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Haptic Responses to Emotionally Evocative Visual Stimuli

Faculty of Information Technology and Communication Sciences (ITC)
Master's thesis
October 2022

Abstract

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Master's Degree Programme in Human-Technology Interaction
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Emotion affects thinking, memory, innovation, and different kinds of behaviours. Response times to emotional visual stimuli reveal human emotion. The purpose of this study was to investigate the interaction among emotion-evocative visual stimuli, response times, response accuracy, and affective experience. In the experiments, 30 participants were asked to perform an emotion-categorization (i.e., negative, neutral, and positive) task while viewing different images. These images varied by dimensions of emotional valence (i.e., negative, neutral, and positive) and arousal (i.e., relaxing, neutral, and arousing). Haptic responses to these stimuli were recorded in terms of response times. Ratings of emotional experiences were collected in terms of valence and arousal.

The results from the statistical analysis showed that the response times for negative images were significantly shorter than both positive stimuli and neutral stimuli. The average numbers of errors were significantly different for different image categories. Participants responded to negative images most accurately, while the neutral image group had the most errors among the three categories. The valence ratings for positive, negative, and neutral images were significantly different from each other. The arousal ratings for the negative images were significantly higher than both positive images and neutral images. The arousal ratings of the correctly responded positive images were higher than the neutral images.

To summarise, three major findings are listed as follows: (1) Emotion-evoking images (including both positive and negative images) elicited faster haptic responses than neutral images. (2) Emotion-evoking images (including both positive and negative images) led to higher accuracy in the emotion-categorization task. (3) Negative high-arousal images elicited the fastest responses, most accurate categorization, and strongest arousal rating for the participants.

Keywords: Response time, emotional stimuli, dimensional emotion, affective ratings.

The originality of this thesis has been checked using the Turnitin Originality Check service.

Acknowledgment

My sincere thanks go to my supervisors, Professor Veikko Surakka and Dr. Aleksi Syrjämäki for their guidance, support, and trust. I would also like to thank my supervisor Deepa Vasara for her help and guidance at the beginning of the study and her review comments on my thesis.

I am also grateful to the researchers from the Research Group for Emotions, Sociality, and Computing for their valuable comments on the pilot tests. I would like to thank each of the participants in this study for their participation.

Finally, I would like to thank my family and friends who supported me during my thesis work.

Contents

1 Introduction

Haptic is a concept derived from Greek that means anything related to the sense of touch. The sense of touch is one of the six senses of humans and is probably one of the most important senses in the development of emotion and social interaction. Harlow's famous experiments on rhesus monkeys indicated that touch plays a critical role in the monkey's early development of affection, security, and social interaction (Harlow et al., 1966; Harlow, 1958; Harlow et al., 1965). For example in this experiment (Harlow, 1958), little monkeys were taken away from their mothers immediately after birth, and started to live with two surrogate mothers. One is a surrogate mother made of wire and it can provide milk, and the other is a surrogate mother made of cloth that does not provide milk. As a result, the little monkeys chose to spend most of their time on the cloth mother, rather than the wire mother. Those monkeys grown up without maternal touch showed negative behaviours both throughout their infancy and when they became parents (Harlow et al., 1966; Harlow et al., 1965). They tended to show rejecting and punitive behaviours toward their infants.

Tactile behaviour is also closely related to human emotions. The sense of touch is probably one of the most important and earliest means of communication for human infants (Hertenstein, 2002). As commonly known, the contact of the young child with the mother builds the bond between the mother and the baby. Mothers use different tactile behaviours (e.g., playful touch, attention-getting touch, nurturing touch) in communication with their infants depending on the context (Jean & Stack, 2012). Different maternal touch (i.e., tension increase, tension decrease, or no tactile manipulation) can regulate young children's (12-month-old) behaviour (Hertenstein & Campos, 2001). Parental touch can also reduce feelings of social anxiety for their children (Brummelman et al., 2019). Touch is crucial not only for infants and young children, but it is also equally important for adults (Hertenstein et al., 2007; Jones & Yarbrough, 1985). For example, responsive touch between romantic couples can transfer the feeling of intimacy and increase positive feelings (Debrot et al., 2013).

People interact with various things by hand, including computing devices, keyboards, and touch screens. Touch is needed with most devices we are interacting with, and it is becoming a part of human-computer interaction and human-robot interaction (e.g., Hibbeln et al., 2017; Yohanan et al., 2012). There are literature regarding different haptic input/output methods (Rantala et al., 2011) and different responses to haptic stimulation (Salminen et al., 2008). So, it is essential to understand the basic mechanisms of tactile behaviour and their potential relation to emotion.

This thesis investigates the effects of different emotion-evocative visual stimuli on people's response times, response accuracy, and affective experience. The primary focus of this study was on how high-arousal (positive and negative) visual stimuli affect response times. The overall structure of the thesis consists of six chapters. Chapter 1 introduces the main scope of the study. Chapter 2 reviews the related work in the field. Chapter 3 describes the methods used in this study and the procedure of the experiment. After that, Chapter 4 analyses the collected data and addresses the aim of the study. Chapter 5 discusses the significant findings in light of other relevant studies. The final Chapter summarises the main findings of this study, discusses the limitation, and proposes future applications.

2 Related Work

This chapter contextualises the research by providing background information on emotion theories, studies related to emotion and attention, haptics and emotions. Then the research aims and significance are discussed.

2.1 Emotion and Emotional Responses

Emotion is a combination of physiological and psychological events, and it is a complex phenomenon that affects significantly people's behaviour, memory, attention, and communication (Calvo & Lang, 2004; Kaestner & Polich, 2011; Tsetserukou et al., 2009; Vasara & Surakka, 2021; Verbruggen & Houwer, 2007). There are two main theoretical approaches to emotion: the discrete and the dimensional theories. The discrete theory of emotion defines emotion as distinct categories, such as anger, joy, and disgust. Evidence shows that there are six universal basic emotions (i.e., anger, happiness, sadness, surprise, disgust, and interest) and their expressions and experiences are invariant across cultures (Ekman, 1992; Ekman & Friesen, 1971). The dimensional theory of emotion defines emotion using two or more dimensions, for example, valence that varies from feelings of unpleasantness to pleasantness, arousal that varies from feelings of being relaxed to excited, and dominance that varies from feelings of being in control of to being in control of, for example, a situation or stimulus (Russell & Mehrabian, 1977). From a motivational point of view, emotion could also be categorised as dimensions of avoidance (withdraw from pain) and approach (approach pleasure) (e.g., James, 2004), that elicit defensive and appetitive reactions (Bradley, Codispoti, Cuthbert, et al., 2001)

As vast amount of discrete and dimensional theory studies were found, considerable evidence has accumulated to show that emotional responses are more explainable using the dimensional emotion theory (e.g., Gunes & Pantic, 2010; Mauss & Robinson, 2009). For example, in a review by Mauss and Robinson (2009), the authors argue that emotional responses may reveal themselves on multiple levels: physiology, behaviour, and experience. The measures of emotion include, for example, self-report, autonomic nervous system (ANS) measures, startle response magnitude, facial behaviour, and whole body behaviour. The review strongly supports the dimensional view of emotion in comparison with the discrete view, as the dimensional framework of emotion better captures the variances in different response systems compared to the discrete framework. Data from automatic human emotion analysis suggest that the dimensional theory of emotion has started to gain favour (Gunes & Pantic, 2010). Such systems have indicated shifts from discrete emotion analysis systems to automatic dimensional affect recognition/classification systems. Multiple modalities, such as visual, audio, tactile, and brain waves, are to be combined in such systems. These different modalities could provide useful information for automatic dimensional affect recognition systems.

