How People with Amputation Interpret Emotions from Touch in Paintings Across Different Social Affective Contexts ?

By

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Preface and Acknowledgement

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INTRODUCTION

An interaction of Proprioception and Exteroception: Amputation and Perceiving Touch

People with amputation experience changes to the limbs and body sensations, which further causes changes to proprioception. Proprioception represents how individuals sense different physical body parts within a spatial area, including the posture and movement of both upper and lower limbs (Delhaye et al., 2018; Héroux et al., 2022). Amputation requires the deafferentation of one or several limbs of their own physical body, which completely changes the proprioception that they get used to as a healthy individual. In contrast, exteroception represents how individuals perceive the stimuli that come from outside the body in the external environment, in which visual and tactile stimuli are two essential forms of exteroception (Kassab and Alexandre, 2015).

From a neuroscientific perspective, previous studies have provided strong evidence of how amputation changes people's brains. For example, most people with amputation will experience some type of phantom limb sensations or phantom limb pain in the post-amputation period (Collins et al., 2018). Phantom limb means people who experienced amputation still sense the existence of a limb even if it's not there (Collins et al., 2018). Studies have shown cortical reorganization and displacement in the somatosensory cortex for people who experienced phantom limbs (Karl et al., 2001; Knecht et al., 1996; Raffin et al., 2016; Valyear et al., 2020). Through analyzing the BOLD responses during body movements and the 3D anatomy of people with amputation, Raffin et al. (2016) found various reorganizational patterns in the hand, elbow, and lips. Apart from the evidence from amputation and phantom limb, the somatosensory area has long been associated with proprioception and touch, which is responsible for processing the neural signals from the skin, muscles, and other body parts like ligaments (Delhaye et al., 2018).

Therefore, as someone who experiences changes to proprioception and the somatosensory cortex, people with amputation are very likely also to experience changes to exteroception of touch or the perception of touch.

Visual perception, as an important form of exteroception, determines how people perceive the touch from touch observation. Studies on healthy participants have demonstrated that the somatosensory cortex has more significant activation when observing the touch, but less activation or completely no activation when observing the touch with non-human objects (Chan & Baker, 2015; Blakemore et al., 2005). When it comes to people with amputation, similar to the present study but different from the studies mentioned above, Chan et al.(2019) conducted an experiment using static images of limbs on lower limb amputees. Out of expectation, they found a strong response from the sensorimotor cortex only from amputation participants when simply presenting the static images of limbs at the baseline, especially for images of the foot. According to the researchers in the study, such strong visual responsiveness in the sensorimotor cortex represents both somatosensory and motor activity in their mind. This result revealed that, different from normal subjects, people with amputation might experience implicit motor imagery when observing the static images of body parts. In addition to the studies above, few studies have examined the observation of static touch, especially for people with amputation. Different from touch in motion, interpreting static touch requires more mental imagery. Static touch is a very common feature in artworks, including paintings and sculptures. Interpreting static touch appropriately is an important component of aesthetic appreciation.

As a result, the current study on how people with amputation observe static touch in paintings will present a precious opportunity to study the interplay between proprioception and exteroception. The results mentioned above have proved that changes to proprioception will change people's perception of touch or body parts in both video and static forms. Different from previous studies, the current study will further examine how such changes to proprioception could impact or distort how visual perception of static touch could evoke social emotional reactions. The study will pave the foundation for further understanding regarding the interaction of proprioception and exteroception of the human body. Furthermore, interpreting emotions from non-verbal social language is an essential component of social life. Current study could help people to further understand the social perspective of people with amputation, and help society to develop better social support intervention for people with amputation to help them adapt to the social life in the post-amputation period, which will facilitate the well-being and mental health among people with amputation.

LITERATURE REVIEW

Touch, Emotion, and Perception

Painting has consistently served as a unique medium for individuals to capture significant moments in their daily lives. Throughout history, painters have employed their craft to convey interpersonal social connections, encompassing friendships, familial bonds, and romantic relationships. Among these paintings, touch is a recurring motif employed to depict the social interactions between figures within the composition. The interpretation of touch in these paintings varies depending on the affective context. From the observer's perspective, observing touch and interpreting the social emotion within it is a highly subjective experience, which depends on individuals' differences in emotionality, visual perception, and overall physical and mental well-being. These three factors are closely interconnected to each other, and they are crucial for people’s daily activities and social functioning. Therefore, observing painting is not just a simple behavior that requires appreciation of the painting; it also reflects factors related to people’s social cognition, which is directly related to people’s social lives and mental health.

In 2006, Hertenstein et al. demonstrated that people could communicate and decode different types of emotions through touch. They found that people possess the capability to differentiate different emotions through observing the touch between other people. Back in 1992, Paul Ekman defined six basic emotions that paved the foundation for the emotional theories in modern psychology — anger, fear, sadness, enjoyment, disgust, and surprise (Ekman, 1992). Among Ekman’s six basic emotions, they revealed that people tend to be good at decoding anger, fear, and disgust through touch, compared to decoding happiness and surprise from touch. Furthermore, individuals are unable to decipher self-centered emotions, such as embarrassment, envy, and gratitude, conveyed through touch. Both groups of participants from the United States and Spain demonstrated the capacity to decode prosocial emotions from touch. Different from touch in the paintings, the studies focused on the real touch between people or the video clips of touch between other people without any affective context. Touch in paintings, however, always provides affective and social context to help the audience understand what the painters want to express, and it’s completely still (Mullennix et al., 2022). The difference in visual perception of motion touch versus still touch could affect how people interpret the social emotion of touch from the paintings (Battaglia et al., 2011). More importantly, touch from paintings, though it can be depicted in a realistic way, is not as realistic as the physical touch between real people (Battaglia et al., 2011).

Observing and interpreting touch could be split into two different components. Through the combination of EEG and fMRI data, Mason and Isik (2023) revealed that there’s an order of information processing when people observe the touch with social emotion. In their experiment, when all the motion, visual, and social-affective features extracted by the brain at the same time, social affective features are processed after the visual features. In addition, they found that the early visual cortex, temporoparietal junction, and posterior superior temporal sulcus explain the EEG neural patterns when people observe the touch rather than the somatosensory cortex. The study also revealed the difference between social and nonsocial touch through early evoked potentials. Social touch has more significant activation in brain regions near the superior frontal gyrus, while nonsocial touch has enhanced activation in brain regions near the lateral occipital cortex. The superior frontal gyrus has been related to emotional regulation and appraisal, which means social touch evokes more emotions than non-social touch (Faquelz et al., 2014). Overall, the study further supports that it's necessary to consider two important components when studying the observation of social and affective touch — visual and social perception. The visual perception corresponds to the visual information processing, while the social perception corresponds to the social emotional processing. The study supports that emotion is a necessary part for interpreting social touch.

Amputation and Changes in Emotion

People with amputation always experience difficulties in psychosocial adaptation, and therefore they always suffer from different psychiatric conditions in post-amputation, like anxiety, depression, and even externalized hostility (Livneh et al., 1999). In a 3- to 4-year follow-up study, Singh et al. (2009) reported that nearly 40% of participants with amputation suffer from anxiety or depression. In addition, the incidence of both psychiatric conditions rises significantly in the post-rehabilitation period. Furthermore, through the qualitative evidence based on interviews, Roșca et al. (2021) found that people with amputation experience social isolation, anxiety, depression, and more importantly, the emotional shock and changes to emotional balancing. Many participants reported that they experience desperation and had a wish for death after the amputation, which reveals that accepting the amputation facts requires emotional adjustment and the overcoming of emotional shock. In addition, they also found that people with amputation adopt different strategies to balance the negative emotions they face. For example, some participants show stronger will and determination for recovery, and other participants choose to seek support from faith or social environment, which proves that social environment could be vital for the mental state and health of people with amputation. In summary, people with amputation experience dramatic changes to their emotionality, which makes their emotional experiences totally distinct from the healthy population. Such changes in emotionality force them to adopt various emotional regulation strategies, which could indirectly influence how they interpret and perceive emotions in social lives.

Currently, few studies have directly addressed how emotions change for people who suffered from amputation, but numerous studies have investigated how depression changes emotionality. Changes to emotion recognition, emotion differentiation, and emotion regulation are common symptoms for people with depression. Studies from Beblo et al. (2012) revealed that people with depression suppress their negative emotions, which is a major factor that causes depressive symptoms. However, they also suppress their positive emotions. While people with depression could recognize both positive and negative emotions, they choose to suppress both to overcome their fear of different emotions. The result proves people with depression naturally perceive the general emotional experience more negatively. Furthermore, through two studies on trait and state positive emotions, Gruber et al.(2011) found that highly depressed people tend to experience less positive emotions with the presence of pride-eliciting visual stimuli compared to happiness and amusement.

