Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

The Use of Facial Hedonic Measurements to Explore Relationships between Food Structure, Oral Processing and Acceptability

Bei Li

2017

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy, completed at the School of Psychology at Massey University (Albany campus), New Zealand.

Acknowledgements

I would like to thank my primary supervisor Dr Peter Cannon for his support, guidance and limitless patience. I know a lot more about Psychophysiology, psychology, SPSS and facial EMG from him.

My thanks go to my previous supervisor Dr Kylie Foster who gave me the financial support to attend international conferences. My thanks also go to Dr John Grigor for his professional guidance of sensory science.

Thank you to everyone in the office with whom I worked: Hongyan Yao, Liangjue Lin, and Shuo Yang. I would also like to thank to my best friends in New Zealand, Tingting Sun, Jessica Zhou and Justin Geng who gave me their time and encouragement. Thank you to everyone who joined my research project. Lastly, thank you to my family, friends and my lovely Doberman for putting up with me while I wrote this thesis.

Conference presentations

Chapter Number 3.2 and 3.3

Li, B., Cannon, P.R., Foster, K.D., & Grigor, J.M.V. (2015). Development of a dynamic psychophysiological technique (facial electromyography) to assessing food appearance. Oral session presented at the 2nd Asian Sensory and Consumer Research Symposium, Shanghai, China.

Chapter Number 4.4

Li, B., Cannon, P.R., Foster, K.D., & Grigor, J.M.V. (2015). Facial Electromyography: Dynamic facial muscle activity predicts affective rating of liquids. Oral session presented at the 7th European Sensory and Consumer Research Symposium, Dijon, France.

Paper

Chapter Number 4.4

P.R.Cannon., B, Li., Grigor, J.M.V. (Submitted, under review). Predicting subjective liking of bitter and sweet liquid solutions using facial electromyography during emptying, swirling, and while thinking about the taste. *PLOS One*

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Bei Li

Name/Title of Principal Supervisor: Dr Peter Cannon

Name of Published Research Output and full reference:

Li, B., Cannon, P.R., Foster, K.D., & Grigor, J.M.V. (2015). Development of a dynamic psychophysiological technique (facial electromyography) to assessing food appearance. Oral session presented at the 2nd Asian Sensory and Consumer Research Symposium, Shanghai, China.

Li, B., Cannon, P.R., Foster, K.D., & Grigor, J.M.V. (2015).Facial Electromyography: Dynamic facial muscle activity predicts affective rating of liquids. Oral session presented at the 7th European Sensory and Consumer Research Symposium, Dijon, France.

In which Chapter is the Published Work:

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate:

  and / or

- Describe the contribution that the candidate has made to the Published Work:

  Bei Li was responsible for designing the experiments (with support from Cannon, Grigor, and Foster), collecting data, analysing data (with training), designing slides for presentation (with support), and presenting at international conferences in Shanghai, China and Dijon, France.

Bei Li — Digitally signed by Bei Li
Date: 2017.01.26 08:42:04 +13'00'

Candidate's Signature

16-01-2017

Date

p.r.cannon@massey.ac.nz — Digitally signed by p.r.cannon@massey.ac.nz
DN: cn=p.r.cannon@massey.ac.nz
Date: 2017.01.25 20:52:40 +13'00'

Principal Supervisor's signature

25-01-17

Date

GRS Version 3– 16 September 2011

Table of Contents

List of Tables

List of Figures

Abstract

Hedonic responses to food should vary over time because flavour perception during oral processing is dynamic. Hedonic liking scales and temporal drivers of liking (TDL) are frequently used to assess food acceptability during product development and evaluation. These tools are only able to provide an assessment of liking at a static time point and they are also interruptive of normal food behaviours. To overcome these limitations, this thesis assesses dynamic affective responses to imagery stimuli and tastant stimuli using facial electromyography as a psychophysiological measurement (EMG) (Chapter 3.3 and 4.4). Facial muscles that are used to display negative affect (M. Corrugator supercilii and M. levator), a muscle that is active when smiling (M. zygomaticus major) and a muscle that is active when chewing (M. masseter) were all recorded using facial EMG. Additionally, multi-level modelling (MLM) was used to predict the hedonic liking ratings to these stimuli (Chapter 5.3.3). This direct measure revealed that dynamic affective responses were able to be discriminated using facial EMG. Strong activity in corrugator and levator muscles was evoked by disliked stimuli, whereas for liked stimuli only the zygomaticus muscle increased in activity. From the multi-level modelling results, hedonic liking ratings were able to be predicted using facial muscle activity. Importantly, hedonic liking ratings were able to be predicted using muscle data at the beginning and the end of the tasting (Chapter 4.4). These experiments confirm that facial EMG is not only able to assess dynamic affective responses to foods, but also that facial muscle activity can predict hedonic liking ratings.

1 Project Overview

Food acceptability is a determining factor in consumer purchasing behaviour. The primary factors affecting food acceptance by consumers can be characterised as food intrinsic characteristics, personal characteristics and the context or environment (Costell, Tarrega, & Bayarri, 2010; McEwan & Thompson, 1988). Food properties, including appearance, aroma, flavour and texture have been considered to be key factors determining consumers' final decisions (Clark, 1998). Individual characteristics, including physiological status, body shape and eating habits also have a significant effect on food acceptability (King, Meiselman, Hottenstein, Work, & Cronk, 2007). Cultural factors, individual past experiences and sociocultural factors always influence whether consumers make the decision whether to accept or reject a food (Prescott & Bell, 1995).

To date, the food industry mainly relies on using scales to understand food acceptability and choice, such as the 9-point scale, magnitude estimation and category-ratio scales (Cordonnier & Delwiche, 2008; Engen & McBurney, 1964; Lim, 2011; Meiselman & Cardello, 2003; Nicolas, Marquilly, & O'Mahony, 2010; Peryam & Pilgrim, 1957). However, the limitations of these scales are often centred around whether the individual makes judgements objectively; also that they are providing hedonic liking ratings at a static point in time rather than providing a dynamic affective response (Vanman, Paul, Ito, & Miller, 1997). However, flavour perception during oral processing is changes across the experience (Heath & Prinz, 1999). New developments have resulted in a variety of dynamic measurements (Bielser, Creze, Murray, & Toepel, 2016; Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017) and these can assess temporal hedonic responses during oral processing such as the temporal dominance of liking (TDL), the temporal dominance of emotion (TDE) and check-all-that apply (CATA) methods (Bemfeito, Rodrigues, e Silva, & Abreu, 2016; Monaco et al., 2016; Jager et al., 2014; Meyners, 2016; Veldhuizen, Wuister, & Kroeze, 2006). However, although these dynamic techniques can provide new approaches for assessing temporal hedonic liking, the participant's objective rating and biased judgement are still the primary drawback (Ohman & Soares, 1994; Vanman et al., 1997). Consequently, it is essential that new techniques that are developed are capable of assessing dynamic affective responses to food acceptability whilst avoiding the interruption of natural food behaviours.

Several recent studies have used a psychophysiological technique to understand human beings' liking and emotion to foods such as EEG and neuroimaging (Bielser, Creze, Murray, & Toepel, 2016; Liu, Gao, Liu, & Fox, 2000; Pliquett et al., 2006; Walsh et al., 2017). In this thesis, facial electromyography (EMG), as a psychophysiological technique is being considered as a method to assess dynamic affective responses to food. This measurement relies on recording and detecting the facial muscular activities that reflect dynamic emotional changes when participants experience different kinds of stimuli (Cacioppo, Martzke, Petty, & Tassinary, 1988; Dimberg, 1997; Jancke, 1996a; Larsen, Norris, & Cacioppo, 2003; Sato, Fujimura, & Suzuki, 2008b; Vrana, 1993b). Interestingly, facial EMG is frequently used to discriminate between emotions in social science. However, there is minimal research that explores the relationship between food stimuli and emotion using facial EMG, and this demonstrates that there is a gap in knowledge and also that there are potential commercial applications for EMG in assessing dynamic food acceptability (Armstrong, Hutchinson, Laing, & Jinks, 2007b; Epstein & Paluch, 1997; Horio, 2003; Hu et al., 1999; Jancke & Kaufmann, 1994).

Therefore, these studies all focus on dynamic hedonic liking and facial EMG. Facial EMG was used to assess dynamic emotion change by detecting facial muscle activities (corrugator, levator, zygomaticus, masseter) when viewing different kinds of visual stimuli (see Chapter 3) and tasting different concentrations of sweet and bitter stimuli (see Chapter 4). Finally, the muscle activity data were used to predict hedonic liking ratings (see Chapter 5).

2 Introduction

This session will give a brief and basic introduction to this research topic, including the influencing factors of food acceptability (see 2.1), the relationship between oral processing and flavour perception (see 2.2), current techniques to assess hedonic liking (see 2.3), and the psychophysiological measurement facial EMG (see 2.4). Finally, the research outline and the hypothesis will be set (see 2.5).