Using pictures is a convenient way to study emotions and emotional responses. Pictures provide visual cues that could activate most of the affective experiences (Bradley & Lang, 2007). The International Affective Picture System (IAPS) is an emotional stimulus database with colour photos of different contents with normative rating data of valence, arousal, and dominance (Lang, Bradley, Cuthbert, et al., 1997). Researchers use IAPS in different fields such as psychology (e.g., Bradley, Codispoti, Cuthbert, et al., 2001), cognitive science (e.g., Verbruggen & Houwer, 2007), and in studies with different cultures (e.g., Huang et al., 2015; Soares et al., 2014), different genders (e.g., Bradley, Codispoti, Sabatinelli, et al., 2001) and different age groups (e.g., Grühn & Scheibe, 2008). The ratings of IAPS have been done using Self-Assessment Manikin (SAM) (Lang, Bradley, Cuthbert, et al., 1997). SAM is ”a non-verbal pictorial assessment technique” (Bradley & Lang, 1994) . It could measure the affective experience of valence (from pleasant to unpleasant), arousal (from excited to relaxed), and dominance (from controlled to controlling) directly. Researchers studying emotions use SAM and its variant numeric rating systems to quickly assess emotional experiences (e.g., Ahmed et al., 2020; Calvo & Avero, 2009; Vasara & Surakka, 2021).

Bradley, Codispoti, Cuthbert, et al. (2001) examined different content pictures from the IAPS. In their study, different physiological measurements and facial muscle activities were measured. The participants were instructed to view the pictures and then give the SAM ratings by selecting a figure along the scale of valence, arousal, and dominance. Startle probes (a loud sound) were presented in half of the trials while the defensive eye blink reflex was measured. The results suggested that picture valence regulated heart rate with greater initial cardiac deceleration when viewing emotional pictures, compared to neutral pictures. Furthermore, unpleasant pictures showed more initial deceleration in heart rate than pleasant pictures while pleasant pictures showed greater peak acceleration, compared with unpleasant pictures. For the measure of skin conductance, larger electrodermal (electrical conductivity of the skin) reactions were observed when viewing pleasant and unpleasant pictures. In addition, viewing unpleasant pictures elicited larger blinks compared with pleasant pictures, and viewing pleasant pictures elicited smaller blinks compared with neutral pictures. Facial EMG (measured over the corrugator and zygomatic muscles) activity showed that greater corrugator activity was observed when viewing unpleasant pictures than viewing pleasant pictures, while greater zygomatic activities were observed when viewing pleasant pictures than viewing unpleasant pictures. The results also showed that the greatest physiological changes occurred when viewing pictures of threat, violent, and erotic scenes. Subjective ratings of the emotional experience showed that the unpleasant pictures were rated as more arousing than the pleasant and neutral pictures. The results supported the motivational view (defensive and appetitive) of picture processing, causing different reactions to emotional stimuli (Lang, Bradley, Cuthbert, et al., 1997).

2.2 Emotion and Attention

Different studies showed evidence that emotional pictures attract more attention compared to non-emotional pictures (Calvo & Lang, 2004; Kaestner & Polich, 2011; Verbruggen & Houwer, 2007). One study by Calvo and Lang (2004) examined the relationship between emotional pictures and attention using gaze-detecting technology. Pictures of pleasant, unpleasant, or neutral scenes were presented together with non-emotional control pictures from the IAPS. The gaze patterns of the participants were studied. The results suggested that emotional pictures attracted more early-stage attention compared to neutral pictures. The probability of the first fixation of gaze was higher for emotional images than the neutral images in the first 500ms. Similar trends emerged for the total viewing time: participants' gazes were more engaged to the emotional stimuli in the first 500ms compared to the latter five 500ms intervals within 3 seconds.

Similar results have been found in cognitive studies related to emotion such as a study by Verbruggen and Houwer (2007). In the study, participants needed to respond to one of the two visual signals ("#" or "@") immediately after an emotional photo (from the IAPS) using their left or right hand, respectively. In 30% of the trials (randomly determined), a stop-signal showed where the participants needed to withhold their response. The authors aimed to discover if emotional stimuli interfered with the tasks and whether the valence or arousal of emotional stimuli caused the potential interference. The results showed that picture arousal affected response time in terms of both response latencies (in the no-signal trials) and stopping latencies (in the stop-signal trials): the higher the arousal level, the slower the response. This indicated that emotional pictures attracted attention away from ongoing cognitive tasks.

In a brain-behaviour relation study, Kaestner and Polich (2011) investigated the interactions between affect and recognition memory from aspects of brain activity and behaviour. The authors selected pictures in four categories (i.e., high-arousal unpleasant, high-arousal pleasant, low-arousal unpleasant, and low-arousal pleasant) from the IAPS. The participants first passively viewed the stimuli. Then, the participants went through a recognition memory task where they needed to determine whether an image was presented before or not. The participants were instructed to press the "S" key (indicating the picture had been presented) or the "H" key (indicating the picture had not been presented) on the keyboard with their left or right-hand index finger respectively. The results indicated that picture valence and arousal affected the recognition memory independently. The low-arousal pictures were responded to more quickly than the high-arousal pictures. This suggested that high-arousal emotional pictures attracted more attention compared to low-arousal pictures. Furthermore, the unpleasant high-arousal pictures were responded to the slowest among the four categories. In addition, the unpleasant pictures elicited greater brain activity. The study showed evidence from both brain activity and behaviour levels that emotional pictures attracted attention, especially, the negative, high-arousal category was privileged to be processed in the memory-related task.

2.3 Haptics and Emotions

Touch plays an important role in expressing and transmitting emotion-related information (Andreasson et al., 2018; Bailenson et al., 2007; Gao et al., 2012; Hertenstein et al., 2006). Haptics can convey emotions in many different situations, including between humans, between humans and haptic devices, and between humans and robots. Examples of these different situations will be discussed below.

Hertenstein et al. (2006)found that in human-human interaction, touch can convey specific emotions: touch or even just watching other people's touch behaviour could communicate distinct emotions. In their study, the participants were to communicate different emotions by touching the arm of a stranger. The participants were divided into encoders and decoders to express distinct emotions. The results showed that touch could transmit different emotions (i.e., anger, fear, happiness, sadness, disgust, love, gratitude, and sympathy) much better than the chance level, with a 50%-70% accuracy rate on average.

