THE PSYCHOPHYSIOLOGICAL EFFECTS OF TOUCH AND ODOR

ผลทางจิตสรีรวิทยาของการสัมผัสและการดมกลิ่น

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ABSTRACT

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KEYWORDS: PSYCHOPHYSIOLOGY/ BIMODAL STIMULI/ OLFACTORY MODALITY / TACTILE MODALITY/ SENSORY INTEGRATION/ EMOTIONAL PERCEPTION

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In everyday life, the emotional perception often occurred in different modalities at once but knowledge about multisensory perception on emotion was minimal. To understand emotional integration, odors and touch were used in two experiments. The first experiment was conducted to distinguish the emotional effects of different odors and to examine the effect of gender difference with respect to emotional perception. The aim of the second experiment was to determine the emotional integration of bimodal stimuli. The self-report and psychophysiological responses from forty-five participants were computed. Data were analyzed by two-way mixed ANOVA and two-way repeated measures ANOVA, statistical significance at the .05 level.

The findings highlight that there was no crossed interaction between olfactory and tactile modalities in the aspect of emotion. The bimodal stimuli did not enhance the emotional perception of unimodal stimuli. Civet oil markedly elicited an unpleasantness. Michelia oil elicited objective arousal, meanwhile, Lavender oil elicited a pleasant feeling. In addition, 3 cm/s stroking touch elicited subjective pleasantness with moderate arousal, and 30 cm/s stroking touch elicited high arousal without the feeling of pleasantness. Moreover, men are more sensitive to some type of odor than women especially unpleasant odors and arousing odors.

This was the first work that studied the bimodal emotional perception between olfactory and tactile modalities and was a first study that revealed the peripheral psychophysiological effect of CT afferents. A further study should investigate an impact of gender and culture to emotional integration and a consistency of finding.

CONTENTS

CONTENTS (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANS	Autonomic Nervous System
cm	Centimeter
cm/s	Centimeter per Second
χ^2	Chi-square
R^2	Coefficient of Determination
CT	C-tactile
df	Degrees of Freedom
ECG	Electrocardiogram
EDA	Electrodermal Activity
ε	Epsilon
η^2	Eta squared
F	F-distribution (F-test)
HRV	Heart Rate Variability
HF	High Frequency
HFnu	High Frequency in Normalized Unit
LFnu	Low Frequency in Normalized Unit
LF	Lower Frequency
µS	Microsiemens
Ml	Milliliters
Mm	Millimeter
mN	Millinewton
Min	Minute
NS.EDRs	Nonspecific Skin Conductance Responses
OFC	Orbitofrontal Cortex
LF/HF ratio	Ratio of Low Frequency power to High Frequency power
s	Second

LIST OF ABBREVIATIONS (cont.)

sig.	Significance
RMSSD	Square root of the Mean Squared Differences
SD	Standard Deviation
SDANN	Standard Deviation of the Average Normal to Normal interval
SDNN	Standard Deviation of the Normal to Normal interval
S.E.M.	Standard Error of Mean
VLF	Very Low Frequency
v/v	Volume by Volume

CHAPTER 1
INTRODUCTION

Statement and significance of the study

In daily life, human interacts with the environment by receiving the manifold signals from the environment via sensory modalities. The occurrence of perception involves in different modalities at once. In the typical research setting, most studies focus on a single modality independently. Lately, research in multisensory processes has burst outward, and there has been an increased interest in investigating the integration of information across modalities to find out how human processes and integrates the converging information from different sensory modalities. Marked advances in the studies of multimodal interaction have been conducted in several fields from single-unit neural, neurophysiological, behavioral, and neuroimaging studies (Baumgartner, Lutz, Schmidt, & Jäncke, 2006; Brouwer, van Wouwe, Mühl, van Erp, & Toet, 2013; Collignon et al., 2008; Francis et al., 1999; Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007).

The primary roles of the sensory modalities are to detect, to discriminate, and to identify external stimuli to make rapid decisions to guide subsequent behavior. In addition to these functions, there are numerous events in the environment that integrate the sensory input with affective aspects. Knowledge in multimodal studies is inextricably linked to the emotional interaction of these senses. In the natural environment, emotional evaluations and judgments arise from the perception of several cues at once, such as, facial expressions, vocal expressions, and body movements. These aspects are simultaneously perceived multimodalities, e.g., auditory and visual. There are several reasons why multimodality is useful. For example, uncertainty in one sensory channel can be easily compensated and complemented by others channels. As a matter of fact, it has been reported that a response to multimodal stimuli was greater than that to unimodal stimuli, and was often larger than the sum of the unimodal responses (Angelaki, Gu, & DeAngelis, 2009).

Over the past decades, several studies have addressed the question of how emotional information from distinct modalities is processed. Many behavioral, neurophysiological, and neuroimaging studies have specifically addressed the merging of emotional information from different sensory modalities. It appears that the interaction of emotion processed by different channels can occur at the very initial stages of neural processing. Thus, the affective stimuli in one sensory modality can powerfully affect emotional processing in the other modalities (Gerdes, Wieser, & Alpers, 2014). Particularly useful data on this issue have been offered by neuroimaging studies of voice and face that have provided new insights into the neural processes underlying this interaction (Baumgartner, Esslen, & Jäncke, 2006; Collignon et al., 2008; Hietanen, Leppänen, Illi, & Surakka, 2004; Klasen, Chen, & Mathiak, 2012).

As a general trend, research on multimodality tends to focus on visual and auditory channels as the major routes for social information. The other modalities, in particular olfactory and tactile, can process significant action in sociality as well. The sense of smell plays a considerable and essential role in social and sexual behavior, identification, and detection of hazards while touch typically implies an interaction with another person. Olfaction extends behind odor discriminative ability, as this sense is also associated with emotional processing: It facilitates the recognition, and memory (Francis et al., 1999; Rolls, Kringelbach, & De Araujo, 2003). The scents can elicit or even modulate an individual psychological and physiological state which may be pleasant, unpleasant, calm, or arousing feeling. Besides the olfaction, the sense of touch is also able to modulate emotion, to enhance the meaning of other forms of communication, or even to allow sharing feelings with others (Diego & Field, 2009; Liljencrantz & Olausson, 2014; Lindgren, Jacobsson, & Lamas, 2014; McGlone, Vallbo, Olausson, Loken, & Wessberg, 2007). A touch on the skin can be a more powerful means of modulating human emotion since the C-tactile (CT) afferents nerves are found in human hairy skin in high quantity (Morrison et al., 2011). A gentle and low-speed stroking to these fibers provide an afferent signal processing of pleasant touch, related the subjective pleasantness to brain reward system (Liljencrantz, Marshall, Ackerley, & Olausson, 2014; Macefield, Norcliffe-Kaufmann, Löken, Axelrod, & Kaufmann, 2014; McGlone et al., 2007; McGlone, Wessberg, & Olausson, 2014; Morrison, 2012; Triscoli, Olausson, Sailer, Ignell, & Croy, 2013). The application in the affective aspect of touch is also clear and plays a crucial role in growth development and well-being (Field, 2014; Field, Diego, Delgado, Garcia, & Funk, 2011; Field, Diego, & Hernandez-Reif, 2007; Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005; Field et al., 1996). Moreover, touch cooperates with odor in enhancing the sense of well-being. The Beneficial effect of the cooperative touch and odor is implicated in applying in clinical setting of a massage together with aromatherapy (Neelakshi & DhivyePraba, 2014; Stevensen, 1994; Wilkinson, Aldridge, Salmon, Cain, & Wilson, 1999; Wilkinson et al., 2007). However, the finding on this topic is not univocal, as there is evidence that fails to support the synergic effect of this combination (Brooker, Snape, Johnson, Ward, & Payne, 1997; Fu, Moyle, & Cooke, 2013; Stevensen, 1994). Up to date, the effect of the synergic effect of the touch-odor combination is not fully understood, and the hypothesis about the efficacy of massage combined with aromatherapy remains clearly unproven.

As mentioned above, most studies on emotional perception focus on using unimodal stimuli. Many early multisensory studies have focused on the study of emotional integration in the audiovisual modalities and have ignored the olfactory and tactile modalities. There are remaining questions how these different stimuli direct at their senses then elicit similar outcomes, and if the multiple sensory modalities are simultaneously elicited at a time whether the result will be a cumulative effect or not. The evidence of subjective measure and neuroimaging studies through a single modality can be assumed that the corresponding underlying mechanism of touch and odor for the bond of emotion might affect the pleasure and reward system (Herz, 2009; Kida & Shinohara, 2013; McGlone et al., 2007). However, there are no many studies examine emotional perception through the combination of different modalities, such as odor and touch.

To investigate the multisensory integration of emotional perception, the emotional stimuli of olfactory and tactile modalities are manipulated in two experiments. The first experiment is conducted to determine the emotional effect of unimodal stimuli, processed through the olfaction channel, in order to detect the emotional effects of different odors and to select two distinctive emotional expression odors. The present study also investigates the effect of gender difference to emotional perception because there is evidence that the emotional and perceptual differences are affected by gender; as men and women process emotions and react to them differently (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Chentsova-Dutton & Tsai, 2007; Lithari et al., 2010). Moreover, two distinctive emotion-elicited odors from the first experiment are used in the second experiment in order to determine the possible integration of emotion between bimodal emotional stimuli when they are simultaneously perceived. To address these issues, therefore, the researcher measures the effects of unimodal and bimodal stimuli regarding the self-report of emotion evaluation and peripheral psychophysiological responses. The self-report is a feeling assessment that infer to present emotional state by follow the dimensional model of Russell & Mehrabian (1977). A 9-point rating scale is used to measure the subjective state along the three dimensions of valence, arousal, and dominance. Stimuli elicit the emotions often lead to autonomic changes (Ekman et al., 2007), physiological indices reflect the nature of emotions as action dispositions that is mediated by sympathetic activity to prepare the organism for appropriate behavioral responses (Cacioppo, Tassinary, & Berntson, 2007). Electrodermal and cardiovascular responses are acknowledged to index the arousal and the valence level of emotional stimuli, respectively. In this study, the peripheral psychophysiological effects are recorded simultaneously and continuously in four variables composed of the heart rate, heart rate variability by frequency domain, skin conductance response amplitude, and breathing rate. The study is hypothesized that individual emotional stimuli evoke different emotional states, and these various emotional perceptions are affected by gender. Also, it is hypothesized that there is an emotional additive effect for bimodal stimuli. Consequently, this study will contribute to gain better insight into the multisensory integration of emotion and to increase experiential data to delineate the significant features of emotional integration. Ultimately, it may help us to understand the underlying emotional, perceptual processing of bimodal stimuli in the olfactory and tactile modalities.

Research questions

This study aimed to address the following issues:

In the first experiment

1. Was there a difference in emotional perception under the experimental condition of unimodal stimuli, processed through odor channel?

2. Was there an interaction effect between odor and participant's gender with respect to the emotional perception?

In the second experiment

1. Was there the integration of emotion for congruent and incongruent bimodal stimuli?

Objectives

In the first experiment

1. To determine the difference in emotional perception of unimodal stimuli *via* the self-report and peripheral physiological response.

2. To determine the interaction effect between gender and odor with respect to the emotional perception *via* the self-report measure and the peripheral physiological response.

In the second experiment

1. To determine the possible of multisensory integration of emotion for bimodal stimuli (i.e. odor and touch) *via* the self-report and peripheral physiological response.

Hypotheses

Based on the review of previous research, it could be hypothesized as follows:

In the first experiment

1. Pleasant odor will elicit pleasant feeling by increase in valence rating score and increase in high frequency in frequency domain of heart rate variability, meanwhile unpleasant odor will result in contradiction.

2. Participants' gender will modulate emotional perception of stimuli.

In the second experiment

1. Multisensory congruent stimuli (i.e., pleasant touch and pleasant odor) will elicit a higher emotion than unimodal stimulus at the same dimension of emotion.

Contribution to knowledge

1. The findings and the knowledge gathered through this research will contribute to further understanding the emotional multisensory integration.

2. The empirical data will ultimately lead us to understand the underlying mechanisms and consequently help to optimize clinical application.

Scope of study

This study focused on the emotional perception of unimodal and bimodal stimuli by using odor and touch as representatives of these modalities. The emotional states were examined via self-report and peripheral psychophysiological responses.

Definition of terms

Psychophysiology is the study of physiological signals to understand psychological processes. It emphasizes the particular relationship between emotion and bodily responses. Psychophysiological indices are used as indicator of emotion in this study since the bodily reactions were emotional experiences to stimuli

Emotion is defined in terms of a temporary change in feeling state. Emotion is elicited by an affectively salient situation through the sensory modalities. Emotion involves coordination of multiple systems, such as physiology, psychology, brain activity, behavior.

Valence domain refers to emotional feeling in the dimension of pleasantness versus unpleasantness.

Arousal domain refers to emotional feeling in the dimension of arousal versus calmness.

Dominance domain refers to emotional feeling in the dimension of the ability of feeling is in control versus the ability of feeling is not in control.

Multisensory refers to the processes that incorporate information from more than one sensory modality at once. Sometimes, the term *multimodal* is used as a synonym.

Multisensory integration is the process of simultaneous stimulation that results in information from two or more sensory modalities are combined and taken into in the brain to form a response that enhances ability to perceive and understand environment, and provides an appropriate interaction with.

Congruent stimuli refer to types of stimuli that produce the same response.

Incongruent stimuli refer to types of stimuli that produce the opposite response.

Superadditivity refers to the value of response that the sum of response to multisensory inputs results higher activity than that predicted by the sum of the response from unisensory input.

CHAPTER 2
LITERATURE REVIEW

The literature review of this study is described in six main parts as outlined below:

1 Emotional experiences
2 Olfactory modality and its affective aspect
3 Touch modality and its affective aspect
4 Multisensory integration
5 Gender difference
6 Peripheral psychophysiological responses

Emotional experiences

In general of daily life, emotions are found to occur in many concrete situations such as a changing in cognitive processes, physiological and behavioral response systems as they were a core of human behavior (Klasen, Kreifelts, Chen, Seubert, & Mathiak, 2014). Emotions evolve to promote survival and to help the organism respond appropriately to environmental challenges (Bradley, Codispoti, Cuthbert, & Lang, 2001). Moreover, emotion has been associated with all mental processes; any activity remaining is accompanied by emotional experiences (Valenza & Scilingo, 2013), sometimes, acts as social regulator to facilitate social interaction, playing a role in guiding cognition, motivated and organizes perception as well as thinking. There are many theories of emotion to be proposed by emotional theorists (Strongman, 2003). The best known of emotional theory is James–Lange theory. This theory is independently created from two theorists called William James (1884) and Carl Lange (1885) with the same idea. They are limited the description of emotion in field of producing bodily expression. This means that the bodily responses follow the perception of an event along with the producing of mental affect that corresponds to the emotional experience. The main point of this theory is a feedback from visceral organs that produces the feeling of emotion. This theory emphasizes that only cognitive processing alone will not be enough evidence of an emotion, the expression on physiological arousal is a crucial reaction of interpreting an emotion. The second theory is proposed by Cannon-Bard as the Cannon-Bard theory (1915, 1927). This theory is an alternative theory away from James-Lange theory. The theory emphasizes on the neurophysiology of emotion regarding the importance of thalamus to emotion. The theory brings into the experience that emotion almost simultaneously happen with the bodily changes. Through their research, Cannon and Bard concluded the experience of an emotion does not depend on input from the body and how it is responding. Both the experience of the emotion and the bodily response occur at the same time independently of each other. The same bodily responses accompany many different emotions. For example, when your heart is racing, it may mean you are angry, but it may also mean you are excited in a positive way. This means that our brain cannot just rely on our bodily responses to know which emotion we are experiencing (i.e., there must be something else that tells us whether we are angry or excited). However, some years later, Stanley Schachter and Jerome Singer (1962) propose another theory called the Schachter-Singer theory. The theory suggests that experiencing an emotion requires both bodily response and an interpretation of the bodily response by considering the particular situation the person is in at the moment. The visceral involvement is necessary although not a sufficient condition for the occurrence of emotion. This theory shows that cognitive processes are important to provide the label of emotion; people will label an emotion in event after they process the physiological arousal through cognition. For instance, if a heart is racing and an alligator is chasing with, this might be interpreted as fear. If a heart is racing while looking at the beloved person, this case might be interpreted as excitement. Even though the bodily response is the same, person might experience very different emotions depending on the type of situation. In this study, emotion will be defined as the feeling/affective states that are elicited by stimuli, when emotion is intense then it results in bodily action (Cacioppo, Tassinary, & Berntson, 2000; Kadohisa, 2013). The state changes have produced bodily changes (including motor behavior, facial expression, autonomic changes, and endocrine changes) and changes in the processing mode of neural systems (a changing in the way that brain processes information) (Borod, 2000; Scherer, 2005).

Several investigations have supported the notion that there is a correlation between emotional perception and reward system, such as the correlation of either arousal stimuli or pleasure stimuli related to rewards. Berridge and Kringelbach, (2008) state that pleasure stimulus evokes a responding in the same direction with a liking reward. Moreover, Lang, Greenwald, Bradley, and Hamm (1993) have found that an increase in arousal is the essential element associated with positive rewards while a decrease in arousal is the key factor with negative punishment. In evaluative hedonic processing, pleasure is divided into two sub-components of core liking and subjective liking that depend on non-concious and concious events, respectively. Besides emotion, subjective liking along conscious emotion also need cognition to vastly expand the range of events that can trigger pleasure including cognitive and cultural sources (art, music, dinner party, intellectual and aesthetic rewards) and provides the regulatory route for new top-down to amplify or dampen a pleasure or displeasure. Brain mechanisms of conscious elaboration are likely needed to convert a physical liking reaction to a pleasant stimulus into a subjectively feel liking experience. To produce pleasure, the cognitive capacity transforms and elaborates our mental representations of the pleasurable events by altering the attention we pay to them and the way we think about pleasure. The added capacity from thinking help to promote a positive hedonic that impacts to the sensation of liking. Without that cognition, even a sweet sensation can remain neutral or become unpleasant. Since pleasure can be subjective as well as objective features, liking can sometimes occur unconsciously as an objective feature. Unconscious emotion occurrs either when people were not consciously aware of the emotional stimulus or when they show any signs of emotion (e.g., psychophysiological changes) even though they do not report any accompanying changes in emotional experience (Wiens & Öhman, 2007). Objective pleasures are an unconscious hedonic reaction where people remain unaware of an emotional stimulus and their hedonic response to it. It should be noted that objective liking-related reactions as well as subjective pleasure ratings (liking in the ordinary sense) can be measured (Berridge & Kringelbach, 2008; Kringelbach, 2005).

Numerous neuroimaging studies have revealed areas of cortical region (e.g. orbitofrontal, anterior cingulate and insula cortices) as well as subcortical structures (nucleus accumbens, ventral pallidum, amygdala, and mesolimbic tegmentum) that can be activated by various sources pleasure (Kringelbach, 2010; Lindgren et al., 2012; Rolls, 2010, 2012; Rolls & Baylis, 1994; Rolls, Kringelbach, et al., 2003; Rolls, O'Doherty, et al., 2003; Royet, Plailly, Delon-Martin, Kareken, & Segebarth, 2003) Moreover, Rolls, Grabenhorst, and Parris (2010) have shown that many stimuli and events represent the affective value in OFC and anterior cingulate cortex, in addition, the representation of these regions in brain also correlate with subjective ratings. However, each psychological pleasure have no them neural circuit. They share mesocorticolimbic circuit or single common neuron currency. In the point of overlapping pattern raises the possibility that the hedonic events is generated in the same circuit and embedded in larger mesocorticolimbic systems even when the ultimate experience of each seems otherwise unique. Moreover, the weight of evidence from the research on causation of emotion reveals that emotional reactions may be generated mainly in subcortical brain structures rather than by any of the cortical regions. Pleasure generators are much more anatomically restricted than previously envisioned, localized to particular sub-regions. There is not find a hedonic-enhancing hotspot, the pleasure-generated areas, in prefrontal cortex. Functionally, restricted hedonic hotspot circuits generate pleasure liking is in nucleus accumbens and ventral pallidum. Nucleus accumbens and ventral pallidum interact together in a single integrated circuit to mediate pleasure enhancements. However, causation may be more anatomically restricted than a representation of emotion because only a few of its structures represent an emotional reaction need to cause that reaction. Other structures may represent emotion as a step to generating their different functions, such as cognitive appraisal, memory, decision making, and so forth (Berridge & Kringelbach, 2013).

Over the years, literature on emotion has resulted in two entirely different models of emotion consisting of the discrete model and the dimensional model (Coan & Allen, 2007). In terms of discrete emotion, the discrete model is referred as basic emotion and is emphasized an existence of single emotional category, such as, fear, anger, happiness, disgust and sadness which are characterized by a distinct response profile in natural kinds of emotional experience. Several theorists have claimed and proposed their supporting theories which are different in minimal numbers of core emotion but they are coherent basic concept of no cross cultural difference. Moreover, discrete emotions can be distinguished by a facial expression and biological responses. For instance, Tomkins (1962), has cited in Gendron and Barrett (2009), proposes that emotion can be expressed basically in eight emotions: Surprise, interest, joy, rage, fear, disgust, shame, and anguish, meanwhile, Izard (1992) declares 12 discrete emotions in his study field by Differential Emotions Scale. A popular theory is a proposal of Ekman and his colleagues' cross-cultural study of 1992, in which they concluded that the six basic emotions are anger, disgust, fear, happiness, sadness, and surprise. In addition, Ekman (1992) has concluded from his study that there is six discrete emotions can be expressed composes of anger, disgust, fear, happiness, sadness, and surprise. By contrast to discrete model, the dimensional model has conceptualized multidimensional space of the underlying emotions such as arousal and valence. There are a several dimensional theories that differ in the minimum number of dimensions to represent emotion, and also differ in the ways in which dimensions combine with other processes to create an emotional experience (Fontaine, Scherer, Roesch, & Ellsworth, 2007). Dimensional models have been shown to be empirically powerful, successfully accounting for a broad range of emotion effects (Hamann, 2012).

Regarding the dimensional model, the three emotional dimensions’s model of Russell and Mehrabian (1977) have focused on the basic dimensions of emotional responses. The model provided a sufficiently comprehensive description of emotional states via its three orthogonal dimensions: Valence, arousal, and dominance. This model is used in several subjects, for example, the studies in neuropsychological sciences, environmental psychology, marketing research, computer systems, and psychological research. Two Mehrabian’s studies have shown that three dimensions independently separate and each dimension has bipolar side of pleasure-displeasure, calmness-arousal, and dominance-submissiveness. Overall, three dimensions are necessary and sufficient to adequately describe the emotional response to all types of stimuli (Russell & Mehrabian, 1977). Valence is defined regarding a person’s level of pleasure on positive versus negative feelings by using adjectives, such as, happy-unhappy, pleased-annoyed, and satisfied-unsatisfied (Bakker, van der Voordt, Vink, & de Boon, 2014). Arousal is defined regarding the level of mental alertness and physical activity by using adjectives, such as, stimulated-relaxed, excited-calm, and wide awake-sleepy (Mehrabian, 1996). Dominance is defined regarding the ability of feeling control versus the influence of stimuli. If the third dimension is dominant, this means a person's feeling is in control and/or powerful and/or not overwhelmed; subject is able to influence over the circumstance. On the other hand, if subject feels overwhelmed and/or not powerful and/or not in control, that meaning is submissive. The dimension of dominance is bonded a relation between the environment and the individual. This dimension is not a truly emotion, but a strong cognitive correlation of emotion. It convey as a controlling in a perceived consequence of emotion, rather than an emotion per se. In other words, it can be said that dominance represents a reaction toward to approach something; meanwhile, submission reacts toward to avoid something. The dominance-submission dimension relates to affective states of high or low coping potential, and emotions, such as, fear versus anger, thankfulness versus contentment, and happiness versus impressiveness. Furthermore, it can be concluded that removing dominance dimension also eliminates the differentiation between approach and avoidance behavior. These three dimensions are independent that any values along one dimension can occur simultaneously with any values on either of the other two dimensions. Bradley and Lang (1994) have supported using a dimensional model in three dimensions for accurately assessing of emotional response and completely representing to emotional experience. Moreover, Bakker et al. (2014) have suggested to replace the two-dimensional model of valence and arousal orthogonal angle by a three-dimensional model with the third axe of dominance.

Several psychological studies, emotion measurements mainly rely on a variety of methods that elicit judgments from participants. The emotion enables to be inferred from three different response systems, namely, self-reports, psychophysiological responses, and motor expressions of behavior. Numerous psychological studies of emotion have been concerned with the patterns of those changes (Scherer, 2000; Wiens & Öhman, 2007). Regarding the feeling assessment, participants declare their emotion via the self-report. On the other hand, overt actions, such as facial expressions are used extensively in studies of motivated behavior. Additionally, physiological responses are not visually observable events that can be assessed using psychophysiological instrumentation.

Altogether, emotions can be elicited by stimuli that result in changing in the neural processing, behaviors, autonomic nervous system, and endocrine system. The alteration of emotion could be conveyed in the aspects of discrete model and dimension model. However, three-dimensional model has been more powerful, and successful for examining a broad range of emotion effects. This model focuses on answering dimensions of valence, arousal, and dominance. To study the occurrence of emotion, its representation can be studied while a presentation of stimuli via sensory modalities. The emotional experience can be inferred from three different response systems, namely, self-reports, psychophysiological responses, and motor expressions of behavior.

Olfactory modality and its affective aspect

The Olfaction system

Olfaction involves the inhalation of volatile chemicals which flow through nostrils into the nasal cavity, passed turbinates, dissolves in the mucous coating and then reaches the olfactory receptor cells within a region of the olfactory epithelium. The receptive parts of the olfactory receptor cells are tiny hairs that usually interact with external odorous molecules through vastly different receptor sites. Since odor interacts to olfactory receptor, result in a depolarization and a generation of nerve impulse that directly conveys to the brain via the olfactory nerve (Axel, 1995; Finger, Restrepo, & Silver, 2000; Laurent, 1999). Individual odor directly processes nerve impulse by mapping via gene-specified receptors to the related glomeruli in the olfactory bulb to the piriform cortex without a thalamic transmission. The piriform cortex also has a projection to the amygdala and prefrontal cortex or orbitofrontal cortex (OFC), which involve in the processes of emotion and emotion-related learning (Calvert, Spence, & Stein, 2004). Moreover, the olfactory bulb and piriform cortex project to the entorhinal cortex, which in turn project to the hippocampus where olfactory information can be incorporated into long-term episodic memory. Furthermore, the olfactory stimuli provide an influenced route to autonomic nervous system and endocrine system through amygdala’s projection to the hypothalamus (Kadohisa, 2013).

Historically, olfaction has been recognized for their power to evoke strong emotional reactions. In contrast to vision, audition, taste, and tactile, that involve early cortical processing in sensory unimodal brain areas, chemosensory processing by olfaction initially happens in limbic, and paralimbic regions that distinctly accompany in emotional processing. Stevenson (2010) emphasizes the strong link between olfaction and emotion. He has classified olfactory functions into three broad categories relates to ingestive behaviors, avoidance from environmental hazards, and social communication. All three functions are inextricably linked with emotional evaluation (Armony & Vuilleumier, 2013).

Affective aspects and the representation to odors

The olfactory modality shows the functioning of detection, discrimination, and identification. Moreover, the inputs receive through the amygdala, and OFC which serve as a sensory gateway to the emotions are a cause of odor’s direct effect on emotional processing (Ehrlichman & Bastone, 1992). A neuroimaging study of Rolls (2000) supports that unpleasant odors and pleasant odors activate the amygdala and OFC, which were consistent with their functions on emotion. Moreover, the elicitation of odors in OFC also correlates with the subjective pleasantness or unpleasantness of odors. Functional magnetic resonance imaging study has revealed that there are separated regions of the human brain represent to pleasant and unpleasant odors. A medial region of the rostral OFC is activated with pleasant odors. The pleasantness activation is also shown in the anterior cingulate cortex, with a middle part of the anterior cingulate cortex by unpleasant odors. Furthermore, there is a correlation between the subjective pleasantness ratings during an activation of a medial region of the rostral OFC and an anterior part of the anterior cingulate cortex (Rolls, Kringelbach, et al., 2003). The strengthened function of OFC to emotion also shows an area specificity of left OFC activation to pleasant odor (Royet, Plailly, Delon-Martin, Kareken, & Segebarth, 2003)

Besides revealing the emotional effects of odors via subjective rating, there is change on physiological indices while odor perception takes place. For instance, pleasant and novel odors produce a decrease in heart rate while the arousal odor increases the skin conductance response (Alaoui-Ismaïli, Robin, Rada, Dittmar, & Vernet-Maury, 1997). Bensafi et al. (2002) have shown that the correlation between pleasantness and heart rate variations, arousal and skin conductance changes. Furthermore, Alaoui-Ismaïli, Vernet-Maury, Dittmar, Delhomme, and Chanel (1997) have shown that there is a specific autonomic pattern to the responding of each odor.

Together, emotion can be elicited by olfaction. Odors are strong linked to the OFC and amygdala in the brain by passing through an olfactory modality that cause olfactory stimuli functionally involve in the emotional processing, and influence the autonomic and endocrine systems. Moreover, odors can elaborate for long-term memory as well. The emotional effects of odors have been revealed by many methods, such as, self-assessment, physiological indices, and neuroimaging in order to specify their associated areas, and their functions on emotion as pleasantness, unpleasantness, or arousal odor. It can be concluded that a pleasant odor produces a decrease in heart rate and heart rate variations, meanwhile, an arousal odor produces an increase in a skin conductance response.

Touch modality and its affective aspect

Touch system

The skin is classified as either glabrous or hairy. As former knowledge, this sense performs primary role similar to other senses as detection, discrimination, and identification external stimuli in order to ultimately making rapid decisions for guidance a subsequent behavior. To achieve these purposes, a significant functional part of the interaction to stimuli is carried out by the palmar surface of the hand. The surface directs to perceive the pressure, vibration, slip, and texture, to provide the tactile information about handled objects and during the exploratory procedure. The skin of palmar surface was the glabrous skin similar as the plantar surface of the sole. Both palmar and plantar surfaces are mediated by low-threshold myelinated mechanoreceptor A-beta afferent nerves enabling fast conduction velocities is known as a rapid touch system. On the other hand, a few decades ago, another one touch system was found. The following system is mediated by low-threshold unmyelinated mechanoreceptor CT afferents responded to light touch, low-force and low-velocity moving stimuli. CT afferents are found only at the human hairy skin, and show a preference for stimulation like a caressing movement across the skin surface. To elicit impulse rates, their conduction velocity is vary between 0.6 and 1.3 m/s with 50–100 impulses/s of frequency responses by touch the skin with force as low as 0.3–2.5 mN (Triscoli et al., 2013). The relationship between stroking velocity and firing rate is distinctly different between CT and myelinated afferents. CT afferents have an inverted U-shaped relationship between stroking velocity and firing rate with highest responses between 1 and 10 cm/s. Very slow stroke (0.3 cm/s) and very fast stroke (30 cm/s) decrease the firing rate of CT afferents. By contrast, the firing rate increases with stroking velocity in all myelinated afferent type (Löken, Wessberg, Morrison, McGlone, & Olausson, 2009).