Social vs Non-Social Touch

In another study, fMRI results by Ebisch et al. (2011) showed that there's overlapping in the activation of different brain regions between social and nonsocial touch, and experiencing and observing touch. The studies allowed the participants to observe the video clips of social and non-social touch, and experience tactile stimuli on both right and left hands. They found the overlapping activation in bilateral occipito-temporal junction, ventral precentral-inferior frontal gyrus, fusiform gyrus, left hemisphere anterior and posterior SII, ventral postcentral gyrus, anterior superior parietal cortex, and right hemisphere posterior superior temporal gyrus/sulcus. However, they also found that some brain regions differentiate social touch from non-social touch, and observation of touch from experiencing touch. Compared to non-social touch, observing social touch activates the left hemisphere anterior insular cortex. Both left and right hemisphere posterior insular cortex were activated when experiencing touch, but they were deactivated when observing the touch. This study also further supports the distinction between social and nonsocial touch based on neuroimaging results. In addition, Keck et al. (2025) found that the inferior parietal lobe in the action observation network showed a geometric neural pattern when people observe the actual emotional touch. Such a geometric pattern reflected the impression of emotional valence for the visual stimuli. All these showed that observation of affective or social touch could not only activate similar brain regions comparable to experiencing the affective or social touch, but also communicate the emotional valence. Emotional valence means the pleasantness and unpleasantness of certain stimuli (Kauschke et al., 2019). People also showed different emotional sensitivity to different types of emotions when observing the touch.

Motion, Motor Imagery and the Observation of Static Touch

However, all these findings are based on the actual touch motion in real life, and few studies have investigated the less realistic touch without any motion in non-realistic contexts. Such a type of touch is not uncommon in daily life, and we can easily find them in animated pictures, paintings, artworks, posters, and even some AI-generated pictures. Therefore, it is crucial to investigate social touch in paintings. Compared to motion touch in physical life, touch in paintings is more static but less realistic. These two important features differentiate the touch in paintings from previous studies, but they did not weaken the emotion expressed through the paintings. Therefore, investigating how people perceive social emotions conveyed through static touch in paintings could provide a novel perspective within this research domain. Detenber et al.(1998) already found that the motion in picture images could increase people's emotional arousal and attention to the pictures. Studies also showed that the motion information is essential for people to identify certain emotions through body gestures or facial expressions(Atkinson et al., 2007; Bould & Morris, 2008). However, without involving any motion, the touch in paintings still presents strong social emotions, as same as motion touch in physical life, under different affective contexts. It's still unknown how people perceive the social emotion conveyed by the touch without any motion in the paintings.

One important factor is motor imagery when people observe the action in the paintings. A visual perceptual experience, like observing the painting, is an interaction of sensory stimulation and visual imagery (Albright, 2012). Battaglia et al.(2011) conducted four experiments to examine people's corticomotor excitability when observing the hands in Expulsion from Paradise, Creation of Adam, and Dead Christ with Angels compared to real photographs of hands. They found an increasing level of cortical-spinal excitability when observing the action of hands in these paintings, while observing the photograph of the same action did not increase the cortical-spinal excitability. It's worth noting that the authors only presented part of the three paintings, and they only cropped the one side in the Creation of Adam. However, such an effect is only for Expulsion from Paradise, not for the other two paintings. The authors attribute such an effect to Michelangelo's outstanding painting skills, but it's more likely due to a higher level of implied motion in the Expulsion from Paradise, while the other two have less implied motion.

Perception Changes for People with Amputation

Previous literature has always targeted healthy populations, and few studies focused on people with amputation, a unique population that could reveal how different interacting factors affect how people receive social emotions from touch, including body signals, psychiatric conditions, and visual perception. People with amputation not only need to adapt to the physical changes but also suffer from psychiatric comorbidities in the post-amputation period (Durmus et al., 2015). Therefore, investigating people with amputation presents an opportunity to study how changes to the physical body and certain psychiatric conditions affect the visual perception of emotion, especially social emotion. The visual perception of social emotion from touch in paintings involves identifying the touch from the paintings and interpreting it based on the affective context and personal experiences and memories, which creates a similarly stimulated environment of real-life social scenarios (Mullennix et al., 2022; McGlone et al., 2014).

Although few studies directly investigated people with amputation and their changes in visual perception, many studies have demonstrated that there's a strong connection between changes in the human body and changes in visual perception. van der Hoort et al. (2011) found that the size of people's own body could affect how people perceive the object size and distance. In their experiment, they used a small body and a giant body to test how people perceive the object. The results revealed that a small body will cause people to perceive the object larger and farther, while a giant body will cause people to perceive the object smaller and nearer. This study brings some implications for people with amputation as they also lose part of their original body and it will directly affect how they perceive their current body size and body ownership. In another study, they also demonstrated that the perceived object size has an inverse relationship with the size of the invisible body illusion (van der Hoort & Ehrsson, 2016). Such findings could bring another angle for how people with amputation experience changes in their visual perception.

Till now, it's still unclear how limb loss and experiencing phantom limb might affect how they interpret emotions from touch. In other words, how might experiencing dysfunctional or lost body parts affect interpreting emotions from actions that require the same body parts? A study on Moebius syndrome (MBS) patients has tested the hypothesis that the identification of emotion from other people's faces depends on how they perceive the facial expression of themselves (Schiano Lomoriello et al., 2024). MBS patients often experience facial paralysis and therefore they might experience more difficulties in recognizing emotion from other people's facial expressions. The study results revealed that they did perceive lower emotional intensity for some primary emotions, like sadness, fear, and anger. This finding again highlights the relationship between body and visual perception for emotion. The finding also supports that dysfunction of certain body parts could affect how people perceive and interpret the emotion from that certain body part. When it comes to people with amputation and touch, it's still unknown whether they will experience the same situation as MBS patients. Touch is a body gesture that requires the use of arms and limbs. People with amputation lost their own hands and arms, though some of them might keep using prostheses. Sailer and Ackerley (2019) have shown that people with lower levels of exposure to affective touch tend to find the affective touch less pleasant. In addition, the curve for the pleasantness of the lower exposure group also showed that people with lower exposure to affective touch are less sensitive to the pleasantness of the touch. However, this result is based on people without amputation. There's still a difference between low exposure to touch and not being capable of doing affective touch by the original hand or arm, in which the amputation causes brain reorganization.

Motor Imagery for People with Amputation

Current findings showed that people with phantom limbs will experience impaired motor imagery in the post-amputation period, which could impact their ability to appreciate paintings. Lyu et al.(2016) reported that unilateral upper-limb amputees, who also experience phantom limb pain, have impaired motor imagery based on the revised Movement Imagery Questionnaire (MIQ-R) score. MIQ-R is a questionnaire that is used to measure the difficulty level of imagining body movements of different body parts (Lyu et al., 2016). Similar to the results above among people with arm or shoulder pain, these amputees with phantom limb pain also showed difficulty in the mental rotation task. However, they did not observe impaired motor imagery in people with amputation but without phantom limb pain. Back in 2012, Raffin et al. demonstrated that people with phantom pain do have the capability to distinguish between executing the movement of phantom limbs and imagining the movement of the amputated limb. They assessed the motor imagery of the amputated limb through the Movement Imagery Questionnaire Revised Second version (MIQ-RS) score, similar to the one Lyu et al. (2016) used. However, this version assesses both visual imagery and kinaesthetic imagery (Raffin et al., 2012). In one of the tasks, they asked participants to do the visuomotor incongruency test, in which they need to imagine the hand touching from the thigh to the mouth. Another task is the finger-to-thumb opposition task. The people with amputation showed comparable performance to normal subjects in the visuomotor incongruency test, which only involved touch. However, in the finger-to-thumb task, individuals with amputation exhibited a significantly longer duration for executing the phantom limb movement or mentally imagining the movement of the amputated arm compared to their healthy arms and the control group.

These two studies further showed that there are different categories of motor imagery. In the case of complex motor imagery, which requires more precise movement control than touch, people with amputation will encounter more difficulties imagining such movement compared to normal subjects. When it comes to touch, a more basic and less complicated action, people with amputation do have the ability to imagine that. In addition, it's important to specify the target of motor imagery. Study results from Raffin et al. (2012) prove that people with phantom limb have no problem imagining the movement of the healthy arms. Lyu et al.(2016) also found that amputees without phantom limb do not have the issue with impaired motor imagery. In conclusion, whether experiencing phantom limb and the complexity of the movement are critical factors that determine whether people with amputation will encounter difficulties with motor imagery.

Emotional Valence, Arousal and Aesthetic Appreciation

Numerous studies have shown that emotions and aesthetic judgement or appreciation are closely associated. Emotions can directly affect people's aesthetic judgement on artworks. Belfi (2019) investigated whether emotional valence, emotional arousal, and vividness of imagery could affect aesthetic appeal in three different genres of music. Emotional valence means the level of pleasantness of emotional stimuli, while emotional arousal means the intensity of emotions felt from the emotional stimuli (Jain et al., 2023; Kauschke et al., 2019). She found that both emotional valence and vividness of evoked imagery have a significant positive relationship with aesthetic appeal in music. Another study on participants in concerts also showed that emotional and psychological responses to music are significantly related to the aesthetic judgement in music (Egermann & Reuben, 2020). On the other hand, aesthetic judgement and appreciation can also influence people's emotions. Jain et al. (2023) demonstrated that participants who experienced aesthetic chills induced by artworks report significantly more positive emotional valence and greater emotional arousal. Through music and gambling tasks, Barbieri et al. (2023) showed that music induced aesthetic appreciation can switch people's anxiety states to curiosity states. This further proves that aesthetic appreciation and judgement have their unique impact on people's emotions.