Bailenson et al. (2007) explored the possibility of transmitting different emotions through handshakes and handheld devices. The media used was a 2 DOF (degree of freedom) force-feedback joystick. The participants were asked to express several different emotions (i.e., disgust, anger, sadness, joy, fear, interest, and surprise) via the haptic device. Metrics of the movement of the haptic device were recorded. After that, each participant was asked to discriminate the intention of the other to convey from a list of seven emotions by trying to recognise the recorded play using the haptic joystick. Finally, the participants were asked to recognise the emotions of their partner just from the handshakes. The study concluded that specific emotions could be inferred through handshakes or handheld haptic devices.

Gao et al. (2012) investigated how the emotional state of the users could affect their finger-stroke behaviours (e.g., the length and pressure of the finger-stroking motion). They used machine learning algorithms to classify users' emotional states.

Their system could discriminate four emotion states: frustrated, excited, bored, and relaxed. The pressure of touch for frustration is distinguishable from other states. Another study used a pressure-sensitive keyboard and a capacitive mouse to study tactile behaviour (Hernandez et al., 2014). In the study, the participants were instructed to type under three different conditions: expressive writing, transcription, and mouse clicking. The results showed that typing is more forceful in stressed conditions, at the same time, contact with the mouse is more frequent.

Andreasson et al. (2018) used human-robot interactions instead of human-human interactions to convey eight emotions. The participants were asked to convey eight emotions (i.e., anger, disgust, fear, happiness, sadness, gratitude, sympathy, and love) to a Nao robot via any form of touch. The tactile information such as the intensity, duration, location, and type of touch was coded and evaluated. The results showed that negative emotions (i.e., anger, disgust, fear) were more effectively conveyed to the robot than positive emotions (e.g., happiness, gratitude, love). Tsetserukou et al. (2009) designed a system called iFeel_IM!. The system could detect nine emotions from the text inputter and reproduce them by creating simulations of tactile information for the text receiver. Their results showed that the haptic device enhanced social interactivity and the online chatting experience.

The above-mentioned studies asked people or systems to express or infer distinct emotions (Andreasson et al., 2018; Bailenson et al., 2007; Hertenstein et al., 2006) and analysed or utilised the touch behaviour from a discrete emotion perspective (Gao et al., 2012; Hernandez et al., 2014; Tsetserukou et al., 2009). These results leave open the question of how emotional stimuli affect touch in the dimensional framework, for example, experiences in terms of valence and arousal. At the same time, touching by hand or finger is one of the manual responses and gives us insight into people's emotional responses at the behaviour level.

Research in Human-Computer Interaction has started to investigate how emotions influence haptic behaviours and experiences of emotions (e.g., Ahmed et al., 2020; Vasara & Surakka, 2021). A recent study by Vasara and Surakka (2021) investigated the relationship between emotional facial stimuli, haptic reactions, and emotional experiences. The authors used facial expressions of happy, angry, and neutral faces. After the display of the facial expression, the participants were to tap a haptic device as quickly as possible. The duration of touch and force of touch were recorded using the haptic device and a computer. The affective experiences of the participants were collected using the scales of valence and arousal. Their results suggested that angry facial expressions provoked a stronger force of touch compared to happy and neutral faces. The ratings of valence performed as expected along the valence dimension. The ratings of arousal showed that angry faces were experienced more arousing than neutral and happy faces.

In a study by Ahmed et al. (2020), the interactions between the emotional expression of a virtual agent (in virtual reality) and people's touch behaviour were investigated. Seven different emotional facial expressions for the agent were used (i.e., anger, disgust, fear, happiness, neutral, sadness, and surprise). The haptic information was collected using a haptic device (the agent's arm). Physiological measures (e.g., heart rate, facial muscle activities), haptic responses and the affective ratings of both the participants and the perceived agent's affective states were collected. The results showed that the emotional expressions of the virtual agent affected the physiological responses of the participants. Facial muscle measurements showed a facial mimicry effect, for example, the frown was detected when viewing angry expressions and mouth-corner lifting and eyelid opening were detected when viewing happy expressions. In addition, heart rate data showed a continued slowdown when viewing the neutral expression compared to other emotional expressions. There was also a significant effect of the emotional expressions on the response onset, response duration, and maximum pressure. The neutral expression elicited weaker and postponed touch than other emotional expressions. Longer touch occurred when participants were viewing fearful and sad expressions than disgusted and happy expressions. The maximum press on average was higher when viewing angry, disgusted, and fearful expressions while sad expressions elicited the lowest pressure, followed by surprise. At the same time, different emotional expressions affected self-reported valence and arousal: the positive expressions were rated more positive than the negative expressions. Furthermore, participants' valence ratings were more positive than the perceived agent's valence ratings while the perceived agents' arousal ratings were higher than the participants' arousal ratings. In addition, it was possible to predict the intensity and duration of touch through the six proposed multilevel linear models with the physiological reactions and valence and arousal ratings of the users.

However, response time as an important aspect of manual responses has yet to be understood. Relatively few studies have examined the direct relationship between response times and visual stimuli. In the literature review, the response times were measured while other cognitive tasks were ongoing at the same time as the stimuli were presented (Kaestner & Polich, 2011; Verbruggen & Houwer, 2007). Among the few relevant studies found that access pure response time to emotional visual stimuli, Botta et al. (2021) assessed the response times to different emotional body postures (fearful, happy, and neutral) using a three-alternative forced choice device. The participants needed to press one of the three keys to determine whether the picture presented was negative, positive, or neutral. Response times (from the stimuli onset to the key press) as well as subjective ratings of valence and arousal were collected for each picture. The results showed that body postures that communicate fear elicited faster responses in comparison with happy and neutral body postures. This is probably because of the activation of the defensive system of the body. This study supported the idea that negative emotion-related stimuli could modulate response times.

Calvo and Avero (2009) created a normative reaction time database based on the IAPS. The database provides a referring source for researchers to select emotional pictures from different display conditions, gender, and emotional content. In the study, 308 different stimuli within the main content categories of IAPS were selected from the IAPS. The pleasant content category included pictures of erotic couples, romance, adventure, sports, and families. The unpleasant content category included pictures of human attacks, mutilation, accidents, and illness. The pictures were presented in four different conditions (no time limit, 250ms, 100ms, and 33ms). The participants were instructed to respond to a forced-choice task by pressing one of the three keys on the keyboard to indicate the valence content of the presented picture (unpleasant, neutral, or pleasant). The results suggested that in all conditions, there was a correlation between the picture valence and reaction times. Reaction times decreased with picture valence for unpleasant pictures and increased with picture valence for pleasant pictures. In other words, the more pleasant/unpleasant the picture, the faster the response. In addition, a significant effect of picture arousal (only for unpleasant pictures) on response times was also found, suggesting that with the increase of the arousal level of the unpleasant pictures, responses became faster. The study also found that reaction times negatively correlated with display time, the shorter the display time, the longer the response time. In addition, different content of the pictures also influenced the response times. The responses to certain categories (i.e., erotic/romance, mutilation, accidents, human attack, and families/babies) were faster while the responses to some other categories were slower (i.e., sports, loss/illness, and adventure).