Affective aspects and the representation to touch

The functional role of unmyelinated afferents in coding the tactile stimuli for affective aspect is in a consideration that CT stimulation have closer relation to limbic function than to cognitive and motor functions (Vallbo, Olausson, & Wessberg, 1999). Olausson et al. (2002) state that CT afferents are the system for limbic touch that may underlie emotional, hormonal, and affiliative responses to cares-like, interpersonal skin-to-skin contact. There are several studies that support the sustainable effects of CT afferents underneath the emotional aspects and are well suited to emotive rather than discriminative functions. By that ways, light or soft touch can be represented through a several biological approach to support the existence of CT afferents and to add a stronger relation between them and some of the affective brain areas. For instance, McGlone et al. (2012) have revealed that a slow brush stroking on forearm can activate posterior insular cortex and mid-anterior orbitofrontal cortex. In addition, the posterior insula also plays an integrative role among somatosensory inputs and interoceptive inputs. This pathway is considered as an afferent limb of the sympathetic nervous system, implying that it carries the information closely to a relationship with regulatory and homeostatic processing (Morrison, 2012). The activity of CT afferents also extend to OFC in brain that implicates in emotional and reward processing. Previous studies by functional magnetic resonance imaging have supported the evidence that the pleasant touch activates OFC and also supported the idea that posterior insular cortex may potentially be a primary cortical target for CT afferents. (Rolls, O'Doherty, et al., 2003; Francis et al., 1999). Additional study to selective CT stimulation in patients, who suffers in a permanent and specific loss of the major myelinated afferents that affects their whole body below the nose, reveal that the insular cortex remain to be activated but not of somatosensory areas S1 and S2 (Olausson et al., 2002; Olausson, Cole, Vallbo, et al., 2008). In addition, Morrison (2012) has shown a correlated result in patients with a congenitally reduced density of unmyelinated sensory fibers that the participants rate less pleasant even stroking gently, and the posterior insula does not show an activation. Besides the posterior insular cortex and OFC, the superior temporal sulcus, pregenual anterior cingulate cortex, and amygdala are brain regions that have been shown responding to slow stroking stimuli (Lindgren et al., 2012). Furthermore, a study by microneurography technique of Löken, Wessberg, Morrison, McGlone, and Olausson (2009) have confirmed that there are a correlation between a soft brush stroking touch and pleasantness, and among the velocities that provide the 1-10 cm/s stroking velocities are perceived as the most pleasantness. Löken et al. (2009) reveal that there is a correlation between firing rates and ratings of pleasantness. Moreover, a study in the neuropathy to investigate the effect of CT afferents against sympathetic skin response results that brush stroking evokes sympathetic responses (Olausson, Cole, Rylander, et al., 2008).

Since, touch technique is applied to clinical and commercial settings, i.e. massage therapy. The touch efficiency is revealed through investigation into the efficiency of light versus modulating touch in preterm infants study reports that both of them decrease heart rate, increase vagal tone, decrease stress behavior. However, moderate pressure massage appears to be more relaxed, less aroused and gain weight (Field, Diego, Hernandez-Reif, Deeds, & Figuereido, 2006). Touch massage on hand and feet by 2.5 N the force and 1–5 cm/s the velocity has shown a decrease in heart rate, HRV, saliva cortisol, and insulin levels (Lindgren et al., 2010). Furthermore, the superior effect of moderate pressure over light pressure is revealed by studies of Diego, Field, Sanders, and Hernandez-Reif (2004), and Diego and Field (2009) that moderate pressure massage increases a HF component of HRV, decreases a LF/HF ratio and increases a heart rate. On the other hand, the light pressure massage exhibits an increase in sympathetic activity and increase in heart rate. Moreover, electroencephalogram study has supported that moderate massage increases a positive emotion as well.

Together, besides the primary roles, touch can produces emotions. Light and slow stroking of touch on the hairy skin elicits the key areas in brain, such as, insular cortex and OFC. The stimulations to these areas support the effect of touch underneath the emotional aspects and imply its relation to emotional and reward processing. A soft brush stroking touch can elicits pleasantness and arousal feeling.

Multisensory integration

Sensory modalities

Theoretically, Sensory neurons process information from sensory receptors to the central nervous system by translation sensory signals, such as, light, pressure, or voice into neural signals. A single neuron enables to transmit the information from a sensory receptor in muscle, skin, or an internal organ, but the retina of the eye, directly to the spinal cord or brain without synaptic neuron processing occurcs before the sensory neurons enter the central nervous system. Once a sensory signal reachs the spinal cord or the brain, other neurons convey that information to sites both within the central nervous system and, in some cases, to motor neurons leading back out of the central nervous system. The neurons system does not connect muscles directly to other muscles or glands, nor does it conduct sensory information from the environment directly to the muscles. Rather, the sensory signal goes straight to the central nervous system, from where it is redistributed. This arrangement provides the capacity for integrating incoming sensory signals with conditions elsewhere in the body where the central nervous system plays an executive capacity for coordinating action and function throughout the body. To explain an accompanied function that body reacts to the external world, Francis and colleagues (1999) state that the functions of taste system are seperated by taste areas. The primary taste cortex represents to the identification taste and intense level of taste, whereas the secondary taste cortex is accounted for the affective aspect of taste that relates with reward region in orbitofrontal cortex. In terms of visuality, the ventral visual system represents objects in the inferior temporal visual cortex, and presents the reward associations of visual stimuli in the OFC and amygdala (Collignon et al., 2008). In the touch system, the outputs of the ventral (anterior) somatosensory pathway is likely to be found in contact to the insula and OFC, and via both structures to the amygdala. The positively affective components of touch are likely represented in the output of central touch system than the somatosensory projections to the parietal cortex, meanwhile, the somatosensory system is involved in spatial aspects, such as, the position of the limbs of somatosensory representation (Francis et al., 1999). In the odorous pathway, this system mainly involves with a perception of chemosensory stimulus through olfactory cavity. Since signal is inputted in olfactory bulb, the projection will be directly transferred to the piriform cortex in the temporal lobe before the tract separates to two different brain's regions: OFC in forebrain region and amygdala provides the further representation in various bodily reactions. In the sense of hearing, once the sound waves enter to ear and the processes go to produce the neural processing. The neural information will be signaled to brain via thalamus and then is passed to the primary auditory cortex where is in the temporal lobe. The primary auditory cortex functions for responding the perception of sound, such as, pitch, rhythm, and frequency

Sensory integration of emotion

In daily events, the perceptions often occurr in multisensory modalities simultaneously, for example, hear voice while seeing a picture. It is clear that information from one modality influences to the perception of another modality. Sometimes, the perceptual information from environment is integrated and unitary. Previously, most studies have focused on finding the ability of modality independently. Later, Tang, Wu, and Shen (2016) reveal that there are a lot of neural areas involve with multisensory integration. The multisensory integration can occur across multiple neural levels; such as, at subcortical levels, at the level of associated cortices, and at the lowest cortical levels in primary sensory areas that are considered to be unisensory area. Several multisensory processing's studies show a number of cortical and subcortical human brain areas are consisted of superior colliculus, superior temporal sulcus, superior parietal lobule, intraparietal sulcus, and prefrontal cortex. Most studies are investigated in superior colliculus as part of the midbrain and contain a large number of multisensory neurons that play an important role in the integration of information from the somatosensory, visual and auditory modalities to play a key role in orienting behaviors (Alais et al., 2010; Barraclough, Xiao, Baker, Oram, & Perrett, 2005; Beauchamp, Yasar, Frye, & Ro, 2008; Foxe et al., 2002; Hein et al., 2007). The other areas mediate multisensory for several meaningful purposes, such as, to benefit the object recognition, facilitate behavior through anticipatory motor control, and to facilitate a semantic categorization.

Recently, there has been more interested in the investigation into sensory integration across and/or within sensory modalities. However, the multisensory integration can yield more beneficial than unisensory integration in an error reduction (Gingras, Rowland, & Stein, 2009). For example, the neural base of cross-modal of the visual and auditory study shows that visual percept objects are more precise and accurate when combine with the second source of information (Murray & Wallace, 2012). It is notable that the OFC may act as a region for convergence of multiple sensory modalities. Most sensory inputs are perceived to the OFC through its posterior parts. The study of some single neurons in the OFC area demonstrates stimulation in more than one modal stimulus (i.e. taste and olfactory stimuli, or taste and visual stimuli). The representation (i.e. taste representations) are brought together with inputs from different modalities (Rolls & Baylis, 1994). The OFC is an essential core for sensory integration, emotional processing, and pleasant experience. The OFC is available for multisensory integration and subsequent encoding of the reward value of the stimulus (Kringelbach, 2005). Increasingly, neuroimaging studies have revealed that the multisensory integration is crucial in emotional processing. The presentation of pleasant or unpleasant stimuli leads to stimulation in OFC, temporal pole, and superior frontal gyrus. Moreover, amygdala stimulation is increased during olfaction. On the other hand, the hypothalamus and the subcallosal gyrus are activated by olfaction and vision but not audition (Royet et al., 2000). Klasen et al. (2014) have concluded that there is no cortex area which can be influenced solely by one sensory modality. At least, three sensory modalities share the same core network indicates to there is no a modality-specific in response to emotional judgments. Corresponding to the study mentioned above, another study also has reported that OFC is activated by pleasant touch, taste or olfaction (Francis et al., 1999). The bimodal stimuli automatically evoke strong emotional feelings and experienced integration, and the integration happens in the early primary sensory cortices (Baumgartner, Lutz, et al., 2006; Kayser, Petkov, Augath, & Logothetis, 2005). The anatomical pathway and physiological basis for the effect of touch and olfaction are shown in Figure 2.1. Moreover, figure also shows brain areas that can be participated to a neural convergence between each other and the neural system of reward value.

Klasen et al. (2014) reveal that emotional content can also modulate multisensory integration areas. The matching affective information in different channels facilitated emotion recognition, whereas non-matching information lead to emotional conflict. The multisensory integrations are explored mainly in the two modalities relationship, auditory, and visual modalities. The congruent stimuli from different modalities have shown the advantages over unimodal stimuli, and increased activity in emotion processing. There are the variety outcomes from the interaction of both modalities that occur in several experimental techniques. The emotional experience of subjective ratings markedly increases in the congruent bimodal stimuli (Baumgartner, Lutz, et al., 2006). Bimodal congruent condition also promotes a perception of emotion expression to be faster and more accurate over the unimodal stimulation (Collignon et al., 2008). The combined conditions help achieve more reliable results, such as, ratings with physiological measures, or even within physiological indices such as, skin conductance response, heart rate, and breathing rate (Baumgartner, Esslen, et al., 2006). Furthermore, the audiovisual study using an event-related functional magnetic resonance imaging has shown that bimodal stimuli increase the performance and enhance the activation in bilateral posterior superior temporal gyrus and also right thalamus. Thus, the gained relationship to these areas serves as a role in the emotion

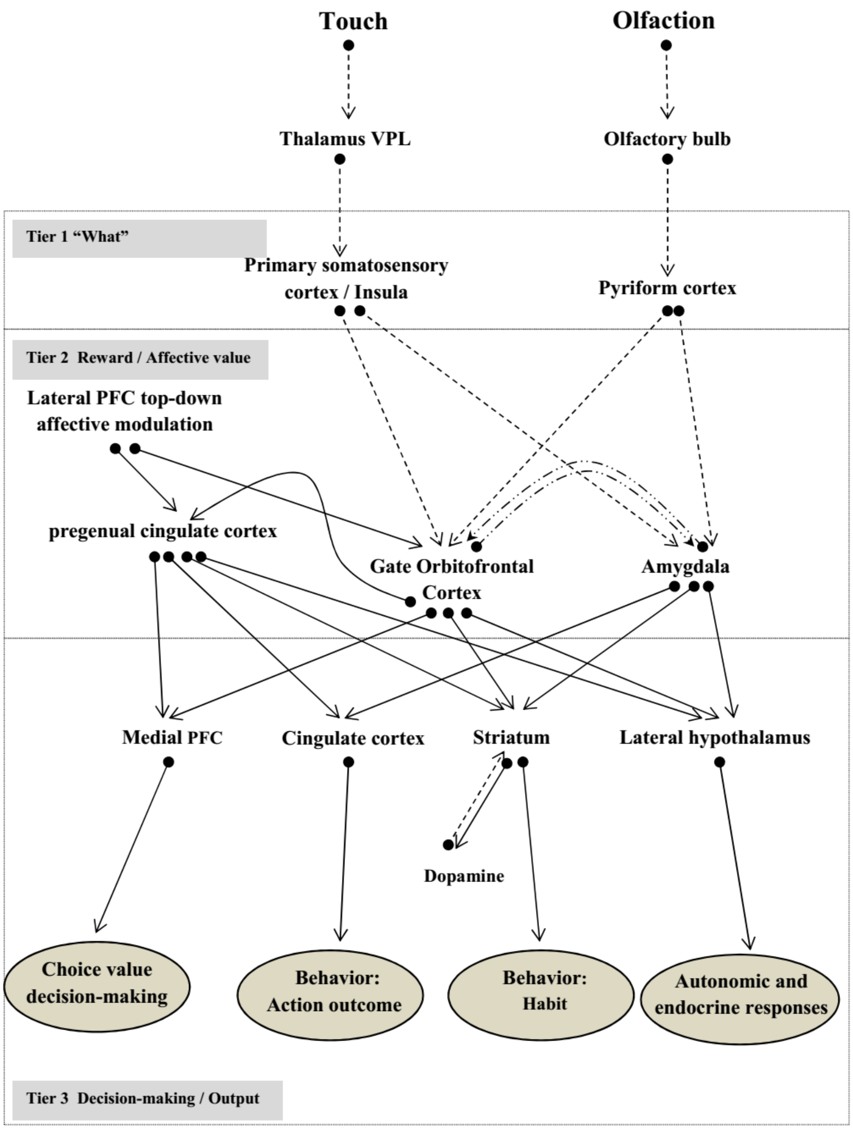

Figure 2.1 Schematic diagram of the tactile and olfactory pathways, the neural convergence, and the neural system of reward value to facilitate responses. Neural pathways of touch and olfaction can converge in various regions in the brain. Senses of touch and olfaction signal to primary sensory cortex individually (in Tier1) and build the representation of "what" object is presented, but not its reward or affective value. At Tier 2, the reward or affective value is represented in regions of the orbitofrontal cortex, amygdala, and anterior pregenual cingulate cortex. To make a decision and choice for further responses, the regions in Tier 3 are functionally based on reward value and response through several parts, such as, cognitive value of decision, behavior responses, autonomic nervous system, and endocrine system. Figure from Grabenhorst and Rolls (2011). Copyright 2016 by the Elsevier. Adapted with permission.

integration process according to the characteristic of these brain regions, (Collignon et al., 2008; Kreifelts et al., 2007). Although most studies on multisensory integrations are carried out by examination on the relation between visual and auditory modalities there are a pairs of other modalities are performed (Demattè, Sanabria, Sugarman, & Spence, 2006; Seo & Hummel, 2011). For instance, Seo and Hummel (2011) have shown that congruent or pleasant auditory stimuli can modulate odor pleasantness. Participants rate odors to be more pleasant while listening to congruent or pleasant sound. To study multisensory integration, tactile modality is brought to study its integrated effect with several modalities. Such as, Demattè et al. (2006) show that olfactory stimuli can modulate tactile perception. The fabric is perceived to be softer while present with a lemon odor compare to an animal-like odor. Even though, the study in multisensory integration would focus on the simultaneous presentation of stimuli. However, there are some studies that show the significant integration which result from pre-emotional stimulation by one modality can alter sensitivity and judgment of the other one. For example, Pollatos et al. (2007) have shown that the early perception of unpleasant picture causes a reduction in olfactory sensitivity, whereas the early perception of pleasant picture induces an increasing of odor pleasantness. Moreover, early perception of unpleasant odor has decreased a pleasantness of pleasant touch (Croy, Angelo, & Olausson, 2014).

Although the perception magnitude of bimodal stimuli to emotion processing may show more advantages over unimodal stimulus, it should be noted that the outcomes do not always gain the same results. In contrary, some studies have found that bimodal stimuli are no more potent and enhanced effects than unimodal stimulus. Brouwer et al. (2013) have supported that both pleasant and unpleasant stimuli of unimodal and bimodal presentation have a similar effect on self-report of valence and arousal, and physiological responses in heart rate, HRV, and skin conductance. The multisensory integration study between auditory and visual stimuli shows that bimodal stimuli do not increase arousal or valence levels over unimodal stimuli.

The principles of multisensory integration

There are various stimuli encounter to sensory modalities at the time. Each sensory modality processes perceptual information via the different neural partway. The neural responses to multisensory stimuli tend to be enhanced compare to one sensory stimuli. The unified response occurs by integrating signals from modalities. The sequence of multisensory processing is shown in Figure 2.2 to assess and to integrate multisensory events from the environment. The interaction between sensory modalities is meaningful in several meanings, such as, cross-modal interaction, multisensory interplay, and multisensory integration. Thus, three principles should be brought to consider for qualifying an interaction between different modalities as integration or the determinants of multisensory integration (Holmes & Spence, 2005).

1. Spatial rule: Signals from two (or more) different modalities show a stronger interaction if they originate from approximately the same location. On the other hand, the simultaneous multisensory stimuli will tend to elicit a lower response than each component alone when stimuli are originated from spatially disparate locations, such as, one falling within a unit’s receptive field and another adjacent to it.

2. Temporal rule: Signals from two (or more) different modalities show a stronger interaction if they occur at approximately the same time.

3. Inverse effectiveness: Signals from two (or more) different modalities show a stronger interaction if one of the unimodal signals is least effective (Alais et al., 2010). This kind of response enhancement is most commonly observed when the component inputs are weak and generate only modest responses on their own. However, results of interaction need to be interpreted with caution because the effects of floor and ceiling and may bias data. Calvert, Spence, and Stein (2004) show that superadditive effects to bimodal stimuli when the stimuli’s conditions meet this criterion might be difficult to detect in case that the event responses to unimodal stimuli are at or near ceiling. Perrault, Vaughan, Stein, and Wallace (2005) reveal that neurons cannot respond higher than at certain rates due to biophysical constraints.

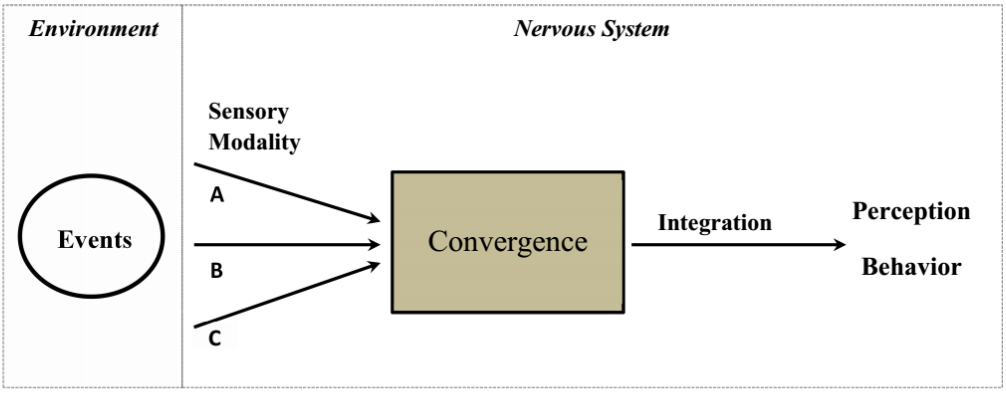

Figure 2.2 The sequence of multisensory processing. Since the environmental events encounter to a specific-modality, they are transduced by receptor specifically. Then, numerous regions of the brain have projections as modality-specific projections ('A', 'B' and 'C') that converge onto individual neurons, creating effects that are influenced by more than one sensory modality. The multisensory integration leads to alterations in perception and or behavior that would not be predicted by responses to unimodal stimuli presented alone. The shaded box indicates that little is known about the functional architecture of multisensory convergence. Figure from Meredith (2002). Copyright 2016 by the Elsevier. Adapted with permission.

Together, multisensory integration can happen in multi-neural levels, such as, subcortical levels, the level of association cortices, and the lowest cortical levels. The combining sensory information enhances ability to perceive and provides complementary information to respond the environment. The beneficial effects of integration are described in situations in which they facilitate to be faster, more accurate, and / or more precise on perception and behavioral response. However, the interpretation of integrated effect will depend on three rules of integration; spatial rule, temporal rule, and the principle of inverse effectiveness.

Gender difference

Gender-related changes can occur in various aspects of olfaction function, such as an ability to detect, to identified, to discriminative, and to memorize odors. Doty et al. (1984) show that women outperformed men at all ages. Women are higher sensitive in the perception of odors than men (Thuerauf et al., 2009). The neuroimaging studies are revealed that women showed up to eight times more activated than men in frontal and perisylvian regions (Yousem et al., 1999), in addition, left orbitofrontal cortex (Royet et al., 2003). Moreover, women respond greater changes in skin conductance and facial electromyographic (EMG) activity than men to emotional material, especially if the material is a negative valence (Chentsova-Dutton & Tsai, 2007; Lithari et al., 2010).

Peripheral psychophysiological responses

Autonomic nervous system (ANS)

We organize our experiences and distinguish our perceptions from the outside world through sensations that arise in the body. The ANS consists of two major branches: The sympathetic nervous system and the parasympathetic nervous system. These two branches differ in both function and structure. The sympathetic nervous system is functionally associated with bodily responses that mobilize the energies of the organism, get it ready to meet a threatening object with fight or flight and prepared it to meet emergencies. It tends to be more active during stress and strong emotions. On the other hand, the parasympathetic nervous system serves to conserve energy, to slow down certain bodily responses; the system is more active while relaxation and rest occur. Levenson (2014) states that ANS can play the severally different roles to serve as a regulator, activator, coordinator, and communicator. The ANS is responsible as a regulator of homeostasis to maintaining our internal bodily state within rigid condition as to minimize damage and maximize function. As an activator, the ANS facilitates short-term deviations away from homeostasis that allocates substantial resources that enable us to deal effectively with significant challenges and opportunities. As a coordinator, the ANS manages a rich, continuous bidirectional flow of data that makes critical information about bodily states and activities. As a communicator, the ANS produces visible appearance changes that have high signal value for conspecifics (Levenson, 2014). The important knowledge is that both the sympathetic nervous system and parasympathetic nervous system innervate most organs by producing opposite reactions. By these functions, the autonomic reactions that are produced by the sympathetic nervous system are dilation of pupil, inhibition of salivation, secretion of sweat, constriction of blood vessels in the periphery of the body, dilation of blood vessels in the muscles and brain, increase in heart rate, increase in blood pressure, and inhibition of digestive processes, meanwhile, the parasympathetic nervous system are constriction of pupil, increase in salivation, decrease in heart rate, decrease in blood pressure, and increase in digestive processes (Grings & Dawson, 1978).

Peripheral psychophysiology

Bodily reactions are intimately involved with emotions and feeling states. Emotional experiences cause peripheral nervous system changes, since the brain sends efferent impulses to the periphery (Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008). The ANS helps to prepare the organism for a set of diverse actions, such as, fighting, fleeing, freezing, comforting and bonding; each of which requires distinctive patterns of physiological responding (Levenson, 2003). The common indicators of emotion base on research findings include heart rate, skin conductance, blood pressure, finger temperature, respiration and pupil dilation. Markedly, emotions can be elicited by presentation of subliminal stimuli that do not enter conscious awareness. Despite the fact that feelings are typically conscious, conditions may arise under the situation which people do not report and/or are not aware of an emotional experience, despite other subsystems, such as, facial expression, physiological activation, and behavioral tendency indicate to the occurrence of emotion. Previous study primarily reveals some evidence to support the notion that the pleasantness dimension of emotion is associated with heart rate, while the intensity dimension relates to skin conductance (Levenson, 1988). Therefore, Physiological sources can importantly elucidate the valence and arousal characteristics of emotion. ANS activity is a crucial component of the emotion response (Kreibig, 2010). In this conception, sympathetic activity is associated with a mobilization in responding to aversive events, whereas pleasant emotion is related to parasympathetic dominance (Cacioppo et al., 2007).

The psychophysiological indices

Heart rate

Heart is innervated by the sympathetic nervous system and parasympathetic nervous system. Both subsystems can influence to the fluctuation of heart rate. Heart rate is the most common psychophysiological measure of cardiac activity and is measured in units of beats per minute (BPM). The normal adult had a rate of approximately 70 BPM. Heart rate can be measured by counting the number of R-waves per unit of time or calculating the interval between the successive R-waves (called either the interbeat interval or heart period). An Early study on the effects of stressors on the cardiovascular system has found that there is a vigorous and concerted action of the sympathetic nervous system in response to potent stressors, such as, fear stimuli. Stimulation of the sympathetic division accelerates heart rate and the force of contraction of the heart while stimulation of the parasympathetic division decelerates heart rate (Stern, Ray, & Quigley, 2001). Furthermore, the vast increasing in sympathetic activation effects on the cardiovascular system produces a concurrent increase in heart rate and blood pressure as well as other arousal-related responses, for instance, an increase in activity of the sweat glands and increase in breathing rate.

Heart rate variability (HRV)

HRV is the beat-to-beat variation in either heart rate or the duration of the R–R interval. HRV has been analyzed by the time intervals between heart beats. A wide range of measurement has been used to assess HRV that consists of two primary approaches by time domain and frequency domain. Time domain methods include measures of the variance among heart period. The time domain methods are simple and widely used, but are unable to discriminate between sympathetic and parasympathetic activities, while the frequency domain parameters give an appreciable contribution. The variability within any of frequency components represents a mixture of sympathetic and parasympathetic activities. Computationally, the variance of a waveform is transformed into its frequency components and transforms the time domain representation of the variance into a frequency domain representation or spectral density function. Simple time domain variables can be calculated in many indices, such as, the standard deviation of the normal to normal interval (SDNN), the standard deviation of the average normal to normal interval calculated over short periods (SDANN), the square root of the mean squared differences of successive normal to normal intervals (RMSSD).

Another approach to HRV is frequency domain analysis that contributes to the understanding of the autonomic background of beat-to-beat interval fluctuations in the heart rate record. All features extract in the frequency domain based on the Power Spectral Density of the HRV that provides the basic information of a decomposition of the total variance (power) of a continuous series of beats into its frequency components. In general, HRV by frequency domain consist of three main spectral components; High frequency (HF) component (range > 0.15 Hz), Lower frequency (LF) component (range [0.04 - 0.15] Hz), and Very low frequency (VLF) component (range < 0.04 Hz). Usually, VLF, LF, and HF power components are measured and given in units of absolute values of power (ms^2), but LF and HF may also be calculated in units of normalized units (n.u.). The normalized units represent the relative value of each power component in proportion to the total power minus the VLF component. The normalization of LF and HF are computed from raw values of either short-term frequency band (LF or HF) divided by the total spectral power (typically LF + HF), with the value of this typically expressed as a percentage or decimal. The representations of LF and HF in n.u. (LFnu and HFnu) emphasize the control and balanced behavior of the parasympathetic nervous system and sympathetic nervous system. Since the short-term recording is performed; a recording duration of approximately 1 min needs to be assessed the HF components of HRV while approximately 2 min were needs to assessed the LF components (Malik et al., 1996).

A variety of emotions have been associated with HRV decrease and increase that show some valence differences. Negative emotions more likely link to decreasing HRV, whereas positive emotions might be related to an increase in HRV. Under resting conditions, vagal tone prevailed and the variation in HF component is largely dependent on vagal modulation. The stimulation at vagal afferent leads to an inhibition of sympathetic efferent activity. On the other hand, the opposite reflex effects are mediated by the stimulation of sympathetic afferent activity. The study of McCraty, Atkinson, Tiller, Rein, and Watkins (1995) has shown that positive emotions may significantly increase HF component of a power spectrum, but the opposite effect to this component occurs with negative emotions. A particular fact of HF component that largely reflects through variations in vagal sinoatrial control and has been applied as a selective index of parasympathetic cardiac control (Valenza & Scilingo, 2013). These can be concluded in that HF component of HRV by frequency domain is largely attributable to variations in parasympathetic control and is widely used as an index of vagal control of the heart (Cacioppo et al., 2007). Meanwhile, the variability in the LF component is driven by both divisions of ANS. Consequently, a change in LF power cannot be taken as an index of alterations in sympathetic cardiac control (Berntson et al., 1997). However, Malliani, Pagani, Lombardi, and Cerutti (1991) has shown an increase in LF and a decrease in HF since the enhancement sympathetic activity occurred. Regarding investigation sympathetic activity, the ratio of low-frequency variability to high-frequency variability (LF/HF ratio) is proposed to reflect more information about the sympathovagal balance or sympathetic modulation (Malliani, 1999). The LF/HF ratio has gained wide acceptance as an index to assess the autonomic regulation of cardiovascular where the augmentation of LF/HF ratio is assumed to reflect a shift to sympathetic dominance and the reduction of this index corresponded to a parasympathetic dominance. However, it should be noted that the LF/HF ratio can be dependent on heart rate, low at decelerating heart rate and high at accelerating heart rate (Billman, 2011; Billman, 2013; Heathers, 2014).