2.1 Food Acceptability

The reason why people consume food is not only to obtain nutrition and keep healthy but also for pleasure. Accepting or rejecting food is a process which has a multi-dimensional nature. Figure 2-1 shows the constitution of the stimuli-response model of food acceptability (Lim, 2011).

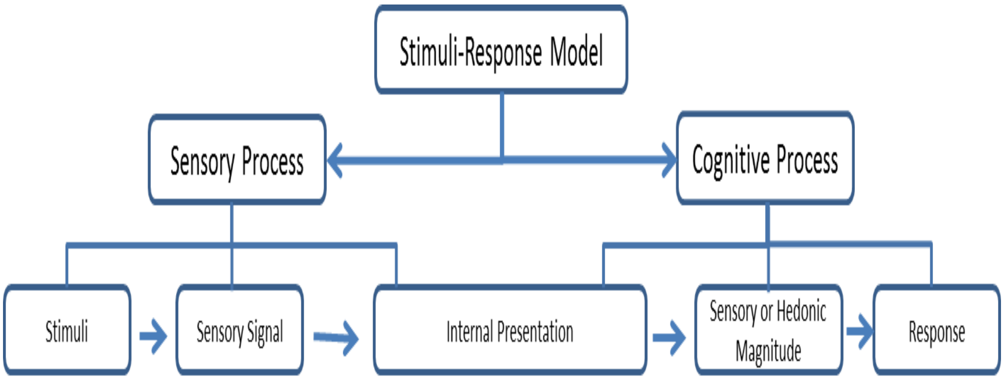


Figure 2-1 Stimuli-Response Model based on Lim (2011)

Accepting or rejecting foods results from affective and behavioural responses to food (Heldman, 2004). There are four main influencing factors on these responses including, sensory (food natural characteristics), affective (positive and negative responses to food), cognitive and behavioural (final purchasing behaviour) components (Costell et al., 2010).

2.1.1 Primarily influencing factors of food acceptability

Food characteristics, individual consumer characteristics, and context have determinant effects on food acceptability by consumers (Meiselman & Cardello, 2003).

Clark (1998) and Costell et al. (2010) found that food intrinsic properties (such as appearance, aroma, flavour and texture) should be considered as key factors on influencing consumers' food choices. Getting nutrition to support daily life is not the only purpose to eating foods, whereas a pleasant and hedonic experience are also expected to be gained from eating (Clark, 1998). For example, Risvik (1994) found colour and texture strongly influenced the choice of meats. Consumers were more willing to accept red meat rather than dark meat, which looked unhealthy (MacDougall, 2003). Sweet aroma and sweet taste were the determinant factors on choosing normal chocolate rather than diabetic by 116 consumers (Melo, Bolini, & Efraim, 2009). Sweet solutions always evoked positive hedonic responses from humans (Rozin & Vollmecke, 1986). However, bitter as a basic taste usually results in food rejection (Rozin & Vollmecke, 1986). Lee et al. (2008) used five green tea samples with different levels of caffeine (0%, 10%, 35%, 60% and 100%) to assess their acceptability by consumers, but he found green tea without caffeine was the most accepted by consumers and this was likely because it was the least bitter.

Individual characteristics such as physiological status (hunger/satiety), body shape (overweight/thin), eating habits, etc. also have specific effects on food acceptability (King et al., 2007; York & Vaisey-Genser, 2003). The studies showed that hunger was a strong influencing factor for accepting and consuming food by humans, even if the food did not look delicious (Gibson, 2006a). Drewnowski (1997) found that people were more likely to intake food rich in sugar and fat, especially women. The related study showed that the acceptability and preference for fatty food increased with body weight (Drewnowski, Brunzell, Sande, Iverius, & Greenwood, 1985).

The environment (context) is essential for understanding the acceptance of food. Indirect environment (cultural factors), indirect personal factors (such as past experience) and social culture are comprised of concurrent contexts that can alter the food acceptability (King et al., 2007; Prescott & Bell, 1995). The acceptability of prepared foods in different eating locations was studied by Edwards, Meiselman, Edwards, and Lesher (2003) and the results showed that participants preferred eating pre-prepared food in a university training restaurant and a 4-star restaurant rather than an army training camp, freshman's buffet, the university staff refectory and a private boarding school. Furthermore, social culture has a significant effect on acceptability. Prescott and Bell (1995) investigated the cross-cultural differences in acceptability for the taster and sensory properties. They found Taiwanese students in the USA gave positive hedonic responses to sweet and salty solutions compared with North American students, furthermore Chinese students living in USA tended to accept more concentrated sweet solutions and weak salty solutions rather than more concentrated salty solutions. Another finding was that for Korean individuals in the USA compared with local North American participants, tomato juice and apple sauce samples were more likely to be accepted by Korean people staying in the USA, furthermore, their preference increased with sweetness (Prescott & Bell, 1995).

2.1.2 Dominant influencing factors – Sensory Attributes

Sensory attributes are the most dominant influencing factors on food acceptability, which are primarily composed of appearance, aroma, texture and basic taste.

2.1.2.1 Appearance

Appearance is the most direct approach to capturing external information. There are two primary factors influencing food appearance. Physical factors include food size, shape, surface gloss or dullness, the light-scattering properties of the food's structure, etc. (MacDougall, 2003). However, colour is also an important attribute associated with food quality. For example, bright red fish and meat are considered fresh. Conversely, consumers often discard dark meat and fish. But food appearance cannot be defined only by colour (MacDougall, 2003). Beyond the food itself, a range of psychological factors such as culture, food habits and preference all influence food acceptability (Kemp, Hollywood, & Hort, 2009).

2.1.2.2 Taste and Odour

The overall perception resulting from the two chemical senses that humans possess is composed of odour and taste. Odour perception is more sensitive than taste because large numbers of odorants can be differentiated by human noses (Mottram & Elmore, 2003; Valentova & Panovska, 2003) in contrast to taste which can only detect a small number of different chemical properties.

According to the British Standards Institute, aroma is described as the detection of certain volatile compounds released from food that can be differentiated by the olfactory receptors located in the nasal cavity. Odour perception is a most sensitive sensory attribute.

Taste perception is a complex process involving the taste organs, composed of taste papillae, taste buds, and taste cells. It starts from the sensory receptor level and ends in the central nervous system (Meiselman & Cardello, 2003). According to the Internal Standards ISO 5492, basic tastes are composed of acid, bitter, salty, sweet, alkaline, umami and metallic. Colour, viscosity, temperature and odour are the main non-gustatory factors affecting taste (Meiselman & Cardello, 2003). In early 1973, Johansson et al. (1973) found that black coffee was not accepted by all consumers owing to its strong aroma, but with the addition of sugar, coffee produces a sweet aroma; black coffee with a sweet aroma was more acceptable than unsweetened. Then, Stevenson, Prescott, and Boakes (1999) investigated the relationship between the perception of odour and taste of sweet and sour solutions. They found certain odours enhanced perceived sweetness, but others suppressed it. The same results were found in acid solutions for sour tastes.

2.1.2.3 Texture

Texture perception is a group of physical characteristics that arise from the structural elements of food. Hardness, cohesiveness, fracturability, chewiness, gumminess, viscosity, springiness and adhesiveness are all common attributes used to describe texture perceptions (Bourne & Szczesniak, 2003). The measurements of texture are composed of two approaches: direct (by touch and movement senses) and indirect (by the senses of vision and hearing). The texture is highly important for food acceptability judgments. Szczesniak and Kahn (1971) investigated the consumer attitudes to food texture in 1971. They found humans rejected eating hard and dry food for their breakfast. They preferred soft food which was easily swallowed and digested without difficulty (Szczesniak & Kahn, 1971). At lunchtime, people were willing to accept a wide range of textures. Furthermore, food texture was the most appreciated and enjoyed during dinner time, where they preferred hard texture foods such as steak and other meats (Szczesniak &Kahn, 1971). Then, in their following study, children were their target group. They found that before four years old, children most easily accepted solid and semi-solid food. Between five and ten years old, children tended to reject soft, moist, and mushy foods, but chose rough and chewy food such as nuts(Szczesniak, 1972).

2.2 Oral processing and dynamic flavour perception

Food oral processing is a complex series of manipulations of the upper and lower jaw, the tongue, lips and cheeks, which purpose is to ingest and digest the food (de Wijk, Engelen, & Prinz, 2003;Foster et al., 2011; Hiiemae et al., 1996). Besides the main objective of breaking down food into a safe size for swallowing, it also provides an opportunity for the consumer to evaluate the texture and flavour of the foods while they break down in the mouth (K. D. Foster et al., 2011). The oral processing and muscle activation during the processing of semi-solid and solid foods are slightly different owing to their initial texture and other properties, which will be discussed in the following section.

2.2.1 The oral movement of semi-and solid foods

In contrast to solid food, semi-solid is a state between solid and liquid. It has a gel-like texture, which is softer and moister than solid food (Lartey, 2013). The notable difference in oral movements between solid and semi-solid foods is that semi-solid food required little mastication and more time was required balancing the food and cavity temperatures or diluting the food with saliva (de Wijk et al., 2003). Less oral manipulation is required with semi-solid foods, indicating reduced mastication time, and there is insufficient time to adjust the food temperature to match the oral cavity temperature (Hiiemae et al., 1996).