While most studies in this field focus on music, there are still some studies that focus on visual art. In a study of aesthetic evaluation through observing everyday photographs, Washizu et al.(2026) found that there is a significant positive relationship between aesthetic evaluation and emotional valence reported. The more positive the emotional valence categories, like relief and joy, the better the aesthetic evaluation. Furthermore, the study also revealed that aesthetic evaluation is related to centered bodily sensations. This finding connects aesthetic evaluation potentially with proprioception and interoception through the bridge of emotions. This proves the significance of the current study focused on the aesthetic appreciation of people with amputation. Although researchers have investigated emotions and aesthetics through music and photographs, few studies have investigated the aesthetic appreciation of classical paintings, a unique style of artwork that exists between reality and imagination.

RESEARCH QUESTION AND HYPOTHESIS

The aim of the current study is to investigate how people with amputation interpret the emotions from social touch, which is an important component in their social lives. The main research question in this study is whether there is a significant difference in how people with amputation interpret the emotional arousal, emotional valence, and aesthetic appreciation from touch paintings compared to non-touch paintings. We expect touch paintings are perceived having more positive emotional valence, more intense emotional arousal and higher aesthetic appreciation rating (*H1*). At next, we will examine whether the emotional valence, emotional arousal and aesthetic appreciation vary across different social affective contexts in touch paintings. We hypothesized that, in touch paintings, emotional valence, emotional arousal and aesthetic appreciation varies across maternal, friendly, and romantic touches (*H2*). Finally, the study will explore the association between emotional valence, emotional arousal and aesthetic appreciation in touch and non-touch paintings. The main hypothesis here is there are positive association between emotional valence, emotional arousal and aesthetic appreciation in touch and non-touch paintings (*H3*).

METHODS

Participants

The study was approved by the Italian Health Ministry on November 19th, 2024. The data was collected at Inail Prosthetic Center, a prosthetic clinic, in Bologna, Italy. In the current thesis project, the data sample has 34 participants with unilateral transradial amputation. Unilateral transradial amputation means experiencing the loss of the arm under the elbow of one side of the limb. All the surveys and experiments are conducted in Italian, and all the participants speak Italian. After exclusion of participants with missing data points, the final data sample has 22 participants with unilateral transradial amputation. In the final data sample, there are 21 males and 1 female. The mean age is 47.41 +/- 11.41 (Median=49; Min=24; Max=64). 5 of 22 participants have some degree of visual impairment, but the visual impairment does not influence the data collection and it will not impact study results based on primary data analysis. Depression data was collected on 5 of the participants. Depression was measured by Beck's Depression Inventory (BDI). BDI is one of the most used psychiatric assessment scales that is used to assess depression (García-Batista et al., 2018). However, all five responses fell within the no to minimal depression range based on BDI clinical criteria. Given the limited number of observations and the absence of moderate to severe depressive symptoms, depression was not included as a covariate in the subsequent data analyses.

Data Analysis

Current study uses R 4.5.3 version for all the data and statistical analysis. For the convenience of statistical analysis, all the ratings from emotional valence, emotional arousal, and aesthetic appreciation are averaged based on the ratings from 30 stimuli. Participants with missing data from the experiments are excluded from the data and statistical analysis. To compare the ratings from touch stimuli and non-touch stimuli, a two-sided paired t-test is applied to determine whether the difference in ratings between the two types of stimuli is significant. For all significant results in the t-tests, Cohen's d was calculated to estimate the effect size. A box plot is applied to visualize the t-test results in emotional valence, emotional arousal, and aesthetic appreciation.

Next, a Friedman test is applied to examine whether there are significant differences in the ratings of emotional valence, emotional arousal, and aesthetic appreciation across all three different social affective contexts in touch paintings. To determine the statistical association between the emotional valence, emotional arousal, and aesthetic appreciation, a generalized linear model (GLM) is applied to analyze the association between the three in touch and non-touch stimuli. The significance level in the statistical analysis is 0.05. MASS package and glmtoolbox package in R for the GLM analysis. To test *H3*, we constructed three GLM models. The model formulas are:

Model 1:

$$Y_{Touch\_Valence} = \beta_0 + \beta_1(Arousal_{Touch}) + \beta_2(Aesthetic_{Touch}) + \beta_{controls} + \epsilon$$

Model 2:

$$\begin{aligned} Y_{Touch\_Valence} = {} & \beta_0 + \beta_1(Arousal_{Touch}) + \beta_2(Aesthetic_{Touch}) + \beta_3(Arousal_{Non-Touch}) \\ & + \beta_4(Valence_{Non-Touch}) + \beta_5(Aesthetic_{Non-Touch}) + \beta_{controls} + \epsilon \end{aligned}$$

Model 3:

$$Y_{NonTouch\_Valence} = \beta_0 + \beta_1(Arousal_{Non-Touch}) + \beta_2(Aesthetic_{Non-Touch}) + \beta_{controls} + \epsilon$$

Furthermore, to evaluate whether the association between emotional valence, emotional arousal and aesthetic appreciation varies based on different context (Maternal, Friendly, Romantic).

Model 4:

$$Y_{Touch\_Valence(Context)} = \beta_0 + \beta_1(Arousal_{Context}) + \beta_2(Aesthetic_{Context}) + \beta_{controls} + \epsilon$$

$\beta_{controls}$ includes age, education and visual impairment. Age is a continuous variable. Education is a binary variable based on whether participants complete high school or equivalent education. Due to the current study involving a large component of visual sensation, visual impairment is also controlled in the models. Visual impairment is a binary variable based on whether participants indicate any visual impairments when participating in the experiment. In all GLM models, Log Likelihood and Akaike Information Criterion (AIC) were applied to evaluate the model fit. Higher value of log-likelihood of the model indicate better representation of the observed data. In contrary, lower value of AIC represents better predictive performance. Data visualization, like box-plot, is applied to visualize the data analysis results. R packages that used for data visualization in the study are ggplot2, ggsci, gtsummary and flextable. All the R codes used for data analysis are attached in Appendix A.

Task and Stimuli

During the experiment, each participant was presented with 30 paintings as an experiment stimulus on the computer screen. These stimuli included both paintings with touch and without touch. 15 of the 30 stimuli were paintings that involve social touch, and there were three different types of social touch, including romantic touch, maternal touch, and friendly touch. Each type of social touch had 5 paintings. The other 15 of the 30 stimuli were also paintings depicting social relationships while not involving any social touch. Sample stimuli were shown in Figure 1. To avoid confounding factors from the artist and painting style, all the paintings were representational paintings in the European academic realist style from the 18th to

19th century. Each painting depicts two naturalistic human figures in a social scenario with realistic anatomy and perspective. Paintings with physical touch involve touch on the upper body of the human figure, while paintings without physical touch only involve non-touch social interaction, like looking or talking to each other. All 30 stimuli were presented in a randomized order during the experiment.

Procedure

The whole experiment is self-paced and does not have a fixed time limit, but participants were instructed to respond to each stimulus spontaneously. Each participant is required to observe each stimulus with a specific focus on the touch if it is presented in the stimulus. After the observation, each participant is required to rate the painting from three different dimensions . The first dimension is emotional valence. Participants are asked to rate emotional valence from 0 to 100, with 0 representing the most negative valence and 100 representing the most positive valence. The second dimension is emotional intensity felt from the painting, with 0 representing the least intense emotions and 100 representing the most intense emotions. The last dimension is aesthetic appreciation. Participants are asked to rate their aesthetic preference for the painting, with 0 representing the least preferred and 100 representing the most preferred. To avoid misconceptions in the rating, each participant is instructed about the difference between emotional valence, emotional intensity, and aesthetic appreciation before the beginning of the experiment.

RESULTS

Firstly, for each participant, the mean values of emotional valence, emotional intensity, and aesthetic appreciation of both touch stimulus and non-touch stimulus are calculated and compared. Through paired-t tests, in line with *H1*, the results showed there are significant differences between touch and non-touch stimulus across all three dimensions (Figure 1 – 3). The comparison between emotional valence in touch stimulus and non-touch stimulus reveals a significant mean difference between the two conditions ($t = 5.591$, $df = 21$, $p < 0.001$) (Table 1). The mean difference is 9.330, and the 95% confidence interval is 5.860 to 12.801. In emotional intensity, there's also a significant difference between the touch and non-touch conditions ($t = 5.559$, $df = 21$, $p < 0.001$). The mean difference is 9.603, and the 95% confidence interval is from 6.011 to 13.195. There's a similar result in aesthetic appreciation ($t = 4.555$, $df = 21$, $p < 0.001$). The mean difference of aesthetic appreciation between the two conditions is 5.903. The 95% confidence interval is from 3.208 to 8.598. The results proved that people with amputation tend to rate touch paintings significantly higher across all three dimensions compared to non-touch paintings. This shows that physical touch is a crucial factor that determines the emotional and aesthetic interpretation for people with amputation.

