significant after FDR correction ($p > 0.05$).

Finally, we examined relationships between neural activity similarity and aesthetic judgment behavior, finding a significant negative correlation between

experts' ISC in prefrontal CH14 and beauty ratings ($r = -0.65$, $p < 0.001$). This indicates that higher neural activity similarity in experts predicted lower beauty ratings for paintings. No correlations with behavioral ratings were found in laypersons ($r = -0.14$, $p > 0.1$). We further examined correlations between CH14 ISC and other behavioral indices (liking ratings, beauty consistency, liking consistency) and between other significant channels (right TPJ CH24) and behavior, all non-significant (all p s > 0.05).

[Figure 5: see original paper] shows neural activity similarity analysis results during Chinese painting appreciation: (A) Brain regions significantly involved in Chinese painting appreciation; (B) Interaction effects in inter-brain activity similarity analysis (significant interactions in left middle frontal gyrus CH14 and right superior parietal gyrus CH24). The negative correlation between CH14 ISC and aesthetic ratings (beauty) in panel B (top left) reveals that experts' ISC can identify Chinese painting quality. Laypersons' ISC showed no correlation with ratings. Error bars represent standard error of the mean (** $p < .01$, * $p < .05$).

3.2.2 Functional Connectivity Results During Chinese Painting Appreciation

Pearson correlation analysis yielded functional connectivity matrices for each participant's intra-brain channels ([Figure 6: see original paper] shows heatmaps of 46×46 channel functional connectivity matrices [inverse Fisher-Z r values] and thresholded correlation matrices for each condition). Next, group-level 2 (expertise: layperson vs. expert) \times 2 (Chinese painting type: high-rated vs. low-rated) mixed-effects ANOVA was conducted on functional connectivity strength. Due to the large number of channel pairs ($46 \times 46 / 2 = 529$ pairs), all effects became non-significant after FDR correction based on all channel pair p -values. Therefore, we performed FDR correction separately for p -values of all channel pairs within each brain region based on channel locations (). Under this approach, only 8 channel pairs showed significant main effects of expertise (see), manifesting as significantly stronger functional connectivity in experts than laypersons during Chinese painting appreciation (all F s > 6.38 , p s < 0.05 after FDR). These included 1 cross-region channel pair (PFC-rTPJ) and 7 channel pairs within the right temporoparietal junction, with brain region distributions shown in [Figure 7: see original paper].

[Figure 6: see original paper]A shows functional connectivity matrix maps (inverse Fisher-Z r values) and B shows thresholding schematic: white areas = below threshold ($r < 0.56$); gray = $r = 0.56-0.75$; black = $r > 0.75$.

shows significant channel pairs for expertise main effect in functional connectivity: - Superior parietal gyrus - middle temporal gyrus - Superior temporal gyrus - superior temporal gyrus - Middle temporal gyrus - middle prefrontal cortex - Supramarginal gyrus - precentral gyrus - Supramarginal gyrus - postcentral gyrus

Note: Blue numbers (16) indicate prefrontal channels; black numbers indicate right temporoparietal channels.

[Figure 7: see original paper] shows brain region distribution schematic for channel pairs with significant expertise main effect (left: sagittal view; right: transverse view). Dots indicate channel spatial locations; different functional regions are color-coded; functional connection strength (channel connection line colors) corresponds to expertise main effect F-value colorbar.

Discussion

Chinese painting serves as an important vehicle for perceiving the unique aesthetics of Chinese art, yet its distinctive creative approach also increases aesthetic difficulty. This study investigated how expertise influences aesthetic judgment of Chinese paintings. Experts and laypersons viewed a series of traditional Chinese ink paintings—flower-and-bird paintings—and rated them on beauty and liking dimensions, while fNIRS recorded neural activity during appreciation.

Behaviorally, first, both experts and laypersons gave significantly higher ratings to high-rated than low-rated Chinese paintings on both beauty and liking dimensions. In other words, people responded more positively to Chinese paintings with higher evaluations (high-rated paintings). This aligns with our hypothesis that both experts and laypersons possess basic aesthetic judgment ability. Furthermore, the study found positive correlations between the two aesthetic judgment ratings (liking vs. beauty), consistent with previous research (Lüdtke et al., 2014; Menninghaus, Wagner, Wassiliwizky, Jacobsen, & Knoop, 2017; Gartus & Leder, 2020), confirming the universal phenomenon that people tend to like what they perceive as more beautiful. This correlation appears unlikely to be affected by individual expertise level differences.