2.2.2 The interaction between oral processing and flavour perception

After solid food is placed in the mouth, sensory attributes will be perceived during a complex series of manipulations of the upper and lower jaw, the tongue, lips and cheeks. However, semi-solid food mastication behaviours are strongly influenced by hedonic responses and other sensory properties rather than the size of a bolus (de Wijk, Janssen, & Prinz, 2011).

For solid foods, Figure 2-2 illustrated that chewing behaviour; the tongue and saliva have significant effects on sensory perception. According to Foster et al. (2011), many sensory attributes are perceived on the first bite. Therefore, the differences between the first and subsequent chewing cycles deserve to be investigated. Duizer, Gullett, and Findlay (1996) found that during the first to fourth chewing cycles, maximum tenderness could be perceived. The changes on physical properties of food can be detected from the first bite to the final swallowing stage. The same results presented by Foster, Bronlund, and Paterson (2006) were that the physical properties of amorphous sugars of glass to rubber were perceived during different chewing stages.

Three key elements that influence texture perception are the mechanical behaviour of food, the contribution of saliva and the chewing sequence (Hutchings & Lillford, 1988). Neyraud, Peyron, Vieira, and Dransfield (2005) have studied the correlation between oral processing and aroma attributes. The results showed that higher bitterness and lower food acceptability generated a longer chewing time (Neyraud et al., 2005). Liking decreased with chewing time, despite the properties of the products' textures (Neyraud et al., 2005). Also, as the complexity of the tongue movement increases, the sensation became more intensive (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009). Lenfant et al. (2009) used breakfast cereals to study the texture sensation in oral processing, and the results showed that hardness, crackliness, and crispness were perceived at the beginning of chewing. Furthermore, with the increased mastication, brittleness and lightness were able to be noted in the middle. In the end, stickiness was identified. Low flavour ratings and weak slippery lip-tooth feelings were reported when participants experienced high concentrations of total protein in their saliva (Engelen et al., 2007).

Figure 2-2 The relationship between sensory attributes and oral processing (Foster et al., 2011)

The same results were also found by de Wijk et al. (2011) in semi-solid foods when certain sensations such as creaminess could be distinguished with the increased tongue movement; furthermore, the thickness was able to be perceived at the beginning. The relationship between oral movements and aroma sensations was studied, and the results found that compared to shearing actions, chewing behaviour generated stronger aroma sensations under the same condition (Buettner, Beer, Hannig, Settles, & Schieberle, 2002).

Food sensory perception begins when the food is seen, touched and smelled and continues to evaluate taste and texture in the oral cavity, which is a changing and dynamic process (de Wijk et al., 2003). Initially, sensory attributes including appearance and texture are first to be perceived by sight and touch. Regarding solid foods, the first chewing cycle begins to break down food structure. Then a coherent bolus is shaped with saliva. With more and more saliva adding into the bolus, attributes regarding physical structure, consistency and adhesion to the palate are perceived (Foster et al., 2011).

The flavour perception during oral processing has been demonstrated to be a dynamic process from previous research findings; therefore the hedonic liking during oral processing should be dynamic as well. Hence, the development of dynamic measurements to assess hedonic liking is essential. The next section will list the current conventional and temporal measurements to assess food acceptability in the food industry, including hedonic scales, the temporal drivers of liking (TDL) and the temporal dominance of emotion (TDE).

2.3 Conventional and dynamic hedonic measurements in the food industry

The measurements for assessing food acceptability are composed of direct and indirect approaches. Direct approaches present observable behaviours towards the food by consumers (such as choice, purchase and consumption). However, alternative approaches (such as preference rating, behavioural intent ratings and appropriateness ratings) usually require indirect measures of hidden behavioural responses to the food. These often make use of verbal behaviours to assess consumers' subjective acceptability to predict their potential consumption behaviours. Compared with direct approaches, they are easy to administrate (Lim, 2011). However, the inability to reflect real consumer behaviours (such as final choices, purchases or consumption) is a clear disadvantage to indirect approaches (Cardello & Schutz, 1996; Hersleth, Ueland, Allain, & Naes, 2005).

2.3.1 Common problems with hedonic measurements

Before introducing the most frequently used hedonic measurements, five common measurement problems related to hedonic liking sampling will be discussed first. These include contrast error, contrast effect, carryover effect, ceiling effect and floor effect.

2.3.1.1 Contrast effect and contrast error

Contrast effect and contrast error are both the result of a rating being affected by previous ratings or marks during hedonic measurements. Regarding contrast error, mistakes always arise from previously appraised or ranked things such as images of food (Kemp, Hollywood, et al., 2009). However, the contrast effect means that the differences in people's perceptions are greater or lesser than are present. For example, there are three images called A, B, C presenting positive, negative and negative images, respectively. When participants are required to rate these three images, if A (positive) is preceded by B (negative); the rating of B (negative)is even lower compared with C (negative) being presented before B (negative). This phenomenon can be explained by human beings always feeling better when a worse contrast is presented. However, a worse feeling will be obtained when people are confronted with a better contrast sample (Kamenetzky, 1959).

2.3.1.2 Carryover effect

The carryover effect is a crucial factor and cannot be ignored when designing a research protocol. Unlike the contrast effect, the carryover effect reflects a remainder of some activity (such as a judgement or emotion) coming from a previous trial. Furthermore, the influence is still likely to appearing in the next trial (Ferris, Kempton, & Muir, 2003; Waters, Sayette, Franken, & Schwartz, 2005). For example, when a participant sees an image of a rotten apple, it may leave a deep impression. Then, when an image of chocolate is presented following this, the participant may still be influenced by the rotten apple image and might not think that the chocolate image is as appetising as they usually might.

2.3.1.3 Ceiling and floor effect

Ceiling effect and floor effect occur when the measurements have distinct upper and lower limits for potential responses. With these effects, a large number of participants are found to give ratings at or close to the upper and lower limits, which is described as the ceiling or floor effect. Regarding rating scales, there are two common methods to solve these problems. One is to expand the number of potential answers on rating scales. Another one is to make use of extreme anchor stimuli (Lewis-Beck, Bryman, & Liao, 2004). For example, if a mildly disgusting image was rated on the nine-point scale before a strongly disgusting food image, there would not be sufficient range on the scale to rate the magnitude of the experienced disgust so that the rater might select the maximum rating possible for both images. This would mean that there would be restricted variability for high disgust items on this scale. Adding an extreme anchor, such as "the most disgusting thing that I can imagine" is likely to reduce the ceiling effect.

2.3.2 Conventional hedonic measurement – Hedonic scales

Studies of food acceptability are focused on evaluating sensory attributes, detecting affective responses and measuring hedonic judgements by consumers (Meiselman & Cardello, 2003). Hence, to make the exact prediction of food acceptability from consumers, various rating scales (such as category rating, line scales, magnitude estimation) have been developed for hedonic and preference measurements (Lawless, Popper, & Kroll, 2010). Currently, in the food industry, hedonic scales, including the 9-point scale, magnitude estimation, and category-ratio scale are most commonly used measurement to assess food acceptability. These typical hedonic scales will now be discussed in depth.

2.3.2.1 The 9-point scale

The 9-point scale, a category scale, (originally developed by Peryam, Pilgrim and other colleagues in the early 1950s for menu planning for the US Army canteens at Quartermaster Food and Container Institute in Chicago) (Moskowit& Sidel, 1971) is the most common method for assessing food preference and acceptability by consumers (see Figure 2-3). For example, two typical 9-point scales were presented in Lim's publication to evaluate hedonic responses to foods (Lim, 2011).

Figure 2-3 The 9-point scales (Lim, 2011)

Properties

The nine-point scale is a balanced bipolar scale, which comprises nine specific categories, a neutral point at the centre, four positive and four negative categories on each side (Cordonnier & Delwiche, 2008; Lim, 2011). The anchor phrases used to label the categories range from dislike extremely to like extremely, representing the various degrees of affect (Cordonnier & Delwiche, 2008; Nicolas et al., 2010). Furthermore, it was reported by Peryam and Pilgrim (1957) that the presentation format of the scale, such as the long or short lines, vertical or horizontal orientation and the beginning with like or dislike do not influence participants' affective results.

Advantages

Compared with other hedonic measurements, the 9-point scale has distinct advantages of easy understanding, simple data handling, subtle sensitivity and high efficiency (Lim, 2011).

Although the 9-point scale is quite simple, it is as useful and efficient as other scaling techniques, such as line scales and magnitude estimation. Its sensitivity, reliability and discrimination power have been reported to be high (Lawless & Malone, 1986a, 1986b;Lim, 2011).

The 9-point scale makes it easy for both experiment participants and researchers to understand and use owing to its categorical nature and limited choices. Furthermore, there is no need to provide specific and extensive training for participants to be able to use the scale effectively (Cordonnier & Delwiche, 2008). A final advantage is that ease of data collection and handling is another unsurpassable merit for researchers using this type of scale (Lim, 2011).