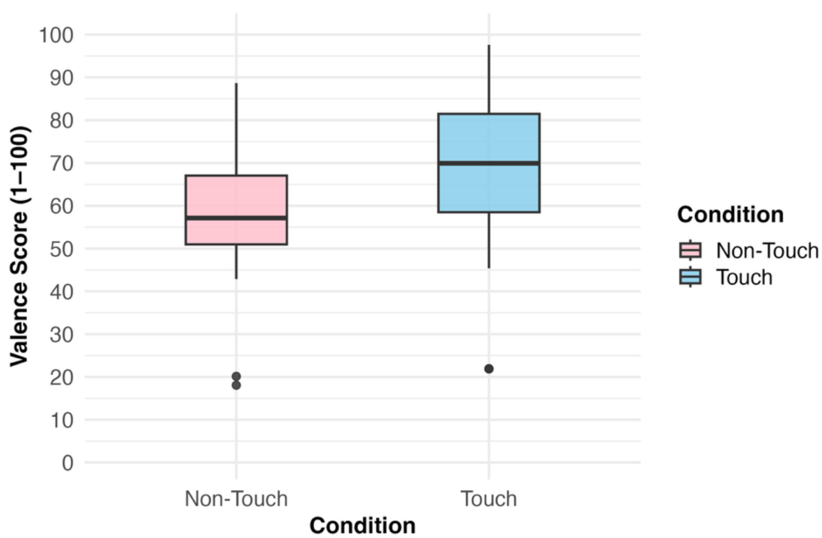

Figure 1. Boxplots comparing valence scores (y-axis, range 1–100) between touch and non-touch conditions (x-axis). Higher scores indicate more positive valence. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

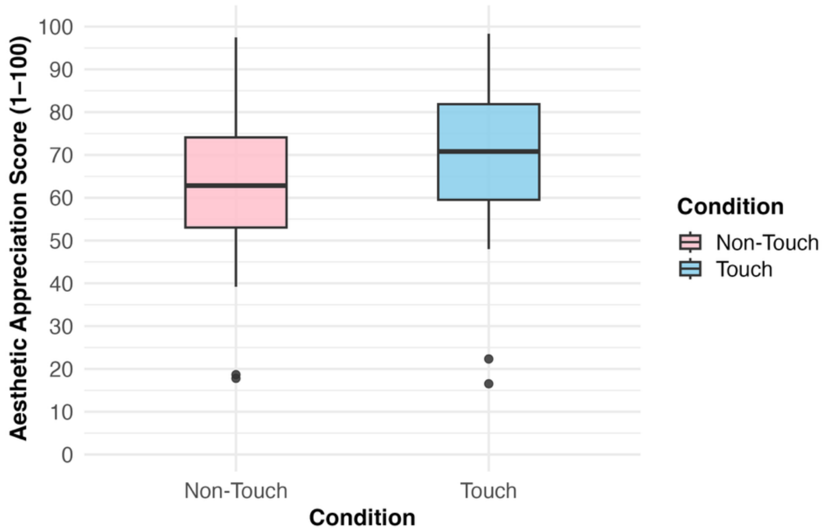

Figure 2. Boxplots comparing aesthetic appreciation (AA) scores (y-axis, range 1–100) between touch and non-touch conditions (x-axis). Higher scores indicate greater aesthetic appreciation. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

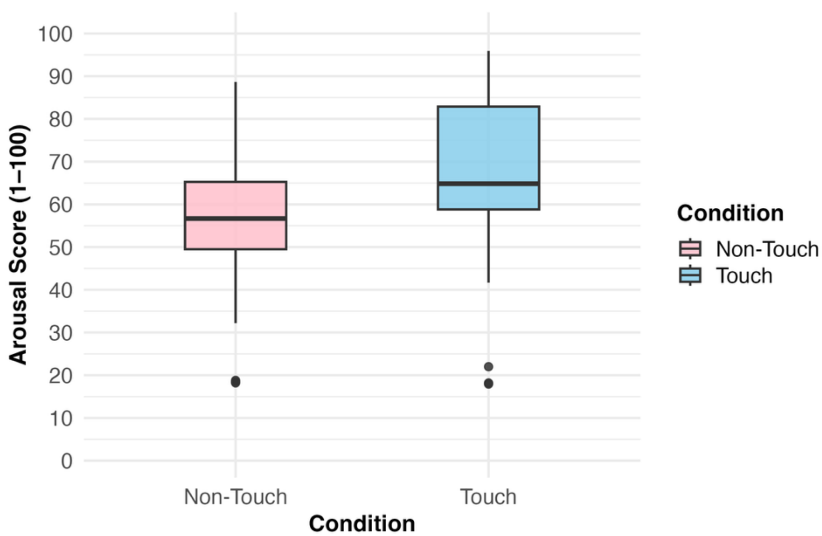

Figure 3. Boxplots comparing arousal scores (y-axis, range 1–100) between touch and non-touch conditions (x-axis). Higher scores indicate greater arousal. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

At next, the data for each social relationship in the touch stimulus are analyzed. Through Friedman test, the emotional valence, emotional intensity and aesthetic appreciation ratings are compared across romantic, maternal and friendly stimulus. Friedman test results showed that there are significant differences of emotional valence ratings between romantic stimulus, maternal stimulus and friendly stimulus (Friedman Chi-Squared = 14.049, df = 2, $p < 0.001$) (Table 2 ; Figure 6). This result supports *H2*.The difference between the ratings of social relationship remains significant in emotional arousal ratings and aesthetic appreciation ratings (Friedman Chi-Squared = 11.012, df = 2, $p < 0.05$; Friedman Chi-Squared = 14.049, df = 2, $p < 0.05$) (Figure 4 – 5). These results reveal that participants' interpretation of emotional valence, emotional intensity and aesthetic appreciation in touch paintings varied across different social relationship depicted. In other words, social relationship associated with the touch could determine people with amputation's interpretation on emotions and aesthetics.

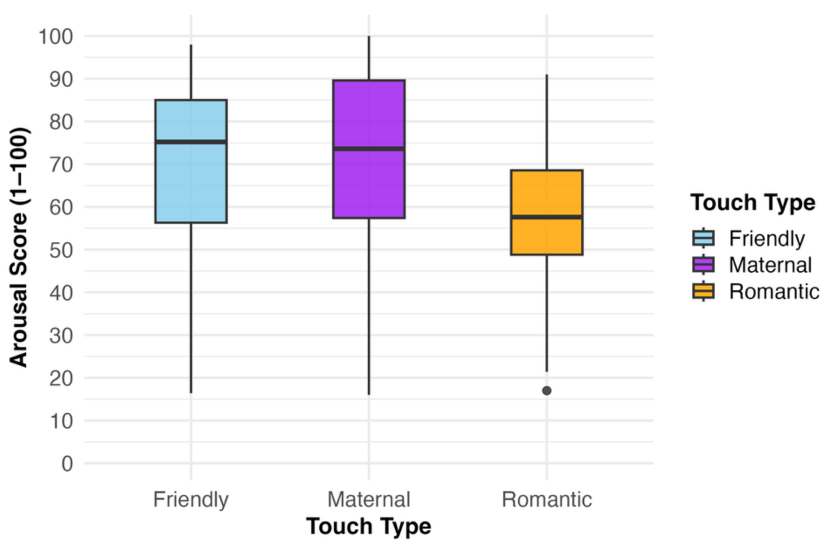

Figure 4. Boxplots comparing arousal scores (y-axis, range 1–100) across three touch types (x-axis): romantic, friendly, and maternal. Higher scores indicate greater arousal. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

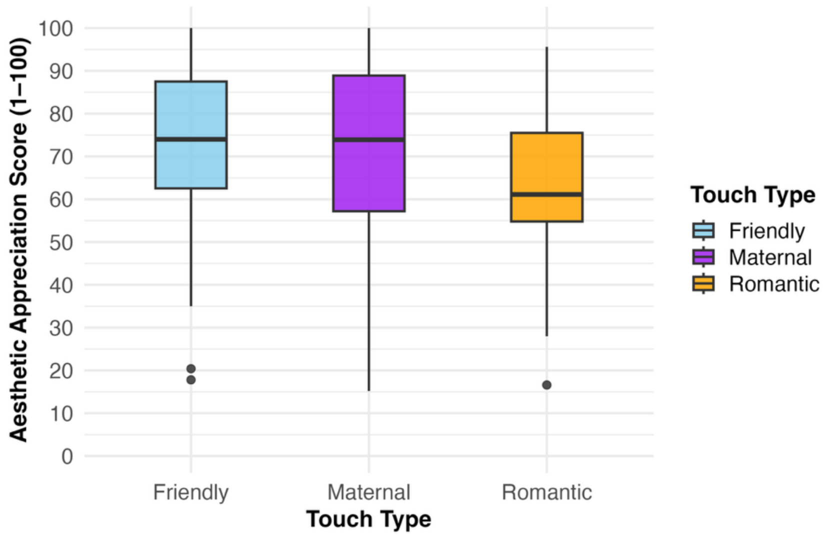

Figure 5. Boxplots comparing aesthetic appreciation (AA) scores (y-axis, range 1–100) across three touch types (x-axis): romantic, friendly, and maternal. Higher scores indicate greater aesthetic appreciation. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