Regarding rating consistency, experts and laypersons were unexpectedly homogeneous—no identifiable differences in aesthetic consistency were observed between experts and laypersons in subjective ratings. Since liking concerns personal preference and is less likely influenced by expertise level, experts and laypersons showed no significant differences. However, experts also failed to show more consistent evaluations on beauty judgments, which partially diverges from previous findings of higher internal consistency in experts' aesthetic evaluations of Western paintings (Müller et al., 2010; Lundy et al., 2018). We attribute this result to limitations of self-report. Subjective rating reports only utilize information related to aesthetic judgment outcomes, not the actual aesthetic evaluation process. In other words, even if each participant shows 100% consistency across tasks, the cognitive processes leading to identical conclusions may still differ. This is corroborated by our neural activity analysis (3.2 fNIRS results), which revealed differences between experts and laypersons during Chinese painting appreciation. Previous studies have confirmed our inference—for example, Müller et al. (2010) found virtually no behavioral differences between experts and laypersons in music aesthetic judgment, yet significant differences in

event-related potential (ERP) parameters: experts invested more in preparatory stages of music aesthetic processing, manifested as stronger contingent negative variation (CNV) components, whereas laypersons showed broader positive responses during later music appreciation stages. Other studies have similarly supported our hypothesis (Koide et al., 2015; Bölte et al., 2017). Moreover, to our knowledge, this study is the first to examine differences in aesthetic judgment consistency between experts and laypersons for Chinese paintings, with stimulus materials differing substantially from Western oil paintings or geometric patterns used in previous research. Previous studies have noted that different stimulus material properties, task settings, and individual characteristic differences (e.g., age, gender) can lead to completely different aesthetic judgments (Tuch, Bargas-Avila, & Opwis, 2010). Therefore, future research requires further corroboration, including increasing participant and stimulus numbers for more stable results.

fNIRS results showed that compared to laypersons, experts exhibited higher neural activity similarity when viewing low-rated paintings, observed in both left middle frontal gyrus (CH14) and right superior parietal gyrus (CH24). These brain regions have been confirmed to play important roles in beauty perception (Babiloni et al., 2013; Chiara et al., 2017; Wang, Luo, & Dong, 2010). Our results partially support the conclusion that experts' aesthetic judgments show greater internal consistency. Further, we propose that experts showing higher internal consistency only when viewing relatively less beautiful Chinese paintings may reveal that experts can pinpoint shortcomings accurately (e.g., line fluency, ink density, composition complexity) when appreciating less successful works. Previous research partially supports this hypothesis: Ticini et al. (2012) found that experts responded faster when evaluating artworks as “not beautiful,” and their evaluations of “not beautiful” works were less influenced by social or non-social salient attributes.

Modern theories of aesthetic processing suggest possible interactive relationships between perceivers and objects (Leder & Nadal, 2014; Pan et al., 2011). Chinese painting is a complex system encompassing Chinese history, allusions, legends, and customs. For knowledgeable appreciators, a good artwork tells a good story, which constitutes the most enjoyable part of “reading Chinese paintings.” However, since experts typically experience works through perceptual and cognitive abilities developed through art experience, they cannot fully comprehend all potential meanings contained in an artwork, leading to incomplete consensus in viewpoints and interpretations of excellent artworks (Kesner, 2006). This is confirmed by our finding that experts showed significantly lower neural activity similarity in prefrontal Channel 14 when viewing high-rated than low-rated paintings. This result reveals that experts have greater interpretive space when appreciating high-rated paintings—so-called “different people see different things” —inseparable from artists' profound aesthetic insight. Yet experts' lower neural activity similarity for high-rated paintings seems contradictory to behaviorally observed higher rating consistency for high-rated paintings. We interpret this as: although experts appreciate excellent Chinese paintings from vastly dif-