Based on Calvo and Avero (2009)'s reaction time database, 30 pictures were selected (10 positive, 10 negative, and 10 neutral) from the IAPS. The purpose of this study was to investigate the interaction among emotion-evocative visual stimuli, response times, response accuracy, and affective experience. The measurement of response times used in this study was different compared to the previous study (Calvo & Avero, 2009). In their study, the participants performed a three-alternative forced-choice task. In this study, the participants were asked to make a binary decision in each of the trials. The process was simplified, and the cognitive load was reduced. In the previous study, participants made decisions between three keys using different fingers on both left and right hand. While in this experiment, only one key is needed to be pressed. The "one-key press" is less demanding and not easy to make a mistake. There is evidence that response to the "go/no-go" (respond/not to respond) task is significantly faster and more accurate than the “choice task” (Miller & Low, 2001). As a result, the measurement of reaction time used in this study was more reliable and straightforward.

The display time in Calvo and Avero (2009)’s study was different for different pictures. The 308 pictures were divided into four groups and the display time was different for each group (no time limit, 250ms, 100ms, and 33ms). The findings from their study showed that display time had a main effect on reaction times (reaction time became longer with the decrease of display time). Although there was also a significant correlation between reaction times in each condition and reaction times in other conditions, the different display times may still become a confounding variable. In this experiment, all images had an equal display time of 2 seconds, eliminating the bias caused by different display conditions. This study will provide a different perspective to understand the relationship between the response times of touch and emotions.

3 Methods

This chapter discusses the specific methods by which the research and analyses were conducted. The research reported in this thesis was empirical. All the instructions were provided in text. Firstly, the experiment was implemented using the Gorilla software platform (a cloud software platform developed specifically for the behavioural sciences), followed by pilot tests to ensure the instructions were clear and easy to understand, also the flow of the experiment was easy to follow.

A mixed methods approach (quantitative and qualitative) was employed in this research. The primary quantitative measure was response times. Response time is one of the key elements of processing efficiency. Another quantitative measure was the number of errors. The main qualitative measure was the participants' experiences of the emotional pictures. Subjective rating scales were used to measure the experiences of the stimuli. In this thesis, one experiment was conducted remotely using Gorilla. The experiment was conducted with thirty participants (15 females, 14 males, and 1 other).

3.1 Participants

Thirty participants (15 females, 14 males, and 1 other) with normal or corrected to normal vision participated in the experiment. Their mean age was 26.9 years (ranging from 19 to 42), and the standard deviation was 7.7 years. The participants were university psychology course students who took part for course credits. Participants were from northern Europe, 29 Finnish and 1 Estonian.

3.2 Apparatus and Software

The experiment was implemented and hosted by the Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine et al., 2020). Gorilla is a cloud software platform developed specifically for the behavioural sciences. Gorilla allows participants to run experiments via the Internet. Data collection occurred between 14 Feb and 26 Feb 2022.

Participants who participated in the experiment needed to have a laptop or a desktop computer with a keyboard and a mouse. Figure 1 shows the Gorilla application open in a web browser with task instructions. A quiet and distraction-free environment with a stable internet connection was also required.

Figure 1. The Gorilla application opens in a web browser with task instructions on a laptop.

3.3 Stimuli Selection

Ten positive, 10 negative, and 10 neutral images were selected from the IAPS using Calvo and Avero (2009)'s reaction time database as a reference for the stimulus material selection. The neutral category were selected so that the average ratings of valence and arousal were close to the midpoint of the 9-point scale (from -4 to +4). The positive and negative categories were selected with similar high valence and arousal levels so that the absolute deviations from the midpoint of the valence and arousal scales were as close to each other as possible. Table 1 shows the average valence and arousal ratings with the standard deviations of the selected images.

Table 1: Average IAPS ratings of valence, arousal, and SDs of selected images

Stimulus category	Valence mean	Valence SD	Arousal mean	Arousal SD
Negative	2.52	0.50	6.38	0.54
Neutral	5.05	0.72	4.95	0.59
Positive	7.41	0.30	6.42	0.35

The positive category included images of sports and adventure. The negative category included, for example, images of human attack, mutilation, and accidents. The neutral category comprised images of animals, objects, and people. Table 2 lists the IAPS numbers of images used in this study with semantic descriptions.

Table 2. List of slides of selected images with semantic description

IAPS Numbers	**Description**
Negative Category	
2800	Sad child
3550	Injury
6230	Aimed gun
6312	Abduction
6550	Attack
6570.1	Suicide
8480	Biker on fire
9050	Plane crash
9250	War victim
9910	Auto accident
Neutral Category	
1390	Bees
1560	Hawk
2220	Male face
2410	Boy
2520	Elderly man
2575	Propeller
6900	Aircraft
7496	Street
7600	Dragon
9582	Dental exam
Positive Category	
5470	Astronaut
5621	Sky-divers
8034	Skier
8080	Sailing
8180	Cliff divers
8210	Boat
8300	Pilot
8370	Rafting
8470	Gymnast
8490	Roller coaster

3.4 Experimental Tasks

3.4.1 Response Time Task

There were three blocks in the response time task. All the pictures were presented in three blocks. In each block, the participants just needed to respond to one type of picture (either pleasant, unpleasant, or neutral) by pressing the space bar. In one block, the participants needed to respond only to images that they felt were neutral. While in another block, the participants needed to respond only to images that they felt were unpleasant. Finally, in the third block, the participants needed to respond only to images that they felt were pleasant. The order of the blocks was counterbalanced.

The response time task started with an introduction page informing the participant that the task comprised three sessions that would appear in random order. Once the participant clicked the "Continue" button, the new screen showed the specific instruction for the first session. When the participant clicked the "Next" button, the response time task started. There were 30 trials on the block. Each trial started with a blank screen lasting either 2000ms, 2500ms, 3000ms, 3500ms, or 4000ms. The intervals of the blank screens were randomly determined. Immediately after this, one image was presented at the centre of the participant's computer screen. The order of the displayed images was random. Each image had a display time of 2 seconds. The participant needed to respond to the image as quickly as possible by pressing the space bar depending on the block (e.g., in a negative block, the participant needed only to respond to images one felt unpleasant). Once the participant pressed the space bar (within 2 seconds), the image disappeared from the screen immediately. Otherwise, the image disappeared by itself when the display time is over. After all 30 images were displayed, the session ended. The participant clicked the "Continue" button on the instruction page after each block when it was finished. After all the three blocks were completed, the participant was ready to proceed to the next rating task.

3.4.2 Rating Task

The second task was the rating task. First, there was a practice session in which the participants practised how to rate their emotional experiences using the dimensional scales of valence and arousal. The scale used was a bipolar 9-point Likert scale varying from -4 to +4. For the ratings of valence, -4 represented the feeling of unpleasantness, and +4 represented the feeling of pleasantness. For the ratings of arousal, -4 represented the feeling of calm, and +4 represented the feeling of aroused. The midpoint of the scales represented a neutral feeling.