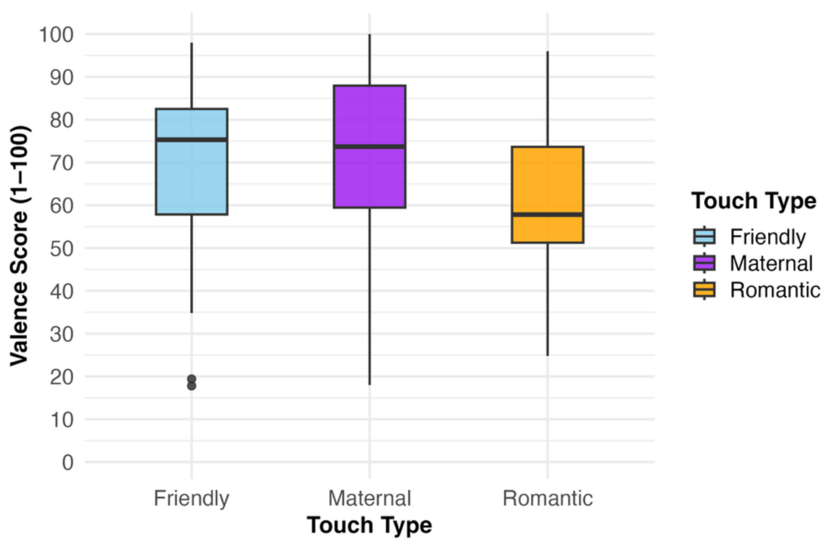

Figure 6. Boxplots comparing valence scores (y-axis, range 1–100) across three touch types (x-axis): romantic, friendly, and maternal. Higher scores indicate more positive valence. Box spans the interquartile range (IQR); horizontal line = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers.

Table 1

Paired t-test Results: Touch vs. Non-Touch					
Comparison	t	df	p-value	Mean Difference	95% CI
Valence (Touch vs. NonTouch)	5.591	21	1.51×10^{-5}	9.330	[5.860, 12.801]
Arousal (Touch vs. NonTouch)	5.559	21	1.62×10^{-5}	9.603	[6.011, 13.195]
Aesthetic Appreciation(Touch vs. NonTouch)	4.555	21	0.0002	5.903	[3.208, 8.598]

Note: All tests are two-tailed paired t-tests.

Table 2

Friedman Rank Sum Test Results				
Outcome	Groups Compared	χ^2	df	p-value
Valence	Romantic, Maternal, Friendly	14.049	2	<0.001
Arousal	Romantic, Maternal, Friendly	11.012	2	0.004
Aesthetic Appreciation	Romantic, Maternal, Friendly	6.537	2	0.038

Note: All tests are two-tailed. N = 22 per test.

Furthermore, to further examine the relationship between emotional valence, emotional intensity, and aesthetic appreciation, a generalized linear model (GLM) is applied to perform the regression analysis. As predicted in *H3*, the GLM regression analysis results showed that in touch paintings, emotional arousal and aesthetic appreciation ratings have a significant positive association with emotional valence ratings ($p < 0.001$) (Table 3). This revealed that emotions and aesthetics are closely related and can affect each other. The more positive emotional valence and the more intense emotion arousal, the better the aesthetic ratings . More interestingly, the emotional valence in touch paintings is not only significantly associated with emotional arousal and aesthetic appreciation in touch paintings, but also in non-touch paintings ($p < 0.05$) (Table 5). This proved that the significant association between the three might not be caused by the presence of touch in paintings, but from similar emotional schemas and cognitive appraisal frameworks. In addition, the regression results also showed that the significant association between emotional valence, emotional arousal, and aesthetic appreciation is not specific to certain social relationships (Table 4). The results remain significant across all three social relationships.

Table 3

Emotional Valence in Touch Paintings

	Model (1)			**Model (2)**		
Predictor	Estimate	Std. Error	p Value	Estimate	Std. Error	p Value
Emotional Arousal (Touch)	0.632***	(0.047)	<0.001	0.779***	(0.124)	<0.001
Aesthetic Appreciation (Touch)	0.336***	(0.052)	<0.001	0.091	(0.197)	0.653
Emotional Arousal (Non-Touch)	—	—	—	-0.531**	(0.226)	0.035
Emotional Valence (Non-Touch)	—	—	—	0.587**	(0.241)	0.030
Aesthetic Appreciation (Non-Touch)	—	—	—	0.080	(0.200)	0.697
Age	0.540	(1.884)	0.778	0.287	(1.813)	0.877
Education	-0.514	(3.652)	0.890	2.494	(3.933)	0.537
Visual Impairment	-0.598	(2.023)	0.771	-0.833	(1.922)	0.672
Constant	3.159	(2.635)	0.248	0.778	(2.695)	0.777

Observations: 22 | Log Likelihood: -55.492 (1), -50.457 (2) | AIC: 122.984 (1), 118.914 (2)

*Note: Standard errors in parentheses. — indicates predictor not included in model. AA = Aesthetic Appreciation. **p<0.05; ***p<0.01*

Table 4

Emotional Valence by Social Affective Contexts

	Romantic			Friendly			Maternal		
Predictor	**Estimate**	**Std. Error**	**p Value**	**Estimate**	**Std. Error**	**p Value**	**Estimate**	**Std. Error**	**p Value**
Arousal	0.646***	(0.116)	<0.001	0.629***	(0.036)	<0.001	0.604***	(0.084)	<0.001
Aesthetic Appreciation	0.322	(0.113)	0.012	0.368***	(0.044)	<0.001	0.268	(0.093)	0.011
Age	-0.702	(4.223)	0.870	0.588	(1.642)	0.725	3.073	(3.553)	0.400
Education	-0.972	(8.677)	0.912	1.257	(3.018)	0.682	-0.839	(6.926)	0.905
Visual Impairment	0.708	(4.812)	0.885	-2.051	(1.652)	0.232	0.310	(3.852)	0.937
Constant	3.509	(6.461)	0.595	0.376	(2.062)	0.858	9.376.	(4.607)	0.059

Observations: 22 per model | AIC: 160.83 (Romantic), 114.68 (Friendly), 151.31 (Maternal)

*Note: Standard errors in parentheses. AA = Aesthetic Appreciation. **p<0.05; ***p<0.01*

Table 5

Emotional Valence in Non-Touch Paintings

Predictor	Estimate	Std. Error	p Value
Emotional Arousal (Non-Touch)	0.634***	(0.051)	<0.001
Aesthetic Appreciation (Non-Touch)	0.276***	(0.047)	<0.001
Age	1.652	(1.712)	0.349
Education	-2.132	(3.411)	0.541
Visual Impairment	-0.612	(1.933)	0.756
Constant	4.914.	(2.460)	0.063

Null deviance: 5952.72 on 21 df | Residual deviance: 160.78 on 16 df | AIC: 120.19

*Note: Standard errors in parentheses. AA = Aesthetic Appreciation. **p<0.05; ***p<0.01*

DISCUSSION

Current study investigates how people with transradial amputation interpret and perceive the emotions from the social touch in classical paintings. The study focuses on three emotional and aesthetic factors—emotional valence, emotional arousal, and aesthetic appreciation. A behavioral experiment was conducted to ask participants to rate the emotional valence, emotional arousal, and aesthetic appreciation from 15 touch paintings and 15 non-touch paintings. The main hypothesis is that people with amputation interpret or perceive the touch paintings more emotionally pleasant, more emotionally intense, and have more aesthetic pleasure. Paired t-tests, Friedman tests, and GLM were applied for the data analysis in this study.

Firstly, the results showed that paintings with social touch, regardless of the specific affective context, are perceived to have significantly more positive emotional valence, which means more pleasant, higher emotional arousal, and higher rating of aesthetic appreciation. This is a significant finding that helps people to better understand the social world among people with amputation. This supports that people with amputation can appropriately interpret the emotions from social touch in all three affective contexts in the study, including maternal, romantic, and friendly. More importantly, the results support that touch is crucial for the aesthetic appreciation for people with amputation. They found touch paintings have more aesthetic pleasure rather than non-touch paintings. The result reveals how people with amputation process the aesthetic information, and touch and emotions could determine their pleasure from the aesthetic experiences.