Breathing rate

Breathing is controled by both the central nervous system and the autonomic nervous system, particularly the parasympathetic branch. Breathing rate is measured as the frequency corresponding to the maximum spectral magnitude. The standard breathing rate in humans is about 12-16 breaths per minute under resting condition. Boiten, Frijda, and Wientjes (1994) state that breathing patterns reflect the general dimensions of emotional response that link to responding requirements of the emotional situations. They have suggested that calmness-excitement, relaxation-tenseness, and active versus passive coping are major dimensions on respiratory activity alteration. Remarkably, the respiratory system is complicated and sensitive to a variety of psychological variables. Breathing is often considered to account for possible artifacts in other response measurements caused either by breathing irregularities or by changes in breathing due to an experimental manipulation that might confound the variable of interest, such as, heart rate and skin conductance. Also, basic changes in breathing have a significant impact on HRV. The ANS disturbance varies directly with the depth of the inspiration; with deeper breaths lead to a decrease in skin resistance, a decrease in heart rate, and an increased vasoconstriction in the finger (Stern et al., 2001). The heart period, the time between successive beats, grows longer during exhalations leading to fewer beats per minute. During a phase of breathing, heart period is shorter during inspiration than expiration, and heart rate consequently appears to increase in an inspiration phase (Cacioppo et al., 2007). Because of the coupling between breathing and cardiac output, heart rate changes as a function of the respiratory cycle. This oscillatory interaction between the cardiac and respiratory system is known as a respiratory sinus arrhythmia. Effect of breathing to heart beating is resulted of the influence of a variety of different physiological systems. For these reasons, it is optimal to obtain breathing measures to ensure that breathing rates are within the high-frequency band and remain constant from condition to condition (e.g., baseline to a task). As mentioned above, monitoring breathing is useful as an index of emotional parameter, and also guaranteed to errorneous analysis from normal cardiorespiratory analysis assumptions (Quintana & Heathers, 2014).

Electrodermal activity (EDA)

The skin is a selective barrier that serves the function of preventing entry of foreign matter into the body and selectively facilitating passage of materials from the bloodstream to the exterior of the body. Skin assists in the maintenance of water balance and of constant body temperature. Skin functions through vasoconstriction/dilation and through variation in the production of sweat. The sweet glands in human have two froms; the apocrine and the eccrine. The main function of most eccrine sweat glands is thermoregulation. However, those sweat glands locate on the palmar and plantar surfaces are more related to grasping behavior than to evaporating heat and they have been considered to be more responsive to psychologically significant stimuli than to thermal stimuli. The psychological events induce a sweat gland activity then raise the measurement of EDA to be more interesting. Nowadays, EDA is a representative of the state which clarifies in the interaction between the organisms and its environment. Generally, it is known that palmar sweat glands are innervated by the sympathetic chain of the ANS, so electrodermal measures are useful indicators of sympathetic nervous system activity. Sympathetic nervous system reflection is not only related to psychological response, such as, emotions but also elicited the cognitive activity, such as, attention (Stern et al., 2001). Because of changes in the electrical activity of palmar and plantar skin are concomitant of psychological phenomena being, thereby, EDA can be considered as one of the origins of psychophysiological recording. Sympathetic nervous system activity is associated with an increasing sweat gland activity and this activity, in turn, is associated with the augmentation of skin conductance level and Skin conductance response (Cacioppo et al., 2007; Grings & Dawson, 1978). Lang and his colleagues (1993) have supported a relation between sympathetic nervous system and Electrodermal activity by showing the positive correlation between arousal feeling and skin conductance response regardless the valence of stimuli. Moreover, Brouwer et al. (2013) have shown that a skin conductance increases in the pleasant stimuli compares to unpleasant stimuli.

EDA can be characterized in two types followed the distinction of responded attribute: Tonic electrodermal response or phasic electrodermal response. The tonic electrodermal response is the spontaneous basal conductance of the skin refers to the raw level of skin activity, a so-called skin conductance level. It is opposed to the definition of phasic electrodermal response that is a short-term change and come up in the elicitation by distinct or novel or unexpected stimuli, so-called skin conductance response. However, skin conductance response can occur spontaneously in the absence of obviously external stimuli, so-called nonspecific skin conductance responses (NS.SCRs). In the case that the elicitation arises by distinct stimuli, the response window of skin conductance response should be ranged from 1 to 3 s (Stern et al., 2001) or 1 to 4 s after a stimulus onset. Moreover, minimum amplitude of 0.05 microsiemens (μS) is common with handed scoring of EDA records, meanwhile the minimum amplitude is down to 0.01 μS since a computerized scoring is conducted (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012). skin conductance response is characterized by a short rise time follows by a slower recovery time (Valenza & Scilingo, 2013). The electrodermal activities are expressed in micromho units. A micromho is 1 millionth of a mho, and a mho is the reciprocal of an ohm. The values depend upon the size of the electrodes, so the units are expressed as micromhos per square centimeter of electrode size (micromhos/cm^2). Most skin conductance levels are in the range of 5-20 micromhos/cm^2 while the typical skin conductance response is about one micromho/cm^2. In general, the unit of EDA can expresses either microsiemen or micromho that is meaningful equal value.

Together, autonomic nervous system consists of two major branches: The sympathetic nervous system and the parasympathetic nervous system that produce opposite reactions. Emotional experiences result in peripheral nervous system changes even experiences are under conscious unawareness. The common indicators of emotion are heart rate, skin conductance, blood pressure, finger temperature, respiration and pupil dilation. Physiological data can importantly elucidate the valence and arousal characteristics of emotion. The activity of sympathetic nervous system indicates to arousal dimension of emotion, meanwhile, the activity of parasympathetic nervous system represents to valence dimension of emotion. In case of emotional study, some autonomic indicators can be implied as the specific-emotion representor, such as, HRV represent to valence and skin conductance response represent to arousal. However, breathing rate and heart rate are physiological indices that reflect to emotional experience and can confound other physiological indices at the same time. These indices should be concerned when interpret results.

In summary, these reviews indicate that there are numerous times while we encounter to environmental events that input signal might generate emotion and might be perceived by multisensory modalities at the time. Emotional experiences can represent via self-assessment, physiology, and behavior. Most studies reveal that orbitofrontal cortex and limbic region are activated when stimuli relate to emotion. Moreover, the activations at both regions result in the representation of reward value in the context of behavioral response, cognition, autonomic response, and endocrine response. Previous studies indicate that there are neural convergences occur in cortical regions and subcortical regions in the brain, while perceiving multisensory stimuli. Multisensory integration can result in neuronal activity which leads to alterations of perception and behavior. In addition, it is clear that there are anatomical and physiological integrations between sensory modality from neuroimaging studies and behavioral responses. However, we still do not know the integration form that may be generated via autonomic nervous system and endocrine system. Furthermore, many studies examine the combination effect between auditory and visual stimuli, but there is less evidence of others pairs especially a pair of olfactory and tactile stimuli.

CHAPTER 3
RESEARCH METHODOLOGY

Research design

This study was an experimental research and employed a within-subjects design to carry out for two experiments. Every participant received all stimuli conditions but was different in the sequence of stimuli presentation. The sequences of stimuli presentation were randomly calculated by computer.

First experiment was conducted to investigate the representation of emotion while perceived unisensory stimuli and investigate the impact of participant's gender with respect to emotional perception. Moreover, the valence's result in the first experiment was brought to consider for choosing two distinctive valence odors to incorporate in the second experiment.

Second experiment was conducted to investigate the integration of emotion while perceived the simultaneous multisensory stimuli. Odor and touch stimuli were used as the representors to olfactory modality and tactile modality. The selective criterion to odor's types based on valence result of first experiment, meanwhile, touch's types based on valence result of Löken et al. (2009) and Morrison et al. (2011).

Participants

There are two experiments were performed in this study. 23 participants were recruited to examine in the first experiment that was prepared for investigating effects of emotional stimuli and gender. 24 participants were recruited to examine in the second experiment that was prepared for investigating the integrated effect of bimodal stimuli. Participants participated in the second experiment were individual who did not participate in the first experiment. Totally, there were 47 participants participated in two experiments but only the data of 45 participants were brought to analyze because two of them were excluded.

Extraneous variables

In the current study, there are the extraneous factors that may probably effect and intervene to the interested variables. To find the right answers to these research questions, the following areas should be controlled.

Caffeine

Caffeine is in some dietary sources consumed worldwide, such as, tea, coffee, coca cola, chocolate, energy drinks and soft drinks. Caffeine absorption from the gastrointestinal tract is rapidly absorbed 99% into the bloodstream of human in about 30-60 min after ingestion (Snel & Lorist, 2011). Caffeine diffuses throughout the entire body; it passes all biological membranes, including the blood–brain barrier and the placental barrier. The peak plasma concentration of caffeine is observed at one to two hours with average five hours a half-life depending on endogenous and exogenous factors (Bruce, Scott, Lader, & Marks, 1986). It has been revealed that caffeine increases skin conductance level, caused alertness, decreased heart rate and skin temperature (Quinlan et al., 2000), increased 6.0 +/- 6.0 mm Hg systolic and 2.6 +/- 3.1 mm Hg diastolic blood pressures (Umemura et al., 2006), also affects to HRV (Sondermeijer, van Marle, Kamen, & Krum, 2002). Moreover, The consumption of caffeine at typical levels of 75 mg caffeine affects a decrease in blood flow to the cerebral cortex as well (Kennedy & Haskell, 2011).

Age

The aging process reduces the ability of smell, and is well known due to the decline in olfactory receptor neurons. Doty et al. (1984) have examined the ability of smell identification in 1955 persons ranging in age from 5 to 99 years old. Capacity to identify odors reachs a peak performance between age 20 and 50 years old, then begin to decline after that, and declines markedly after 70 years old. It is corresponding to the study of Evans, Cui, and Starr (1995) that have found the correlation of age increased with a decline of the odor identification and Tahir, Shoro, and Minhas (2008) that the loss of olfactory cells is strongly marked after 50 years old.

Health Status (Illness/Medication)

Bodily impairment may interfere with experimental outcome through imperfect health, such as, common cold, allergic rhinitis, cardiovascular disorders, and psychological disorders and also taking some medicines. Common colds diminish a sense of smell, impair olfaction and change the ability of smell (Akerlund, Bende, & Murphy, 1995). Meanwhile, allergic rhinitis elevates the olfactory threshold and impairs a detection sensitivity (Hinriksdóttir, Murphy, & Bende, 1997). Furthermore, the psychological disorder, such as, depression increases a heart rate and decreases a cardiovagal activity and its modulation (Agelink, Boz, Ullrich, & Andrich, 2002). Likewise, benzodiazepines influence cardiac autonomic regulation, and causes a reduction of central vagal tone (Agelink, Majewski, Andrich, & Mueck-Weymann, 2002).

Smoking

Cigarette smoking influences the sense of smell. Smoking is found to be adversely associated with odor identification ability (Frye, Schwartz, & Doty, 1990; Katotomichelakis et al., 2007). Moreover, cigarette smoking is known to lead to widespread augmentation of sympathetic nervous system activity, such as, a decrease in pupil diameter, an increase in heart rate, cardiac output, and blood pressure (Furuta & Miyao, 1992; Sato, Kunishi, Kameyama, Takano, & Saito, 1991), an increase in HRV (Sjoberg & Saint, 2011), a decreases in muscle sympathetic nerve activity and RR interval spectral power at the respiratory frequency (Niedermaier et al., 1993).

Alcohol

The alcohol-related olfactory deficit, alcohol dependence causes an olfactory dysfunction by reducing the olfactory sensitivity, the discrimination quality, and the identification ability (Rupp, 2004; Rupp et al., 2003). Alcohol is a potent central nervous system depressant with a range of effects on all systems particularly on ANS. It lead to a peripheral vasodilation and results changes in heart rate and blood pressure (Johnson, Eisenhofer, & Lambie, 1986). Additionally, Alcohol affects ANS by increases in skin conductance and decreases in HRV (Schrieks et al., 2013).

The prior exposure to odors

The attendance in olfactory study should be aware and avoid to exposure to fragrance before the test. Fasunla, Douglas, Adeosun, Steinbach, and Nwaorgu's (2014) study show that the perfume can reduce the olfactory detection threshold.

Odor familiarity and intensity

Beside valence and arousal of odor perception, two important factors familiarity and intensity have shown their influence to the perception of emotions that lead to interference of the purposive outcome. Pleasant odor could obviously reduce a stress in the pleasant familiar odor group (Joussain, Rouby, & Bensafi, 2014). Furthermore, Armony and Vuilleumier (2013) have supported that there is a correlation of familiarity and pleasantness. Besides odor familiarity, odor intensity also affects the evaluation of pleasantness (Armony & Vuilleumier, 2013). Moreover, the odor intensity shows its correlation with odor arousal as well (Bensafi et al., 2002; Winston, Gottfried, Kilner, & Dolan, 2005).

Inclusion criteria

1. Participants aged 18 to 50 years old.
2. Participants had a normal sense of smell. They could distinguish the concentration between n-butyl alcohol and water at lower than step 6 (5.48×10^{-3} v/v) of n-butyl alcohol in water.
3. Participants did not have cardiovascular disorders or psychiatric disorders or chronic health conditions.
4. Participants did not have respiratory tract infection, common cold, or nasal inflammation.
5. Participants did not have the injury on hand and arm.
6. Participants were not taking medication that effect on the central nervous system or the autonomic nervous system.
7. Participants did not have an allergy to odor.
8. Participants did not smoke (no-smoking participants).
9. Participants abstained caffeine products and alcoholic beverages at least 24 hours before the experiment.

10. Participants did not use fragrance products on the experimental date.

Participant recruitment

To recruit the participants, the text of advertisement was advertised in public posts and placed on a web page. Participants could choose either to receive the participated credit or take 7 Euros compensation for their time and effort (Appendix 1).

Screening methods

To select the participants; who fitted in this study, the screening was performed before the attenders gave the informed consent to enroll the research. The participants were asked to complete the questionnaires and tests regarding the following issues:

1. The general health and medication taking (Appendix 2).
2. The olfactory function test by n-butanol odor threshold test (Appendix 3).

The single ascending series of butanol odor detection threshold test was conducted to select the participants. Each participant was asked to identify the n-butanol dilution bottle from two bottles of water. The odor threshold test employed aqueous dilutions of 1-butanol, ascending staircase differed by a factor of three, a forced-choice method that was applied from (Croy et al., 2009) and Lehrner, Glück, & Laska (1999). The highest aqueous concentration equal 4% in water was successively diluted in 10 steps. On a given trial, participants sniffed consecutively from three bottles and indicated which bottle contained the butanol solution or stronger smell. If the participant indicated the incorrect bottle at low one concentration, then the next higher concentration was presented. The threshold was defined at the butanol concentration by correctly chosing over water in four consecutive trials. The corresponding number of the concentration was taken as the threshold; a high corresponding number represented a low threshold. The participants who could distinguish the two differentiations of odors, n-butanol and water, at the concentration lower than Step 6 dilution (5.48×10^{-3}v/v) will be included in the research.

The first experiment: Unimodal stimulus study

Stimuli

Olfactory stimuli

The stimuli consisted of four olfactory stimuli, including (1) Michelia alba oil (*Michelia alba D.C.*) obtained from Central Laboratory and Greenhouse Complex, Research and Development Institute, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom, Thailand (2) Lavender oil (*Lavandula angustifolia*) obtained from Sigma-Aldrich (3) Civet oil obtained from Agieffe International SAS, Italy and (4) Sunflower oil obtained from Thai-China Flavours and Fragrance Industry.

Task and procedure

Unimodal stimulation task

Four olfactory stimuli conducted for four contradistinct conditions. The diluted concentration of 10 ml Lavender oil 10% v/v by Sunflower oil, Michelia oil 5% v/v by Sunflower oil, 100% Sunflower oil, and 10% Civet oil were filled separately in an amber glass bottle. Single test session, each stimulus was presented to the participants by positing at 4 cm under the noses for a two-minute stimulus and four-minute inter-stimuli interval. The order of conditions for olfaction was randomly assigned among the participants. Complete amounts of experimental duration were approximately 30 min.

Experimental procedures

The experiment was conducted as the following orders (Figure 3.1):

1. To avoid any confounding effects, the participants were asked to abstain from drinking caffeine, drinking alcohol, and cigarette smoking for at least 24 hours before the experiment. They were also asked not to use any fragrance products on the day of the test. Furthermore, the participants were screened the general health, medication taking, and olfactory threshold at first.

2. Written and verbal information were provided briefly to all participants describing the purpose and process of study (Appendix 4).

3. Participants were informed about the consent (Appendix 5).

4. Participants were asked to score their emotion by rating valence, arousal, and dominance.

5. The physiological devices were placed for continuous recording on the wrist and ankle for ECG recording, on the fingers for EDA recording , on the chest for breath recording of participants.

6. Participants were instructed to set a comfortable position, be relaxed, breathe normally through their noses, and sit quietly. Moreover, to shield the participants from distracting stimuli such as audition and vision, they were asked to wear a blindfold and headphone and keep their eyes opened during the periods of the experiment.

7. The physiological signals of Electrocardiogram (ECG), Breathing, and EDA were recorded continuously in real time for two-minute-baseline session.

8. The olfactory stimuli were presented under the noses continuously for two-minute-intervention session, and participants were asked to breathe normally.

9. During olfactory elicitation, the physiological signals of ECG, Breathing, and EDA were recorded continuously in real time for two min.

10. The participants took two-minute-withdrawal session, and during this session they were asked to score their emotion by rating valence, arousal, and dominance again.

11. The processes turned back to step 7 and was repeated from step 7 to 10 until the numbers of condition were conducted completely.

12. At the end of the four conditions, participants were asked to rate the intensity and familiarity of odors.

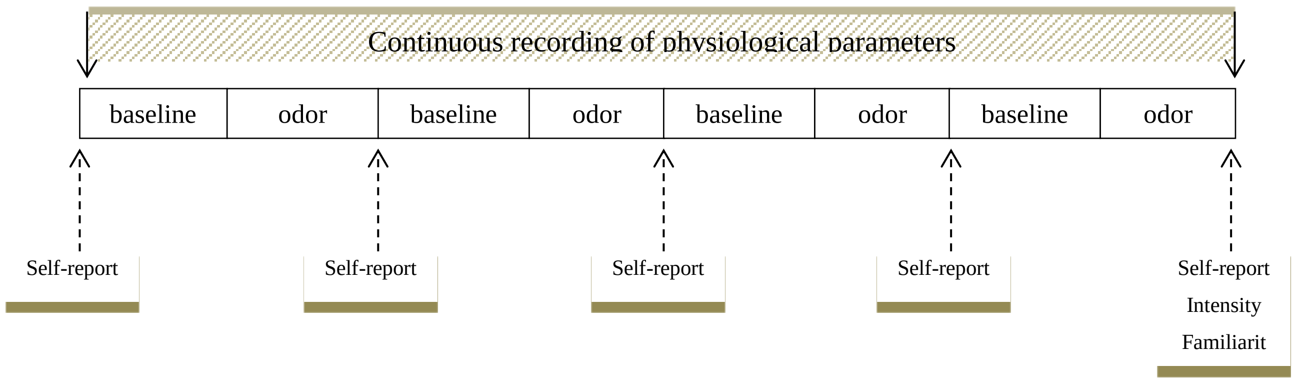

Figure 3.1 The Experimental Diagram of Unimodal Stimuli Study.

The second experiment: Bimodal stimuli study

Stimuli

Olfactory stimuli

The stimuli consisted of three olfactory stimuli, including one pleasant odor [Lavender oil (*Lavandula angustifolia*) obtained from Sigma-Aldrich], one unpleasant odor [Civet oil obtained from Agieffe International SAS, Italy], and one neutral odor [no odor]. Two stimuli were chosen from the result of experimental one where participants scored the emotional experience in terms of the most distinct valence rating for the followed bimodal study and used the concentration same as the first experiment.

Tactile stimuli

The stimuli consisted of four-tactile stimuli, including one pleasant touch [continuous touch with velocity 3 cm/s], one unpleasant touch [continuous touch with velocity 30 cm/s], and two neutral touch [discontinuous touch or jump touch, and no touch]. The stroking velocity was selected from the foregoing studies of Löken et al. (2009) and Morrison et al. (2011) that showed the most subjective pleasantness of touch at velocity of 3 cm/s, and less subjective pleasantness of touch at velocity of 30 cm/s.

Task and procedure

Bimodal stimulation task

Twelve different conditions were conducted by crossing variation of emotional stimuli between three olfactory stimuli and four tactile stimuli (Table 3.1). The orders of condition for olfactory and tactile elicitations were arranged automatically via computer. The emotions were elicited, in separate runs, from two modalities simultaneously, which matched to twelve conditions for two-minute-single test session, and four-minute inter-stimuli interval. Total amounts of experimental duration were approximately 90 min.

Table 3.1 The Twelve Conditions of Bimodal Stimulation Task from Crossed Variation between Olfactory and Tactile Stimuli.

Conditions	Tactile stimuli	Olfactory stimuli
1	No touch	No odor
2	3 cm/s continuous touch	No odor
3	30 cm/s continuous touch	No odor
4	Discontinuous touch	No odor
5	No touch	Lavender oil
6	3 cm/s continuous touch	Lavender oil
7	30 cm/s continuous touch	Lavender oil
8	Discontinuous touch	Lavender oil
9	No touch	Civet oil
10	3 cm/s continuous touch	Civet oil
11	30 cm/s continuous touch	Civet oil
12	Discontinuous touch	Civet oil

In olfactory stimulation, the 10 ml of diluted concentration of Lavender oil 10% v/v by Sunflower oil, and 10% of Civet oil was filled separately in an amber glass bottle. Each stimulus was presented to the participants by positing at four cm under the noses.

In tactile stimulation, The Psychtoolbox 3.0 in Matlab R2013a (The MathWorks, Inc.) was used to create and present the simulated movements on screen for regulating the velocity of touch while experimenter presents touch stimuli. Tactile stimuli were delivered manually by an experimenter who was trained to deliver three velocities with the steady force. Manual stimulation method was sufficient to induce an optimized CT afferents (Triscoli et al., 2013). The stroke was performed in a two-way direction through a soft goat's hair brush (4 cm wide, 3 cm long). The receptive field was 20 cm range on the left dorsal forearm.

Experimental procedure

The experiment was conducted as the following orders (Figure 3.2):

1. To avoid any confounding effects, the participants were asked to abstain from drinking caffeine, drinking alcohol, and cigarette smoking for at least 24 hours before experiment. They were also asked not to use any fragrance products on the day of the test. Furthermore, the participants were screened the general health, medication taking, and olfactory threshold at first.
2. Written and verbal information were provided briefly to all participants describing the purpose and process of study.
3. Participants gave informed consent.
4. Participants were asked to score their emotion by rating valence, arousal, and dominance.
5. The physiological devices were placed for continuous recording on the wrist and ankle for ECG recording, on the fingers for EDA recording , on the chest for breath recording of participants.
6. Participants were instructed to set a comfortable position, be relaxed, breathe normally through their noses, and sit quietly. Moreover, to shield the participants from distracting stimuli such as audition and vision, they were asked to wear a blindfold and headphone and keep their eyes opened during the periods of the experiment.
7. The physiological signals of ECG, Breathing, and EDA were recorded continuously in real-time for two-minnute-baseline session.

8. The olfactory and tactile stimuli were presented under the noses, and the latter on left dorsal forearm continuously for two-minute-intervention session, and the participants were asked to breath normally.

9. During emotional elicitation, the physiological signals of ECG, Breathing, and EDA were recorded continuously in real-time for two min.

10. The participants took two-minute-withdrawal session and during this session they were asked to score their emotion by rating valence, arousal, and dominance again.

11. The processes turned back to step 7 and was repeated from step 7 to 10 until the numbers of condition were conducted completely.

12. At the end of the 12 conditions, participants were asked to rate the intensity and familiarity of odors.

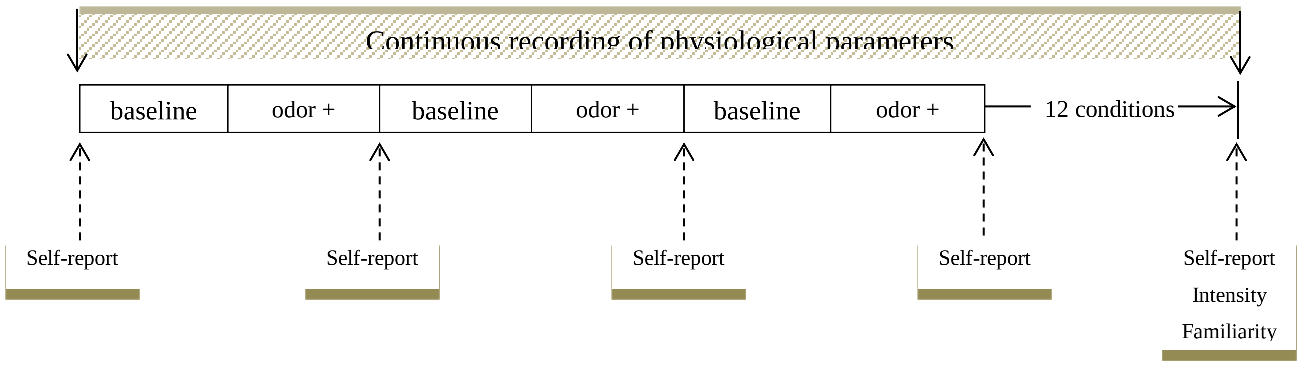

Figure 3.2 The Experimental Diagram of Bimodal Stimuli Study.

Data acquisitions

Self-report questionnaire

To measure a subjective emotion, a questionnaire was performed by following a dimensional model of Russell & Mehrabian (1977) that was applied by Bradley and Lang (1994). The measurement was a 9-point rating scale that ranged from 1 to 9 for measuring the emotional experience to stimuli. The emotional aspects associated with three dimensions in terms of the valence (pleasantness or unpleasantness), arousal (arousal or calmness), and dominance (feeling of influence/being in control or feeling of lack of control). Participants were asked to choose the fitted number that was considered to reflect their emotional state (Appendix 6). The emotional states were computed as the change scores between intervention and baseline periods before applying to analysis.

However, odor intensity and familiarity were the extraneous variables in this study. To avoid an ensure different sensory quality of the stimuli that affected the pleasantness and arousal ratings eventually, the researcher also asked about the perceived intensity and familiarity and controlled these two variables by statistical technique later. Odor intensity and familiarity scales were 100 mm of a visual analogue scale ranging from not-at-all intense/familiar (0) to very intense/familiar (100). The participants were asked to rate the intensity, and familiarity of odors, by giving a mark on the horizontal line to answer how much they perceived the intense odors and how much they were familiar with odors (Appendix 7).

Physiological responses

Skin conductance responses, heart rate, HRV as well as breathing rate were measured simultaneously and in real-time via the Biopac student lab PRO (Biopac Systems, Inc., Santa Barbara, California, USA) and Biopac student lab analysis (V 3.7.7) with a sampling rate of 2000 samples/s (2 KHz) (Appendix 8).

ECG

Beat-to-beat heart rate was recorded via Biopac electrode lead sets (SS2L). ECG signal was recorded from three Ag/AgCl surface electrodes, band pass filtered (0.05–35 Hz). ECG electrodes were placed follow to the standard Bipolar Lim Lead, Lead II placement [right arm (-), left leg (+)]. The ECG signal was recorded for two-minute-baseline session, and two-minute-intervention session. ECG data was edited for artifact and computed off-line heart rate and HRV by using Kubios software (V2.2), developed by the Biosignal Analysis and Medical Imaging Group, Department of Applied Physics, University of Kuopio, Finland.

EDA

EDA was recorded via electrodermal transducer (SS3LA), band pass filtered (0–35 Hz). Electrodermal electrodes were placed on the distal phalanges of the index and middle finger of the left hand by follow the recommendation of Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures (2012). EDA data were edited for artifact and computed off-line using Ledalab software (V3.4.7).

Breathing

Breathing was recorded via a respiratory effort transducer belt (SS5LB) as the breathing cycle. The belt was placed around the chest below the sternum (below the armpits and above the nipples) with slightly tight at the point of maximal expiration. Changes in the belt's length was recorded by the electric sensor. Transducer converted changes in chest and then display as a waveform. Data was computed off-line using Biopac student lab analysis in breaths per minute.

Data preprocessing

ECG

The ECG beat-to-beat data were visually screened for physiologically impossible readings and was manually corrected. Heart rate in beats per minute and HRV was calculated by Kubios software.

Heart rate was computed on heart rate scores over a period of two-minute-intervention minus two-minute-baseline period. For HRV, frequency components were computed by Autoggressive method as change scores in HRV between two-minute-intervention and two-minute-baseline period. In this case, the variation of generalized frequency components, LF (0.04–0.15 Hz) and HF (0.15–0.4 Hz), ranges in the power of spectral density (ms^2), and normalized units [LFnu or HFnu = LF or HF/(LF+HF)] were performed (Malik et al., 1996). Moreover, change scores in LF/HF ratio between baseline and intervention periods were also computed in each condition.

EDA

The skin conductance response was computed as change scores in amplitude of response by subtracting 10 s baseline preceding the presentation of stimuli from response score of the intervention period. The time window for the latency response was 1 to 4 s after stimulus onset. The criterion for skin conductance responses in the analysis was 0.01 $\mu S/cm^2$ (Cacioppo et al., 2007).

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Breathing

Positive and negative peaks of each breathing cycle were extracted by using the peak detection function that implemented in Biopac student lab analysis. The time intervals between positive peaks were used to estimate breathing periods. The breathing periods were converted into breathing rate for the ease of reading. The change scores in breathing were computed by minimizing breathing scores of intervention period with baseline period.

Data analysis

The general information was described as frequency, mean, and standard deviation. All statistical analyses were performed by using the statistical software package SPSS PC (version 13). The self-report rating and psychophysiological variables, such as, skin conductance response, heart rate, breathing rate, and HRV were analyzed by using the two-way mixed ANOVA on unimodal testing of the first experiment and the two-way repeated measure ANOVA on bimodal testing of second experiment. The results were reported by using the Greenhouse-Geisser correction in a value of epsilon (ε), considered as significant at the level of $p < .05$ (Howell, 2010; Maxwell & Delaney, 2004). In case that there was a significantly different effect between variables, post hoc paired t-tests were computed by using the Tukey's multiple comparison test. Furthermore, the effect size measure partial eta squared (η^2) was also reported.