After the practice session, the participants rated the valence of all the images. First, the participants were informed by writing that they were going to rate the pleasantness of each image. The meaning of valence was explained briefly in text. When the participant clicked the "I am ready!" button, the first image was displayed together with the rating scale of valence. Once the participant clicked one rating number on the scale, the image disappeared. After 1 second, another image was displayed with the rating scale of valence. The order of the displayed images was randomised. The session continued until the participants had rated the valence of all 30 images. Figure 2 shows the screenshot of an example of the rating sessions for valence.

After the participants finished rating the valence of the images, they proceeded to give ratings of arousal. First, the screen showed the meaning of arousal. And when the participant clicked the “I am ready” button, the first image was displayed together with the scale of arousal. The procedure was the same as in the valence rating session. The session continued until the participants rated the arousal for all 30 images. Figure 3 shows the screenshot of an example of the rating session for arousal.

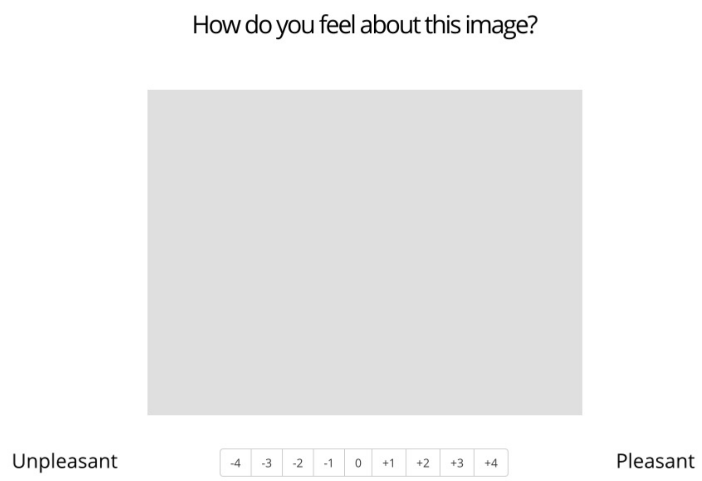

Figure 2. *Screenshot of rating for image valence. (Note: The image is not displayed here due to copyright protection).*

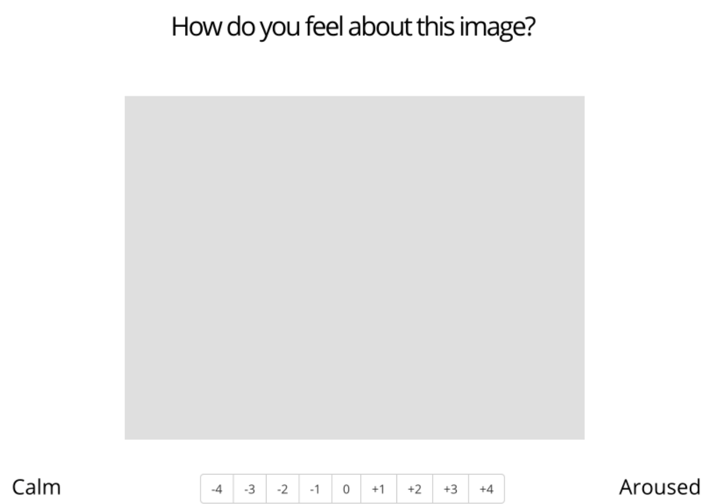

Figure 3. *Screenshot of rating for image arousal. (Note: The image is not displayed here due to copyright protection).*

3.5 Procedure

In the beginning, an invitation letter was sent to the psychology course students, inviting them to take part in the study, and the students were instructed to contact the experimenter by email if interested. After receiving the request from the students, the experimenter emailed the students with additional information about Gorilla and instructions on how to log in to the experiment. A privacy notice was sent as an attachment in the email. The experimenter assigned a unique ID to each participant in Gorilla. Once the status of the participants was activated by the experimenter in Gorilla, the link to the study and the IDs were sent to each participant by email. The IDs were used to identify the data if the participants would withdraw later.

Participants logged in to Gorilla with the link and the IDs. After logging in, an information sheet was displayed informing them that the purpose of the study was to investigate people's responses to different types of images, and they were to respond to the images using their keyboard and mouse/touchpad. In addition, the information sheet stated that participation was voluntary, and participants could withdraw at any time. At the bottom of the information sheet, the participants needed to check the consent box indicating that they agreed to participate in the study before proceeding.

Next, an introductory page was displayed that explained to the participants that there were two tasks, first a response time task, where participants needed to respond to specific images as quickly as possible, followed by a rating task. After the introductory page of the experiment, the participants filled out a background form, where they filled in their age, gender, and nationality. They also confirmed that they fulfilled the prerequisites of the study by ticking the checkboxes describing the requirements of the study. All the instructions were provided in writing.

The participants first completed a practice task to get familiar with the task procedure before proceeding to the response time task. The stimuli used in the practice task were six different English words. After the practice sessions, an instruction page was displayed to the participants. The participants were instructed to click the "Continue" button when they were ready to proceed to the actual response time task. The response time task had three blocks (as mentioned in Section 3.4.1). After the completion of the response time task, the participants practiced how to rate valence and arousal using the same six English words used in the previous practice session. Once ready, the participants first rated the valence for each image, then they rated the arousal for each image, too (as mentioned in Section 3.4.2). A study feedback form was presented after the participants finished the rating task. Information about the image display, technical issues (i.e., potential problems), and general feedback on the study were collected. Participants could also leave comments about the study. Then, a participant debriefing sheet was presented. The participants were informed that the purpose of the study was to investigate people's responses to different emotion-evoking visual stimuli. Finally, participants were instructed to click the "Submit" button at the bottom of the page to submit their data. After clicking the "Submit" button, the complete data of the participants were recorded. The experiment took approximately 20 minutes to finish, and all participants completed the experiment.

3.6 Data Analysis

Demographic, response time task, and rating task data were generated and downloaded as excel forms from Gorilla. All the response time data and rating data were included for analysis.

Response times

Response times were analysed as the interval from the image onset to the space bar press. The recorded response time data within the 2-second time interval from the image onset was first filtered out. Then, the recorded response times were listed for each block. Only the correctly responded stimulus (emotional stimuli responded in the right block) response times were included in the analysis. Response times recorded in the wrong blocks were excluded from the data analysis. A One-way ANOVA was conducted using the statistical software SPSS for response times using the stimulus content as within-subjects factor. Pairwise Bonferroni corrected t-tests were used for pairwise post hoc tests.

Number of Errors

The definition of an error was when the image was reacted in a wrong way. There were two kinds of errors. The first kind of error was that the participants responded too slowly, longer than 2 seconds from the stimulus onset, or the participants did not respond to an image that belongs to the stimulus category that they should have responded to. In the above two situations, no response time data were recorded, and the trial was defined as erroneous. The second kind of error was when the participants responded to a stimulus within 2 seconds that they should not have responded to. For example, the participants responded to a neutral picture in the negative block. Those trials were also categorised as errors. The number of these two kinds of errors was summed up as errors for analysis. The percentage of these two kinds of errors was also calculated.