Secondly, the study finds that people with amputation's perception or interpretation of emotional valence in touch paintings varies across different affective contexts. Different social relationships presented in the painting could impact how people interpret the emotional valence from the touch. Data analysis results showed that people with amputation tend to perceive paintings with maternal touch most emotionally pleasant, most emotionally intense, and have the most aesthetic pleasure. In comparison, romantic touch is considered the least emotionally pleasant, the least emotionally intense, and having the least aesthetic pleasure. This reveals that people with amputation have better capability in interpreting emotions from touch in the maternal contexts, while they have relatively worse capability in interpreting emotions from touch in the romantic contexts. This could bring further implications about how people with amputation adapt in different social affective relationships in the post-amputation period. Different from maternal relationships, romantic relationships require more effort and time to build the relationship. Romantic relationships are crucial for a person's life development, and they help many people to build a happy family or find a long-lasting partner. All these could effectively bring more joy for people with amputation. Therefore, further support in helping people with amputation adapt in the romantic social contexts might be needed.

Finally, the study also finds that there's a significantly positive association between emotional valence, emotional arousal, and aesthetic appreciation in both touch and non-touch paintings. The more people with amputation feel emotionally pleasant and intense, the more aesthetic pleasure they feel. This reveals a close connection between emotions and aesthetic appreciation. It further proves that emotions can be an important part of aesthetic information processing for people with amputation. Aesthetic beauty exists everywhere in daily life. It brings unique pleasantness for people and helps people to regulate their emotions (Bellaiche et al., 2025). People always gain joy from these aesthetic pleasures. It can be a person, a building, a natural landscape, or a pet. The result emphasizes the importance of emotionality for people with amputation. Emotionality does not only affect how people interpret emotions in social affective contexts, but also affects how people gain joy from aesthetic pleasure, one of the most common resources for joy and happiness. The exact causal relationship between emotions and aesthetic pleasure is still poorly understood, which can be a potential research topic for future study. Understanding the causal relationship between emotions and aesthetic pleasure could help develop potential emotional support interventions for people with amputation through observing artwork or art creation.

One limitation of the current study is that it failed to include depression data in the data analysis due to the delay in data collection. The current study only has a BDI depression score from five participants, and none of them showed clinically significant depression symptoms. However, many people with amputation have always suffered from psychiatric comorbidities. There is a large amount of neuroscientific evidence showing that depression could change people's visual perception. From a molecular level, the changes in serotonergic and noradrenergic systems by depression could affect people's ability to process emotion from facial expression (Fitzgerald, 2013). In addition, in an experiment on monkeys, Morrison and Foote (1986) also found that noradrenergic fibers and serotonergic fibers could innervate specific areas in the visual cortex that are responsible for face processing. Back in 2010, Bubel et al. already reported that patients with major depressive disorders (MDD) have much lower contrast gain compared to normal controls. Therefore, future studies should investigate how psychiatric conditions, like depression, could affect the perceived emotions and aesthetics among people with amputation.

Furthermore, depression might be a crucial factor that could distort the perception of social touch. Tinker et al. (2023) found that people with more severe depression tend to have lower pleasantness of observed social touch. In addition, they did not find any significant association between longing for social touch and the severity of depression. In a study conducted on a normal population during the Covid-19 period, in which people tend to have fewer chances to have social touches, Meijer et al.(2022) reported that the longing for touch is increased by the increase in duration and severity of the quarantine regulations. The change in longingness will then affect the perceived pleasantness of social touch. This proves that while touch exposure could shape the longingness for social touch in a normal population, people with depression are incapable of adjusting their longingness in response to the change in touch exposure. This could be interpreted as an insensitivity of longingness for social touch. Kaletscher et al.(2014) conducted a similar study regarding emotional body movements. They investigated how people with depression perceive the emotion from body movements compared to healthy controls. The results indicated that people with depression tend to hold a more distorted perception of emotion from observing body movements. They perceive the emotion from the same body movements more negatively and more intensely. However, there are few studies that specifically focus on psychiatric conditions or disorders and the interpretation or perception of emotions from touch, especially for people with amputation. This is a topic worth exploring for future research.

In addition, the current study does not involve any healthy controls in the experiment. A comparison of perceptions or interpretations between people with amputation and healthy controls could allow us to see how people with amputation perceive or interpret touch differently than healthy controls. Therefore, future research should include healthy participants as a control group for comparison. Moreover, the current study only used quantitative methods. A mixed method approach that also includes qualitative data might reveal more information about how people with amputation feel, perceive, and interpret the emotions from social touch.

Another limitation of the current study is that it only investigates static social affective contexts, while social affective contexts in real life tend to involve more dynamics and maybe more people involved. Interpreting emotions appropriately from static social affective contexts does not mean people with amputation could also interpret emotions appropriately from dynamic social affective contexts, which involves higher complexity. Therefore, future research should investigate how people with amputation adapt to dynamic social affective contexts. In addition, the current study only used classical paintings, and it cannot be generalized to modern artworks and other art styles. Different art styles could bring distinct emotional valence and emotional arousal for different people. Everyone has their own preferences and different levels of familiarity for different art styles. However, the current study does not have information about participants' preferences and familiarity of any art styles. Familiarity could impact people's perception, and being more familiar with classical paintings could potentially help people to interpret the emotions from the paintings (Garcia-Marques & Mackie, 2006). Future research should control the familiarity and preferences of art styles.

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Appendix A

```
library(gtsummary)
library(tidyverse)
library(tableone)
library(GGally)
library(knitr)
library(MASS)
library(haven)
library(broom)
library(Metrics)
library(broom)
library(caret)
library(glmtoolbox)
library(pROC)
library(gt)
library(foreign)
theme_set(theme_minimal())
```

```
library("readxl")
thesis<-read_excel("~/Desktop/Thesis/Data/ImpliedTouch_dataset_MSc.xlsx")
```

```
cleandata<-na.omit(thesis)
cleandata$Touch_Valence <- rowMeans(sapply(cleandata
[, paste0(1:15, "_mainBlock_1")], as.numeric), na.rm = TRUE)
cleandata$NonTouch_Valence <- rowMeans(sapply(cleandata
[, paste0(16:30, "_mainBlock_1")], as.numeric), na.rm = TRUE)
cleandata$Touch_Arousal <- rowMeans(sapply(cleandata
[, paste0(1:15, "_mainBlock_2")], as.numeric), na.rm = TRUE)
cleandata$NonTouch_Arousal <- rowMeans(sapply(cleandata
[, paste0(16:30, "_mainBlock_2")], as.numeric), na.rm = TRUE)
cleandata$Touch_AA <- rowMeans(sapply(cleandata
[, paste0(1:15, "_mainBlock_3")], as.numeric), na.rm = TRUE)
cleandata$NonTouch_AA <- rowMeans(sapply(cleandata
[, paste0(16:30, "_mainBlock_3")], as.numeric), na.rm = TRUE)
cleandata$Romantic_Valence <- rowMeans(sapply(cleandata
[, paste0(c(2,11,12,14,15), "_mainBlock_1")], as.numeric), na.rm = TRUE)
cleandata$Romantic_Arousal <- rowMeans(sapply(cleandata
[, paste0(c(2,11,12,14,15), "_mainBlock_2")], as.numeric), na.rm = TRUE)
cleandata$Romantic_AA <- rowMeans(sapply(cleandata
[, paste0(c(2,11,12,14,15), "_mainBlock_3")], as.numeric), na.rm = TRUE)
cleandata$Friendly_Valence <- rowMeans(sapply(cleandata
[, paste0(c(1,4,5,8,10), "_mainBlock_1")], as.numeric), na.rm = TRUE)
cleandata$Friendly_Arousal <- rowMeans(sapply(cleandata
[, paste0(c(1,4,5,8,10), "_mainBlock_2")], as.numeric), na.rm = TRUE)
cleandata$Friendly_AA <- rowMeans(sapply(cleandata
[, paste0(c(1,4,5,8,10), "_mainBlock_3")], as.numeric), na.rm = TRUE)
```

```
cleandata$Maternal_Valence <- rowMeans(sapply(cleandata
[, paste0(c(3,6,7,9,13), "_mainBlock_1")], as.numeric), na.rm = TRUE)
cleandata$Maternal_Arousal <- rowMeans(sapply(cleandata
[, paste0(c(3,6,7,9,13), "_mainBlock_2")], as.numeric), na.rm = TRUE)
cleandata$Maternal_AA <- rowMeans(sapply(cleandata
[, paste0(c(3,6,7,9,13), "_mainBlock_3")], as.numeric), na.rm = TRUE)
```

```
valence <- sapply(cleandata[, paste0(c(2,11,12,14,15), "_mainBlock_1")], as.numeric)
arousal <- sapply(cleandata[, paste0(c(2,11,12,14,15), "_mainBlock_2")], as.numeric)
valence2 <- sapply(cleandata[, paste0(c(1,4,5,8,10), "_mainBlock_1")], as.numeric)
arousal2 <- sapply(cleandata[, paste0(c(1,4,5,8,10), "_mainBlock_2")], as.numeric)
valence3 <- sapply(cleandata[, paste0(c(3,6,7,9,13), "_mainBlock_1")], as.numeric)
arousal3 <- sapply(cleandata[, paste0(c(3,6,7,9,13), "_mainBlock_2")], as.numeric)
valence4 <- sapply(cleandata[, paste0(16:30, "_mainBlock_1")], as.numeric)
arousal4 <- sapply(cleandata[, paste0(16:30, "_mainBlock_2")], as.numeric)

pattern1 <- valence>arousal
pattern2 <- valence2>arousal2
pattern3 <- valence3>arousal3
pattern4 <- valence4>arousal4
cleandata$pattern_consistency <- rowMeans(pattern1, na.rm = TRUE)
cleandata$pattern_consistency2 <- rowMeans(pattern2, na.rm = TRUE)
cleandata$pattern_consistency3 <- rowMeans(pattern3, na.rm = TRUE)
cleandata$pattern_consistency4 <- rowMeans(pattern4, na.rm = TRUE)
```