Limitations

The typical 9-point scale is not able to provide ratio data on liking or disliking for stimuli because it only offers verbal phrases for participants to choose (see Figure 2-3) (Moskowit & Sidel, 1971). Furthermore, it is meaningless to make a comparison of hedonic assessment between individuals and groups (Lim, Wood, & Green, 2009). These are because the scale can generate only ordinal or interval data owing to its inequality intervals and lack of a zero point (Peryam & Pilgrim, 1957).

Due to the limited categorical numbers on the nine-point scale, participants are not thoroughly free to express the full range of their hedonic experiences. Furthermore, ceiling effects often occur, in which there is difficulty discriminating extreme responses close to the upper (or lower) limit when participants try to use extreme categories on the scale for several items that are similar valence with extreme arousal but with slight variation between them (Lim, 2011).

Although data on the 9-point scale is easy to use, owing to the scale's categorical and discrete data, without the presence of a true zero point they are not always the best choice for discriminating hedonic liking (Lim, 2011).

2.3.2.2 Magnitude Estimation

Stevens developed magnitude estimation in the 1950s by revolutionizing the original ratio scaling (Stevens, 1956, 1957). Originally, it was used to assess large numbers of sensory modalities. Then, in the 1960s, magnitude estimation was gradually developed to evaluate the preference of a wide range of odours as a hedonic measurement by Engen and McBurney (1964). In 1971, it was introduced to food research formally by Moskowit and Sidel (1971).

Properties

Magnitude estimation has unique properties compared with other hedonic measurements because it does not depend on visual or semantic aids during the assessment (Lim, 2011). The participants are required to assign numbers to sensory stimuli or hedonic intensity of a food product without any restrictions (Moskowit & Sidel, 1971).

Advantages

Not only can the relationship between changes in physical sensory intensity and overall preference be illustrated by magnitude estimation, but it also provides a direct approach to emphasizing basic research and sensory evaluation. For example, different groups of individuals are available to be investigated by hedonic magnitude estimation (Lim, 2011). Furthermore, it was that the 9-point scale and magnitude estimation (unipolar/bipolar) showed quite similar spreads of rating, precision in differentiating samples and discrimination (Pearce, Korth, & Warren, 1986).

Limitations

There are also several limitations to magnitude estimation. It is meaningless to compare the direct rated values between participants without anchoring judgments of individual participants (Lim, 2011). Then, owing to the lack of semantic information, it is difficult to translate ratio differences into meaningful comparisons between various product perceptions (Lim, 2011). Furthermore, compared with the nine-point scale, the quality of acquired data depends on whether the participant has had previous related experience or specific training in using the scale. With respect to naive participants, this scale is harder to understand without training (Lim, 2011). Finally, normalization and standardization of data required before statistical analysis starts, which further increases the difficulty and complexity of handling data using magnitude estimation (Moskowitz., 1977).

2.3.2.3 Category-ratio scales

A rating scale called *category-ratio scale* was proposed by Borg (1982). It combined and integrated the previous outstanding features with the category and ratio scale. Furthermore, various extension category-ratio scales were developed to meet different testing requirements, for example, labelled affective magnitude (LAM), labelled magnitude scale (LMS), generalized labelled magnitude scale (gLMS), a bipolar hedonic scale, oral pleasantness and unpleasantness scale (OPUS) and labelled hedonic scale (LHS) (Cordonnier & Delwiche, 2008; Lim, 2011).

Properties

The category-ratio scale is a continuous line (Lim, 2011). The verb phrases describing magnitude, located at selected positions along the line, make significant contributions to obtaining hedonic ratio-level data at the same time. This data can show subtle differences in liking/disliking among stimuli (Dine & Olabi, 2009). Additionally, it is easy to obtain meaningful semantic information and participants' experiences by the locations of categorical semantic marks (Lim, 2011). Its properties, similar to magnitude estimation, can understand the hedonic acceptability, but also provide information on the different dimension of the stimulus (such as the concentration) and ratio statements about intensities in liking (such as A was liked three times as much as B) (Lim, 2011).

Advantages

The category ratio is as easy to use as the 9-point scale. However, unlike the 9-point scale, it is essential to give instructions and opportunities to practice before assessment in order to obtain high-quality data (Lim & Fujimaru, 2010). Another obvious advantage that exists is the ability to handle large amounts of data with ease. There is no need for any data transformation for category ratio before parametric analysis can be used (Cordonnier & Delwiche, 2008; Lim & Fujimaru, 2010).

Limitations

A limitation of reducing the discrimination power results from making a contraction of ratings toward the centre of the category-ratio scale by inclusive end anchors (Cardello, Lawless, & Schutz, 2008). It is suggested instructions and practice scoring should be provided for participants before assessment. Naive and scale-experienced participants are more likely to misuse this scale. For example, it was found by Cardello et al. (2008) that a large number of panellists misused the LAM scale and treated this scale like a categorical scale by mistake.

Summary of hedonic scales

These hedonic scales are the most commonly used measurements used to assess hedonic liking, but there are some further limitations that should be discussed. First, these hedonic scales are only able to provide an overall hedonic liking for foods. In other words, they are not able to detect the dynamic liking/disliking of food, especially for complex foods such as coated food or food with textural changes or dynamic thermal properties. Second, the hedonic liking rating is easily influenced by participants' biased judgement such as their physiological status and past eating experiences. The common problems listed in 2.3.1 demonstrate that some influences on ratings are unavoidable and vary depending on the type of scale. Last, asking participants to rate their experience is an interruptive evaluative behaviour that does not necessarily relate to everyday food behaviours.

Although there are lots of advantages to using hedonic scales, there are also some issues that are difficult to avoid with these scales. Firstly, these hedonic scales are only able to provide an assessment of the overall hedonic liking rating statically, rather than with dynamic emotion change. When tasting more complicated food such as food with a coating, hedonic scales are not able to provide dynamic hedonic liking of the outside coating or inside component. Secondly, the ratings by these scales are more likely to be influenced by the participants' biased judgement. For example, if the participant is happy, she/he is more likely to give a higher rating. Moreover, most of the self-reporting is based on the participant's memory and experience. Importantly, the carryover effect, ceiling effect and floor effect all reveal the high risk of biased judgement from participants. Thirdly, asking the participant to rate foods is an interruptive behaviour. Therefore, there is scope to develop new techniques to assess dynamic hedonic liking that do not have these disadvantages.

As a result of the development of new techniques, some forms of dynamic measurement are now available to the food industry, enabling the assessment of dynamic acceptability and hedonic liking. Because the temporal change in hedonic assessments is important for product evaluation, dynamic sensory measurement methods, including time-intensity (TI) and temporal dominance of sensation (TDS) will be introduced first then dynamic hedonic liking measurements will follow.

2.3.3 Dynamic measurements of sensory evaluation

Sensory evaluation was originally referred to as organoleptic testing in early work in the field. However, this term was discarded in the 1960s because it did not capture the range of high complexity sensory impressions required to assess foods (York & Vaisey-Genser, 2003). The US Institute of Food Technologists modified the definition in 1975. From then on, as a new scientific discipline, the term sensory evaluation is used to describe the investigation, measurement, and analysis of food characteristics that are perceived by the senses of sight, smell, taste and touch.

Specifically, the evolution of techniques in sensory evaluation has provided a direct approach to obtaining more precise knowledge using critical measurement to investigate consumer attitudes, food acceptability and food perceptions. Furthermore, this research area has gradually become an independent function within the food industry that enhances product development and revenue generation (Kemp, Hollywood, et al., 2009). Flavour perception during oral processing is dynamic so it is vital that temporal measurements are developed to assess dynamic sensory perception of this process. Time-intensity (TI) and the temporal dominance of sensation (TDS) are two typical dynamic measurements that have resulted from the demand for dynamic techniques.

2.3.3.1 Time–Intensity (TI)

In order to obtain temporal evaluation during oral processing, dynamic perception was first investigated in 1978 by Larson-Powers and Pangborn (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009) whose pioneering studies were focused on measuring the intensity and duration of sweetness, bitterness, sourness and flavour with different solutions, by means of the Time-Intensity methodology. Thus, TI methodology was invented as a solution to the problem of dynamic assessment and gradually developed over the last five decades from quantifying the temporal responses using scorecards to the current computerized TI system (Jellinek, 1964).

As an extensional measurement of conventional sensory profiling, TI characterizes specific dynamic sensory properties over a period by recording the intensity evolution of a given sensory attribute (Cliff & Heymann, 1993; Le Révérend, Hidrio, Fernandes, & Aubry, 2008; Sinesio, Moneta, & Esti, 2005). The length of sensation, changes in quality of sensation and differing intensities in quality over time are the most prominent advantages of TI over traditional descriptive techniques (Kemp, Hollowood, & Hort, 2009).There are alternative methods of TI such as dual-attribute time intensity (Duizer, Bloom, & Findlay, 1997), modified time intensity (Pionnier et al., 2004) and discontinuous time intensity without a halo-dumping effect (Clark & Lawless, 1994).