A one-way ANOVA was conducted for the number of errors using the stimulus content as within-subjects factor. Degrees of freedom and p-values were adjusted using Greenhouse-Geisser correction. Pairwise Bonferroni corrected pairwise t-tests were used for post hoc tests.

Ratings of Valence

First, a one-way ANOVA was conducted for the ratings of valence for only the correctly responded stimuli in the response time task using the stimulus content as within-subjects factor. Pairwise Bonferroni corrected t-tests were used for pairwise post hoc tests.

Second, a one-way ANOVA was conducted for the ratings of valence for all images of different categories using the stimulus content as within-subjects factor. Degrees of freedom and p-values were adjusted using Greenhouse-Geisser correction. Pairwise Bonferroni corrected t-tests were used for pairwise post hoc tests.

Ratings of Arousal

First, a one-way ANOVA was conducted for the ratings of arousal for only the correctly responded stimuli in the response time task using the stimulus content as within-subjects factor. Pairwise Bonferroni corrected t-tests were used for pairwise post hoc tests.

Second, a one-way ANOVA was conducted for the ratings of arousal for all images of different categories using the stimulus content as within-subjects factor. Degrees of freedom and p-values were adjusted using a Greenhouse-Geisser correction. Pairwise Bonferroni corrected t-tests were used for pairwise post hoc tests.

4 Results

This chapter is subdivided into four sections. The results of statistical analysis are presented in four aspects: correctly responded image response times, the number of errors, and subjective ratings of valence and arousal.

4.1 Response Times

Figure 4 shows the means and the Standard Error of the Means (S.E.M.) of response times for different stimulus categories. From the figure, it can be seen that participants on average responded faster to negative stimuli than to neutral and positive stimuli. Participants also responded faster to the positive stimuli than to the neutral stimuli.

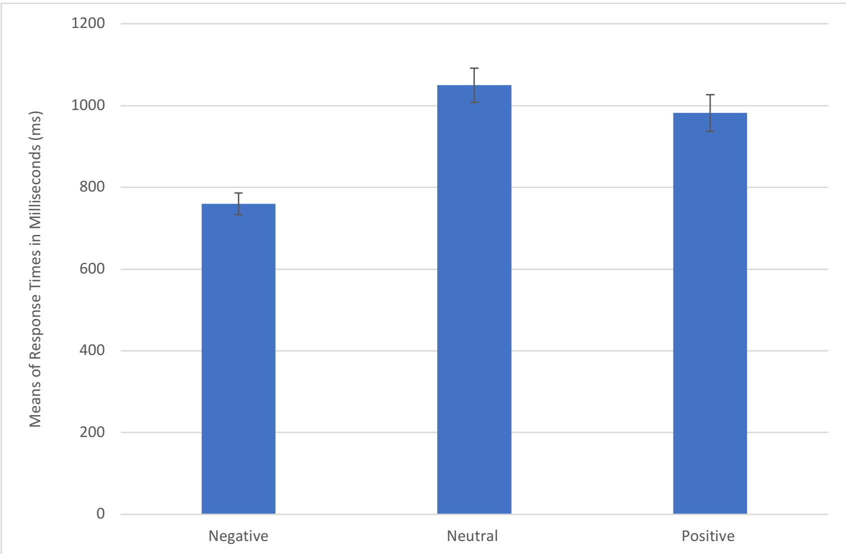

Figure 4. Means and S.E.M. of response times for the different stimulus categories

A one-way within-subject repeated-measures analysis of variance (ANOVA) showed a statistically significant effect of the stimulus content on the response times, $F(2, 58) = 17.23$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons for the response times revealed that the participants responded significantly faster when viewing negative stimuli than viewing positive stimuli, $t(29) = 4.51$, p $< .001$, and neutral stimuli, t $(29) = 5.96$, $p < .001$. However, there was no significant difference between the response times of positive and neutral stimuli, $t(29) = 1.19$, $p = .243$.

4.2 Number of Errors

The means and S.E.M of the number of errors are shown in Figure 5. What is interesting from the graph is that the number of errors to negative stimuli was close to 0. This means that participants made almost no mistakes in identifying the negative images and were efficient enough to respond to them within 2 seconds. It also indicates that negative stimuli were rarely mistakenly responded to in the positive or neutral stimulus blocks. The number of errors was fewer for the positive stimuli than for the neutral stimuli. The neutral stimuli had the most errors among the three categories.

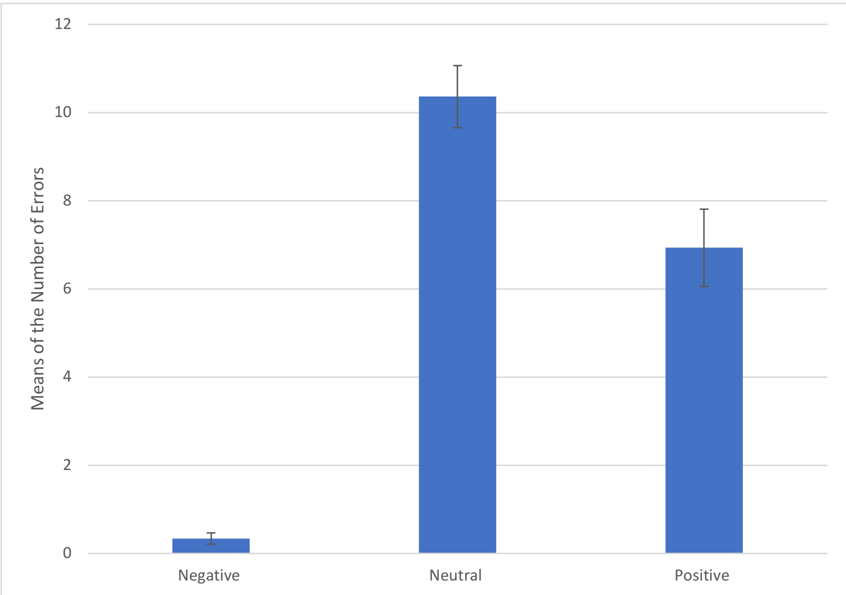

Figure 5. Means and S.E.M of the number of errors for the different stimulus categories

A one-way within-subjects ANOVA showed a statistically significant effect of the stimulus content on the number of errors, $F(1.46, 42.22) = 58.02$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons for the number of errors showed that the participants made significantly fewer errors with the negative stimuli than with the neutral stimuli, $t(29) = 14.85$, $p = <.001$ and positive stimuli, $t(29) = 7.23$, $p < .001$. Participants made significantly fewer errors with the positive stimuli than with the neutral stimuli, $t(29) = 2.90$, $p = .007$.

The percentages of the different kinds of errors for each stimuli category are presented in Table 3-5. (see Section 3.6 for more details).