CHAPTER 4
RESULTS

The first experiment: Unimodal stimuli study

The unimodal perception study was conducted by using olfactory stimuli to measure the emotional perception via the self-report and peripheral physiological response. Twenty-three participants, 11 men, and 12 women were recruited to this study. All participants received course credit for their participation. The mean age of the participants was 24.7 years old (ranges 20 – 38). To process statistical analysis, the data were calculated as the change scores of the score at intervention minus the score at baseline periods. A two-way mixed analysis of variance was conducted the emotional responses on the influence of within-between independent variables (odors and gender). Odors included four categories (Lavender oil, Michelia oil, Sunflower oil, and Civet oil) and gender consisted of two categories (men and women). All effects were analyzed with the concerning to the gender differences among respondents might impact to the emotional perception of odors. The odors might contribute to emotions, in three dimensions of emotion and the psychophysiological indices, but that effect might differ across gender. Means of the change scores and standard deviations for odors and gender on self-report ratings and psychophysiological response were showed in Table 4.1 and 4.2. There were no outliers, as assessed by examination of studentized residuals for values greater than ± 3. The data were normally distributed, as assessed by Normal Q-Q Plot. There were homogeneity of variances ($p > .05$) and the homogeneity of covariances ($p > .05$), as assessed by Levene's test of homogeneity of variances and Box's M test of equality of covariance matrices, respectively. The analysis of variance results of the effects of gender and unimodal stimuli through odors via self-report ratings and psychophysiological response were reported by using Greenhouse-geisser correction. The results are presented as follows:

Table 4.1 Means and Standard Deviations of Change Scores for Odors and Gender on Self-report Ratings.

Odor	Men (n = 11)		Women (n = 12)	
	M	*SD*	*M*	*SD*
	Valence			
Lavender oil	-.455	1.809	-.083	1.975
Michelia oil	-1.364	2.014	-2.000	2.763
Sunflower oil	-1.000	1.613	-1.250	1.765
Civet oil	-2.182	1.722	-2.167	2.038
	Arousal			
Lavender oil	1.182	2.523	.667	2.708
Michelia oil	.273	2.149	1.000	2.828
Sunflower oil	.818	2.228	.167	2.290
Civet oil	.634	2.292	1.667	1.875
	Dominance			
Lavender oil	-.818	2.822	-.583	1.311
Michelia oil	-1.182	2.639	-.583	1.505
Sunflower oil	-.636	2.203	-.333	1.775
Civet oil	-1.273	1.737	-1.417	1.564

The statistical control for extraneous variables

In this study, there were two extraneous variables; the intensity, and familiarity of odors. To analyze the data with covariates by the analysis of variance method, the assumption of a linear relation between the emotional perceptual effects on self-report and covariates at each type of odor and gender needed to be tested by plotting a scatterplot (Appendix 9). The relationship score (R^2) results were presented in the table (Table 4.3). The relationship score indicated that there was no linear relationship between the valence/arousal rating and odor intensity and familiarity since relationship scores were low; most of the pair relations were almost zero. Now, result can be assumed that odor intensity and odor familiarity cannot be a potential confounder in this study, so these two variables were excluded from statistical analysis.

Table 4.2 Mean of Change Scores on Emotional Perception via Peripheral Physiological Responses by Odor and Gender.

Odor	Men (n = 11)		Women (n = 12)	
	M	*SD*	*M*	*SD*
	LF/HF ratio			
Lavender oil	-.378	1.234	-.202	1.083
Michelia oil	.194	.686	-.461	.672
Sunflower oil	-.208	.533	-.263	.519
Civet oil	2.091	2.132	.331	.655
	LFnu			
Lavender oil	-5.311	10.643	-7.717	17.426
Michelia oil	-.873	10.970	-9.880	16.837
Sunflower oil	-4.671	8.004	-8.138	13.623
Civet oil	12.616	12.549	7.597	12.736
	HFnu			
Lavender oil	5.311	10.643	7.717	17.426
Michelia oil	.873	10.970	9.880	16.837
Sunflower oil	4.671	8.004	8.138	13.623
Civet oil	-12.616	12.549	-7.597	12.736
		SCR amp.		
Lavender oil	1.242	1.561	1.722	2.199
Michelia oil	1.889	2.486	2.437	2.375
Sunflower oil	.667	1.172	1.318	1.466
Civet oil	.764	.721	2.213	2.225
		HR		
Lavender oil	-.451	3.040	-.720	3.078
Michelia oil	.046	1.444	-.524	2.393
Sunflower oil	-.876	1.359	-1.277	2.324
Civet oil	.812	2.400	-.478	3.435
		BR		
Lavender oil	-.002	1.989	.278	2.031
Michelia oil	.044	1.064	.672	1.965
Sunflower oil	.070	1.410	-.179	2.022
Civet oil	-.151	2.271	-.205	2.596

Note: LF/HF ration = Ratio of low frequency variability to high frequency variability, LFnu = low frequency power in normalized unit, HFnu = high frequency power in normalized unit, SCR amp. = Skin conductance response amplitude, HR = Heart rate, BR = Breathing rate

Table 4.3 The Linear Relationship Scores Between the Valence / Arousal Rating and Odor Intensity / Familiarity by Odors and Gender.

Dimensions of emotion	*N*	Odor intensity				Odor familiarity			
		L	M	S	C	L	M	S	C
Valence									
Men	11	.303	.127	.113	.181	.145	.002	.094	.242
Women	12	.021	$2.012E^{-4}$	.009	.053	.162	.165	.295	.202
Arousal									
Men	11	.040	.063	.089	.057	.003	.027	.001	$3.638E^{-4}$
Women	12	.004	.054	.016	.119	.020	.004	.003	.130

Note: N = number of participants, L = Lavender oil, M = Michelia oil, S = Sunflower oil, C = Civet oil

The self-report rating

The emotional perceptions were measured by self-report along three dimensions of emotion including valence, arousal and dominance. In the valence dimension, there was no significant interaction between odors and gender on valence score (F(2.345, 49.240) = .723, p = .511, partial η^2 = .033, ε = .782) (Table 4.4). The main effect of odors indicated a significant effect of odor to the level of pleasantness (F(2.345, 49.240) = 10.672, p < .001, partial η^2 = .337). There was no statistically significant difference for the main effect of participant's gender to the level of pleasantness (F(1, 21) = 0.031, p = .863, partial η^2 = .001). As showed in the Figure 4.1, irrespective of gender, unimodal stimuli by Lavender oil elicited pleasantness 1.413, p = .011, 95% CI [.258, 2.568], and 1.905, p < .001, 95% CI [1.097, 2.713] greater than Michelia oil and Civet oil, respectively. In addition, Sunflower oil elicited pleasantness 1.049, p = .035, 95% CI [.052, 2.047] greater than Civet oil.

Table 4.4 Analysis of Variance Results for Odor and Gender Variables on Self-report of Valence.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	.359	.359	.031	.863	.001
Error 1	21	245.250	11.679			
			Within subjects			
Odor	2.345	45.986	19.612	10.672	< .001	.337
Gender x Odor[a]	2.345	3.116	1.329	.723	.511	.033
Error 2	49.240	90.492	1.838			

[a]Greenhouse-Geisser's epsilon = .782

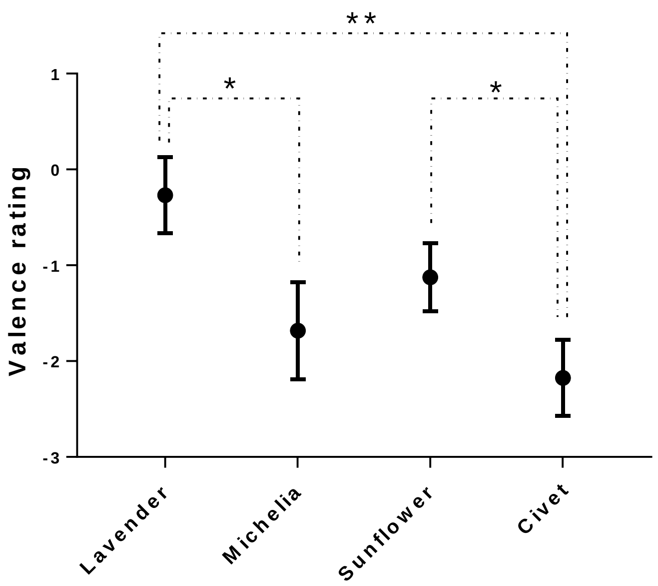

Figure 4.1 The mean change scores of valence rating under different odors. Odors elicited the different level of pleasantness. Lavender was more pleasant than Michelia and Civet. Sunflower was more pleasant than Civet. The rating scale was from 1 to 9. Error bars correspond to ± S.E.M.. Significant difference * $p < .05$, ** $p < .001$.

In the arousal dimension, There was no significant interaction between odors and gender on arousal score (F(2.721, 57.132) = 2.184, p = .106, partial η^2 = .094, ε = .907) (Table 4.5). There was no statistically significant difference of the main effect of odors to the level of arousal (F(2.721, 57.132) = 1.037, p =.378, partial η^2 = .047). Also, there was no statistically significant effect of gender to the level of arousal (F(1, 21) = .030, p = .865, partial η^2 = .001).

Table 4.5 Analysis of Variance Results for Odor and Gender Variables on Self-report of Arousal.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	.501	.501	.030	.865	.001
Error 1	21	355.977	16.951			
			Within subjects			
Odor	2.721	5.977	2.197	1.037	.387	.047
Gender x Odor[a]	2.721	12.586	4.626	2.184	.106	.094
Error 2	57.132	121.023	2.118			

[a]Greenhouse-Geisser's epsilon = .907

In the dominance, there was no significant interaction of odors and gender on dominance score (F(2.408, 50.573) = .406, p = .706, partial η^2 = .019, ε = .803) (Table 4.6). There was no statistically significant difference on the main effect of odors to the level of dominance (F(2.408, 50.573) = 2.332, p =.098, partial η^2 = .100). In addition, there was no statistically significant effect of gender to the level of dominance (F(1, 21) = .118, p = .734, partial η^2 = .006).

Table 4.6 Analysis of Variance Results for Odor and Gender Variables on Self-report of Dominance.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	1.413	1.413	5.605	.734	.006
Error 1	21	250.456	11.926	.118		
			Within subjects			
Odor	2.408	9.214	3.826	2.332	.098	.100
Gender x Odor[a]	2.408	1.605	.666	.406	.706	.019
Error 2	50.573	82.960	1.640			

[a]Greenhouse-Geisser's epsilon = .803

The peripheral physiological responses

The psychophysiological variables associated with emotional processing were recorded consisting of the indices of LFnu, HFnu, the LF/HF ratio, heart rate, breathing rate, and SCR amplitude to represent as in the dimension of valence and arousal.

The LF/HF ratio

In the LF/HF ratio, the significant interaction between odors and gender on the change scores of LF/HF ratio was observed (F(1.998, 41.950) = 3.917, p = .028, partial η^2 = .157, ε = .666) (Table 4.7). The participant's gender effected the change scores of LF/HF ratio significantly at the senses of Michelia oil and Civet oil (F(1, 21) = 5.332, p = .031, partial η^2 = .202), and (F(1, 21) = 7.440, p = .013, partial η^2 = .262), respectively. The different odors showed the statistically significant difference of the change scores of LF/HF ratio in male group (F(1.699, 16.992) = 8.290, p = .004, partial η^2 = .453). As showed in the Figure 4.2, the change scores of LF/HF ratio were significantly greater in Michelia oil (Mean difference = .654, p = .031, 95% CI [.065, 1.243]) and Civet oil of men (Mean difference = 1.760, p = .013, 95% CI [.418, 3.102]) than women. Moreover, the change score of LF/HF ratio of Civet oil was significantly greater than Sunflower oil in male group (Mean difference = 2.299, p = .033, 95% CI [.159, 4.439]).

Table 4.7 Analysis of Variance Results for Odor and Gender Variables on LF/HF Ratio.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	7.541	7.541	6.417	.019	.234
Error 1	21	24.676	1.175			
			Within subjects			
Odor	1.998	35.540	17.791	10.800	< .001	.340
Gender x Odor[a]	1.998	12.889	6.452	3.917	.028	.157
Error 2	41.950	69.107	1.647			

[a]Greenhouse-Geisser's epsilon = .666

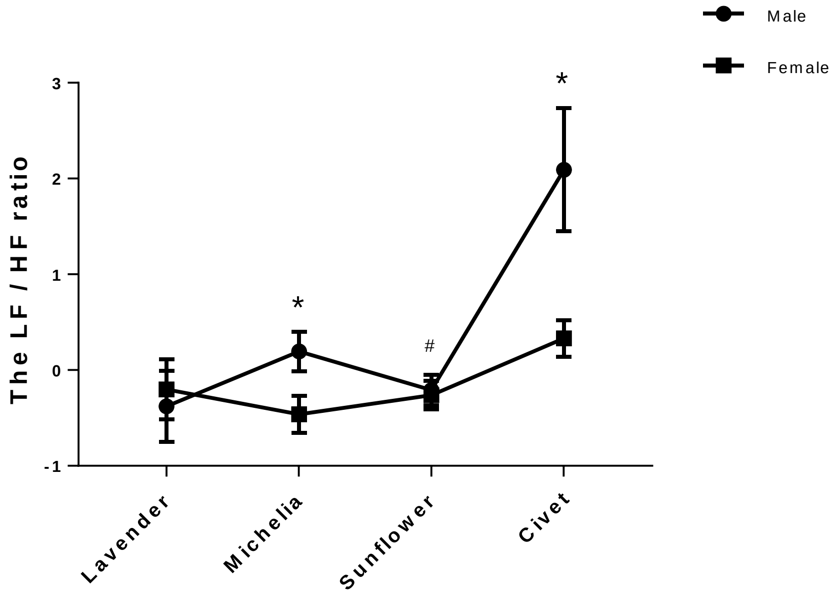

Figure 4.2 The mean change scores of the LF/HF ratio between men and women under different odors. There was an interaction effect between odors and gender difference on the LF/HF ratio. The change score of the LF/HF ratio in male group was greater than female group at Michelia and Civet. In male group, the change score of the LF/HF ratio of Civet was greater than Sunflower. Error bars correspond to ± S.E.M.. Significant difference * $p < .05$ male vs female at same odor, # $p < .05$ Civet vs other odor in male group.

HFnu

There was no significant interaction of odors and gender on the change scores of HFnu ($F(2.853, 59.913) = .330$, $p = .794$, partial $\eta^2 = .015$, $\varepsilon = .951$) (Table 4.8). The different odors showed a significantly different response in the change scores of HFnu ($F(2.853, 59.913) = 10.390$, $p < .001$, partial $\eta^2 = .331$). There was no statistically significant difference in the change scores of HFnu between men and women ($F(1, 21) = 2.107$, $p = .161$, partial $\eta^2 = .091$). As showed in the Figure 4.3, irrespective of gender, Lavender oil, Michelia oil, and Sunflower oil elicited the change scores of HFnu 16.620, $p = .001$, 95% CI [6.023, 27.218], 15.483, $p = .002$, 95% CI [4.984, 25.982], and 16.511, $p = .001$, 95% CI [5.723, 27.299] greater than Civet oil.

Table 4.8 Analysis of Variance Results for Odor and Gender Variables on HFnu.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Between subjects						
Gender	1	568.140	568.140	2.107	.161	.091
Error 1	21	5661.210	269.581			
Within subjects						
Odor	2.853	4539.284	1591.065	10.390	.000	.331
Gender x Odor[a]	2.853	144.242	50.558	.330	.794	.015
Error 2	59.913	9174.281	153.128			

[a]Greenhouse-Geisser’s epsilon = .951

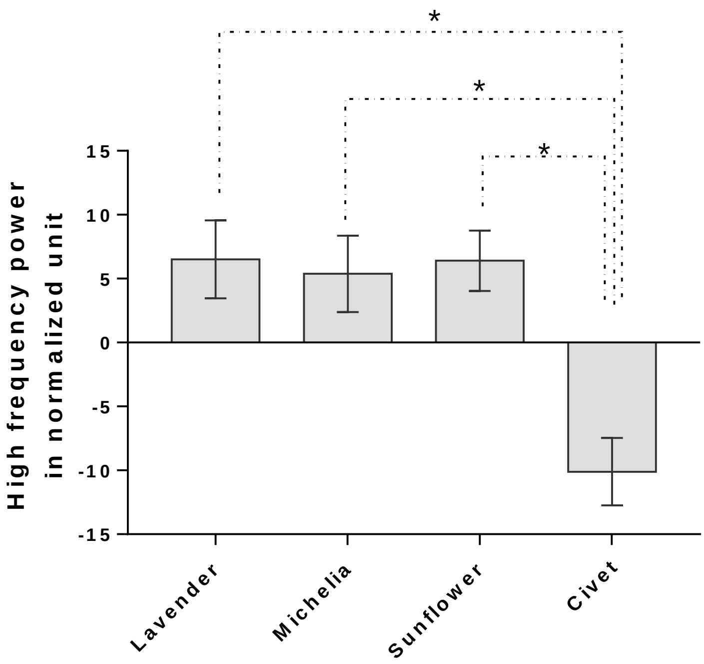

Figure 4.3 The mean change scores of High frequency power in normalized unit (HFnu) under different odors. Odors differently effected to HFnu. Civet elicited HFnu less than Lavender, Michelia, and Sunflower. Error bars correspond to ± S.E.M.. Significant difference * $p < .01$.

SCR

There was no interaction of odors and gender on the change scores of SCR amplitude (F(2.017, 42.361) = 1.007, p = .375, partial η^2 = .046, ε = .672) (Table 4.9). The main effect of odors indicated a significant effect of odors to the change scores of SCR amplitude (F(2.017, 42.361) = 4.595, p = .015, partial η^2 = .180). There was no statistically significant difference of the main effect between men and women to the change scores of SCR amplitude (F(1, 21) = 1.306, p = .266, partial η^2 = .059). As showed in the Figure 4.4, irrespective of gender, Michelia oil elicited the change scores of SCR amplitude 1.171, p = .025, 95% CI [.111, 2.230], higher than Sunflower oil.

Table 4.9 Analysis of Variance Results for Odor and Gender Variables on SCR.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	14.036	14.036	1.306	.266	.059
Error 1	21	225.656	10.746			
			Within subjects			
Odor	2.017	15.923	7.894	4.595	.015	.180
Gender x Odor[a]	2.017	3.489	1.730	1.007	.375	.046
Error 2	42.361	72.777	1.718			

[a]Greenhouse-Geisser’s epsilon = .672

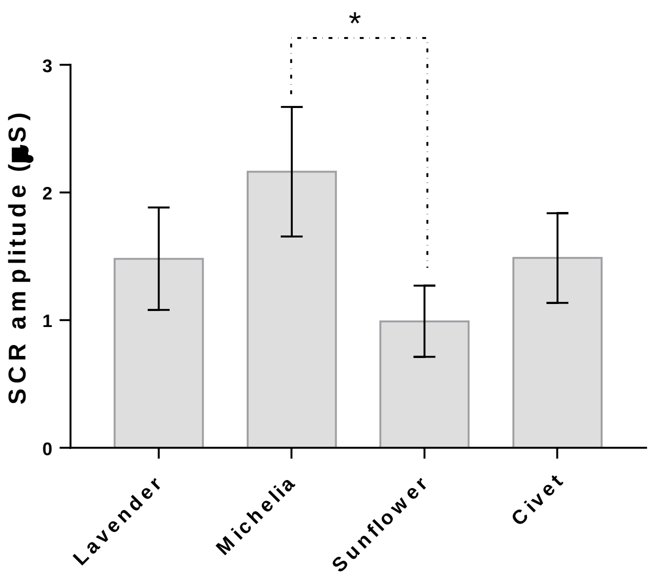

Figure 4.4 The mean change scores of skin conductance response amplitude under different odors. Odors elicited the different SCR amplitude significantly. Michelia stimulated SCR greater than Sunflower. Error bars correspond to ± S.E.M.. Significant difference * $p < .05$.

Heart rate

There was no interaction of odors and gender on the change scores of heart rate (F(2.547, 53.486) = .227, p = .847, partial η^2 = .046, ε = .849) (Table 4.10). There was no statistically significant difference of main effect of odors on the change scores of heart rate (F(2.547, 53.486) = 1.217, p = .310, partial η^2 = .055). There was no statistically significant difference on the change scores of heart rate between men and women (F(1, 21) = .896, p = .355, partial η^2 = .041).

Table 4.10 Analysis of Variance Results for Odor and Gender Variables on Heart Rate.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Between subjects						
Gender	1	9.184	9.184	.896	.355	.041
Error 1	21	215.297	10.252			
Within subjects						
Odor	2.547	19.145	7.517	1.217	.310	.055
Gender x Odor[a]	2.547	3.570	1.402	.227	.847	.011
Error 2	53.486	330.313	6.176			

[a]Greenhouse-Geisser's epsilon = .849

Breathing rate

There was no interaction of odors and gender on the change scores of breathing rate (F(2.319, 48.707) = .402, p = .701, partial η^2 = .019, ε = .773) (Table 11). There was no statistically significant difference on the change scores of breathing rate at the different odors (F(2.319, 48.707) = .592, p = .581, partial η^2 = .027). There was no statistically significant difference on the change scores of heart rate between men and women (F(1, 21) = .056, p = .815, partial η^2 = .003).

Table 4.11 Analysis of Variance Results for Odor and Gender Variables on Breathing Rate.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
			Between subjects			
Gender	1	.525	.525	.056	.815	.003
Error 1	21	195.422	9.306			
			Within subjects			
Odor	2.319	3.773	1.627	.592	.581	.027
Gender x Odor[a]	2.319	2.562	1.105	.402	.701	.019
Error 2	48.707	133.781	2.747			

[a]Greenhouse-Geisser's epsilon = .773

The second experiment: Bimodal stimuli study

The bimodal perception study was conducted by the simultaneous presentation of olfactory stimuli and touch stimuli. The two olfactory stimuli were selected from the pleasantness score of the odors in the first experiment as the representative of pleasant and unpleasant odor combined with touch. The emotional perceptions were examined using the self-report and peripheral physiological response. Two of the original 24 participants were excluded due to the technical problem from the system error while recording the physiological data. Thus, the data from twenty-two participants, 4 men, and 18 women, were brought to analyze in this study. Six of the participants received course credit for their participation, and eighteen of participants received 7 euros in compensation. The mean age of the participants was 23.4 years old (ranges 19 – 29). Data were calculated as the change scores of the score at intervention minus the score at baseline period. A two-way repeated measure Analysis of Variance was conducted to measure the emotional responses on the influence of two within independent variables (odor and touch). Odors included three categories (no odor, Lavender oil, and Civet oil) and touch consisted of four categories (no touch, continuous touch with velocity 3 cm/s, continuous touch with velocity 30 cm/s, and discontinuous touch). All effects were analyzed concerning the changes in emotional response might be the result of the interaction between odor and touch. Olfactory stimuli might contribute to emotion to be dependent on the value of touch. Means of the change scores and SD between intervention and baseline periods by odors and touch were showed in Table 4.12 and 4.13. There were no outliers, as assessed by examination of studentized residuals for values greater than ± 3. The data was normally distributed. There were homogeneity of variances (p > .05) and the homogeneity of covariances (p > .05), as assessed by Levene's test of homogeneity of variances and Box's M test, respectively. The analysis of variance results of the effects of bimodal stimuli via self-report ratings and psychophysiological response were reported by using Greenhouse-geisser correction. The results are presented as follows:

Table 4.12 Means of Change Score on Emotional Perception via Three Emotional Dimensions by Odor and Touch.

	Odor					
	No odor		Lavender oil		Civet oil	
Touch	*M*	*SD*	*M*	*SD*	*M*	*SD*
			Valence			
NT	-.545	1.683	.091	1.9325	-2.546	2.064
3 cm/s CT	.955	1.133	.955	1.527	-2.136	2.356
30 cm/s CT	-.136	2.587	.227	2.114	-2.409	2.462
DCT	-.136	2.077	-.046	1.704	-2.864	2.532
			Arousal			
NT	-.727	2.354	-.091	2.926	.591	2.806
3 cm/s CT	-.864	2.550	-.818	2.788	.682	2.476
30 cm/s CT	.409	3.018	.455	2.857	1.091	2.448
DCT	-.682	2.767	.046	2.734	1.000	1.800
			Dominance			
NT	-.955	1.786	-.864	1.885	-1.500	1.504
3 cm/s CT	-1.591	2.175	-1.091	1.998	-1.455	1.845
30 cm/s CT	-.591	1.709	-1.000	1.718	-1.773	1.901
DCT	-1.182	1.736	-1.136	2.145	-1.546	1.766

Note: NT = No touch, CT = Continuous touch, DCT = Discontinuous touch

Table 4.13 Mean of Change Scores on Emotional Perception via Peripheral Physiological Responses by Odor and Touch.

	Odor					
	No odor		Lavender oil		Civet oil	
Touch	*M*	*SD*	*M*	*SD*	*M*	*SD*
			LF/HF ratio			
NT	-.601	1.755	-.865	.773	.266	1.092
3 cm/s CT	-.936	.980	-1.307	1.656	.754	.736
30 cm/s CT	-.676	1.557	-.663	1.283	.445	.824
DCT	-.371	.732	-.746	1.485	.885	.909
			LFnu			
NT	.162	11.897	-10.695	6.567	5.211	10.075
3 cm/s CT	-9.214	8.858	-9.692	10.232	6.792	6.465
30 cm/s CT	-7.676	12.989	-9.354	12.752	1.904	9.564
DCT	-5.117	9.452	-8.765	8.278	8.707	12.031
			HFnu			
NT	-.160	11.893	10.675	6.575	-5.343	10.102
3 cm/s CT	9.222	8.871	9.672	10.226	-6.838	6.453
30 cm/s CT	7.665	13.000	9.323	12.756	-1.933	9.592
DCT	5.111	9.452	8.735	8.280	-8.757	12.080
			SCR amp.			
NT	0.000	0.000	0.641	1.022	1.517	2.412
3 cm/s CT	2.393	3.326	2.198	3.135	2.456	3.629
30 cm/s CT	3.570	5.044	3.193	3.544	4.325	5.017
DCT	1.643	2.755	1.012	1.477	1.365	1.760
			HR			
NT	0.196	2.277	-2.679	3.672	-0.562	2.710
3 cm/s CT	-2.206	4.909	-3.139	3.942	-1.511	6.953
30 cm/s CT	-2.254	3.260	-1.832	4.270	-1.890	3.351
DCT	-1.883	4.307	-2.439	4.610	-2.113	2.691
			BR			
NT	0.500	1.420	0.205	2.085	-0.652	1.212
3 cm/s CT	-0.075	1.528	-0.340	1.933	-0.061	1.626
30 cm/s CT	0.878	1.721	-0.164	1.836	-0.058	1.855
DCT	0.729	1.500	0.628	1.684	0.202	1.701

Note: NT = No touch, CT = Continuous touch, DCT = Discontinuous touch
LF/HF ration = Ration of low frequency variability to high frequency variability, LFnu = low frequency power in normalized unit, HFnu = high frequency power in normalized unit, SCR amp. = Skin conductance response amplitude, HR = Heart rate, BR = Breathing rate

The statistical control for extraneous variables

In this study, there were two extraneous variables; the intensity, and familiarity of odors. To analyze the data with covariates by the analysis of variance method, the assumption of a linear relation between the emotional perceptual effects on self-report and covariates at each type of odor and touch need to be tested by plotting a scatterplot (Appendix 10). The relationship score (R^2) results were presented in table (Table 4.14). The relationship score indicated that there was no linear relationship between the valence/arousal rating and odor intensity and familiarity since relationship scores were low; most of the pair relations were almost zero. Now, result can be assumed that odor intensity and odor familiarity cannot be a potential confounder in this study, so these two variables were excluded from statistical analysis.

Table 4.14 The Linear Relationship Scores Between the Valence / Arousal Rating and Odor Intensity / Familiarity by Odor and Touch.

Dimensions of emotion	***N***	**Odor intensity**			**Odor familiarity**		
		No odor	Lavender	Civet	No odor	Lavender	Civet
Valence							
NT	22	.006	.005	.097	.004	.048	.009
3 cm/s CT	22	$4.328E^{-5}$	.051	.064	.017	.020	.024
30 cm/s CT	22	.008	.024	.112	$3.287E^{-7}$	.010	.004
DCT	22	$1.603E^{-4}$	.004	.266	.024	.034	.040
Arousal							
NT	22	.003	.001	$6.297E^{-4}$	.148	.291	.143
3 cm/s CT	22	.060	$4.155E^{-4}$	.001	.153	.226	.029
30 cm/s CT	22	.005	.006	.016	.229	.130	.053
DCT	22	.018	.002	.029	.125	.270	.020

Note: *N* = Numbers of participant, NT = No touch, CT = Continuous touch, DCT = Discontinuous touch

The self-report rating

The emotional perceptions of bimodal stimuli for 12 conditions were investigated via self-report along three dimensions of emotion including valence, arousal and dominance. In the valence dimension, there was no statistically significant interaction between odor and touch on valence scores ($F(4.832, 101.469) = 1.077$, p = .377, partial η^2 = .049, ε = .805) (Table 4.15). The olfactory stimuli showed a significant difference on the change scores of valence at the different odors ($F(1.526, 32.039) = 33.185$, $p < .001$, partial η^2 = .612). The touch stimuli also showed a significant difference on the change scores of valence at the different touch ($F(2.188, 45.950) = 5.948$, $p = .004$, partial η^2 = .221). As showed in Figure 4.5, irrespective of touch, no odor and Lavender oil elicited a pleasantness 2.523, $p < .001$, 95% CI [1.614, 3.431], and 2.795, $p < .001$, 95% CI [1.574, 4.017] greater than Civet oil. As showed in Figure 4.6, irrespective of odor, continuous touch with velocity 3 cm/s elicited a pleasantness .924, $p = .001$, 95% CI [.325, 1.523], and .939, $p < .001$, 95% CI [.426, 1.453] greater than no touch and discontinuous touch, respectively.

Table 4.15 Analysis of Variance Results for Odor and Touch Variables on Self-report of Valence.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.526	418.091	274.035	33.185	.000	.612
Error (Odor)	32.039	264.576	8.258			
Touch[b]	2.188	38.496	17.593	5.948	.004	.221
Error (Touch)	45.950	135.920	2.958			
Odor x Touch[c]	4.832	7.970	1.649	1.077	.377	.049
Error (Odor x Touch)	101.469	155.364	1.531			

[a, b, c] Greenhouse-Geisser's epsilon = .763,.729, and .805 respectively.

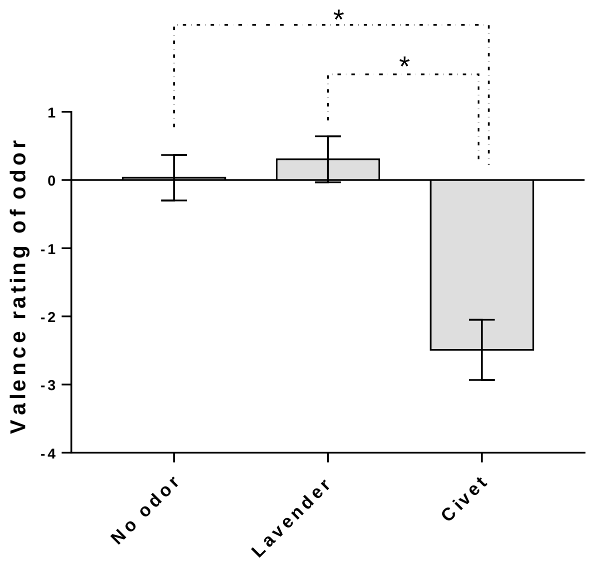

Figure 4.5 The mean change scores of valence rating under different odors. There was a significant pleasantness effect of odors. Civet was pleasant less than No odor and Lavender. The rating scale was from 1 to 9. Error bars correspond to ± S.E.M.. Significant difference * p < .001.