Although this technique provides some dynamic information on specific sensory characteristics, there are some unavoidable limitations of the technique. Firstly, it is problematic that only a small number of attributes can be measured on each occasion, and this is the dominant factor hampering the development and usefulness of TI (Ng et al., 2012; Pineau et al., 2009). Additionally, recording two attributes at the same time from panellists is difficult (Dijksterhuis

& Piggott, 2000). Also, halo-dumping, in which a participant assesses one sensory domain with categories from another domain, such as a *sweet* or a *salty* smell, cannot be avoided if using TI (Clark & Lawless, 1994; Ng et al., 2012; Pineau et al., 2009). Because only one attribute is rated at a time, if the participant misses out on the natural perception of this attribute, inappropriate scales will be used with the limitation of response alternatives (Clark & Lawless, 1994). Although TI technique can provide a temporal sensory perception of the specific attribute, the sequence of sensations is not able to be acquired (Le Révérend et al., 2008).

Studies of time-intensity tend to focus on taste attributes, the effects of multiple sample ingestion, and real food products.

Fundamental studies have laid a solid foundation for perception models such as sweetness perception patterns (Birch, Latymer, & Hollaway, 1980; Birch, Odonnell, & Musgrave, 1982), speculation about bitterness perception (Leach & Noble, 1986) and the development of an absorption-desorption model for oral irritation (Cliff & Heymann, 1992). Leach and Noble (1986) found bitterness perception from caffeine had a faster rate than quinine using TI owing to the faster absorption and slower desorption of caffeine. Later, Cliff and Heymann (1992) used maximum intensities to assess the appropriateness of the Beidler taste equation and calculated the degree of affinity of the stimuli using TI.

Sensory attributes relating to bitterness (Guinard, Pangborn, & Lewis, 1986a), astringency (Guinard, Pangborn, & Lewis, 1986b), and irritation (Nasrawi & Pangborn, 1990) have also been investigated to study the effect of multiple sample ingestions using TI.

Time-intensity has been used to investigate flavour perception of fruit flavoured beverages (Matysiak & Noble, 1991), chocolate pudding and cream (Pangborn & Koyasako, 1981) and palm oils (Lee, 1986). For texture perception, TI has been used to understand perceived viscosity of melting ice cream (Moore & Shoemaker, 1981), the viscosity of chocolate pudding and cream (Pangborn & Koyasako, 1981), and firmness of gels (Larson-Powers & Pangborn, 1978).

2.3.3.2 Temporal Dominance of Sensation (TDS)

To overcome the deficiencies of time-intensity measures, the dynamic sensory analysis technique, the *temporal dominance of sensations* (TDS), was developed at The European Centre for Science and Taste and initially presented by Pineau et al. (2009) and Labbe et al. (2009). In the field of dynamic evaluation, Pineau introduced TDS to evaluate multidimensional perceptions of food for a predefined period, such as from the mastication period to the aftertaste period (Meyners & Pineau, 2010; Pineau et al., 2009). Specifically, it is a unique dynamic approach to identifying the most dominant sensory attribute first, and then, where appropriate, scoring its intensity at each specific time until the sensation ends or another new dominant attribute appears (Albert, Salvador, Schlich, & Fiszman, 2012; Meyners, 2011).

TDS is a useful complementary tool to characterize specific and temporal organoleptic properties over time. There are some outstanding advantages of this technique: 1) multiple sensory attributes can be evaluated and tracked at the same time during food consumption (Meillon, Urbano, & Schlich, 2009); 2) the sequence of dominant sensations and interaction between the evolutions of attributes can be recorded and described during oral processing (Dinnella, Masi, Zoboli, & Monteleone, 2012; Le Révérend et al., 2008; Sokolowsky & Fischer, 2012); 3) the dynamic perception after swallowing can also be detected (Meyners & Pineau, 2010); 4)the halo-dumping effect can be avoided by providing several attributes for panellists to choose between (Clark & Lawless, 1994; Ng et al., 2012; Pineau et al., 2009; Sokolowsky & Fischer, 2012); and 5) TDS is faster to run than TI because multiple domains can be measured simultaneously (Meillon et al., 2009; Ng et al., 2012; Pineau et al., 2009).

There are some limitations to this technique: firstly, it can be difficult to determine how to select a list of attributes for TDS testing and this affects the number, attributes, and sequence that are chosen. Ten was found to be the maximum number of attributes that can be used effectively, but it is hard for a panellist to remember these many attributes (Pineau et al., 2012). Secondly, the full-time perception pattern for each attribute over time is not able to be tracked by TDS because the focus is on the dominant sensation and a changing dominance doesn't reflect absence of other sensations (Meillon et al., 2009). Thirdly, it is important to spend time training panellists because the sensitivity of attributes is affected by the level of training (Ng et al., 2012). Lastly, individual panellist performance is not easy to be assessed, and is approximated by computing a distance index between the sequences of sensations (Ng et al., 2012). Studies of TDS have so far prioritised focussing on technique development for its accuracy, comparison studies with other sensory profiling techniques, and the application of this technique to assess dynamic sensory perception, which is listed in Table 2-1. Various foods and beverages have been studied using this technique, such as dairy products (Pineau et al., 2009), wine (Meyners & Pineau, 2010), hot beverages (Le Révérend et al., 2008), flavoured gels (Labbe et al., 2009), and breakfast cereals (Lenfant et al., 2009). As a dynamic technique, TDS has been compared with other sensory profiling techniques, such as comparing TI with TDS using hot beverages (Le Révérend et al., 2008) and dairy products (Pineau et al., 2009), a comparison between TDS and descriptive analysis (DA) using extra-virgin olive oil in vegetable foods (Dinnella et al., 2012) and blackcurrant squashes (Ng et al., 2012), comparison between TDS and sensory profiling using 9 flavoured gels (Labbe et al., 2009), and comparison between TDS and key-attribute to evaluate fish sticks (Albert et al., 2012). The main influencing factors in TDS measurement such as how to select the attribute list (Pineau et al., 2012), how to train the panel (Meyners., 2011), and how to arrange the sequence of the list (Pineau et al., 2012) have been studied.

Table 2-1 A summary of recent studies using TDS

Authors	Samples	Methodology	Attributes Number	Panellist Number	Replications	Results
Albert et al. (2012)	2 fish sticks	TDS & sensory profiling	7	9	2	TDS and sensory profiling gave silimar results for the different fish sticks.
						The crunchiness, oiliness, juiciness were the three dominant attributes for one fish stick.
Le Reverend et al (2008)	6 hot beverages	TDS & TI	6	12	2	The results of 'time-intensity'curves were similar.
						The similar results showed in the product perception pattern over the time.
						Products and techniques comparsion was able to be obtaned by 'score over time'curve.
Labbe et al. (2009)	9 flavoured gels	TDS & sensory profiling	5	43	1	The sequence of dominat attribute with TDS was coldness, overall intensity, sourness, sweetness and bitterness. The same result also found with sensory profiling.
						Compared with sensory profiling, TDS also provded the dynamic perception after product consumpiton.
Sokolowsky et al. (2012)	28 dry white wines	DA & TDS & TI	6	18	3	Bitter parameters including bitter intensity and bitter persistency showed the similar results with TDS, DA and TI.
Mellion et al. (2009)	8 wines	TDS & sensory profiling	10	16	3	For Merlot, alcohol reduction affected texture and astringency sensations. The dominant sensations were heat sensation, astringent, bitter with TDS.
						For Syrah, sweet sensation was influenced by alcohol reduction. The sensation perceived by TDS were heat, red fruits, bitter.
Ng et al (2012)	11 blackcurrant squashes	QDA & TDS	9	11		Both methods illustrated that the level of dilution and complexity of sample compostion combined with blackcurrant juice content affected flavour profile
Pineau et al (2009)	5 dairy product	TDS & TI	10	16	4	Pasty, diacetyl, melting and sour were dominant attributes for product FC by TDS.
						For FC, pasty and diacetyl were the most often chosen as dominant with TDS and also occupied the highest intensity scores with TI.
						TI and TDS results showed similar patterns of sensations.
						TDS was able to provide the sequence of the sensations over time.

In conclusion, owing to the dynamic flavour perception during food consumption, the invention of TDS and TI techniques have made great contributions to enable the description of dynamic sensations of various foods and these will be a promising method in the description of products with weak sensory differences in the future. However, in the food industry, the measurement of temporal hedonic liking is always based on TDS and TI, and this will be discussed in the following section.

2.3.4 Temporal hedonic measurements in the food industry

Initially, TI was used to evaluate specific attributes over time, but this technique has also been used to assess temporal hedonic responses. Taylor and Pangborn (1990) and Yoshida, Mochizuki, and Gillmore (1992) used chocolate milk and umami substances to measure hedonic responses using time-intensity, respectively. It was found by Taylor and Pangborn (1990) that the positive hedonic ratings were increased by milk fat (0-36%) in chocolate milk, and achieved maximum liking after swallowing. This paper elucidated that the aftertaste mouth feeling could be detected using Yoshida et al. (1992) found that participants were more willing to accept umami substances dissolved in the soup rather than dissolved in pure water by using TI.