FormaL Analysis

```
cleandata <- cleandata[-1, ]
t.test(cleandata$Touch_Valence, cleandata$NonTouch_Valence, paired = TRUE)
t.test(cleandata$Touch_Arousal, cleandata$NonTouch_Arousal, paired = TRUE)
t.test(cleandata$Touch_AA, cleandata$NonTouch_AA, paired = TRUE)
```

```
friedman.test(as.matrix(cleandata
                        [, c("Romantic_Valence", "Maternal_Valence",
                             "Friendly_Valence")]))
friedman.test(as.matrix(cleandata
                        [, c("Romantic_Arousal", "Maternal_Arousal",
                             "Friendly_Arousal")]))
friedman.test(as.matrix(cleandata
                        [, c("Romantic_AA", "Maternal_AA",
                             "Friendly_AA")]))
```

```
cleandata$education_1 <-
  ifelse(cleandata$Education %in%
           c("Laurea Magistrale", "Maturità liceale"),1, 0)
cleandata$gender_1 <- ifelse(cleandata$Gender %in% c("Donna"), 1, 0)
cleandata$vision <- ifelse(cleandata$`visual imp` %in% c("S√¨"), 1, 0)
cleandata$age_1 <- ifelse(cleandata$Age>=45, 1, 0)
```

```
model1 <- glm(Friendly_AA ~ age_1 + education_1 + vision, data = cleandata)
summary(model1)
```

```r
model2 <- glm(Touch_Valence ~ Touch_Arousal + Touch_AA + age_1 + education_1
              + vision, data = cleandata)
summary(model2)
model3 <- glm(Touch_Valence ~ Touch_Arousal + Touch_AA + NonTouch_Arousal
              + NonTouch_Valence + NonTouch_AA + age_1 + education_1 + vision,
              data = cleandata)
summary(model3)
```

```r
library(flextable)
library(officer)
```

```r
df <- data.frame(
  Predictor = c(
    "Emotional Arousal (Touch)",
    "Aesthetic Appreciation (Touch)",
    "Emotional Arousal (Non-Touch)",
    "Emotional Valence (Non-Touch)",
    "Aesthetic Appreciation (Non-Touch)",
    "Age",
    "Education",
    "Visual Impairment",
    "Constant"
  ),
  Est1  = c("0.632***", "0.336***", "-", "-", "-", "0.540",
            "-0.514", "-0.598", "3.159"),
  SE1   = c("(0.047)", "(0.052)", "-", "-", "-", "(1.884)",
            "(3.652)", "(2.023)", "(2.635)"),
  P1    = c("<0.001", "<0.001", "-", "-", "-", "0.778", "0.890",
            "0.771", "0.248"),
  Est2  = c("0.779***", "0.091", "-0.531**", "0.587**", "0.080",
            "0.287", "2.494", "-0.833", "0.778"),
  SE2   = c("(0.124)", "(0.197)", "(0.226)", "(0.241)", "(0.200)",
            "(1.813)", "(3.933)", "(1.922)", "(2.695)"),
  P2    = c("<0.001", "0.653", "0.035", "0.030", "0.697", "0.877",
            "0.537", "0.672", "0.777")
)

ft <- flextable(df) %>%
  set_header_labels(
    Predictor = "Predictor",
    Est1 = "Estimate", SE1 = "Std. Error", P1 = "p Value",
    Est2 = "Estimate", SE2 = "Std. Error", P2 = "p Value"
  ) %>%
  add_header_row(
    values = c("", "Model (1)", "", "", "Model (2)", "", ""),
    colwidths = c(1, 1, 1, 1, 1, 1, 1)
  ) %>%
  add_header_row(
    values = c("", "Model (1)", "Model (2)"),
    colwidths = c(1, 3, 3)
  ) %>%
  delete_rows(i = 2, part = "header") %>%
  theme_booktabs() %>%
```

```r
  bold(i = 1, part = "header") %>%
  bold(j = 1, part = "body") %>%
  align(align = "center", part = "header") %>%
  align(j = 2:7, align = "center", part = "body") %>%
  align(j = 1, align = "left", part = "body") %>%
  width(j = 1, width = 2.5) %>%
  width(j = 2:7, width = 0.9) %>%
  add_footer_lines("Observations: 22  |  Log Likelihood: -55.492 (1),
                   -50.457 (2)  |  AIC: 122.984 (1), 118.914 (2)") %>%
  add_footer_lines("Note: Standard errors in parentheses.
                   - indicates predictor not included in model.
                   AA = Aesthetic Appreciation. *p<0.1; **p<0.05; ***p<0.01") %>%
  italic(i = 2, part = "footer") %>%
  set_caption("Emotional Valence in Touch Paintings")


save_as_docx(ft, path = "model_summary_with_p.docx")
```

```r
model4 <- glm(Romantic_Valence ~ Romantic_Arousal + Romantic_AA + age_1 +
                education_1 + vision, data = cleandata)
summary(model4)
model5 <- glm(Friendly_Valence ~ Friendly_Arousal + Friendly_AA + age_1 +
                education_1 + vision, data = cleandata)
summary(model5)
model6 <- glm(Maternal_Valence ~ Maternal_Arousal + Maternal_AA + age_1 +
                education_1 + vision, data = cleandata)
summary(model6)
```

```r
df <- data.frame(
  Predictor = c(
    "Arousal",
    "Aesthetic Appreciation",
    "Age",
    "Education",
    "Visual Impairment",
    "Constant"
  ),
  Est1  = c("0.646***", "0.322*",  "-0.702", "-0.972", "0.708",  "3.509"),
  SE1   = c("(0.116)",  "(0.113)", "(4.223)", "(8.677)", "(4.812)", "(6.461)"),
  P1    = c("<0.001",   "0.012",   "0.870",   "0.912",   "0.885",   "0.595"),
  Est2  = c("0.629***", "0.368***", "0.588",  "1.257",  "-2.051",  "0.376"),
  SE2   = c("(0.036)",  "(0.044)",  "(1.642)", "(3.018)", "(1.652)", "(2.062)"),
  P2    = c("<0.001",   "<0.001",   "0.725",   "0.682",   "0.232",   "0.858"),
  Est3  = c("0.604***", "0.268*",  "3.073",   "-0.839",  "0.310",   "9.376."),
  SE3   = c("(0.084)",  "(0.093)", "(3.553)", "(6.926)", "(3.852)", "(4.607)"),
  P3    = c("<0.001",   "0.011",   "0.400",   "0.905",   "0.937",   "0.059")
)

ft <- flextable(df) %>%
  set_header_labels(
    Predictor = "Predictor",
    Est1 = "Estimate", SE1 = "Std. Error", P1 = "p Value",
    Est2 = "Estimate", SE2 = "Std. Error", P2 = "p Value",
```

```r
    Est3 = "Estimate", SE3 = "Std. Error", P3 = "p Value"
  ) %>%
  add_header_row(
    values = c("", "Romantic", "Friendly", "Maternal"),
    colwidths = c(1, 3, 3, 3)
  ) %>%
  theme_booktabs() %>%
  bold(i = 1:2, part = "header") %>%
  align(align = "center", part = "header") %>%
  align(j = 2:10, align = "center", part = "body") %>%
  align(j = 1, align = "left", part = "body") %>%
  width(j = 1, width = 2.2) %>%
  width(j = 2:10, width = 0.85) %>%
  add_footer_lines("Observations: 22 per model  |  AIC: 160.83 (Romantic),
                    114.68 (Friendly), 151.31 (Maternal)") %>%
  add_footer_lines("Note: Standard errors in parentheses.
                    AA = Aesthetic Appreciation. *p<0.1; **p<0.05; ***p<0.01") %>%
  italic(i = 2, part = "footer") %>%
  set_caption("Emotional Valence by Social Relationship Type")

save_as_docx(ft, path = "model_summary_relationship.docx")
```

```r
model7 <- glm(Romantic_Valence ~ Romantic_Arousal + Romantic_AA +
                Friendly_Valence + Friendly_Arousal + Friendly_AA +
                Maternal_Valence + Maternal_Arousal + Maternal_AA + age_1 +
                education_1 + vision, data = cleandata)
summary(model7)
```

```r
model12 <- glm(NonTouch_Valence ~ NonTouch_Arousal + NonTouch_AA +
                 age_1 + education_1 + vision, data = cleandata)
summary(model12)
```

```r
cleandata2<-na.omit(thesis)
cleandata2 <- cleandata2[-1 , -c(1:5)]
```

```r
model9 <- glm(Touch_AA ~ Touch_Arousal + Touch_Valence + age_1 +
                education_1 + vision, data = cleandata)
summary(model9)
```

```r
library(ggsci)
```

```r
cleandata_long <- cleandata %>%
  pivot_longer(cols = c(Touch_Valence, NonTouch_Valence),
               names_to = "variable", values_to = "score") %>%
  mutate(variable = recode(variable,
    "Touch_Valence"    = "Touch",
    "NonTouch_Valence" = "Non-Touch"
  ))

p <- ggplot(cleandata_long, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
```

```
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Touch" = "skyblue", "Non-Touch" = "pink"),
    name = "Condition"
  ) +
  labs(
    x = "Condition",
    y = "Valence Score (1-100)",
    caption = "Figure 1. Boxplots comparing valence scores
    (y-axis, range 1-100) between\ntouch and non-touch conditions (x-axis).
    Higher scores indicate more positive\nvalence.