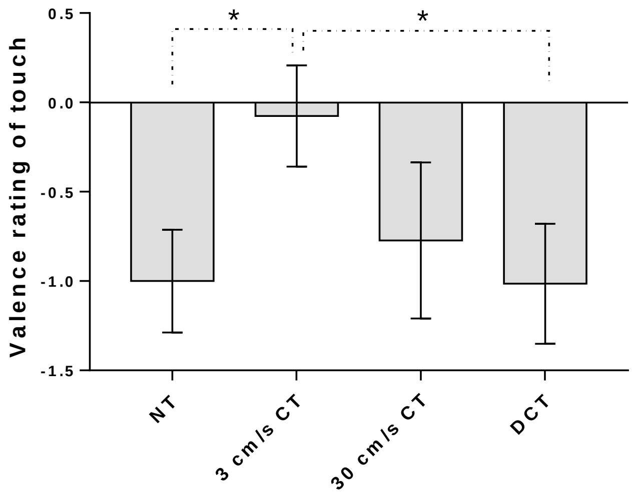

Figure 4.6 The mean change scores of valence rating under different touch. Different touch influenced the different level of pleasantness. Continuous touch with velocity 3 cm/s was more pleasant than no touch and discontinuous. The rating scale was from 1 to 9. Error bars correspond to ± S.E.M.. Significant difference * p < .01. NT = no touch, CT = continuous touch and DCT = discontinuous touch

In the arousal dimension, there was no statistically significant interaction between odor and touch on arousal score ($F(4.696, 98.616) = 1.001$, $p = .419$, partial $\eta^2 = .045$, $\varepsilon = .783$) (Table 4.16). The olfactory stimuli showed a significant difference on the change scores of arousal at the different odors ($F(1.426, 29.948) = 5.971$, $p = .012$, partial $\eta^2 = .221$). The touch stimuli also showed a significant difference on the change scores of arousal at the different touch ($F(2.927, 61.475) = 3.387$, $p = .024$, partial $\eta^2 = .139$). As showed in Figure 4.7, irrespective of touch, Civet oil elicited an arousal feeling 1.307, $p = .017$, 95% CI [.203, 2.410] greater than no odor. Also, as showed in Figure 4.8, irrespective of odor, continuous touch at velocity 30 cm/s elicited an arousal feeling .985, $p = .027$, 95% CI [.085, 1.885] higher than continuous touch at velocity 3 cm/s.

Table 4.16 Analysis of Variance Results for Odor and Touch Variables on Self-report of Arousal.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.426	80.068	56.145	5.971	.012	.221
Error (Odor)	29.948	281.598	9.403			
Touch[b]	2.927	34.515	11.791	3.387	.024	.139
Error (Touch)	61.475	213.985	3.481			
Odor x Touch[c]	4.696	10.780	2.296	1.001	.419	.045
Error (Odor x Touch)	98.616	226.220	2.294			

[a, b, c] Greenhouse-Geisser’s epsilon = .713,.976, and .783 respectively.

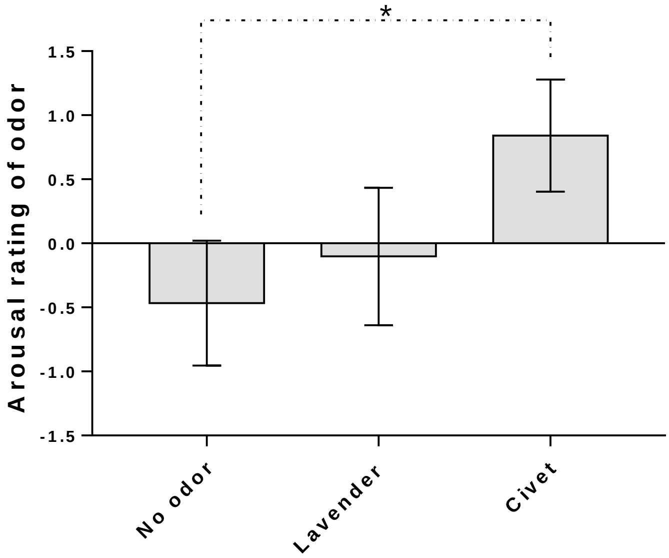

Figure 4.7 The mean change scores of arousal rating under different odors. Odors elicited a different level of arousal.Civet was more arousal than No odor. The rating scale was from 1 to 9. Error bars correspond to ± S.E.M.. Significant difference * $p < .05$.

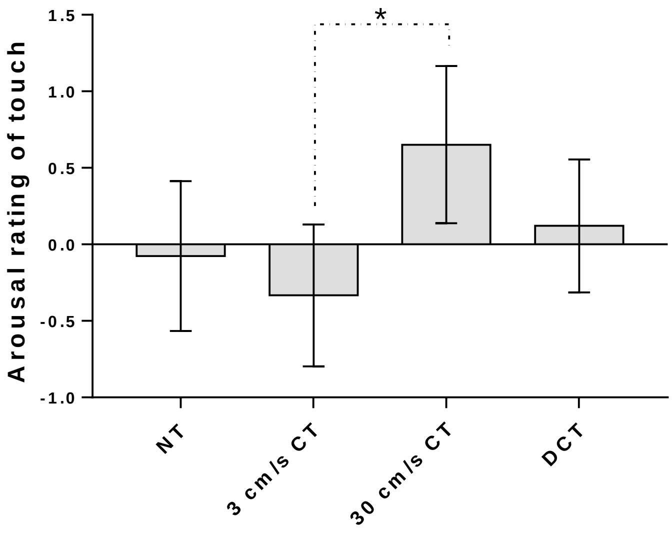

Figure 4.8 The mean change scores of arousal rating under different touch. Different touch elicited the different level of arousal. Continuous touch with velocity 30 cm/s was more arousal than continuous touch with velocity 3 cm/c. The rating scale was from 1 to 9. Error bars correspond to ± S.E.M. Significant difference * $p < .05$. NT = no touch, CT = continuous touch and DCT = discontinuous touch.

In the dominance dimension, there was no statistically significant interaction between odor and touch on dominance scores (F(3.679, 77.265) = 1.529, p = .206, partial η^2 = .068, ε = .613) (Table 4.17). There was no statistically significant difference on the change scores of dominance at the different odors (F(1.458, 30.611) = 2.079, p = .153, partial η^2 = .090). Also, there was no statistically significant difference on the change scores of dominance at the different touch (F(2.678, 56.232) = .698, p = .542, partial η^2 = .032).

Table 4.17 Analysis of Variance Results for Odor and Touch Variables on Self-report of Dominance.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.458	15.826	10.857	2.079	.153	.090
Error (Odor)	30.611	159.841	5.222			
Touch[b]	2.678	3.466	1.294	.698	.542	.032
Error (Touch)	56.232	104.284	1.855			
Odor x Touch[c]	3.679	10.386	2.823	1.529	.206	.068
Error (Odor x Touch)	77.265	142.614	1.846			

[a, b, c] Greenhouse-Geisser's epsilon = .729,.893, and .613 respectively.

The peripheral physiological responses

The psychophysiological variables associated with emotional processing were recorded consisting of the indices of LFnu, HFnu, the LF/HF ratio, heart rate, breathing rate, and SCR amplitude to represent as in the dimension of valence and arousal.

The LF/HF ratio

In the LF/HF ratio, there was no statistically significant interaction between odor and touch on pleasantness scores (F(2.973, 62.440) = 1.028, p = .386, partial η^2 = .047, ε = .496) (Table 4.18). The olfactory stimuli showed a significant difference on the change scores of the LF/HF ratio at the different odors (F(1.835, 38.545) =

32.750, $p < .001$, partial $\eta^2 = .609$). Meanwhile, there was no statistically significant difference on the change scores of the LF/HF ratio at the different touch (F(2.244, 47.115) = 1.452, $p = .244$, partial $\eta^2 = .065$). As showed in Figure 4.9, irrespective of touch, Civet oil elicited the change scores of LF/HF ratio 1.233, $p < .001$, 95% CI [.664, 1.803], and 1.483, $p < .001$, 95% CI [.965, 2.000] greater than no odor and Lavender oil, respectively.

Table 4.18 Analysis of Variance Results for Odor and Touch Variables on LF/HF Ratio.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.835	110.913	60.427	32.750	< .001	.609
Error (Odor)	38.545	71.120	1.845			
Touch[b]	2.244	6.401	2.853	1.452	.244	.065
Error (Touch)	47.115	92.584	1.965			
Odor x Touch[c]	2.973	7.887	2.652	1.028	.386	.047
Error (Odor x Touch)	62.440	161.035	2.579			

[a, b, c] Greenhouse-Geisser's epsilon = .918,.748, and .496 respectively.

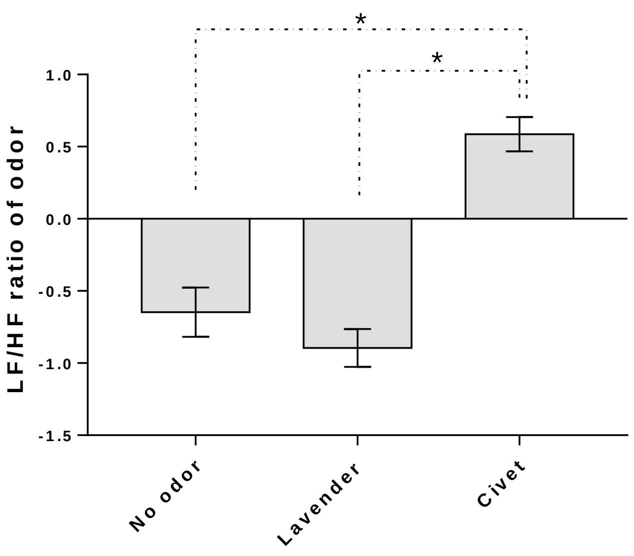

Figure 4.9 The mean change scores of the LF/HF ratio under different odors. The change scores of the LF/HF ratio of Civet was greater than no odor and Lavender significantly. Error bars correspond to ± S.E.M.. Significant difference * $p < .001$.

HFnu

There was no statistically significant interaction between odor and touch on HFnu score (F(4.155, 87.253) = 2.059, p = .091, partial η^2 = .089, ε = .692) (Table 4.19). The olfactory stimuli showed a significant difference on the change scores of HFnu at the different odors (F(1.935, 40.625) = 66.744, p < .001, partial η^2 = .761). There was no statistically significant difference on the change scores of HFnu at the different touch (F(2.681, 56.291) = 1.585, p = 207, partial η^2 = .070). As showed in Figure 4.10, irrespective of touch, no odor and Lavender oil elicited the change scores of HFnu 11.178, p < .001, 95% CI [7.939, 14.416], and 15.319, p < .001, 95% CI [11.676, 18.962] greater than Civet oil. Moreover, Lavender oil elicited the change scores of HFnu 4.142, p = .030, 95% CI [.342, 7.941] greater than no odor.

Table 4.19 Analysis of Variance Results for Odor and Touch Variables on HFnu.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.935	11051.837	5712.949	66.744	< .001	.761
Error (Odor)	40.625	3477.277	85.594			
Touch[b]	2.681	553.506	206.491	1.585	.207	.070
Error (Touch)	56.291	7333.850	130.284			
Odor x Touch[c]	4.155	1154.986	277.983	2.095	.091	.089
Error (Odor x Touch)	87.253	11778.203	135.001			

[a, b, c] Greenhouse-Geisser's epsilon = .967,.894, and .692 respectively.

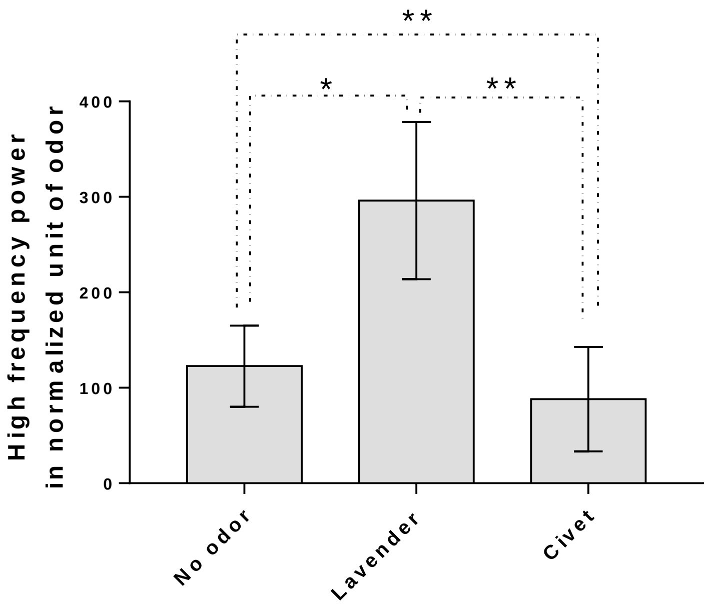

Figure 4.10 The mean change scores of High frequency power in normalized unit (HFnu) under different odor. Odors significantly affected on the HFnu. Lavender elicited HFnu greater than No odor and Civet. Moreover, No odor elicited HFnu greater than Civet as well. Error bars correspond to ± S.E.M.. Significant difference * p < .05, ** p < .001.

SCR

There was no statistically significant interaction between odor and touch on SCR amplitude (F(3.791, 79.607) = 1.945, p = .115, partial η^2 = .085, ε = .632) (Table 4.20). There was no significantly statistical difference on the change scores of SCR amplitude at the different odors (F(1.699, 35.686) = 2.300, p = .122, partial η^2 = .099). Touch stimuli showed a statistically significant difference on the change scores of SCR amplitude at the different touch (F(1.333, 27.996) = 10.864, p = .001, partial η^2 = .341). As showed in Figure 4.11, irrespective of odor, continuous touch at velocity 3 cm/s elicited the SCR amplitude 1.630, p = .048, 95% CI [.011, 3.249] greater than no touch. The continuous touch at velocity 30 cm/s elicited the SCR amplitude 2.977, p = .011, 95% CI [.539, 5.414], 1.347, p = .023, 95% CI [.139, 2.555], and 2.356, p = .010, 95% CI [.463, 4.249] greater than no touch, continuous touch at velocity 3 cm/s, and discontinuous touch, respectively.

Table 4.20 Analysis of Variance Results for Odor and Touch Variables on SCR.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.699	20.895	12.296	2.300	.122	.099
Error (Odor)	35.686	190.762	5.346			
Touch[b]	1.333	334.703	251.063	10.864	.001	.341
Error (Touch)	27.996	646.970	23.109			
Odor x Touch[c]	3.791	24.427	6.444	1.945	.115	.085
Error (Odor x Touch)	79.607	263.729	3.313			

[a, b, c] Greenhouse-Geisser's epsilon = .850,.444, and .632 respectively.

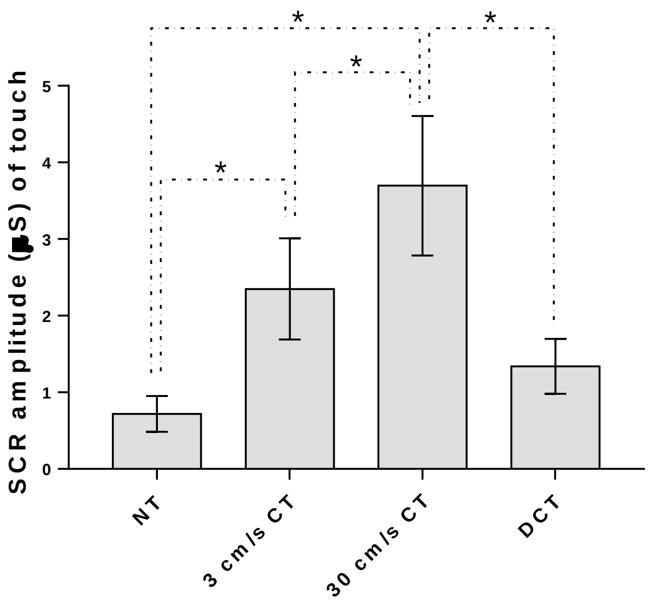

Figure 4.11 The mean change scores of skin conductance response amplitude under different touch. Tactile stimuli affected on the SCR amplitude significantly. Continuous touch with velocity 3 cm/s elicited SCR greater than no touch. In addition, continuous touch with velocity 30 cm/s elicited SCR greater than no touch, continuous touch with velocity 3 cm/s, and discontinuous touch. Error bars correspond to ± S.E.M.. Significant difference * $p < .05$. NT = no touch, CT = continuous touch and DCT = discontinuous touch.

Heart rate

There was no statistically significant interaction between odor and touch on heart rate (F(3.408, 71.565) = 1.166, p = .331, partial η^2 = .053, ε = .568) (Table 4.21). There was no statistically significant difference on the change scores of heart rate at the different odors (F(1.982, 41625) = 1.674, p = .200, partial η^2 = .074). Also, there was no statistically significant difference on the change scores of heart rate at the different touch (F(2.130, 44.738) = 1.656, p = .201, partial η^2 = .073).

Table 4.21 Analysis of Variance Results for Odor and Touch Variables on Heart Rate.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.982	58.029	29.276	1.674	.200	.074
Error (Odor)	41.625	727.884	17.487			
Touch[b]	2.130	65.580	30.783	1.656	.201	.073
Error (Touch)	44.738	831.563	18.587			
Odor x Touch[c]	3.408	74.741	21.932	1.166	.331	.053
Error (Odor x Touch)	71.565	1345.971	18.808			

[a, b, c] Greenhouse-Geisser’s epsilon = .991,.710, and .568 respectively.

Breathing rate

There was no statistically significant interaction between odor and touch on breathing rate (F(4.120, 86.517) = 1.230, p = .304, partial η^2 = .055, ε = .687) (Table 4.22). There was no statistically significant difference on the change scores of breathing rate at the different odors (F(1.326, 27.853) = 2.303, p = .134, partial η^2 = .099). Also, the was no statistically significant difference on the change scores of breathing rate at the different touch (F(2.582, 54.229) = 2.001, p = .133, partial η^2 = .087).

Table 4.22 Analysis of Variance Results for Odor and Touch Variables on Breathing Rate.

Source	*df*	*SS*	*MS*	*F*	*p*	Partial η^2
Odor[a]	1.326	19.201	14.477	2.303	.134	.099
Error (Odor)	27.853	175.092	6.286			
Touch[b]	2.582	16.771	6.495	2.001	.133	.087
Error (Touch)	54.229	176.029	3.246			
Odor x Touch[c]	4.120	15.551	3.775	1.230	.304	.055
Error (Odor x Touch)	86.517	265.608	3.070			

[a, b, c] Greenhouse-Geisser's epsilon = .663,.861, and .687 respectively.

CHAPTER 5
DISCUSSION AND CONCLUSION

This study aimed to investigate the emotional perception in unimodal stimuli of olfaction and in multimodal stimuli that process through olfaction and touch. The study was carried out for two experiments. In the first experiment, the researcher investigated the emotional effects of unimodal stimuli, processed through the olfaction channel, to examine the emotional effects of four different odors and to select two distinctive emotional expression odors for examining in the second experiment. Moreover, the first experiment also investigated the effect of gender differences on the emotional perception. In the second experiment, researcher investigated the capable integration of emotion from multimodal inputs while presented congruent or incongruent emotional stimuli simultaneously. To find out answers, this study measured the emotional outcome via self-report rating in three dimensions (i.e., valence, arousal, and dominance). Because self-report was a subjective measure that can occur an easily bias, thus, in order to reduce bias objective measure peripheral physiological responses (i.e., heart rate, breathing rate, skin conductance, and heart rate variability) were monitored during a stimuli presentation as well. The emotional characteristics of stimuli were interpreted from the change scores of stimuli compared with baseline. This study was a within-subjects design, thus, every participant received all stimuli conditions but was different in the sequence of stimuli presentation. This study expected that participants would respond to be more pleasure while perceived the pleasant stimuli by an increase in rating of valence scores, and exhibited an upward parasympathetic activity that characterized by an increase in HFnu, and decrease in the LF/HF ratio suggesting increased vagal efferent activity and the sympathovagal balance shifted from sympathetic to parasympathetic activity, respectively. On the other side, these results would be expressed in a contradiction to unpleasantness stimuli. Furthermore, participants would respond to be more arousal while perceived the arousing stimuli by an increase in rating of arousal scores, and a sharp increase in skin conductance response amplitude. Moreover, men would represent their emotional changes to odor that differ from women. In addition, the multisensory congruent stimuli would elicit emotional expression higher than unimodal stimulus. The general information was described as frequency, mean, and standard deviation. SPSS were used to analyze data. Two types of statistical analysis, the two-way mixed ANOVA and the two-way repeated measure ANOVA, were performed for the first and second experiment, respectively.

Discussion

There were twenty-three participants, 11 men, and 12 women, were recruited to participate in the first experiment. The mean age of participants was 24.7 years old (ranges 20 – 38). In the second experiment, twenty-four participants were recruited, but two of them were excluded from the experiment due to the technical problem from the system error while recording the physiological responses. Thus, there were twenty-two participants, 4 men, and 18 women, remain in the experiment till the end of second experiment. The mean age of the participants was 23.4 years old (ranges 19 – 29). The results were discussed by following the hypothesises of study:

The first hypothesis: This study was hypothesized that there were different emotional perceptions for different odors. Pleasant odor would elicit pleasant experience; meanwhile an unpleasant odor would elicit an opposite feeling. Three different odors (Lavender oil, Michelia oil, and Civet oil) were tested to compare with Sunflower oil, odorless oil, as the neutral (control) stimuli. The findings of this study were consistent with the hypothesis that each odor can elicit different emotions. This finding supported Zald and Pardo's (1997) study that odors effected on emotional perception has been associated with altered brain activity in limbic structures (i.e., amygdala, orbitofrontal cortex and anterior cingulate cortex). In addition, odors have been effected in the alteration in peripheral autonomic responses (Vernet-Maury, Alaoui-Ismaïli, Dittmar, Delhomme, & Chanel, 1999). Comparing with control (Sunflower oil), the self-report on valence score showed that Civet oil elicited unpleasant feeling, participants felt more unpleasantness after smell. In addition, the unpleasant character of Civet oil was supported by a decrease in HFnu that meant Civet oil reduce a parasympathetic activity. Despite in the first experiment the fact that Lavender oil did not elicit a significant pleasantness compared to control

(Sunflower oil), but in the second experiment Lavender oil significantly elicited a pleasant feeling. Besides valence domain, the result on arousal domain showed that Michelia oil elicited arousing feeling compared to control by increase in SCR amplitude response. The distinction between pleasant and unpleasant odors that was found in this study is consistent with Bensafi et al. (2002) that showed the correlation of pleasantness with heart rate variation and arousal with skin conductance. Moreover, the greatly significant result of Civet oil on subjective and objective measures also supported Delplanque et al.'s (2008) study that ANS activity can be an important index of unpleasant odor.

The second hypothesis: This study was hypothesized that gender difference impacted to emotional perception of odors. The result showed that men and women perceived some type of odor differently. Gender difference effected to the perception of pleasant feeling of some odor. Considering at LF/HF ratio, men felt more unpleasant than women when smell Michelia oil and Civet oil. The high LF/HF ratio meant a decrease in parasympathetic activity. Taken together with the result of Civet oil in the first hypothesis, men were sensitive to unpleasant odors they perceived Civet oil to be more unpleasant than women. Moreover, Civet oil elicited unpleasant feeling in men compared to others odor, meanwhile, women showed a likeness tendency to Civet oil to elicit their unpleasant feeling. The finding show a controversial result with the study of Chentsova-Dutton and Tsai (2007) that reveal an increase in sympathetic activity in women than men when smell unpleasant odor. This finding also contrast to Croy et al.'s (2014) study that they do not find the effect of gender difference. Nevertheless, the researcher cannot conclude that Croy and his colleagues' study show the apparently incongruous result because they examined the effect of gender by self-report rating, while this study revealed effect of gender via psychophysiological responses.

The third hypothesis: This study was hypothesized that there was a multisensory integration of emotion between olfaction and touch which could be measured via self-report and peripheral physiological responses. Based on first experiment, Lavender oil showed a significant difference on valence score of self-report compare to Civet oil. These odors that showed distinctively different valence were selected to combine presentation with touch. To investigate an emotional integration of bimodal stimuli, the 12 conditions of congruent and incongruent stimuli between odor and touch were presented to participants; odor (neutral, pleasant, and unpleasant stimuli) and touch (neutral I, neutral II, pleasant, and unpleasant stimuli).

There was no interaction effect between odor and touch. The result did not support the hypothesis, it was contrary to expectation. The presentation of congruent bimodal stimuli did not increase any effects. The emotional consequences of any stimuli occurred due to their individual modality. This finding supported Alvarado, Vaughan, Stanford, and Stein's (2007) study, and Brouwer et al.'s (2013) study that bimodal stimuli did not enhance arousal or valence perception over unimodal stimuli. The physiological responses in this study showed that odor and touch elicited emotions in a different dimension. Odors mainly influenced toward valence dimension, but touch influenced toward arousal dimension. A result also supported Wiens and Öhman’s (2007) study that emotion aspects were often conceptualized as being separate processing levels of response systems that were not closely linked. Thus, it was likely to find out that there was no integration effect between odor and touch.

By contrast, this finding is inconsistent with Arimoto and Okanoya's (2011) study, Croy, Angelo, and Olausson's (2014) study, and Ellingsen et al.'s (2014) study that found an interaction effects of bimodal stimuli. Ellingsen and colleagues' (2014) showed a positive integration of congruent stimuli between pleasant touch and happy face. Croy, Angelo, and Olausson (2014) found that unpleasant odor (Civet) decreased the pleasant perception of touch, while the congruent bimodal stimuli did not enhance an effect. However, a contradictory result in the study of Croy and colleagues (2014) cannot lead to an obvious conclusion regarding a multisensory integration. In this case, it should be noted that the integration effect is the influence of induction of emotion from pre-emotional induction. Participant did not receive emotional stimuli simultaneously; unpleasant odor changes an emotional state leading to the perception of touch changes later. The presentation time of bimodal stimuli does not match to the principle rules of integration (Holmes & Spence, 2005) regarding temporal rule. The temporal rule ascribe that the result will be interpreted as multisensory integration if the bimodal stimuli must occur at approximately the same time. Even though, the multisensory integration was found in the study of Arimoto and Okanoya, a discrepancy between Arimoto and Okanoya's (2011) study and this study might be because of a difference in type of measured outcome. This study measured integral result of former expression that could be expressed by participants in a unimodal perception, whereas Arimoto and Okanoya measured a representation of emotion that was not expressed and can not be measured in unimodal condition.

In the second experiment, Civet oil still elicited an unpleasant feeling via self-report of valence compared to control (no odor). Moreover, the unpleasant character of Civet oil was also found on LF/HF ratio, and HFnu. The effect of Civet oil confirmed finding in the first experiment and can be summarized that Civet oil is an unpleasant odor. Moreover, Civet oil also elicited an arousing feeling compared to control by increasing in arousal rating score. Besides Civet oil, Lavender oil elicited a pleasant feeling compared to control (no odor) by increase in HFnu score.

This study found that the gentle brush stroking with velocity 3 cm/s elicited a pleasant feeling on valence score compared to control (no touch and discontinuous touch), whereas the brush stroking with velocity 30 cm/s did not show a significant difference from neutral contact. By affective touch, a pleasant feeling could raise while presented a touch stimuli to hairy skin because influence of CTs fibers at the receptive field. The previous study of Francis et al. (1999) indicated that the stimulation at CT afferents activated OFC; the area that processed reward. In addition, the positive correlation of touch's pleasantness rating with the rewarding region in the brain was shown in many studies (Olausson et al., 2002; Rupp et al., 2003; Lindgren et al., 2012; Vallbo et al., 1999). This study supported studies of Löken et al. (2009), McGlone et al. (2007, 2014), Morrison (2012), Morrison et al. (2011), and Triscoli et al. (2013) that soft and low-velocity stroking touch was more pleasant than high-velocity stroking, unmoved touch, and no touch.

On the other hand, considering a peripheral physiological effect showed that touch had an arousing effect. Both 3 and 30 cm/s velocity of soft touch elicited an arousing feeling compared to control (no touch and discontinuous touch) by increase in SCR amplitude. In addition, 30 cm/s velocity of soft touch also elicited arousing feeling greater than 3 cm/s velocity of soft touch by increase in arousal rating and

SCR amplitued. It was not only self-report, but skin conductance response also showed a positive effect of arousal domain, especially to soft brush stroking with velocity 30 cm/s by giving highest scores among other type of stimuli. This arousing attribute confirmed a finding of Olausson, Cole, Rylander, et al. (2008) in neuronopathy subjects that a brush stroking elicited sympathetic skin response. Most studies in the emotional perception of touch concluded touch accomplishment in reward system via a liking component. It was because early of many studies investigated the emotional processing by using only valence dimension of self-report and then displayed a positive correlation to rewarding regions. Of course, in this sense, the following conclusion should be reported that slow stroking touch elicited a pleasant feeling and found a correlation between a pleasantness rating and the region that processed a reward system, if this study did not find a positive effect of touch in another one dimension, arousal. Indeed, the reward system composed of the complex parallel components of three subtype; liking, wanting, and learning (Rolls, Kringelbach, et al., 2003; Berridge, 2003). Lang et al.'s (1993) study revealed that an increase in arousal was a crucial element associated with positive rewards. Neuroimaging study of Francis et al. (1999) has shown that pleasant touch activates the orbitofrontal cortex, a limbic region related corresponding with the study of Grabenhorst and Rolls (2011) showed that not only OFC that associated with affective value but amygdala and pregenual cingulate cortex also involved with reward processing and they could represent to reward stimuli. In terms of arousal. Arousing feeling induced dopamine neurotransmitters that played an important role in the regulation of arousal state in actively interacted with the environment (Ikemoto, 2007). In case that found an arousal effect of touch, touch might not be only liking stimulus but this social stimulus also be a wanting stimulus (Horvitz, 2000). Soft touch-induced arousal supported a usefulness of applied touch in massage’s studies of Diego et al. (2004), Diego and Field (2009), Field et al. (2006), and Field, Diego, and Hernandez-Reif (2010) that light pressure touch elicited a sympathetic nervous system response and increased arousal.