With the development of TDS, some scientists tried to assess the temporal hedonic liking with TDS technique. Specifically, after the most dominant attribute is selected by the participant, a 9-point scale is provided for the participant to give a hedonic liking rating of the selected attribute, and this means that it is possible to record the temporal hedonic response to the dominant attribute. In 2013, temporal liking was first used by Thomas, Visalli, Cordelle, and Schlich (2015) to record the temporal hedonic response to six flavoured cheeses with TDS in a sample of 68 consumers. The results demonstrated that sampling temporal liking is more discriminating than a single measurement of liking, the influencing factors on liking or disliking of the product were the selected dominant attributes and the times to which there was perception of those attributes. In the same year, the temporal dominance of emotion (TDE) was also developed to assess the temporal food-evoked emotions that can be related to dynamic sensory perception. The first published study using TDS evaluated the dynamic sensory perception of dark chocolates were, but this time, after selecting the dominant attribute, 10 emotional attributes rather than a hedonic scale were provided for participants to give their affective responses to this selected attribute (Jager et al., 2014). The results showed TDE to be a promising new avenue in characterising food that evoked emotions in relation to sensory attribute characterisation, but combining the sensory and emotion attributes is more complex than previous methods. In 2015, flavoured fresh cheese was used as the target food to study temporal hedonic liking again by TDS and a method called Check-all-that-apply (CATA). The results showed that for these cheeses, the presence of fresh herbs and cooked herbs seem to be the main drivers of liking within the different TDS attribute curves for these products. Garlic and salt dominance is the next most important positive predictor, with pepper featuring as a negative driver of liking using CATA (Meyners, 2016). Later, TDS and temporal-check-all-that-apply (TCATA) were used

to assess a temporal hedonic perception of dynamic sensory profile on French bread and vanilla milk desserts. These results suggested that these techniques can provide similar information about the main drivers of liking and disliking, especially when there are clear differences in liking for the food products (Ares et al., 2017).

In summary, temporal assessment of hedonic liking has been studied recently in the food industry. However, there are some potential limitations to these methods. Firstly, TDL and TDE are only able to assess the temporal liking or emotion to the dominant selected attribute over time rather than the whole dynamic emotion change during food consumption. Secondly, these techniques still require participants' objective hedonic rating using a 9-point scale or emotion judgement using selective emotional attributes, and this is an interruptive behaviour, which is likely to be influenced by participants' physiological status, measurement error, and judgement biases. Lastly, combining TDL and TDE with TDS makes the experiment complicated for both the participants and the experimenter.

Therefore, measurements such as hedonic scales and temporal hedonic assessment are all interruptive of behaviours owing to participants being asked to make ratings. Additionally, TDL and TDE are only able to record temporal hedonic responses to the specific attribute rather than detecting the dynamic emotion change during food consumption. However, these previous research findings demonstrate that during oral processing, hedonic responses are changeable along with flavour perception and can be detected. To understand the dynamic emotion change during oral processing in depth, psychophysiological measurement, facial EMG, will be used to assess dynamic food acceptability by detecting facial muscle activity without interrupting behaviour.

2.4 Psychophysiological measurement - Facial electromyography (EMG)

2.4.1 Emotion and Affect

2.4.1.1 Differences between emotion and affect

Emotion is an extraordinary method of communication between human beings, and has a significant influence on social interactions, thinking, physical and mental health. Regarding the definition, how to define the term *emotion* exactly has confused scientists for a long time due to its complexity (Cabanac, 2002; Dixon, 2012; Izard, 2010). However, abundant different definitions exist, and a lack of a singular or preferred definition of emotion is still a big problem. To make the concept easier to understand, a descriptive definition will be commonly used rather than the scientific ones that failed to reach a consensus in Izard's survey (Izard, 2010). Emotion is a kind of mental feeling or affection with reactions to some sudden trouble, emergent event or acute personal experience. It is composed of neuronal networks, physiological changes and conscious responses (Briner & Kiefer, 2005; George & Brief, 1992; Izard, 2010). Compared with moods, the most obvious characteristics of emotions are that they are momentary, target-focused and intense (Fisher, 2002; Gohm & Clore, 2002).

Human beings experience different levels of affective responses, which has a considerable effect on a wide range of human behaviours and cognition (Schwarz, 1998). Furthermore, compared with emotion, affect is more abstract and unable to be recognised and described using language and is always unavailable to consciousness (Meiselman & Cardello, 2003). Overall, affect is composed of two fundamental dimensions, including *valence* and *arousal* (Watson, Clark, & Tellegen, 1988; Zevon & Tellegen, 1982). Positive affect (PA), which represents such characterised emotions as excitement, enthusiasm and joy, reflects the individual's pleasantness level associated with the environment (Finch, Baranik, Liu, & West, 2012; Zevon & Tellegen, 1982). However, guilt, fear, anger, disgust, nervousness, sadness and contempt are all typical representatives of negative affect (NA). These aversive emotions show grief, dissatisfaction or an annoying personal experience (Finch et al., 2012; Zevon & Tellegen, 1982). Furthermore, deeper and scientific thinking frequently results from high levels of negative affect (Sanna, Turley, & Mark, 1996). Moreever, positive affect is accompanied by judgmental biases and is more likely to generate surface thinking and decisions based on simple information (Schwarz, 1998).

2.4.1.2 The psychophysiological methods to measure affect and emotion

Owing to the complexity of emotion and different emotional response systems, how to measure emotional state is one of the most difficult problems in the psychology discipline (Mauss & Robinson, 2009). The measurement of emotional state is listed in Table 2-2.

Table 2-2 Review of emotion measurements adapted from (I. Mauss & M. Robinson, 2009)

Response System	Measurement	Main contents
Subject's experience	Self-report	Personal experience description
Peripheral physiology (ANS)	Autonomic nervous system (ANS) measures	Electrodemal response, Cardiovascular response
Affect-modulated startle	Startle response magnitude	Eye blinks
Central physiology	EEG, fMRI, PET	Frontal and back brain stimuli responses
Behaviour	Vocal characteristics, Facial behaviour, Whole body behaviour	Voice, behaviour, facial muscles

Self-report is the most common method to describe personal experience of participants. It tends to be most valid and useful when the current experience is depicted rather than distant experience (Robinson & Clore, 2002). Furthermore, transient emotional states are not easy for all participants to report (Paulhus & Reid, 1991). Even if momentary emotions can be described by individuals, biases among different groups cannot be avoided (Robinson & Clore, 2002).

Electrodermal and cardiovascular responses make up the main assessed indices of autonomic nervous system (ANS) activation (Mauss & Robinson, 2009), which primarily measures sympathetic activity and parasympathetic activity (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). Skin conductance level (SCL) measures sympathetic activity and short-duration skin conductance responses (SCRs). On the other hand, many techniques can measure cardiovascular responses such as heart rate (HR), blood pressure (BP), total peripheral resistance (TPR), cardiac output (CO), pre-ejection period (PEP) and heart rate variability (HRV). To study discrete emotional states rather than dimensions, researchers often combine multiple ANS measurements, such as described by Cacioppo et al. (2000) and Kreibig, Wilhelm, Roth, and Gross (2007). Strong evidence showed that the dominant reflex during a startle response was eye blinking (Davis, 1989; Lang, 1995). Therefore, electromyography (EMG) can measure the muscle activity of the orbicularis oculi region to reflect the intensity of emotion during a startling experience. However, discrete emotions are not capable of being assessed using EMG on the orbicularis oculi muscle (Mauss & Robinson, 2009).

Behaviours are the most direct, efficient and easy approach to revealing emotional states in the laboratory. This is because for human beings in their daily communication, bodily behaviours have evolved to present the individual's emotional state to others (Ekman, 1992b). According to Lang, Bradley, and Cuthbert (1997), an individual's emotional state is likely to be inferred successfully by vocal characteristics, facial displays and whole-body behaviours. Vocal characteristics, voice amplitude and pitch are composed of the most commonly used measurements, which is particularly useful for understanding the intensity of emotional arousal (Mauss & Robinson, 2009). However, there is an obvious limitation of this research field - not all emotional states have distinct bodily behaviour (Mauss & Robinson, 2009), which is why this emotional communicative channel has not been adopted by all researchers (Adolphs, 2002). Examples of previous research using behaviour include pride and embarrassment, which have been proven to evoke distinct body postures, involving expansive and diminutive behaviours respectively (Stepper & Strack, 1993; Tracy & Robins, 2004) although no obvious facial expressions can be observed for these emotions (Keltner & Buswell, 1997; Tracy & Robins, 2004). The outstanding limitation of using observation of body behaviour and facial expressions is that sometimes these are not strong enough to be observed even though the individual is experiencing a distinct emotional state. In other words, subtle affective responses are not able to be observed. Here, facial electromyography (EMG) can be used to measure changes in facial muscle activity to detect changes in emotion. Previous work has mainly focussed on the corrugator supercilii muscle that knits the eyebrows and the zygomaticus major muscle that lifts the corners of the lips when smiling. Numerous studies have illustrated that facial behaviour is closely tied to contractions of these muscles, such as smiling involving wrinkling the orbicularis oculi muscles and raising lip corners related to positive emotion (Keltner & Buswell, 1997), with expressions of disgust being presented by corrugator supercilii (Pochedly, Widen, & Russell, 2012). Therefore, facial EMG is a highly valuable, important method and it will be discussed in the following section in more detail.