Table 3: Negative stimuli error distribution

Error types	**Percentage**
Not responded in the negative block	50%
Responded in the positive block	20%
Responded in the neutral block	30%

Table 4: Neutral stimuli error distribution

Error types	**Percentage**
Not responded in the neutral block	49%
Responded in the positive block	14%
Responded in the negative block	37%

Table 5: Positive stimuli error distribution

Error types	**Percentage**
Not responded in the positive block	48%
Responded in the negative block	11%
Responded in the neutral block	41%

4.3 Ratings of Valence

Two sets of valence and arousal rating data were analysed. First, the valence and arousal ratings for *correctly responded* stimuli only. Second, valence and arousal ratings for *all* images (i.e., independent of correct vs. incorrect responses) in different stimulus categories (see Figure 6 and Figure 7).

Figure 6 shows the means and S.E.M. for ratings of valence for (1) the *correctly responded* stimuli, and (2) *all* images in the stimulus category. Figure 6 shows that participants rated negative stimuli as unpleasant, positive stimuli as pleasant, and neutral stimuli close to the centre of the scale, that is, as neutral.

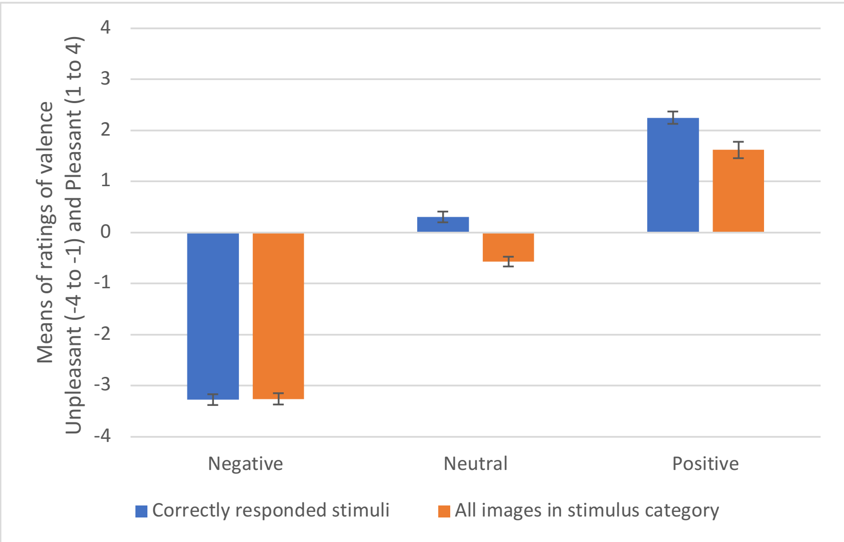

Figure 6. Means and S.E.M. of ratings of valence for the different stimulus categories

A one-way within-subject ANOVA showed a statistically significant effect of stimulus content on the ratings of valence for only the *correctly responded* images, $F(2, 58) = 693.07$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons showed that there was a statistically significant difference between the ratings of valence for *correctly responded* positive and negative stimuli, $t(29) = 30.77$, $p < .001$, positive and neutral stimuli, $t(29) = 14.59$, $p < .001$, and negative and neutral stimuli, $t(29) = 26.72$, $p < .001$.

A one-way within-subject ANOVA showed a statistically significant effect of stimulus content on the ratings of valence for *all* images in different categories, $F(1.24, 35.86) = 509.10$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons for the ratings of valence revealed that there was a statistically significant difference between the ratings of valence for positive and negative categories, $t(29) = 26.90$, $p < .001$, positive and neutral categories, $t(29) = 12.14$, $p < .001$, and negative and neutral categories $t(29) = 37.96$, $p = < .001$.

4.4 Ratings of Arousal

Figure 7 shows the means and S.E.M for ratings of arousal for (1) the *correctly responded* stimuli and (2) *all* stimuli in the stimulus category. From the figure, it could be seen that both negative and positive images were rated in the aroused direction. The figure shows that participants' experiences of the negative images were extremely arousing, while the positive images were experienced as relatively less arousing. The neutral images were experienced as close to the middle of the rating scale.

A one-way within-subject ANOVA for the *correctly responded* stimuli showed a statistically significant effect of stimulus content, $F(2,\ 58) = 41.32$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons for the ratings of arousal revealed that the *correctly responded* negative stimuli were rated significantly more arousing than the positive stimuli $t(29) = 5.28$, $p < .001$, and the neutral stimuli, $t(29) = 8.82$, $p < .001$. The *correctly responded* positive stimuli were rated as more arousing than neutral stimuli, $t(29) = 3.82$, $p < .001$.

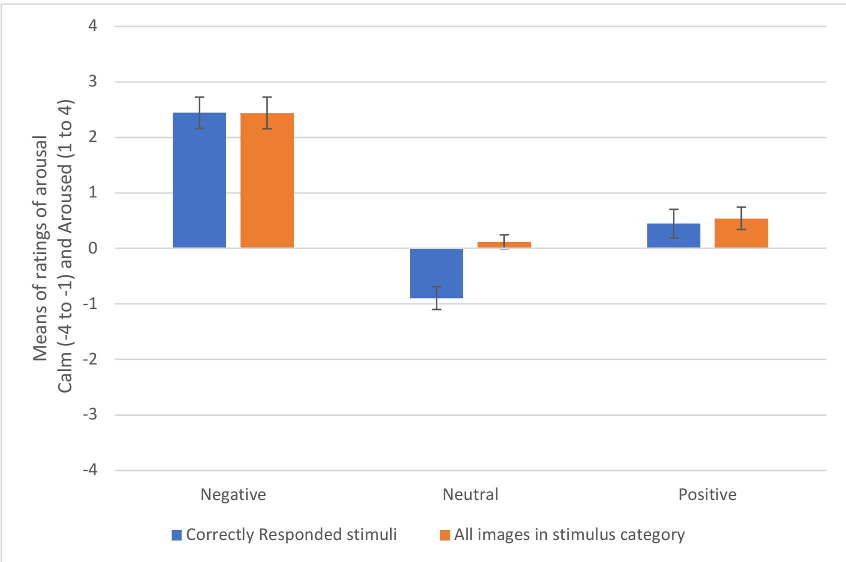

Figure 7. Means and S.E.M. of ratings of arousal for the different stimulus categories

A one-way within-subject ANOVA for *all* the stimuli in the stimulus category showed a statistically significant effect of stimulus content, $F(1.61, 46.53) = 42.11$, $p < .001$. Bonferroni corrected (the corrected $\alpha = 0.017$) post hoc pairwise comparisons for the ratings of arousal revealed that the negative stimuli were rated significantly more arousing than positive stimuli, $t(29) = 5.86$, $p < .001$ and neutral stimuli, $t(29) = 8.80$, $p < .001$. However, there was no significant difference between the ratings of arousal for positive and neutral stimuli, $t(29) = 2.01$, $p = .054$.

5 Discussion

The results showed that responses to negative stimuli were statistically significantly faster than to neutral and positive stimuli. The number of errors in the three categories differed significantly from each other. For the negative category, the number of errors was close to 0, the neutral category had an enormous amount of errors. The ratings of valence differed from each other along the valence scale for both corrected responded stimuli and all stimuli in the three categories. The same trend existed for the ratings of arousal except for the arousal rating for all images in three categories: the arousal ratings for all images in the negative category were significantly higher than that of the positive and neutral categories. However, there was no significant difference between the arousal ratings of positive and neutral categories for all images in these two categories.