However, arguments that a result did not show interaction effect of bimodal stimuli might occur from the limitation of study, such as, a repetition of stimuli and using manual stroking touch. It is true that the repetition of stimuli might change its emotional perception. Triscoli, Croy, Olausson, and Sailer's (2014) study showed that wanting and liking rating decreased significantly over repeated exposure of odor presentation. The perceived pleasantness of pleasant odors was maintained over repetitions, whereas the perceived unpleasantness of unpleasant odors decreased (Croy, Maboshe, & Hummel, 2013). By contrast, the intensity and perception of odors were found to change but not in the subjective value due to habituation and potential desensitization processes (Andersson, Claeson, Ledin, Wisting, & Nordin, 2013). These evidence showed inconsistency information. However, in order to control error of a repetitive stimulation; the order of stimuli presentation was performed a random order and the washout period was extended sufficiently. Moreover, it seems less possible to be argued that the pleasant effect of touch may be obscured from a touch's method. In case of manual stroking touch, even this study did not use the machine to present touch stimuli, but experimenter used soft artist's brush to present touch by following a study of Triscoli et al. (2013) that the manual capability of brush stroking to make a pleasure feeling was sufficient to present optimized stimuli and stimulated CT afferents to gain a similar pleasantness with robot touch.

Nevertheless, a rational thing that might distort an analytical result in this study is a point of stimuli's type. Triscoli, Ackerley, and Sailer (2014) showed that even though the stroking 3 cm/s was more pleasantness rating than the stroking at 30 cm/s, however, participants never rated both types of stroking as unpleasantness touch even after 50 min. of stroking. Representations in each emotional dimension of stimuli were a light relation and they did not show a truly distinctive effect on a panel, especially unpleasant touch, thus their effectiveness were easy to be obscured. Another concern is about the effect of top-down factors. In self-report, the perception through subjective rating probably depended on not only bottom-up neural signaling that has been driven by stimuli but also on top-down factors including earlier experience, expectation, culture (Löken et al., 2009). Cognitive influences on affective representation were revealed by study of McCabe, Rolls, Bilderbeck, and McGlone (2008). They show that cognitive can modulate the affective value of slight and soft touch. In addition, cognitive also influences on olfaction. A previous study of de Araujo, Rolls, Velazco, Margot, and Cayeux (2005) has been shown that a semantic information of visual stimuli can modulate olfactory representation in the brain's regions that related to affective value. Participants rate to be more pleasant feeling when a presentation of odor was correlated with semantically congruent stimuli. Furthermore, Sharvit, Vuilleumier, Delplanque, and Corradi-Dell'Acqua (2015) reveal that expectancy of one modality can cross to effect the other modalities, such as, unpleasant event can elicit the representation of unpleasant consequences. On the other hand, even the psychophysiological response was an objective measure, but a perception through this method may be confounded and resulted in the distortion of signaling output by top-down factors. Previous studies have been shown that imagery effect to affective valence and arousal. For instance, imagery can elicit skin conductance, moreover, the effect of imagery on skin conductance sustains its level over 1 min (Haney & Euse, 1976), high-arousal imagery increases heart rate and skin conductance response (Witvliet & Vrana, 1995), and imagery increases skin conductance but no heart rate increasing (Hägni et al., 2008). As mentioned above, there are many factors that can confound outputs of self-report rating and psychophysiological response in this study. To reduce the problem of top-down factors, this study measured the emotional state by the self-report as the subjective measure and also the peripheral physiological response as the objective measure, and participants were instructed to be in a relaxation position during experiment. In addition, participants were asked to blindfold and headphone in order to shield them from distracting stimuli that process through audition and vision. Moreover, odor familiarity was measured and taken a statistical control to reduce the effect of familiarity to experience that may interfere results. However, there is still having several top-down factors that were not controlled in this study and can influence to the result. The later concern that may distort the integrative result between bimodal stimuli result in the multisensory integration did not find in this study may be the effect of ceiling (Holmes & Spence, 2005). One principle rule of multisensory integration is that one of the unimodal signal should has least effective in order to enhance their effect after combined signals as superadditive effects (Alais et al., 2010). If the neurons responses to unimodal stimuli are near or at ceiling, the integrative effects are difficult to be found. Perrault et al. (2005) reveal that neurons cannot respond higher than at certain rates due to biophysical constraints. Thus, if the olfactory neurons or tactile neurons in this study responses to unimodal stimuli that almost meet to its highest responding rate, when bimodal stimuli are simultaneously presented then there is no integration to be found. The effect of ceiling may bias data or cannot be detected the integration

There were no significant changes were observed for the ability of participants in dominance dimension, heart rate, breathing rate throughout the presentation of stimuli of the first and second experiment. Because the emotional expression on dominance dimension did not different between stimuli, it means that participant can control their feeling over the influence of stimuli, and the cognitive or top-down process can influence to the responses. The study of Grabenhorst and Rolls (2011) show that top-down process can modulate the affective value that results to outputs. This finding supports a mentioning that this study may be distorted by top-down factors.

Furthermore, there was likely that one stimulus might stimulate more than one emotion. Whereas, Civet oil was confirmed its consistent effect as unpleasant odor via valence rating, LF/HF ratio and HFnu, in the second experiment, Civet oil showed a second attribute as arousing odor as well. This result is supported by a study of Royet et al. (2003) that unpleasant odors induce more arousal than pleasant odors. However, repetitive experiment should be conducted in order to confirm an effect of Civet oil.

Implication

This is the first work that investigates the psychophysiological effects of simultaneous perception of bimodal stimuli process through olfactory and tactile modalities. Besides examining the influence of stimuli on emotional state, this is the first study that reveals the peripheral psychophysiological effects of the stimulation of CT afferents. The findings showed a significant main effect of odor and touch on emotional perceptions. These findings are not entirely consistent with hypothesis, but they guide to a reconsideration of applied touch and odor in healthcare or clinical standpoint. The study raises questions regarding the integration of both modalities by using other peripheral physiological variables, the others technical study, or the onward behavioral effect of combined modalities. Are there emotional integration displays via pupil activity, skin temperature, and muscle tension? What regions are stimulated in the brain when perceiving combined odor and touch? Is there intervention that increases or decreases perception in the brain? How the combined modalities affect behavior or cognition? Is there a cultural and gender impact on the integration of odor and touch? If the kinds of odor are changed, such as, changes in pleasant odor to arousing odor, or changes from one pleasant odor to another pleasant odor whether the integration results will be constant?

Conclusion

Taken together, the present findings highlight that there was no crossed interaction between olfactory and tactile modalities in the aspect of emotion. Bimodal stimuli did not increase arousal or valence levels of unimodal stimuli by self-report rating and psychophysiological measures. Markedly, the findings gained the emotional effect of Civet oil as strikingly unpleasant odor; it elicited unpleasantness on the indices of self-report and psychophysiological responses. Michelia oil elicited objective arousal, meanwhile, Lavender oil elicited a pleasant feeling. In addition, soft and low-velocity stroking touch at 3 cm/s could provide subjective pleasantness with moderate arousal. Meanwhile, soft and low-velocity stroking touch at 30 cm/s elicited high arousal without the feeling of pleasantness. Moreover, men were more sensitive to some type of odor than women especially unpleasant odors and arousing odors.

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APPENDIX 1

Public Announcement for participating in the experiment

Adult Volunteers

Ages 18 to 50

This is a research project about smell, touch, and psychophysiology

We are looking for non-smoker healthy volunteers to study smell and touch effects on Heart function, Electrodermal activity, and Respiratory function. The recruiting time start from ___________.

Experimental duration: 90 minutes

Place: Palazzo Istruzione.

MORE INFORMATION

3285441221

asalouch@gmail.com

Receive 90 min credit for experimental attending

APPENDIX 2

Questionnaire for the participant

Directions: I would like some information about your health history and current medication. Any information you provide will be used only for research purposes and will be held in strict confidence. It will not be released to anyone, other than researcher involved in the study. Please feel free to answer and complete as fully and accurately as possible. Check (☑) on the check boxes or/and fill answers in the blank (………) in response to the following questions:

Participant Code No………

1. Gender: ☐ Man ☐ Woman
2. Age ……………
3. Have you had Congenital diseases or Chronic health conditions?
   - 3.1 Cardiovascular disorders such as hypertension, chest pain (angina), heart attack ☐ Yes ☐ No
   - 3.2 Psychiatric disorders such as depression, anxiety ☐ Yes ☐ No
   - 3.3 Respiratory disorders such as asthma, allergic rhinitis ☐ Yes ☐ No
   - 3.4 Others ………………………………………..
4. Do you have arm and/or finger injury? ☐ Yes ☐ No
5. Are you taking some medicine? ☐ Yes …………………….. ☐ No
6. Are you pregnant? (for women only) ☐ Yes ☐ No
7. Do you smoke? ☐ Yes ☐ No
8. Are you willing to stop drinking caffeine and alcohol for 24 hours before experiment? ☐ Yes ☐ No

Name ……………………………………………………….

Address ……………………………………………..….

Mobile ………………………………………

E-mail ………………………………………

Questionario per i partecipanti (Italian Version)

Istruzioni: Vorremmo raccogliere alcune informazioni circa il Suo stato di salute e su eventuali trattamenti/cure a cui è sottoposto al momento. Tutte le informazioni che fornirà saranno utilizzate esclusivamente ai fini della ricerca e saranno trattate in maniera strettamente confidenziale. Solo i ricercatori coinvolti in questo studio avranno accesso a questi dati. Per favore cerchi di rispondere accuratamente e di completare ogni parte del questionario. Spunti (☑) la casella appropriata e/o utilizzi lo spazio (………) per scrivere la Sua risposta.

Codice del partecipante………

1. Genere: ☐ Maschio ☐ Femmina
2. Età ……………
3. Soffre di qualche malattia congenita o cronica?
   - 3.2 Disturbi cardiovascolari come ad esempio ipertensione, angina pectoris o infarto. ☐ Si ☐ No
   - 3.2 Disturbi psichiatrici come ad esempio depressione o ansia. ☐ Si ☐ No
   - 3.3 Disturbi respiratori come ad esempio asma o riniti allergiche. ☐ Si ☐ No
   - 3.4 Altro ………………………………………..
4. Ha una lesione alle braccia e/o alle dita? ☐ Si ☐ No
5. Sta assumendo qualche medicinale? ☐ Si …………………….. ☐ No
6. È incinta? (solo per donne) ☐ Si ☐ No
7. Fuma? ☐ Si ☐ No
8. Sarebbe disponibile a non assumere alcool o caffeina nelle 24 ore prima dell’esperimento? ☐ Si ☐ No

Nome ……………………………………………………….

Indirizzo …………………………………………..….

Telefono ……………………………………

E-mail ………………………………………

APPENDIX 3

Butanol Threshold Test

Participant Code No.........

Step	Concentration (%)	1	2	3
10	6.77×10^{-5}	B	W	W
9	2.03×10^{-4}	W	B	W
8	6.09×10^{-4}	W	W	B
7	1.82×10^{-3}	B	W	W
6	5.48×10^{-3}	W	B	W
5	1.64×10^{-2}	B	W	W
4	4.9×10^{-2}	W	W	B
3	14.8×10^{-2}	B	W	W
2	0.44	W	B	W
1	1.33	W	W	B
0	4	B	W	W

B = Butanol W = Water

APPENDIX 4

Information Sheet

Department of Psychology and cognitive Sciences
University of Trento
Coroso Bettini 31, rovereto (TN)

Title of Project: The Psychophysiological Effects of Touch and Smell

Researcher's Name: Anuch Salout

Contact Detail: If you have any questions at any times about this research or procedures, you may contact the principle researcher, Anuch Salout, at 3285441221 or asalouch@gmail.com

I would like to invite you to participate in this research project. Before agreeing to participate, it is important that you read and understand the following explanation of the purpose and benefits of the research and how it will be conducted.

Purpose of the research

The aim of this research project is to investigate how human being represent and integrate emotions generated by the stimulation of two different sensorial channels.

Experimental procedure

To help me in this test, I will ask you to participate in an experiment for 90 minutes. You will be place with the physiological devices for real-time recording till the end of experiment period. You will be asked for wearing the sleep mask and headphone to prevent the affective interference from other sensory modalities. You will asked to complete the questionnaire during the experimental sessions correspond with the stimuli's presentation. Information gathered from your sessions will be grouped with information from other participants, to provide outcomes about psychophysiological effects of two sensory modalities.

Possible risks or uncomfortable situations

There are no foreseeable risks or uncomfortable situations for the participants in this research.

Possible benefits

Results of this research will contribute to our scientific understanding of human's representation to sensory modalities.

Arrangements for ensuring anonymity and confidentiality

All data will be collected and stored in accordance with the Data Protection Act. 13 Legislative Decree n. 196/2003. The data obtained in this study will be treated as confidential information. The paper information related to declaration of consent and screening process will be stored securely by lock and key and the information in electronic form will be stored on computer and accessed by only the researchers who involve in the project. Your name will not be used in reports or publications.

Participation

The choice to consent to participation in this research is completely voluntary and the refusal to participate as well as the withdrawal from the research at any time of the same does not have any consequences. In the case of college students attending a graduate program of the Department of Psychology and Cognitive Science, the refusal to participate, the abandonment of the experiment and the level of performance will not have any effect on its academic activities (frequency of courses, exams, vote degree, internship). In case of neglect all the collected data will be deleted. If you decide to participate in the experiment you will be given this information sheet to keep a copy of which we recommend to be able to eventually see in the future.

Please take note of all the information provided, to discuss it with others if you wish, and if there was something that was not the light or which would like to have more information, we invite you to give all question to the research team.

Foglio Informativo (Italian Version)

Dipartimento di Psicologia e Scienze Cognitive

Università di Trento

Coroso Bettini 31, rovereto (TN)

Titolo del Progetto: Gli effetti psicofisiologici del tatto e degli odori.

Nome del Ricercatore: Anuch Salout

Contatti: Se ha domande riguardo questa ricerca, può contattare la ricercatrice responsabile dello studio, Anuch Salout, al numero 3285441221 o usando la seguente email asalouch@gmail.com

La invitiamo a partecipare a questo studio. Prima che dia il Suo consenso a partecipare, è importante che legga e comprenda la descrizione degli scopi e dei benefici di questa ricerca, e il modo in cui essa sarà condotta.

Scopo della ricerca

Lo scopo di questo progetto di ricerca è di investigare come gli esseri umani rappresentano ed integrano le emozioni generate mediante la stimolazione di due diversi canali sensoriali.

Procedura sperimentale

Questo esperimento ha una durata di circa 90 minuti. Durante l'esperimento, sarà utilizzato un dispositivo usato per la registrazione in tempo reale di attività fisiologica. Le sarà richiesto di indossare una benda sugli occhi e cuffie per prevenire interferenze da parte di altre modalità sensoriali (vista o udito). Durante l'esperimento, Le sarà inoltre richiesto di completare alcuni questionari riguardanti gli stimoli che Le verranno presentati. I dati ottenuti durante l'esperimento saranno utilizzati, insieme a quelli degli altri partecipanti, per studiare gli effetti psicofisiologici delle emozioni generate mediante due modalità sensoriali (tattile e olfattiva).

Possibili rischi o situazioni di disagio

Non è previsto nessun rischio o situazione di disagio per i partecipanti a questa ricerca.

Possibili benefici

I risultati di questa ricerca contribuiranno alla comprensione di come gli esseri umani rappresentano le modalità sensoriali.

Procedura per assicurare l'anonimato e la confidenzialità dei dati

Tutti i dati saranno raccolti e conservati in osservanza del Codice in Materia di Protezione dei Dati, decreto legislativo n. 196/2003. Ogni informazione raccolta sarà considerata come confidenziale. Tutti i documenti compilati dai partecipanti saranno conservati in modo sicuro e depositati in luoghi chiusi a chiave. Ogni dato convertito in formato elettronico sarà salvato su computer protetti da password. Solo i ricercatori coinvolti nello studio avranno accesso ai suoi dati. I dati saranno divulgati, a conferenze o in articoli scientifici, in forma aggregata e l'anonimato del partecipanti sarà sempre garantito.

Partecipazione

La scelta di acconsentire alla part ecipazione alla presente ricerca è completamente volontaria ed il rifiuto a parteciparvi, così come il ritiro dalla ricerca in qualsiasi momento della stessa, non hanno alcuna conseguenza. Nel caso di studenti universitari frequentanti un corso di laurea del Dipartimento di Psicologia e Scienze Cognitive, il rifiuto a partecipare, l'abbandono dell'esperimento ed il livello di prestazione non avranno alcun effetto sulle relative attività accademiche (frequenze di corsi, esami, voto di laurea, tirocinio). Nel caso di abbandono tutti i dati raccolti verranno cancellati. Se deciderà di partecipare all'esperimento le verrà fornito questo foglio informativo di cui Le consigliamo tenere copia per poterlo eventualmente consultare in futuro.

La preghiamo di prendere visione di tutte le informazioni fornite, di discuterne con altri se lo desidera, e nel caso ci fosse qualcosa che non Le fosse chiaro o di cui vorrebbe avere maggiori informazioni, La invitiamo a porgere tutte le domande al team di ricerca.

APPENDIX 5

Consent to Participate in Research Project

Department of Psychology and Cognitive Sciences

UNIVERSITY OF TRENTO - Italy

University of Trento

Corso Bettini 31, Rovereto (TN)

Participant's Name: …………………………………………………………………….….

Title of Project: The Psychophysiological Effects of Touch and Smell.

Research's Name: Anuch Salout

Thank you for your interest in taking part in this research. Before you agree to take part, the person organizing the research must explain the project to you. Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in.

Participant's Statement

1. I have read the notes written above and the Information Sheet, and understand what the study involves.
2. I understand that if I decide at any time that I no longer wish to take part in this project, I can notify the researchers involved and withdraw immediately.
3. I consent to the processing of my personal information for the purposes of this research study.
4. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act. 13 Legislative Decree n. 196/2003.
5. I agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.
6. I agree that my non-personal research data may be used by others for future research. I am assured that the confidentiality of my personal data will be upheld through the removal of identifiers.

This consent form establishes that you have read and understand what taking part in this research study will involve.

Participant's signature …………………………………Date ……..…………

Dichiarazione di consenso alla partecipazione al progetto (Italian Version)

UNIVERSITY OF TRENTO - Italy

Dipartimento di Psicologia e Scienze Cognitive

Università di Trento

Corso Bettini 31, Rovereto (TN)

Nome del partecipante: ……………………………………...……………………..….

Titolo del progetto: Gli effetti psicofisiologici del tatto e degli odori.

Nome del ricercatore: Anuch Salout

Grazie per il Suo interesse a prendere parte a questa ricerca. Prima che dia il Suo consenso alla partecipazione, il responsabile della ricerca le spiegherà in cosa consiste il progetto. Per favore, completi questo documento dopo aver letto il Foglio Informativo e/o dopo aver ascoltato la spiegazione fornita dal/dalla ricercatore/ricercatrice.

Se ha dubbi o domande riguardo al Foglio Informativo o alla spiegazione della ricerca, non esiti a chiedere ulteriori spiegazioni al ricercatore/ricercatrice prima di decidere se partecipare.

Dichiaro:

1. di avere letto questo documento, di aver preso visione del Foglio Informativo, e di aver capito in che cosa consiste questo studio.
2. di essere a conoscenza di potermi ritirare dallo studio in ogni momento senza dovere fornire spiegazioni.
3. di consentire al trattamento dei miei dati personali per gli scopi della ricerca.
4. di aver capito che tali informazioni saranno trattate in maniera strettamente confidenziale e gestiti in osservanza del Codice in Materia di Protezione dei Dati, decreto legislativo n. 196/2003.
5. che le finalità, le modalità di svolgimento ed i rischi dello studio mi sono stati illustrati in maniera chiara e dettagliata dalla persona indicata sopra e che acconsento a partecipare a questo studio.
6. Di acconsentire che i dati sperimentali ricavati dalla mia partecipazione potranno essere usati da altri ricercatori per ulteriori elaborazioni in ricerche future, ma soltanto in forma anonima. L’anonimato di questi dati sarà garantito mediante la cancellazione di tutte le informazioni associate alla mia identità.

Pertanto, dichiaro di aver letto questo documento e di essere consapevole delle attività previste in questo studio.

Firma del partecipante ………………………………….Data ……..…………

APPENDIX 6

Questionnaire on emotions

Directions: Please complete the scales below, rate the emotional states in terms of how you feel at the present time by making cross (✕) on the appropriate number between 1 to 9

Participant Code No………

How pleasantness do you feel now?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Very unpleasant — Very pleasant

How aroused do you feel now?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Calm — Alert

How much can you control your feelings now?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Feeling of lack of control — Feeling of being in control

Questionario sulle emozioni (Italian Version)

Istruzioni: Per favore completi le scale sottostanti, indicando il grado di stato emozionale in cui si trova al momento, mettendo una crocetta (✕) il numero appropriato tra 1 e 9

Codice del partecipante………

Quanto piacevolezza si sente in questo momento?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Molto sgradevole Molto
piacevole

Come definirebbe il suo grado eccitazione (arousal) ?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Calmo Vigile

Quanto è in grado di controllare le sue sensazioni in questo momento?

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Sento una mancanza di controllo — Sento di averne il controllo

APPENDIX 7

Odors intensity and familiarity

Directions: Please making cross (✕) on the scale at the position that represent how you feel about the odorants on dimensions of intensity, and familiarity.

Participant Code No………

Odor intensity

|———————————————————|

Not at all intense Extremely intense

Odor familiarity

|———————————————————|

Not at all familiar Extremely familiar

Intensità e familiarità degli odori (Italian Version)

Istruzioni: Per favore, indichi, con una croce (✕) sulle linee sottostanti, la posizione che rappresenta le sensazioni prodotte dagli odori, utilizzando le dimensioni di intensità e familiarità.

Codice del partecipante ………

Intensità dell'odore

Per niente intenso — Estremamente intenso

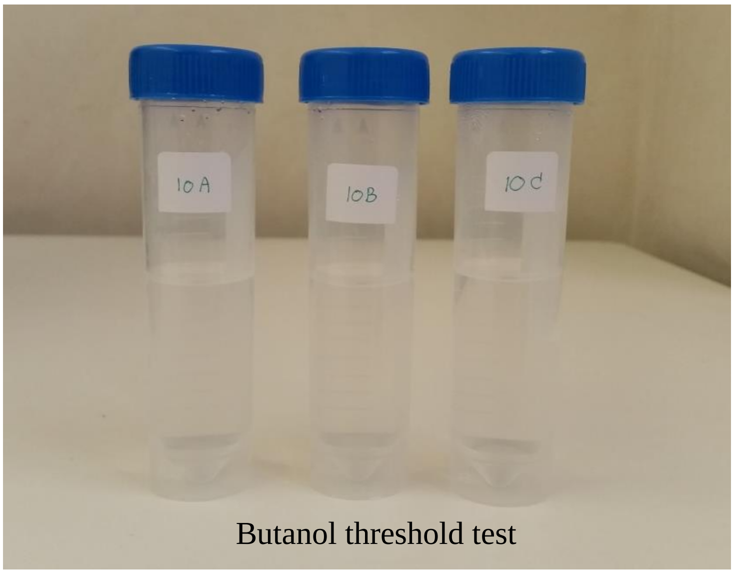
Familiarità dell'odore

Per niente familiare — Estremamente familiare

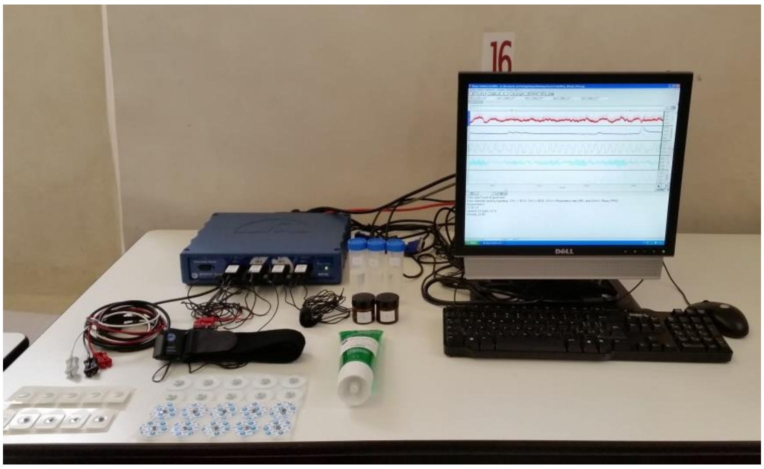
APPENDIX 8

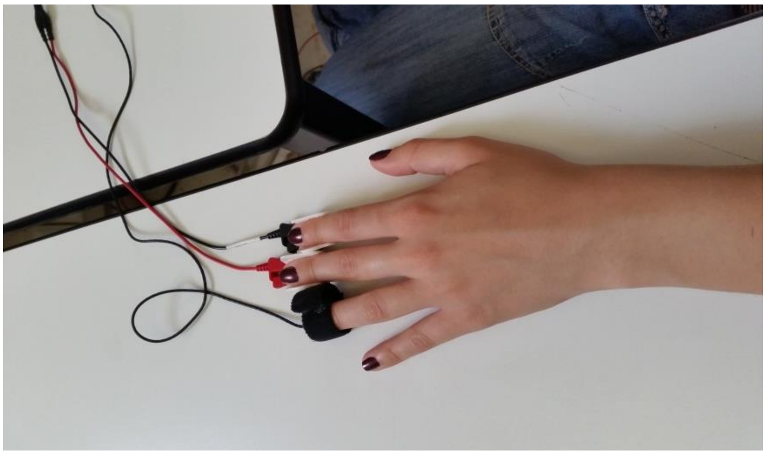
Experimental instruments

Odorous stimuli



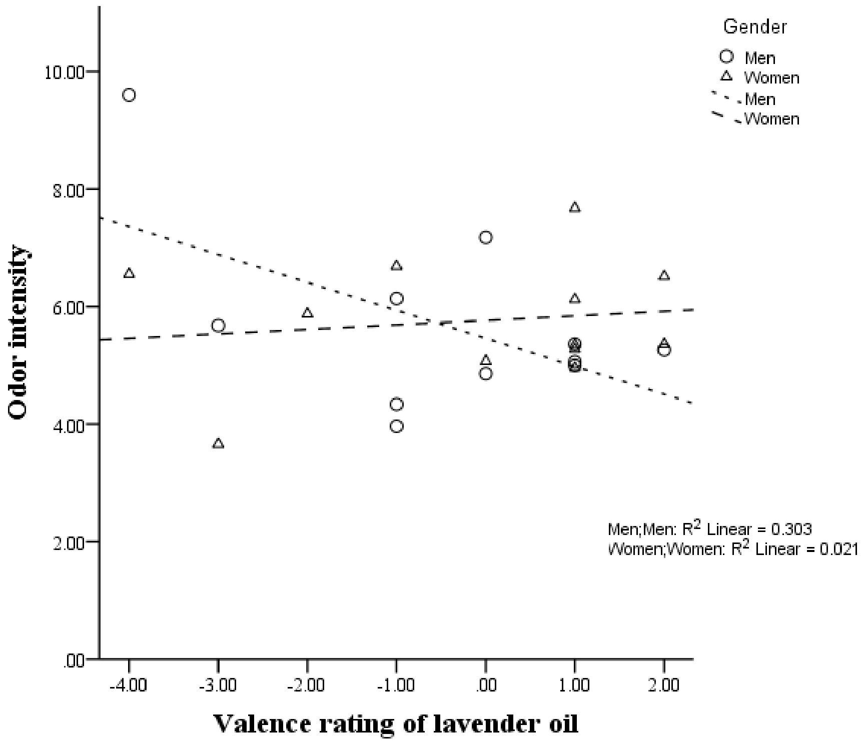
Butanol threshold test

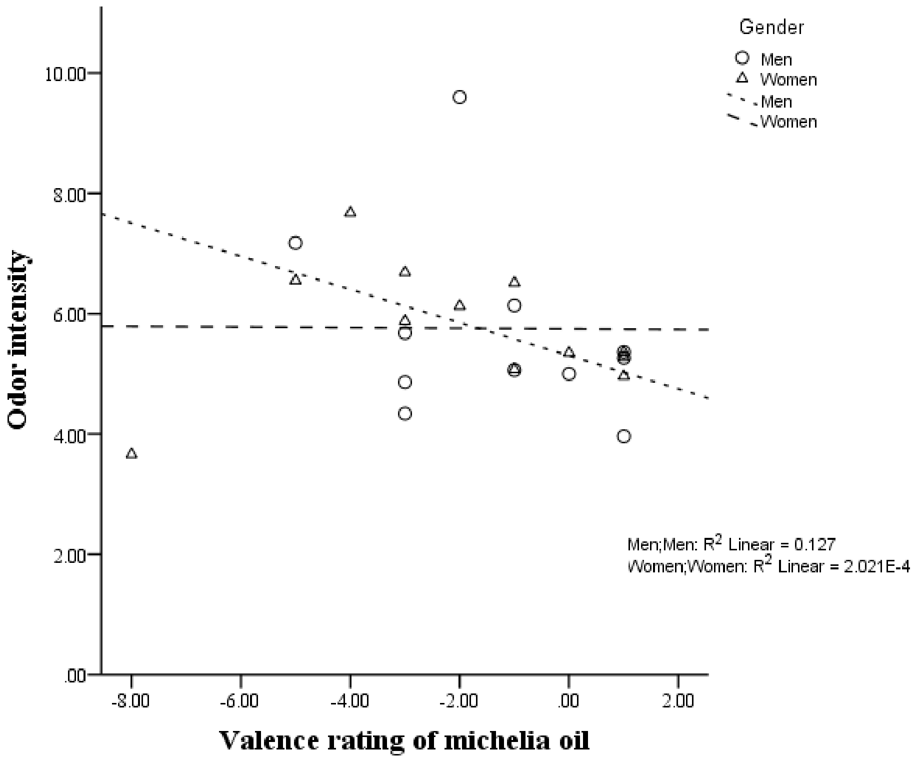

16

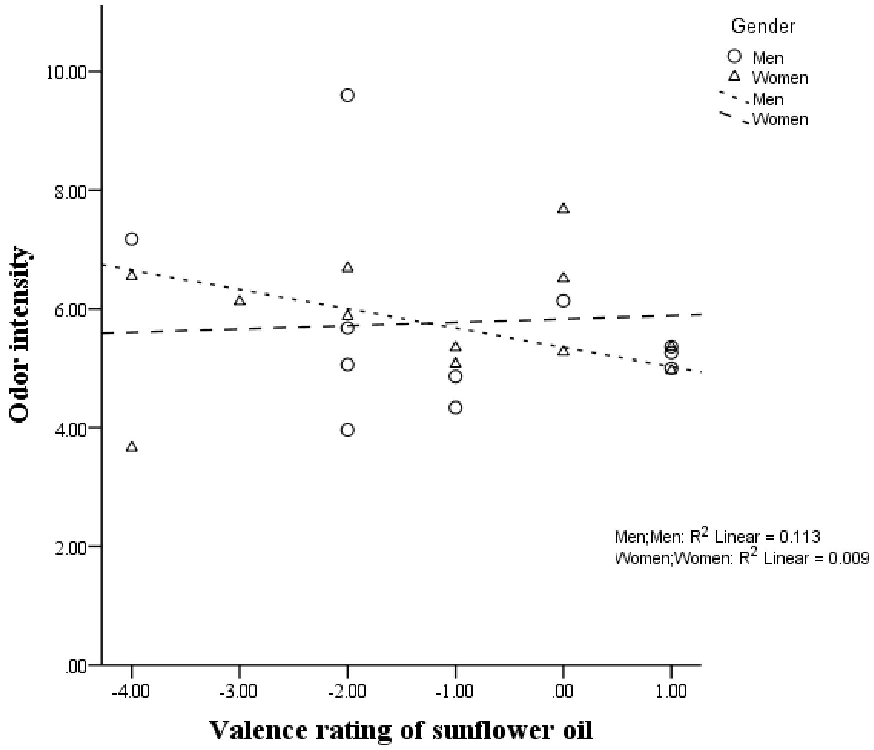


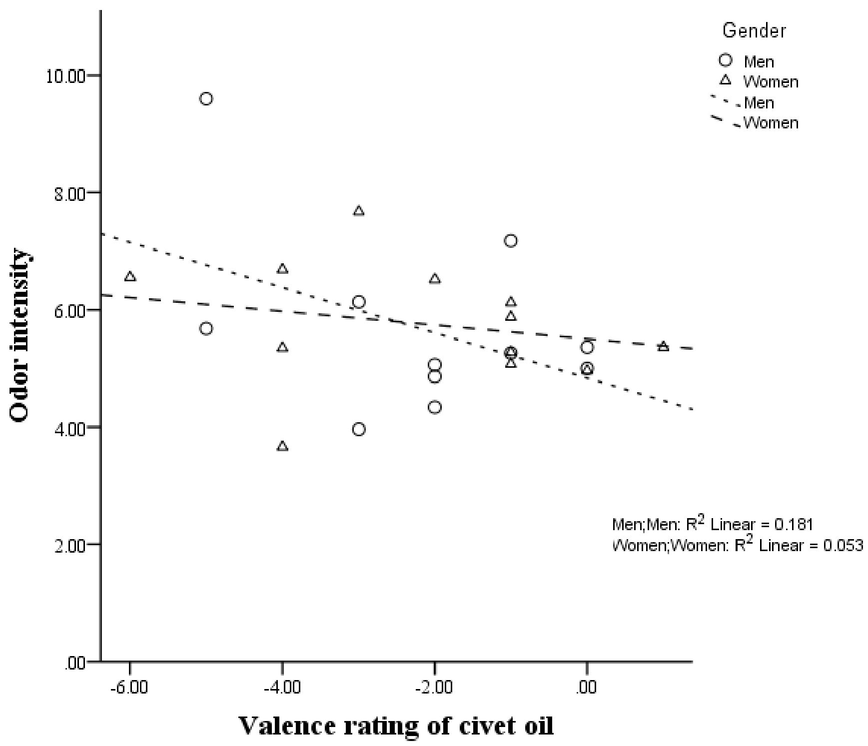
APPENDIX 9

Scatterplot between odor intensity and valence score of odor under different gender