    Box spans the interquartile range (IQR); horizontal line = median;
    \nwhiskers extend to 1.5× IQR; points beyond whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin = margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure1_EV.png", plot = p, width = 8, height = 6, dpi = 300)
```

```
cleandata_long2 <- cleandata %>%
  pivot_longer(cols = c(Touch_AA, NonTouch_AA),
               names_to = "variable", values_to = "score") %>%
  mutate(variable = recode(variable,
    "Touch_AA"    = "Touch",
    "NonTouch_AA" = "Non-Touch"
  ))
p <- ggplot(cleandata_long2, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Touch" = "skyblue", "Non-Touch" = "pink"),
    name = "Condition"
  ) +
  labs(
    x = "Condition",
    y = "Aesthetic Appreciation Score (1-100)",
    caption = "Figure 2. Boxplots comparing aesthetic appreciation (AA) scores
    (y-axis, range 1-100)\nbetween touch and non-touch conditions (x-axis).
    Higher scores indicate greater aesthetic\nappreciation.
    Box spans the interquartile range (IQR); horizontal line = median;
    whiskers\nextend to 1.5× IQR; points beyond whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
```

```r
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin = margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure2_AA.png", plot = p, width = 8, height = 6, dpi = 300)
```

```r
cleandata_long3 <- cleandata %>%
  pivot_longer(cols = c(Touch_Arousal, NonTouch_Arousal),
               names_to = "variable", values_to = "score") %>%
  mutate(variable = recode(variable,
    "Touch_Arousal"    = "Touch",
    "NonTouch_Arousal" = "Non-Touch"
  ))

p <- ggplot(cleandata_long3, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Touch" = "skyblue", "Non-Touch" = "pink"),
    name = "Condition"
  ) +
  labs(
    x = "Condition",
    y = "Arousal Score (1-100)",
    caption = "Figure 3. Boxplots comparing arousal scores (y-axis, range 1-100)
    between\ntouch and non-touch conditions (x-axis). Higher scores indicate
    greater arousal.\nBox spans the interquartile range (IQR);
    horizontal line = median; whiskers\nextend to 1.5× IQR; points beyond
    whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin = margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure3_Arousal.png", plot = p, width = 8, height = 6, dpi = 300)
```

```r
cleandata_long4 <- cleandata %>%
  pivot_longer(cols = c(Romantic_Arousal, Friendly_Arousal, Maternal_Arousal),
               names_to = "variable", values_to = "score") %>%
```

```r
  mutate(variable = recode(variable,
    "Romantic_Arousal" = "Romantic",
    "Friendly_Arousal" = "Friendly",
    "Maternal_Arousal" = "Maternal"
  ))

p <- ggplot(cleandata_long4, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Romantic" = "orange", "Friendly" = "skyblue", "Maternal" = "purple"),
    name = "Touch Type"
  ) +
  labs(
    x = "Touch Type",
    y = "Arousal Score (1-100)",
    caption = "Figure 4. Boxplots comparing arousal scores (y-axis, range 1-100)
    across\nthree touch types (x-axis): romantic, friendly, and maternal.
    Higher scores\nindicate greater arousal. Box spans the interquartile
    range (IQR);\nhorizontal line = median; whiskers extend to 1.5× IQR;
    points beyond whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin = margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure4_TouchArousal.png", plot = p, width = 8, height = 6, dpi = 300)
```

```r
cleandata_long5 <- cleandata %>%
  pivot_longer(cols = c(Romantic_AA, Friendly_AA, Maternal_AA),
               names_to = "variable", values_to = "score") %>%
  mutate(variable = recode(variable,
    "Romantic_AA" = "Romantic",
    "Friendly_AA" = "Friendly",
    "Maternal_AA" = "Maternal"
  ))

p <- ggplot(cleandata_long5, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Romantic" = "orange", "Friendly" = "skyblue", "Maternal" = "purple"),
    name = "Touch Type"
  ) +
  labs(
```

```
    x = "Touch Type",
    y = "Aesthetic Appreciation Score (1-100)",
    caption = "Figure 5. Boxplots comparing aesthetic appreciation (AA) scores
    (y-axis, range 1-100)\nacross three touch types (x-axis): romantic,
    friendly, and maternal. Higher scores\nindicate greater aesthetic
    appreciation. Box spans the interquartile range (IQR);\nhorizontal line
    = median; whiskers extend to 1.5× IQR; points beyond whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin =
                                     margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure5_TouchAA.png", plot = p, width = 8, height = 6, dpi = 300)
```

```
cleandata_long6 <- cleandata %>%
  pivot_longer(cols = c(Romantic_Valence, Friendly_Valence, Maternal_Valence),
               names_to = "variable", values_to = "score") %>%
  mutate(variable = recode(variable,
    "Romantic_Valence" = "Romantic",
    "Friendly_Valence" = "Friendly",
    "Maternal_Valence" = "Maternal"
  ))

p <- ggplot(cleandata_long6, aes(x = variable, y = score, fill = variable)) +
  geom_boxplot(width = 0.4, alpha = 0.85) +
  scale_y_continuous(limits = c(1, 100), breaks = seq(0, 100, 10)) +
  scale_fill_manual(
    values = c("Romantic" = "orange", "Friendly" = "skyblue",
               "Maternal" = "purple"),
    name = "Touch Type"
  ) +
  labs(
    x = "Touch Type",
    y = "Valence Score (1-100)",
    caption = "Figure 6. Boxplots comparing valence scores (y-axis, range 1-100)
    across\nthree touch types (x-axis): romantic, friendly, and maternal.
    Higher scores\nindicate more positive valence. Box spans the interquartile
    range (IQR);\nhorizontal line = median; whiskers extend to 1.5× IQR;
    points beyond whiskers are outliers."
  ) +
  theme_minimal(base_size = 16) +
  theme(
    legend.position       = "right",
    legend.title          = element_text(face = "bold", size = 15),
```

```
    legend.text           = element_text(size = 14),
    axis.title            = element_text(face = "bold", size = 15),
    axis.text             = element_text(size = 14),
    plot.caption          = element_text(size = 12, hjust = 0, margin = margin(t = 10)),
    plot.caption.position = "plot",
    plot.margin           = margin(t = 10, r = 20, b = 20, l = 20)
  )

ggsave("figure6_TouchValence.png", plot = p, width = 8, height = 6, dpi = 300)
```

```
df <- data.frame(
  Predictor = c(
    "Emotional Arousal (Non-Touch)",
    "Aesthetic Appreciation (Non-Touch)",
    "Age",
    "Education",
    "Visual Impairment",
    "Constant"
  ),
  Estimate = c("0.634***", "0.276***", "1.652",  "-2.132", "-0.612", "4.914."),
  SE       = c("(0.051)",  "(0.047)",  "(1.712)", "(3.411)", "(1.933)",
               "(2.460)"),
  P        = c("<0.001",   "<0.001",   "0.349",   "0.541",   "0.756",   "0.063")
)

ft <- flextable(df) %>%
  set_header_labels(
    Predictor = "Predictor",
    Estimate  = "Estimate",
    SE        = "Std. Error",
    P         = "p Value"
  ) %>%
  theme_booktabs() %>%
  bold(i = 1, part = "header") %>%
  align(align = "center", part = "header") %>%
  align(j = 2:4, align = "center", part = "body") %>%
  align(j = 1, align = "left", part = "body") %>%
  width(j = 1, width = 2.8) %>%
  width(j = 2:4, width = 1.0) %>%
  add_footer_lines("Null deviance: 5952.72 on 21 df  |  Residual deviance:
                   160.78 on 16 df  |  AIC: 120.19") %>%
  add_footer_lines("Note: Standard errors in parentheses.
                   AA = Aesthetic Appreciation. ·p<0.1; ***p<0.001") %>%
  italic(i = 2, part = "footer") %>%
  set_caption("Emotional Valence in Non-Touch Paintings")

save_as_docx(ft, path = "model_summary_nontouch_valence.docx")
```