2.4.2 Food and Emotion

It is widely accepted that enjoyment, pleasure and positive emotions can be experienced by eating (Davis et al., 2008). Furthermore, individual final purchasing choice is also affected by affective responses relating to food (Canetti, Bachar, & Berry, 2002; Rousset, Deiss, Juillard, Schlich, & Droit-Volet, 2005). Food emotion sources are composed of sensory properties, experienced consequences, personal or social meanings and behaviour of agents.

Regarding emotion and food, two important concepts relating to these topics are emotional eating and emotion regulation. Emotional eating means increased food intake is associated with different emotions (Conner, Fitter, & Fletcher, 1999), especially leading to an increased consumption of high fat, high sugar snack foods such as ice cream, cakes and chocolates (Nguyen-Michel, Unger, & Spruijt-Metz, 2007; Wallis & Hetherington, 2004, 2009). It was found that humans preferred to consume healthy foods when experiencing positive emotions. Conversely, the probability of impulsive eating of junk food increased owing to negative emotions (Lyman, 1982; Macht, 1999). For example, emotional stress eaters tend to choose high-energy sweet snacks to relieve their stress (Oliver & Wardle, 1999; Zellner et al., 2006). Furthermore, the amount of food consumed with positive and negative emotions is more than that with neutral emotion (Patel & Schlundt, 2001).

Relating to food, emotion regulation refers to people using eating to modify their emotional experience (Christensen, 1993; Desmet & Schifferstein, 2008; Macht & Simons, 2000). For example, the release of endorphins from high-energy foods can improve negative emotion (Macht, Gerer, & Ellgring, 2003). Diets high in carbohydrate, fat and sugar (such as chocolate and cake) have been illustrated to have a close short-term association with improving negative emotions (Benton & Donohoe, 1999). Furthermore, it was found that ice cream and chocolate can relieve sadness and stress in humans (Canetti et al., 2002). According to Ekman (1992a), both positive and negative affect influences the whole eating process, from eating behaviour to entire food ingestion—such as eating motivation (Macht & Simons, 2000), food choices (Gibson, 2006b; Oliver & Wardle, 1999), chewing (Macht, 1999), eating speed (Krebs, Macht, Weyers, Weijers, & Janke, 1996), intake amount (Greeno & Wing, 1994), metabolism and digestion (Blair, Wing, & Wald, 1991).

The studies relating anger with eating focus on characteristics of eating in anger, eating disorders and eating pathology. Macht (1999) compared anger with fear and sadness, and found that participants experiencing anger tended to suffer from high levels of hunger. Furthermore, they were more likely to experience impulsive eating that involved fast, irregular and careless consumption of food, especially among female participants. Anger affected eating frequently resulted in the tendency to binge eat. In 2008, there was a survey of the Busan area of South Korea to explore the interrelations among fast food, beverage intake and anger in adolescents. The results showed 'carbonated drink' consumption had a negative effect on anger control. 'Hamburgers', 'carbonated drink', and 'coffee' showed a positive effect on anger reduction

(Desmet & Schifferstein, 2008). Anger has also been shown to have a close relationship with eating disorders and eating pathology (Desmet & Schifferstein, 2008; Fox & Harrison, 2008).

It is also interesting that some types of food can arouse a feeling of disgust and elicit nausea in humans. Angyal (1941) noted animals or animal products were the main food sources that evoke disgust. Rozin and Fallon (1980) found that cockroaches or excretory products occupied the highest proportion of disgusting things identified by their 241 participants. Then in his following article, it was stated that contaminants such as the faeces of animals (for example, dogs and insects) led to an aversion reaction (Rozin & Vollmecke, 1986b). Disgust for food is closely related to culture although this was originally ignored (Korsmeyer, 2002). Taking culture into consideration, Korsmeyer (2002) provided a controversial list of disgusting food in an article specifying six basic disgusting food categories. Firstly, innate revulsion examples are the fishy smell in cod liver oil or the putrid smell of meat. Secondly, when a human eats too much and reaches satiation, even small quantities of food will also result in repellency, especially for sweet desserts. Thirdly, eating creatures such as spiders, crocodiles and snakes that are unusual and alien in most daily diets, but human beings might encounter in nature. Fourthly, eating some objects extremely close but not alien to us such as human beings, pets (cats and dogs). Fifthly, eating creatures that are still alive and especially when they are resistant to being consumed. Lastly, eating a creature that has been dead for such a long time that its corpse has started to decompose (Korsmeyer, 2002). Disgust has been demonstrated to have a close relationship with problematic eating such as eating pathologies and eating disorders (Fox & Harrison, 2008; Miotto, Pollini, Restaneo, Favaretto, & Preti, 2008).

Humans frequently consume food in association with happy events (Christensen & Brooks, 2006), such as birthdays, weddings and other social functions. Furthermore, there is a tendency for people to be more willing to eat healthy food when experiencing positive affect (Lyman, 1982). Importantly, experiencing pleasure enhanced the probability of hedonic eating (Macht, 1999). Here, gender is a vital factor. When confronted by red meat, men commonly felt happy with seeing and eating it, whereas discomfort was frequently reported by women (Rousset et al., 2005). In similar studies, gender was found to have a significant influence on food selection. Men, following a happy event, consumed snack food. However, sweet food was the first choice of women following a sad event (Christensen & Brooks, 2006). Human beings reflected happiness and surprise when they were exposed to sweet solutions. However, anger and disgust were the main hedonic responses resulting from experiencing bitter solutions. Furthermore, there was no specific affective reaction to salty and sour solutions (Robin, Rousmans, Dittmar, & Vernet-Maury, 2003).

Boredom and sadness were both illustrated to relate to increased and decreased appetite, respectively (Wallis & Hetherington, 2004). In summary, more frequent experiences of anger and enjoyment had the strongest influence on eating, compared with sadness, fear, surprise and boredom (Macht, 1999).

2.4.3 Facial Electromyography (EMG)

Weddell first developed facial EMG in 1943. As a psychophysiological measurement, it does not only enable us to record facial muscular activities using electrodes for assessing facial expressions, but also detects the subtle neurophysiological changes relating to emotion (Cacioppo et al., 1988; Dimberg, 1997; Sato et al., 2008b; Vrana, 1993b).

2.4.3.1 Advantages

As a psychophysiological measurement, there are many advantages to EMG over other coding techniques, such as observational methods. Firstly, the outstanding advantage is that it is more sensitive and precise in detecting facial muscle reactions objectively, even if the reactions are too small to be observed from facial movement. This advantage reveals a potential to detect dynamic emotion change by facial muscular activities. Secondly, subjective errors resulting from observing participants' assessments can be eliminated (Dimberg, 1997). Thirdly, training for coding participants' facial expressions is not essential (Armstrong et al., 2007b; Dimberg, 1997). Lastly, videotaping can also be used during facial EMG measurement (Jancke, 1996a). These outstanding advantages can overcome the limitations of current hedonic measurements used in the food industry.

2.4.3.2 Apparatuses

Figure 2-4 Facial EMG Facility

The basic procedure of facial EMG is shown in Figure 2-4 (Gonzalez, Montoya, & Carcel, 2001). From Figure 2-4, bipolar surface electrodes detect muscular activities. These electrodes are usually silver-silver chloride (Ag – AgCl) electrodes and frequently placed on the left side of the face (Fridlund & Cacioppo, 1986; Gonzalez et al., 2001). Electrodes are placed on the exact muscle location beneath the skin according to the muscles that are being measured.

To overcome the low amplitude of EMG signals, specific experimental protocols must be followed. Shielding signals from electrical noise is necessary. For example, artefacts, mainly coming from lights, electrical transformers, relay equipment, the computer clock, A/D converters, televisions, video displays, and imperfect grounding generate 50-Hz noise which is dangerous to the fidelity of the signal (Fridlund & Cacioppo, 1986).

In this study, facial EMG was recorded with a system from Biopac Systems Inc. (USA). The EMG signals used were notch filtered at 50Hz (mains current), low pass filtered at 500Hz (to remove signals outside of the range of muscle activity), and a High Pass filter at 20Hz (to remove interference from movement of the electrode leads). Acknowledge 4.2.0 was used in this study to record EMG signals.

2.4.3.3 Typical facial expressions

Facial expressions are ubiquitous in human beings' social intercourses. Furthermore, crucial information can be derived from facial expressions during social interactions to understand and infer the others' intentions (Chen & Chen, 2010; de Jong, Koster, van Wees, & Martens, 2010).