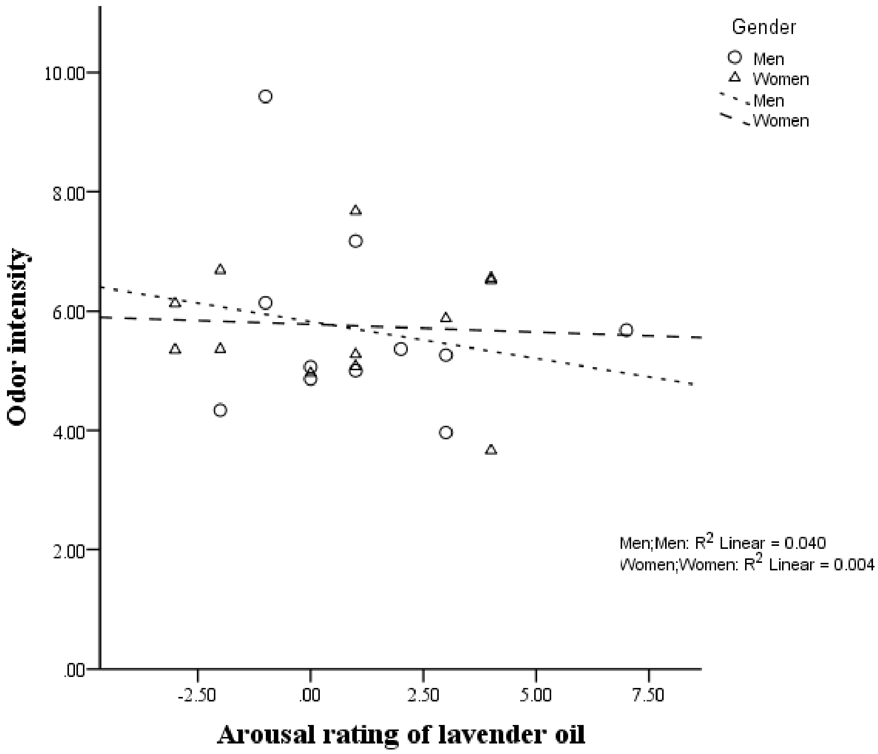


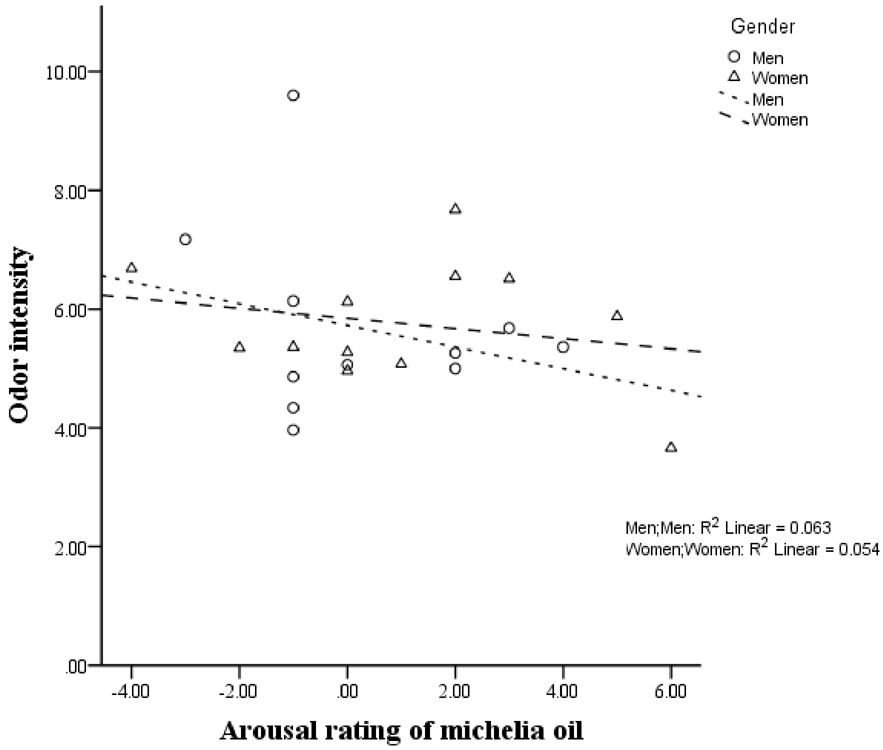


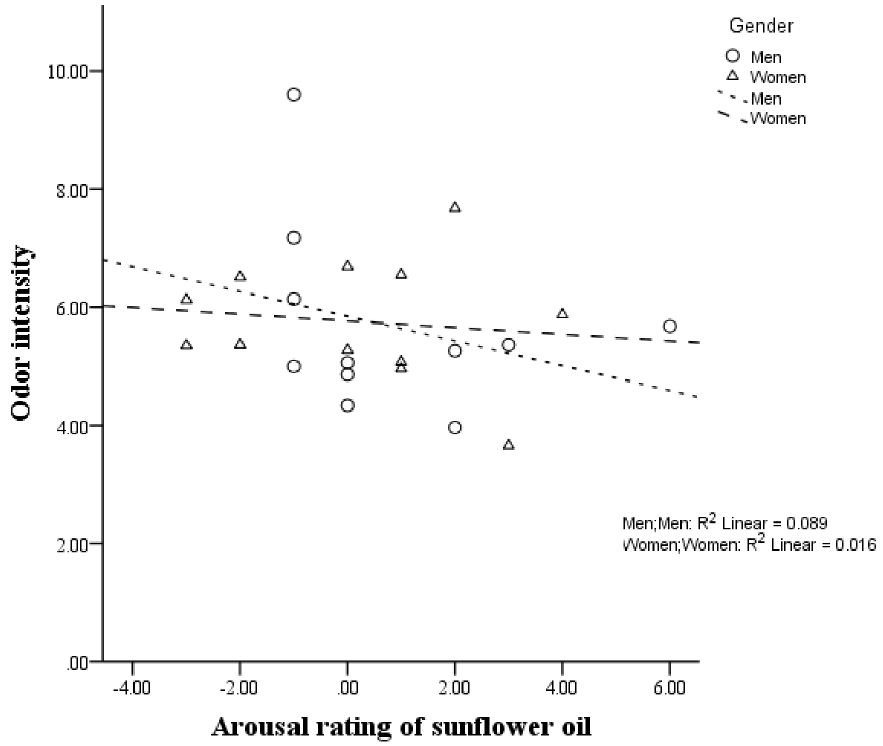

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
Odor intensity
-4.00
-3.00
-2.00
-1.00
.00
1.00
Valence rating of sunflower oil
Men;Men: R^2 Linear = 0.113
Women;Women: R^2 Linear = 0.009

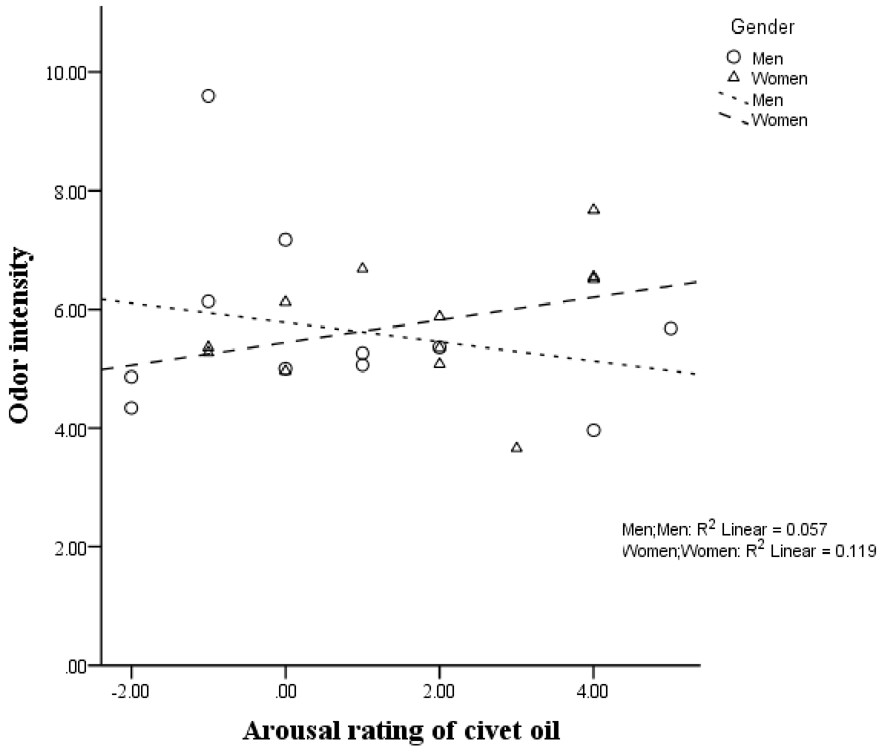

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
Odor intensity
-6.00
-4.00
-2.00
.00
Valence rating of civet oil
Men;Men: R^2 Linear = 0.181
Women;Women: R^2 Linear = 0.053

Scatterplot between odor intensity and arousal score of odor under different gender

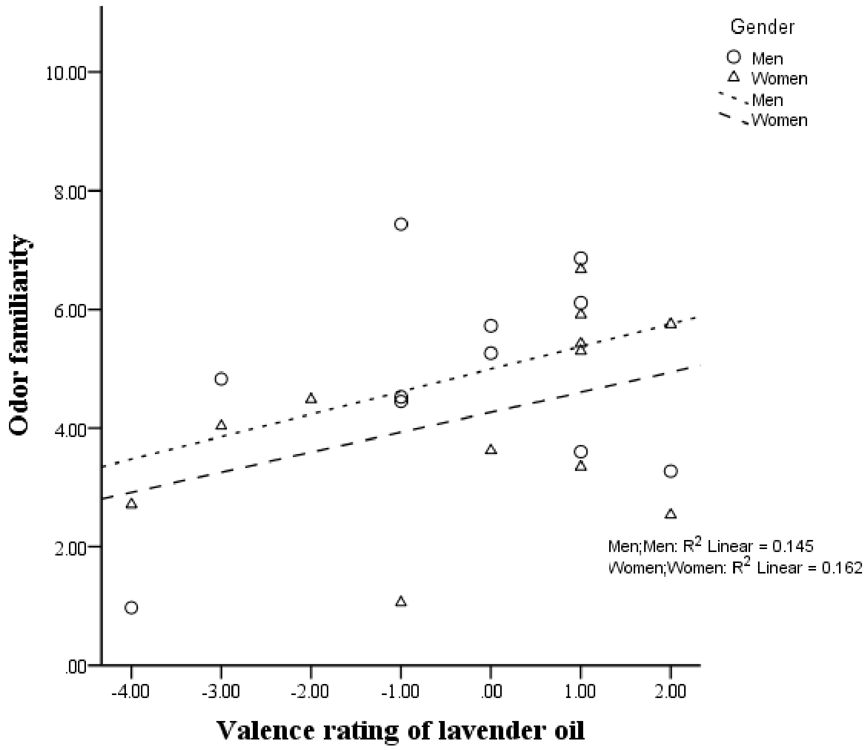


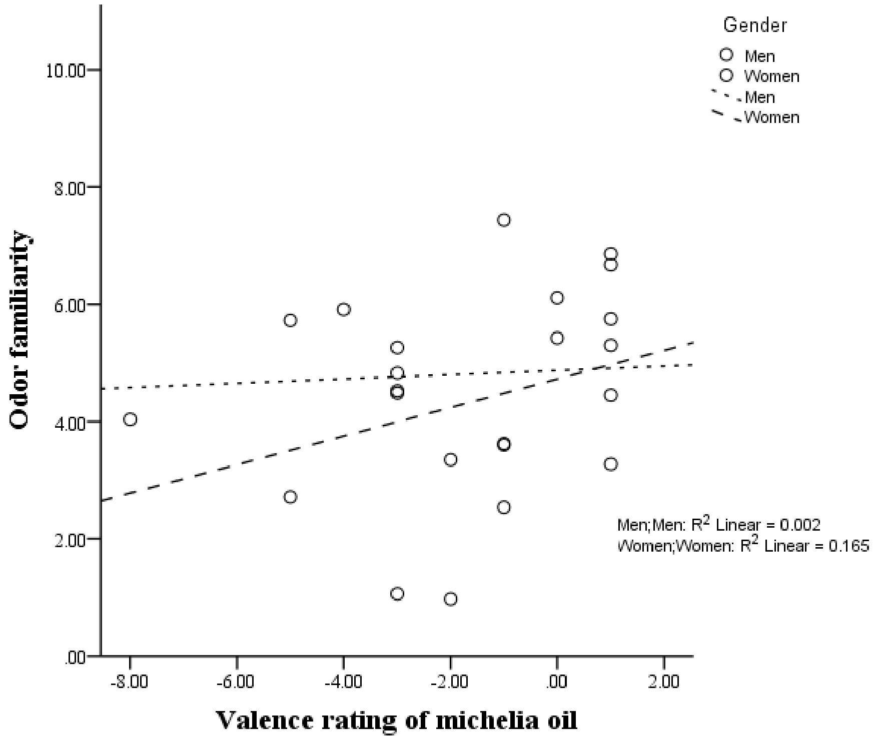


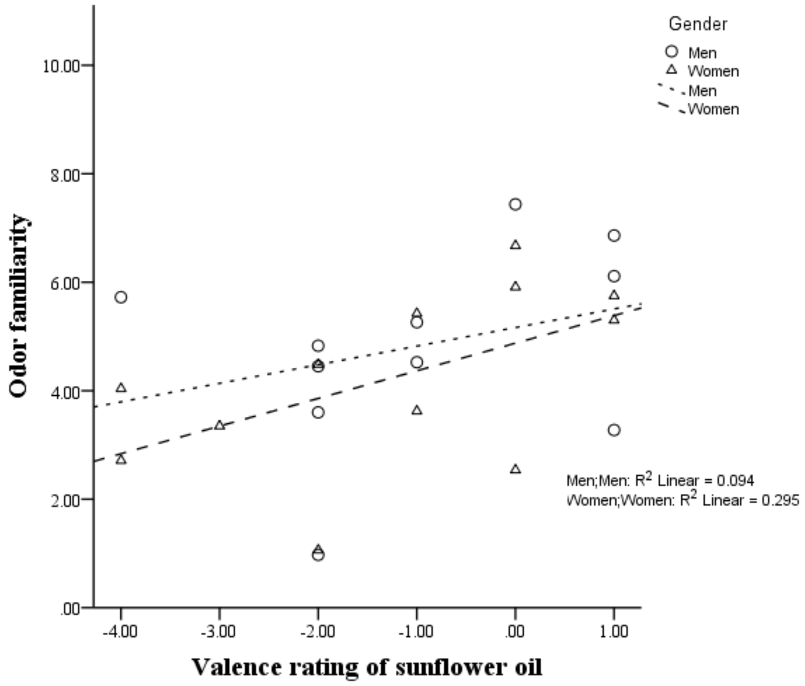

Gender
Men
Women
Men
Women
Odor intensity
10.00
8.00
6.00
4.00
2.00
.00
-4.00
-2.00
.00
2.00
4.00
6.00
Arousal rating of sunflower oil
Men;Men: R2 Linear = 0.089
Women;Women: R2 Linear = 0.016

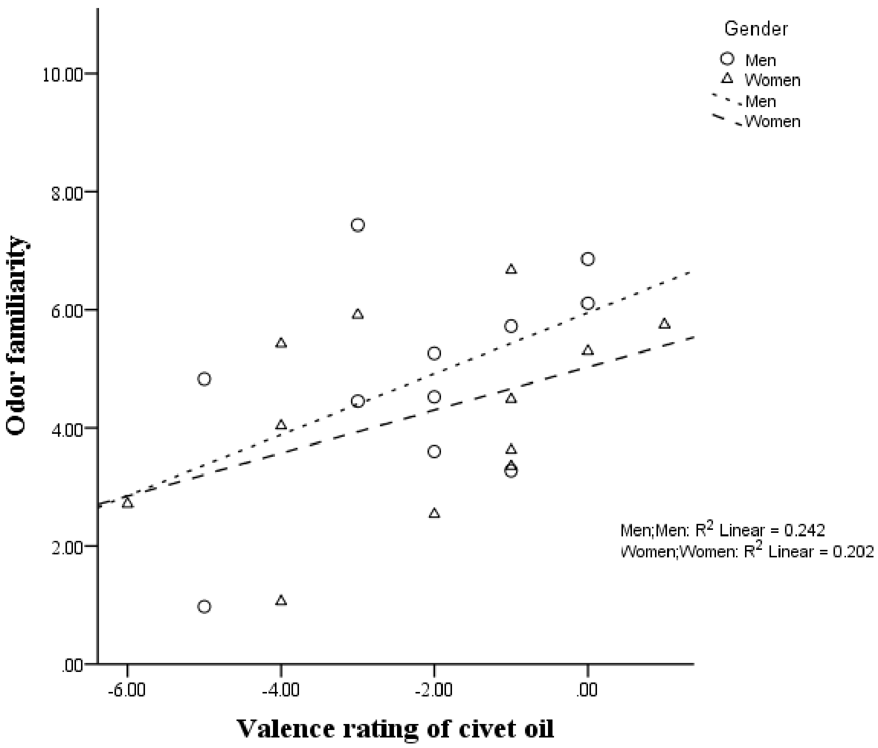

Gender
Men
Women
Men
Women
Odor intensity
10.00
8.00
6.00
4.00
2.00
.00
-2.00
.00
2.00
4.00
Arousal rating of civet oil
Men;Men: R2 Linear = 0.057
Women;Women: R2 Linear = 0.119

Scatterplot between odor familiarity and valence score of odor under different gender

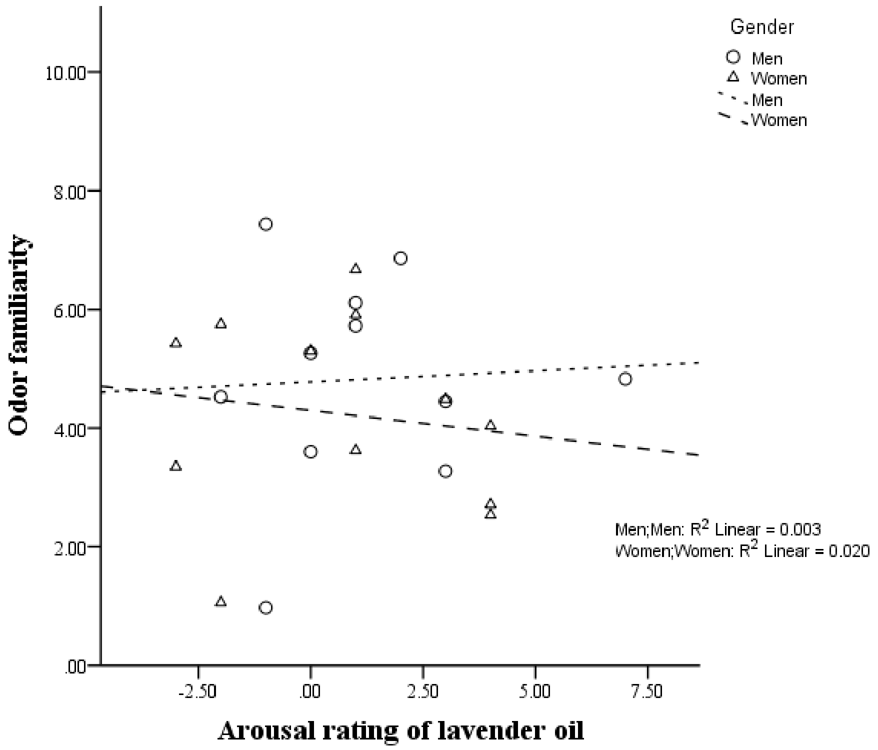


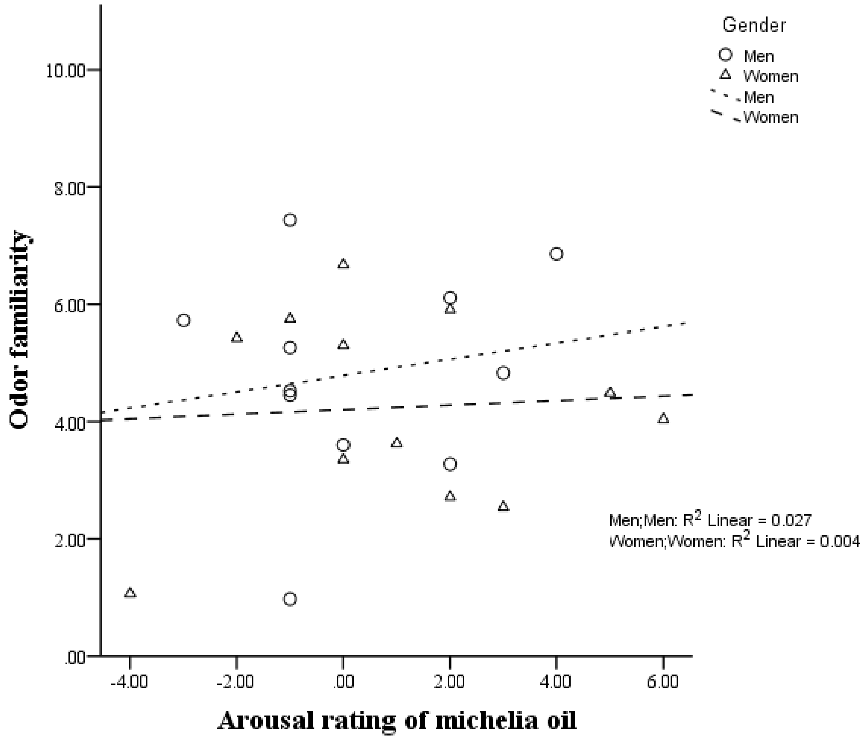


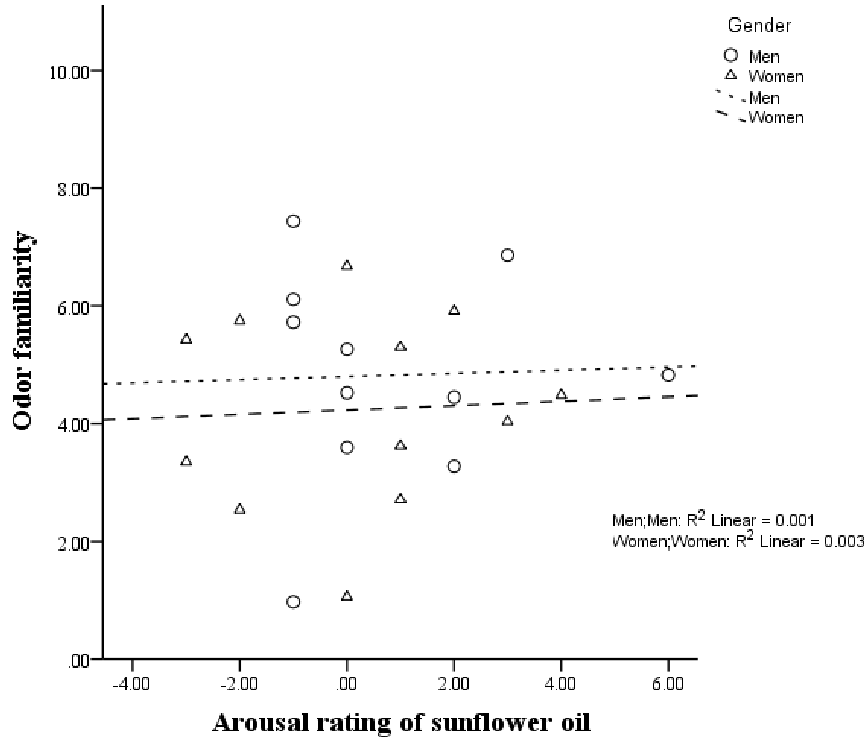

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
-4.00
-3.00
-2.00
-1.00
.00
1.00
Odor familiarity
Valence rating of sunflower oil
Men;Men: R2 Linear = 0.094
Women;Women: R2 Linear = 0.295

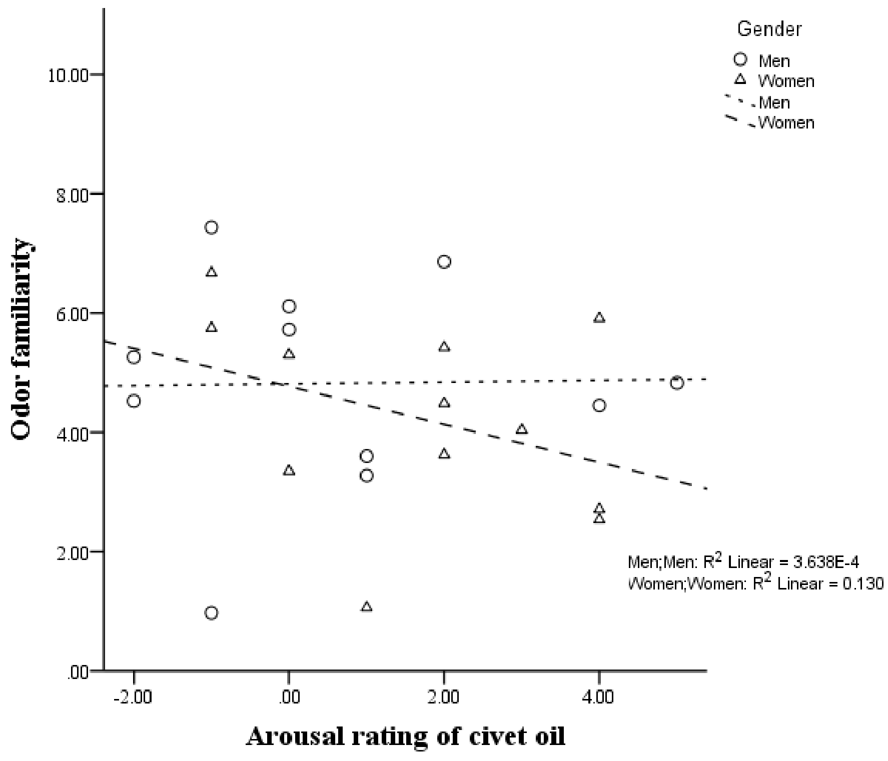

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
-6.00
-4.00
-2.00
.00
Odor familiarity
Valence rating of civet oil
Men;Men: R2 Linear = 0.242
Women;Women: R2 Linear = 0.202

Scatterplot between odor familiarity and arousal score of odor under different gender