ferent perspectives, this does not affect their ultimate consistent conclusion of “beautiful.” However, as discussed, future research should enhance self-report accuracy and add post-hoc verbal statements for further evidence. Our finding of no significant differences in laypersons across high- and low-rated paintings also confirms that lack of art-related expertise indeed hinders Chinese painting aesthetic appreciation. Previous research found that laypersons’ eye-scanning paths during painting appreciation show similarity, with both social (human figures) and non-social features in paintings guiding laypersons’ fixation patterns similarly (Lu, Gao, Qin, Zhao, & Liu, 2008). Therefore, our findings further explain why laypersons in previous studies often considered Chinese paintings “all the same” and struggled to recognize their artistic value (Jin, 2004). Finally, correlation analysis between significant channels’ ISC and aesthetic behavioral ratings revealed that only experts’ ISC in prefrontal CH14 correlated significantly and negatively with beauty ratings ($r = -0.65$, $p < 0.001$), while no correlation existed for laypersons ($r = -0.14$, $p > 0.1$). This further supports that experts’ neural activity similarity can distinguish Chinese painting quality—higher ISC predicted lower painting quality ratings—whereas laypersons’ neural activity similarity lacked discriminative power for Chinese paintings.

Functional connectivity strength has been shown to reflect differences among characteristic groups performing specific cognitive and emotional tasks (Finn et al., 2015). Therefore, we further employed functional connectivity analysis to test expertise effects on Chinese painting aesthetic judgment. We found that expert participants showed significantly stronger intra-brain functional connectivity than laypersons during Chinese painting appreciation, primarily occurring in the right temporoparietal junction (r-TPJ, as shown in [Figure 7: see original paper]), including extensive connections across the superior parietal gyrus, middle temporal gyrus, supramarginal gyrus, and pre- and postcentral gyri. The TPJ has been identified as a key region for imagining others’ thoughts and purposes and for emotional resonance (Ashar et al., 2017), which readers also use to reconstruct characters’ thoughts in stories (Thomas, 2014). Extensive art training and artwork reflection are necessary for acquiring high-level art expertise. Previous research found that bilateral temporal lobes showed greater activation when appreciating representational than abstract paintings because representational art better triggers associations (Lengger et al., 2007; Cela-Conde et al., 2011). Given this, we propose that experts’ stronger functional connectivity in right TPJ found in this study relates to associations triggered by Chinese painting aesthetics—experts more closely link aesthetic concepts with emotional associations and empathic understanding during Chinese painting appreciation. The Empathizing-Systemizing Theory also posits that whether artworks can change individuals’ emotional states constitutes an important criterion for aesthetic capacity (Greenberg, Rentfrow, & Baron-Cohen, 2015). Our findings support previous research and theory.

In conclusion, this study represents an active attempt to explore how artistic expertise influences aesthetic judgment of traditional Chinese art (Chinese paintings) using functional near-infrared spectroscopy, holding important guid-

ing significance for domestic public art educators to conduct knowledge popularization and help the public better understand and appreciate traditional Chinese art. However, several limitations remain. First and most importantly, our expert participants were relatively limited in source with lenient selection criteria. Since we recruited art undergraduates and graduates, the proportion of individuals with extremely high artistic expertise may have been low, somewhat limiting our conclusions, as we cannot determine whether advanced experts' aesthetic judgments differ from those of moderately skilled art students. Second, our data sources were relatively limited (behavioral + neural). Future research could combine eye-tracking, verbal statements, and other multi-modal data for mutual corroboration to enable more detailed exploration of the neuropsychological basis underlying Chinese painting aesthetics.

This study combined fNIRS brain imaging technology to reveal the neural basis of experts' greater artistic appreciation ability compared to laypersons, extending this conclusion for the first time to appreciation of traditional Chinese art forms—Chinese paintings—providing support from both inter-brain neural activity similarity and intra-brain functional connectivity strength. (1) Experts' neural activity similarity can distinguish Chinese painting quality (higher ISC predicts lower painting ratings), whereas laypersons' neural activity similarity lacks discriminative power for Chinese paintings. (2) Experts' stronger functional connectivity in right temporoparietal junction during Chinese painting appreciation reveals that expertise leads experts to more closely link aesthetic concepts with emotional associations and empathic understanding than laypersons during Chinese painting aesthetic processing.

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