The responses to negative stimuli were the most efficient and accurate. This could be explained by the following reasons: firstly, the high arousal level and the salient aversive content of the images caused the negative images distinguishable from other stimuli. The negative pictures were recognised immediately in the negative block, and they were correctly and efficiently omitted in the neutral and positive blocks within 2 seconds. This is consistent with the findings from the study by Calvo and Avero (2009), that certain categories of emotional pictures elicited faster responses than some other categories, for example, the categories of mutilation, accident, and human attack elicited faster responses compared to the categories of sports and adventures. However, there was also differences in the results: results of Calvo and Avero (2009) study showed that both picture valence and arousal modulated response times, while in this study, response times were affected by picture arousal but not valence. Similarly, previous research has indicated that body postures that communicate fear elicited faster responses compared with happy and neutral body postures ((Botta et al., 2021). Secondly, physiological and haptic behaviour findings also supported the findings. For example, Bradley, Codispoti, Cuthbert, et al. (2001) found that the negative high arousal content (i.e., attack and mutilated bodies) evoked most physiological arousal in terms of skin conductance responses and startle reflex potentiation in the brain compared to other emotional contents(i.e., pictures of negative valence and low arousal, positive valence and high arousal, and positive valence low arousal contents). Other haptic measures also showed that the negative content (angry faces) evoked stronger force of touch (Vasara & Surakka, 2021). Thirdly, when the participants viewed the pictures for the second and third time they tended to remember the pictures. However, only the negative images were responded to the fastest among the three groups. One possible explanation for this is that the negative high-arousal stimuli had a privileged processing priority. The result could be explained using the findings from the discrimination task related to memory (Kaestner & Polich, 2011). In the study, high-arousal unpleasant pictures used the most attention sources compared to the emotional picture of low arousal (both pleasant and unpleasant) and high-arousal pleasant pictures. In addition, the greatest brain activity occurred when participants viewed high-arousal unpleasant pictures. The findings from their study indicated that people used vast amount of attention source and the brain was working hard when processing negative high-arousal pictures.

The responses to neutral stimuli were the slowest and most erroneous. The first type of error was that the neutral pictures were not correctly responded to in the neutral block. One possible reason was that the participants did not have enough time to respond to the stimuli. In the case of neutral images, people tended to need more time to give a response, and the default maximal allowed time of 2 seconds is not enough for them to give the right response. Results from another study supported the findings: participants used postponed touch when viewing neutral faces compared to other emotional expressions and the heart rate data also showed a slowdown trend (Ahmed et al., 2020). The second type of error was that the neutral pictures were incorrectly responded to both in the positive and negative blocks instead. Calvo and Avero (2009)'s study also found that in different display conditions, the probability of response selection for neutral pictures were lowest. However, the different display time also affected the response time in their case. The methods used in the study better justified the results.

Taken together, emotion-evoking visual stimuli modulated response efficiency and accuracy on the behaviour level. How do emotional visual stimuli modulate people's emotional experiences? As can be seen from Figure 6, the negative stimuli were experienced as highly unpleasant and the positive stimuli were experienced as pleasant. As can be seen from Figure 7, the negative stimuli were experienced as extremely aroused and activated. The positive category was experienced as less aroused compared to the negative category. In this respect, the stimuli did not function as planned. This may be because of the emotional space created by these 30 pictures: the high arousal level of the negative pictures caused the experience of the positive stimuli to be less arousing, although, in the stimuli selection phase, they were similar in arousal level. The neutral images were experienced as close to the middle of the rating scale. These results reconfirmed that the negative, especially negative high-arousal stimuli, had a processing advantage over the positive and neutral stimuli, and the negative stimuli were experienced most aroused or participants had the most activating experience (Bradley, Codispoti, Cuthbert, et al., 2001; Kaestner & Polich, 2011; Vasara & Surakka, 2021).

In a more general framework, it can be proposed that defensive and appetitive motivations modulate people's behaviour and emotional experience (Bradley, Codispoti, Cuthbert, et al., 2001). An emotional bias emerged, as the positive and negative categories resulted in fewer errors compared to the neutral category. The reason for this could be that emotional stimuli attracted attention, especially early attention (Bradley, Codispoti, Cuthbert, et al., 2001; Calvo & Lang, 2004). Moreover, the negative stimuli may have privileged processing priority in memory (Verbruggen & Houwer, 2007), which resulted in faster response and fewer errors. The fast and accurate responses to the negative stimuli could also be explained using the Defense Cascade model that with the increase of the arousal level of the stimuli, the behaviour of humans or animals will change from freezing to "fight or flight" (Lang, Bradley, Cuthbert, et al., 1997). Although in the picture viewing context, the "fight or flight" behaviours rarely happen, the fast response may represent the intention to quickly remove the negative stimuli.

Taken together, the results of the current thesis showed that different emotion-evocative visual stimuli have significantly different effects on the emotional system in terms of behavioural responses (response times and the number of errors) and subjective ratings. Different motivational systems and the automatic physiological reaction activated by the stimuli is probably the reason behind the effects.

The findings of this study could be applied to human-computer interaction, human-robot interaction, and mediated interpersonal interaction. For example, robots, touch screens, mouses, keyboards, and other haptic devices could become sources of input of emotion-related information. The computer or robot could infer and predict the negative emotional states of humans according to relatively fast responses and react accordingly. When a user touches a robot, the fast touch could potentially indicate negative emotion.

6 Conclusion

The main purpose of this study was to understand how emotion-evocative and high-arousal visual stimuli affect response times, response accuracy, and subjective emotional experiences.

6.1 Research Objectives: Summary of Findings

The main findings of this study were as follows:

1. Emotion-evoking images (including both positive and negative images) elicited faster haptic responses than neutral images.

2. Emotion-evoking images (including both positive and negative images) led to higher accuracy in the emotion-categorization task.

3. Negative high-arousal images elicited the fastest responses, most accurate categorization, and strongest arousal rating for the participants.

6.2 Limitations

It was not the task of this thesis to examine an extended range of emotional stimuli. Only high-arousal images were selected in the pleasant and unpleasant dimensions. However, the images were carefully selected and fulfilled the aim of the study with reference response time data (Calvo & Avero, 2009). The experiments were conducted remotely with some potentially confounding variables, e.g., different places to take tests, different display resolutions, and internet speed. During the Covid-19 pandemic, the online experiment was one of the most proper alternatives, because there were restricted rules about face-to-face interaction.

6.3 Future Research

In this study, the only collected haptic information was response times. However, a more complete understanding of emotions can be obtained by collecting additional haptic information, for example, the force of touch and duration of touch. The force of touch and the duration of touch could be collected using a force-sensing resistor (Vasara Surakka, 2021). Instead of an online study as described in Section 3.5, the experiment can be carried out in a more controlled lab setting.

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