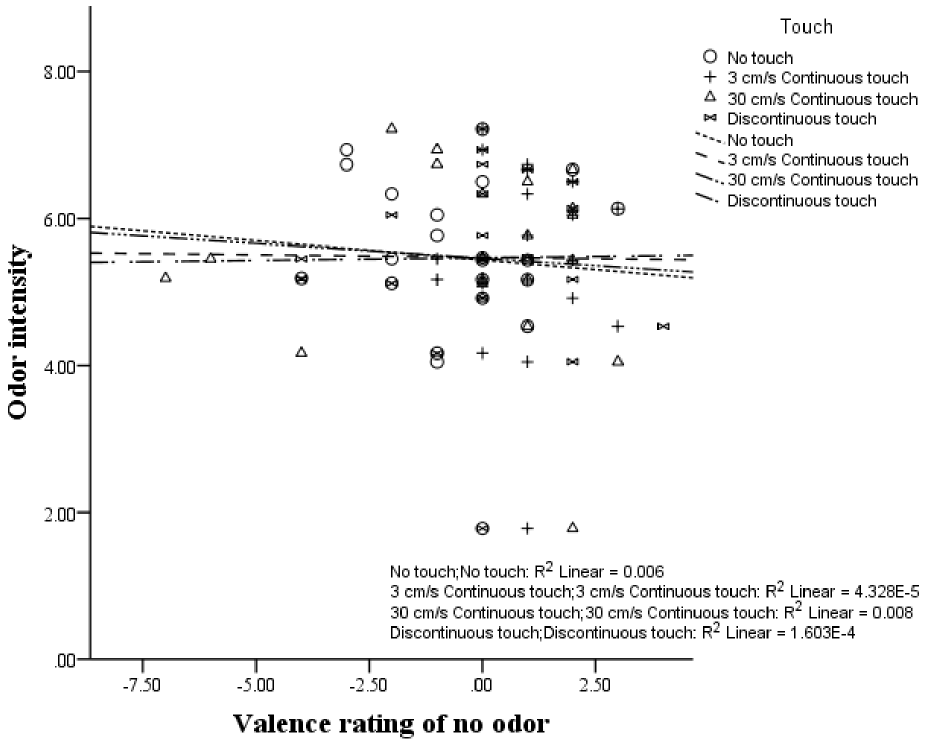


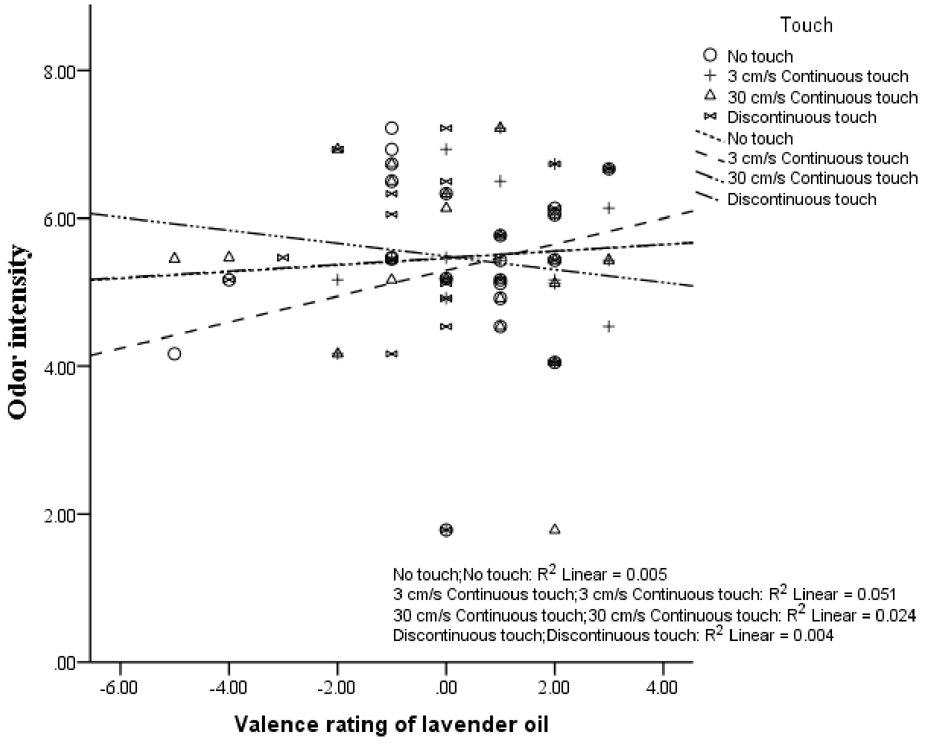

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
Odor familiarity
-4.00
-2.00
.00
2.00
4.00
6.00
Arousal rating of sunflower oil
Men;Men: R^2 Linear = 0.001
Women;Women: R^2 Linear = 0.003

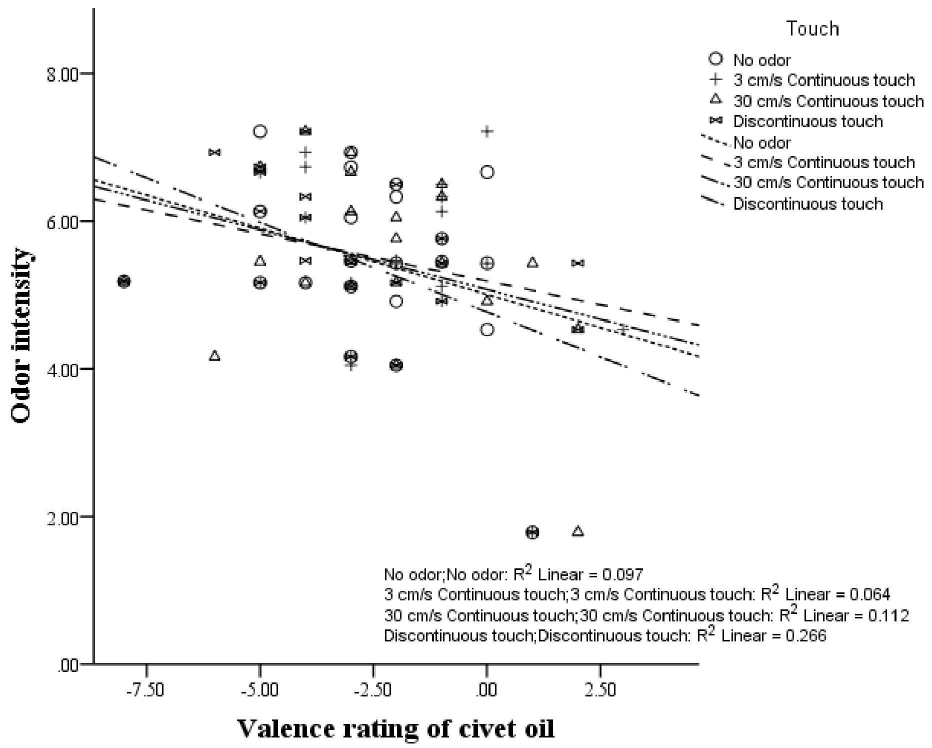

Gender
Men
Women
Men
Women
10.00
8.00
6.00
4.00
2.00
.00
Odor familiarity
-2.00
.00
2.00
4.00
Arousal rating of civet oil
Men;Men: R^2 Linear = 3.638E-4
Women;Women: R^2 Linear = 0.130

APPENDIX 10

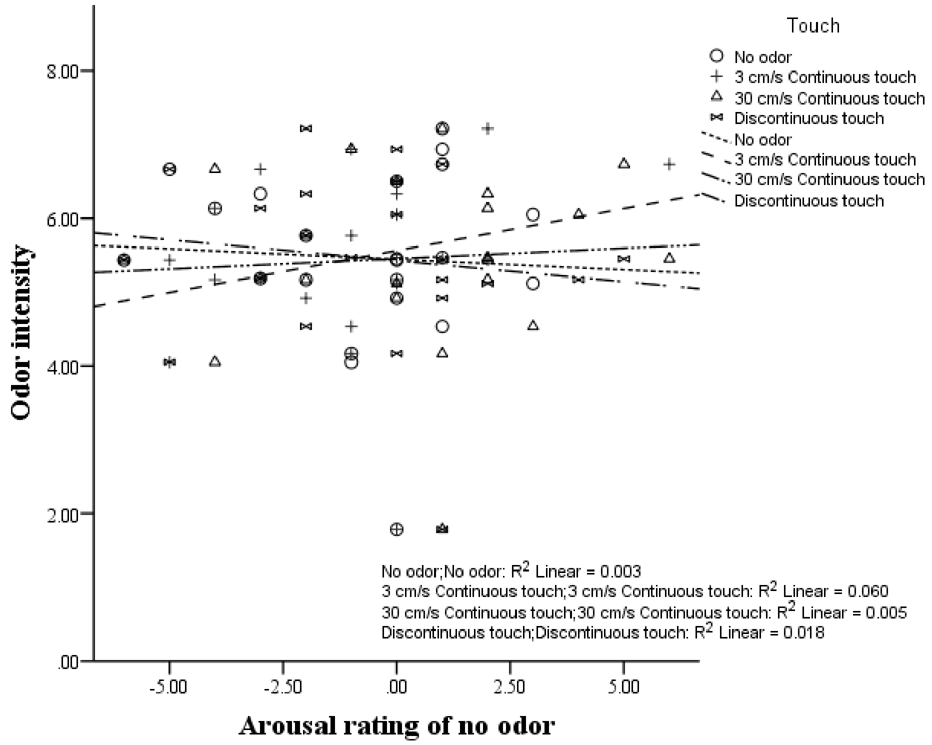
Scatterplot between odor intensity and valence score of odor under different touch

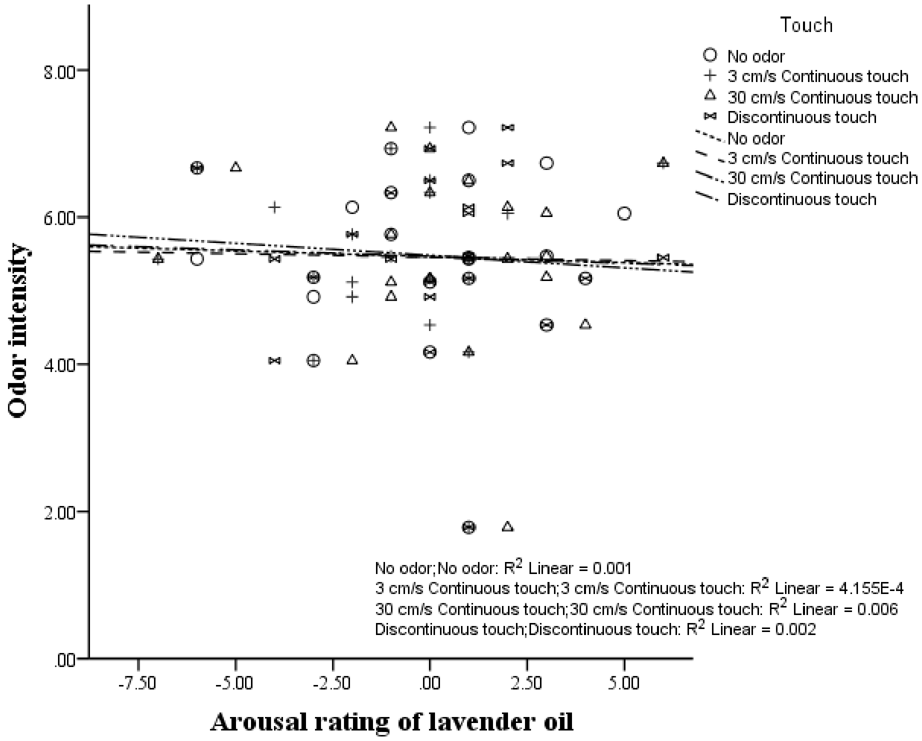




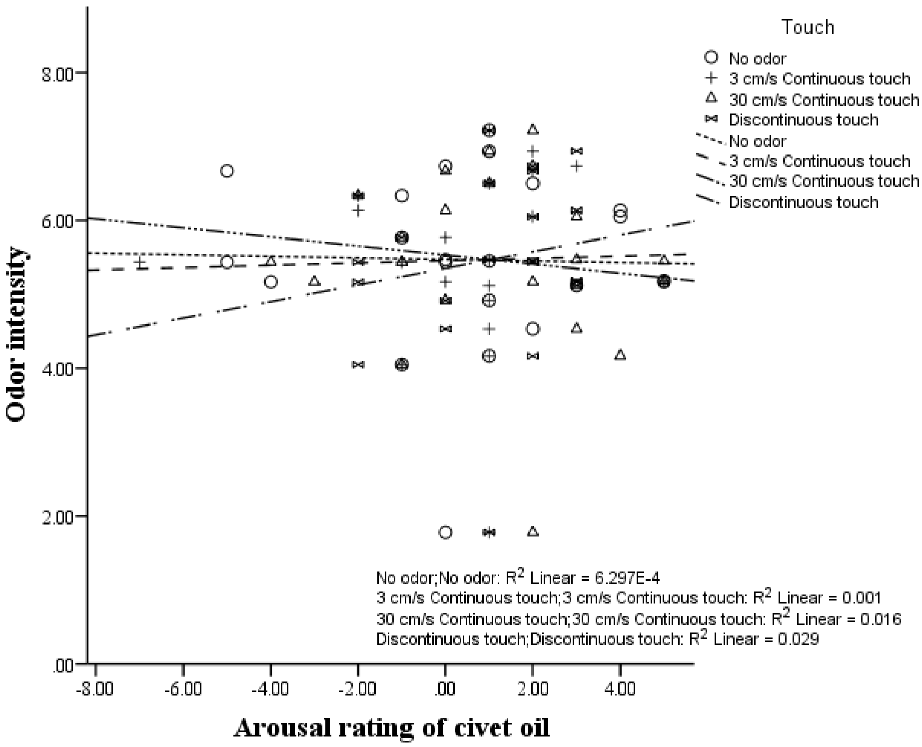


Scatterplot between odor intensity and arousal score of odor under different touch



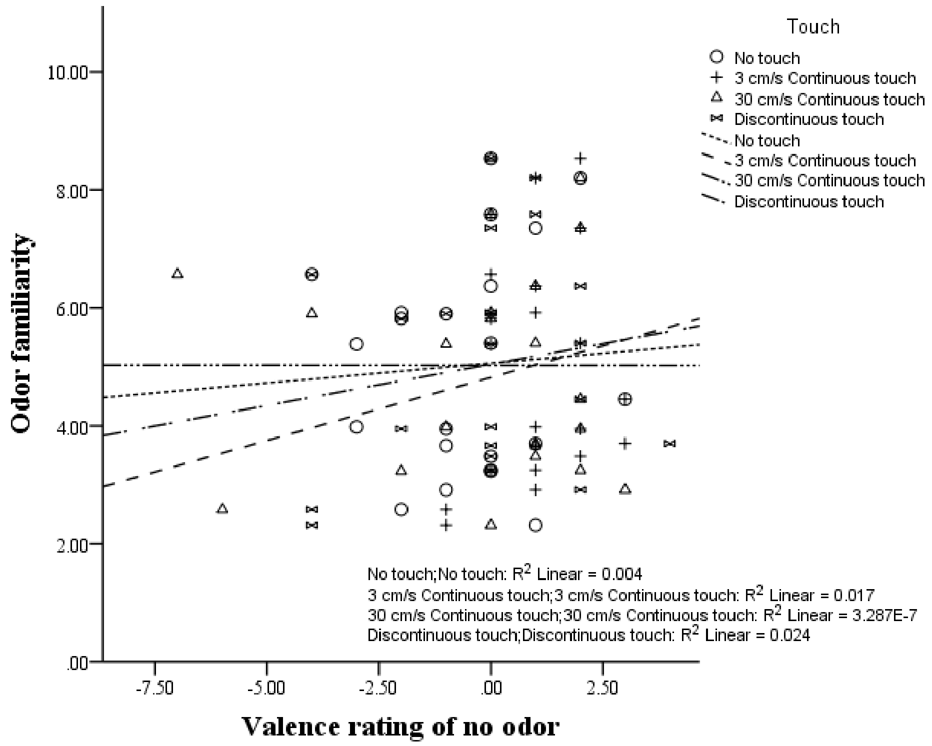


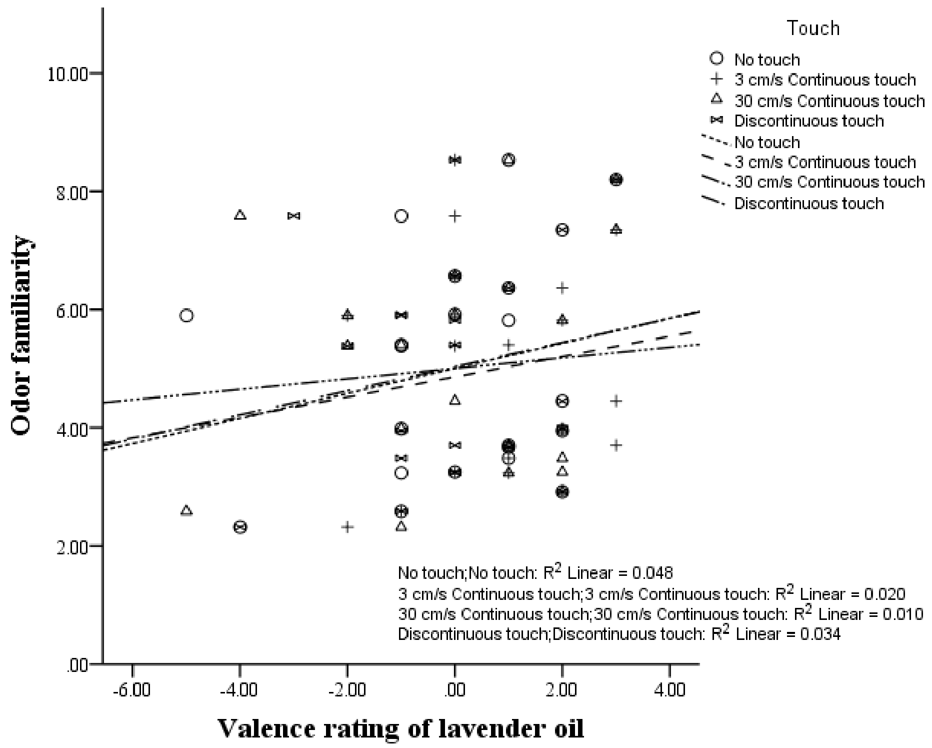
Touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor;No odor: R2 Linear = 0.001
3 cm/s Continuous touch;3 cm/s Continuous touch: R2 Linear = 4.155E-4
30 cm/s Continuous touch;30 cm/s Continuous touch: R2 Linear = 0.006
Discontinuous touch;Discontinuous touch: R2 Linear = 0.002
Odor intensity
Arousal rating of lavender oil

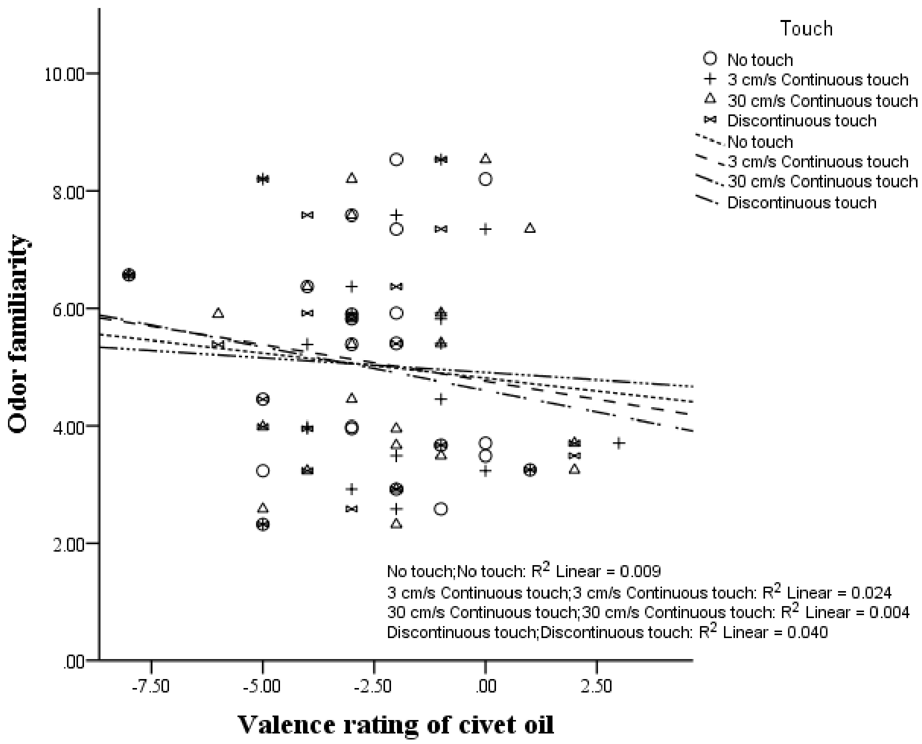


Touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor;No odor: R2 Linear = 6.297E-4
3 cm/s Continuous touch;3 cm/s Continuous touch: R2 Linear = 0.001
30 cm/s Continuous touch;30 cm/s Continuous touch: R2 Linear = 0.016
Discontinuous touch;Discontinuous touch: R2 Linear = 0.029
Odor intensity
Arousal rating of civet oil

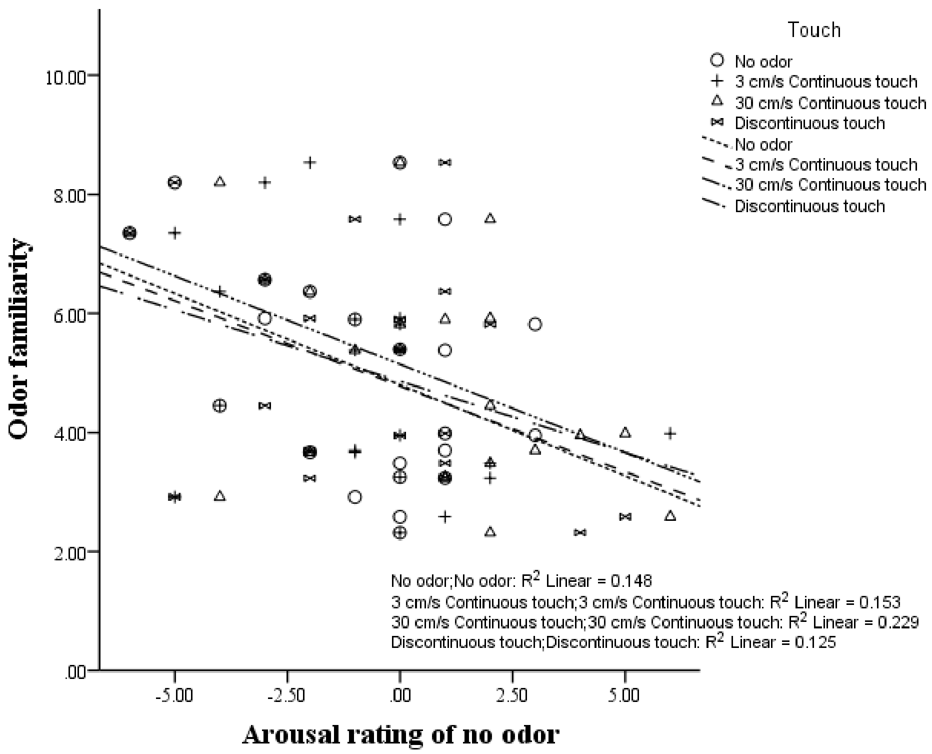
Scatterplot between odor familiarity and valence score of odor under different touch

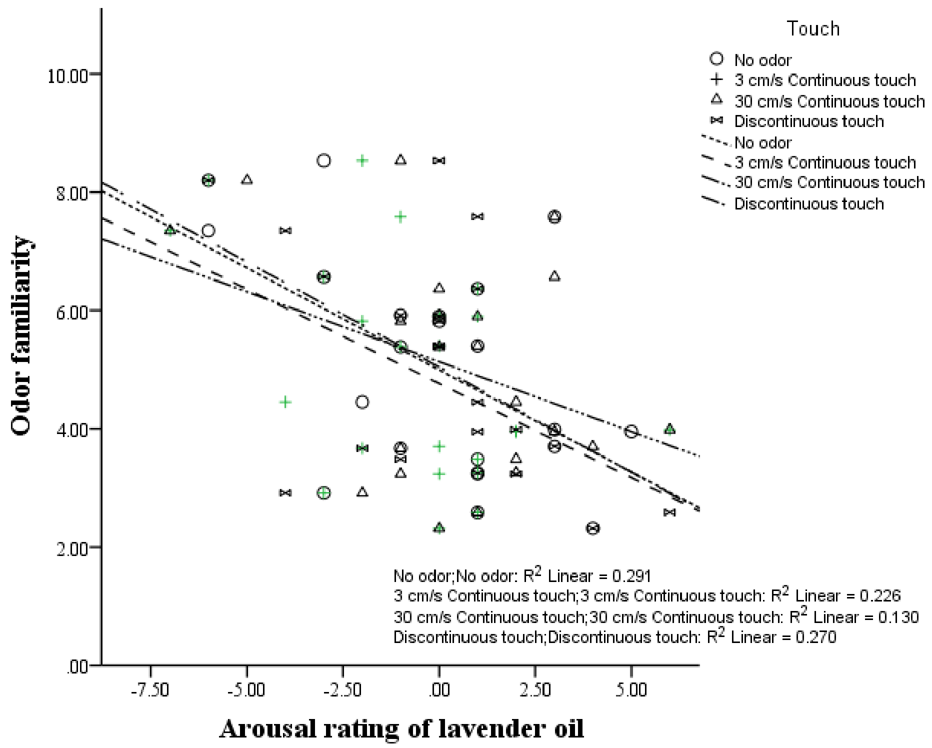


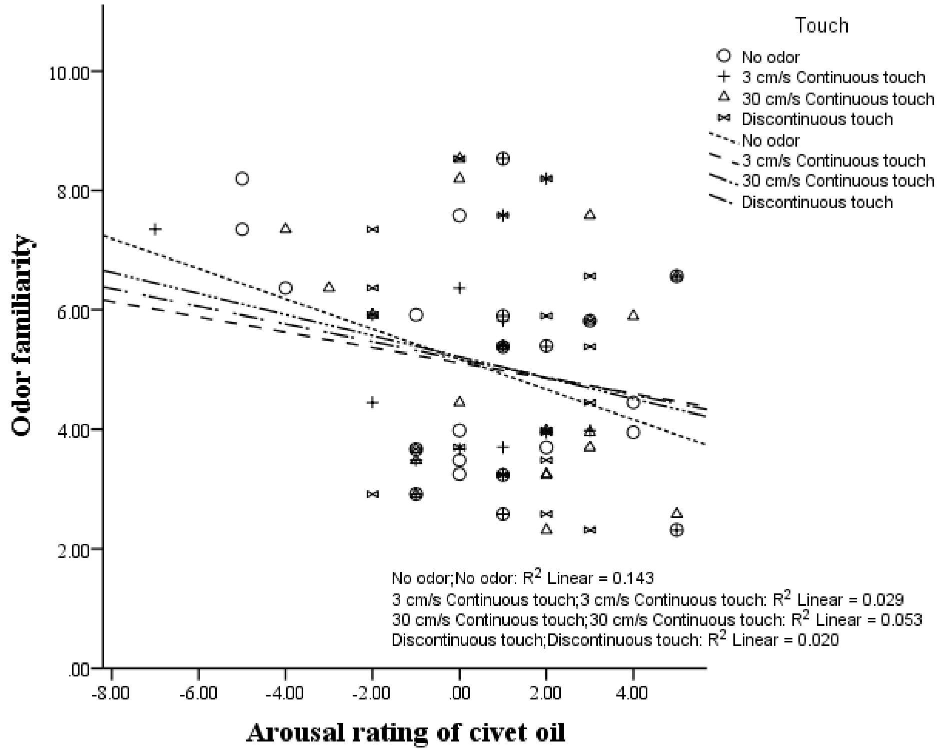




Scatterplot between odor familiarity and arousal score of odor under different touch




Touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor;No odor: R^2 Linear = 0.291
3 cm/s Continuous touch;3 cm/s Continuous touch: R^2 Linear = 0.226
30 cm/s Continuous touch;30 cm/s Continuous touch: R^2 Linear = 0.130
Discontinuous touch;Discontinuous touch: R^2 Linear = 0.270
Odor familiarity
.00
2.00
4.00
6.00
8.00
10.00
-7.50
-5.00
-2.50
.00
2.50
5.00
Arousal rating of lavender oil


Touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor
3 cm/s Continuous touch
30 cm/s Continuous touch
Discontinuous touch
No odor;No odor: R^2 Linear = 0.143
3 cm/s Continuous touch;3 cm/s Continuous touch: R^2 Linear = 0.029
30 cm/s Continuous touch;30 cm/s Continuous touch: R^2 Linear = 0.053
Discontinuous touch;Discontinuous touch: R^2 Linear = 0.020
Odor familiarity
.00
2.00
4.00
6.00
8.00
10.00
-8.00
-6.00
-4.00
-2.00
.00
2.00
4.00
Arousal rating of civet oil

BIOGRAPHY

Name	Ms. Anuch Salout
Date of birth	May 23, 1976
Place of birth	Buddhachinaraj hospital, Phitsanulok, Thailand
Present address	29 Moo 4, Bansuan, Muang District, Chonburi, 20000, Thailand
Position held	
1999 - Present	Academic Pharmacist Sirindhorn College of Public Health, Chonburi; 29 Moo 4, Bansuan, Muang District, Chonburi, 20000, Thailand
Education	
1994 - 1999	Bachelor of Pharmacy Program Faculty of Pharmaceutical Sciences, Naresuan University, Thailand
2001 - 2004	Master of Science in Pharmacy Faculty of Pharmaceutical Sciences, Department of Pharmacology, Chulalongkorn University, Thailand
2011-2016	Doctor of Philosophy in Research and Statistics in Cognitive Science, College of Research Methodology and Cognitive Science, Burapha University, Thailand
Scholarship	
2014	Erasmus Mundus Scholarship, Swap&Transfer Action II, Student Mobilization at the University of Trento, Italy.
Oral presentation	
2013	The oral presentation in the title of "Commutative property and arithmetic facts memory: Does 7x4 produce the same result as 4x7?" was presented at Burapha University International Conference 2013 on July 4-5, 2013.

Published paper

2014	The research article "A Causal Relationship Model of Practice to Reduce Hypertension Risk of People in Bansuan Municipality, Muang District, Chonburi Province" was published in the Public Health Journal of Burapha University: Vol.9 No.2 July - December 2014.