The characteristics of facial expressions can be grouped into three factors: happening without consciousness, involuntary and rapid automatic reactions, and intentional (Dimberg, Thunberg, & Elmehed, 2000; Root & Stephens, 2003). Anger, happiness/joy, fear, disgust, sadness and surprise are six basic facial expressions (Batty & Taylor, 2003). Facial expressions are generated by the contraction of facial muscles resulting in the movement of facial skin and corresponding connective tissue. Apart from facial muscles, striated muscles in the neck, back and arms and smooth muscles of the blood vessels have effects when producing facial expressions (Rinn, 1984).

2.4.3.3.1 Anger

Definition

When human beings are facing a series of specific uncomfortable, unfair or threatening experiences, anger will appear accompanied by verbal, facial and bodily reactions (Kassinove & Sukhodolsky, 1995). The general features of the anger emotion are basic, negative; the highest frequency experienced and the most commonly recognised (Ekman et al., 1987). However, regarding definition, there is no agreement on how to define *anger* exactly. Here, a clear definition is presented. Anger, a negative arousal emotional state, is composed of variable insensitive feelings from mild levels in the circumstances of the threat or frustration (Spielberger et al., 1985). Anger-in and anger-out are two typical and converse halves of anger. Anger-in is the process of restraining or denying the outburst of anger affect and blocking the outward performances of anger such as facial expression, bodily postures and verbal language

(Spielberger et al., 1985). Briefly, anger-out is a neutral autonomic physiological reaction process (Spieberger, Johnson, Russell, Crane, & Worden, 1985).

Prototypical expression

Anger, a basic emotion, can be distinguished from other emotions by typical facial expressions and corresponding autonomic physiological phenomenon (Hepworth, Mogg, Brignell, & Bradley, 2010). The movements of the brow, lip and eyelid are key parts of the typical anger expressions. Specifically, the brow is pulled down and furrowed by the actions of the corrugator sucpercilii muscle. At the same time, the eye opens wide. Furthermore, the upper eyelid is raised, and the lower eyelid is tightened, which illustrates the movement of the orbicularis oculi muscle region (Matsumoto, Yoo, & Chung, 2000). Lastly, the lip is tensed and narrowed, which shows another important symbol of anger expressions for which the compressed lip is a part of the response (Matsumoto et al., 2000). However, it is notable that the typical symbolic expressions of anger sometimes are not always the same because anger expressions are not static but dynamic and these related movements rarely occur at the same time (Scherer & Ellgring, 2007). Apart from that, physiological changes such as increased heart rate, blood pressure and blood flow, leading to an erect head, expanded chest, rigid arms and trembling are found when humans experience anger (Tassinary, Cacioppo, & Geen, 1989b).

Elicitors

As a social emotion, elicitors of anger include the following: the internal or external detection of unfairness; moral violations (such as impoliteness, insults, betrayal), direct or direct threatened actions, aggression from others' words or body actions and goal obstruction (Canary, Cupach, & Messman, 1995).

Disadvantages

Experiencing and expressing anger causes costs to the individual and others (Hepworth et al., 2010). However, the most prominent problem caused by anger is health risks (Kerr & Schneider, 2008). For adults, the outcomes of exposure to anger for a long time are hypertension (Hauber, Rice, Howell, & Carmon, 1998), cardiovascular disease (Harburg, Julius, Kaciroti, Gleiberman, & Schork, 2003), asthma (Friedman & Booth-Kewley, 1987) and cancer (Thomas et al., 2000). Furthermore, Kerr and Schneider (2008) mentioned that the health problems resulting from anger even appeared in youth. Depression, aggression, problem behaviour and poor physical status are the main consequences for teenagers who suffer from anger (Kerr & Schneider, 2008).

Functions

Apart from the disadvantages mentioned above, undoubtedly anger serves a variety of different social functions. Anger contributes to mastering and managing social or interpersonal behaviours, interactions and relationships (Lewis, Sullivan, Ramsay, & Alessandri, 1992). Next, anger is useful in adjusting and organising psychological processes such as self-defence and aggression (Lewis et al., 1992). Lastly, anger is helpful in overcoming difficulties to accomplish goals or tasks because sometimes negative emotions can transfer the power to progress (Lewis et al., 1992).

Measurement

The most common methods to assess anger are self-report and behaviour observation. According to Spielberger et al. (1985), self-report originated from the state-trait anger scale and the anger expression scale, which had commonly been used to measure state-trait anger, anger expression and anger-control. However, the characteristics of self-report such as subjectivity are likely to cause biased results. Therefore, behaviour observation is a method to observe expression changes and behaviours to assess the anger emotion, because the typical facial and body features can be observed during the experience of anger (Kerr & Schneider, 2008). The facial expression of anger has been discussed above.

2.4.3.3.2 Disgust

Disgust, composed of discrete emotions along with anger, sadness, fear, surprise and joy originally hadn't attracted much attention. However, psychophysiology studies show that research emphasis has transferred to the disgust expression and emotion in a variety of research areas (Angyal, 1941; Chapman, Kim, Susskind, & Anderson, 2009; Ekman, Friesen, & Ancoli, 1980; Pochedly et al., 2012; Wolf et al., 2005).

Definitions

The definitions of disgust varied from person to person. In 1872, Darwin, who was the first person to analyse the facial pattern of disgust, described disgust as an aversion, which is caused by the sense of taste as a primary factor and then anything resulted in a similar feeling by means of smell, touch and even eyesight (Darwin, 1872). Later, Angyal defined the term as a specific revolting attitude when confronted with offensive objects such as the waste products of the human and animal body (Angyal, 1941; Ekman et al., 1980). Ekman et al. (1980) laid an emphasis on using mouth and ingestion to explain their disgust definition.

Domains

Based on surveys in Japan and Northern America, the domains of disgust can be arranged into 9 factors, including poor hygiene, social person to person contamination, body products (such as odour), animals, sexual behaviour, certain foods or potential foods (such as decayed meat, rotten apple), touching corpses, certain moral disturbances and interventions to the exterior envelope of the body (Rozin, Lowery, & Ebert, 1994).

Function

There are a lot of different functions of disgust, including avoidance of poisons, infections and contaminants - useful in diagnosing neurological disorders and determining the preference of food and other objects, promoting moral decisions and actions - relating to psychiatric disorders (Pochedly et al., 2012).

Components

Disgust is composed of four components that are behavioural, physiological, an emotional component and qualia, indicating a rejection behaviour. Regarding a physiological component, nausea is the most specific state. Furthermore, increased secretion of saliva, lowered heart rate and increased skin conductivity are all recognised physiological markers (Levenson, Ekman, & Friesen, 1990; Vrana, 1993b). Revulsion is the outstanding characteristic, but it does not last very long (Scherer & Wallbott, 1994).

The reason why more emphasis is laid on the emotional component is that the look of disgust on the face can be recognised easily by basic characteristics of facial movements including muscles and organs. Although researchers such as Darwin (1872) and Rozin et al. (1994) didn't reach an agreement on a typical facial expression of disgust, corresponding facial movements were demonstrated to be around the mouth and nose. Specifically gape, retraction of the upper lip and the nose wrinkle are considered to be three primary characteristics of the facial expression of disgust (Rozin et al., 1994). Furthermore, dropping of the mouth corners and raising the chin are likely to appear with prototypical facial movements (Rozin et al., 1994).

Prototypical expression

The changes in facial expression are all caused by facial muscle activity. M. Levator labii superioris has been reported as the most significant muscle for the expression of disgust (Ekman, 1992b; Vrana, 1993b). Its main function is to retract the upper lip, thus creating wrinkles on both sides of the nose (Susskind et al., 2008). Furthermore, potential information conveyed by the nose wrinkles to others is a negative sensory signal about an environmental threat, such as rotten meat and bad taste (Vrana, 1993b; Wolf et al., 2005). M. corrugator supercilii, a key muscle for all negative emotions, lowers the inner region of the brow along with M. orbicularis oculi thus leading to tension in the corrugator brow region (Vrana, 1993b; Wolf et al., 2005). Additionally, the lower lip is likely to be exerted by M. depressor labii (Wolf et al., 2005).

2.4.3.3.3 Joy

Positive Affect

Positive affect is composed of excitement, enthusiasm, happiness, joy and contentment, which reflects the different levels of enjoyable involvement by human beings (Pressman & Cohen, 2005). The common scales used to assess positive affect are the Positive and Negative Affect Scale (Watson et al., 1988), Profile of Mood States (Mcnair, 1984).

Functions of Positive Affect

Positive emotions have a significant effect on human beings' health and lives. Positive emotions relieve the negative impact of stress (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008), benefit human health by increasing longevity (Moskowitz, 2003), improve the functioning of the immune system (Cohen, Doyle, Turner, Alper, & Skoner, 2003), reduce pain perception and decrease mortality associated with chronic diseases (Pressman & Cohen, 2005).

Prototypical Expression of Joy

The typical facial pattern of joy can be identified as a "felt smile" that involves the contractions of zygomaticus major, minor, and orbicularis oris muscle regions, lifting the upper lip and generating the furrow near the nose (Wolf et al., 2005). Smiling, laughing, clapping hands, jumping and trembling are also typical behaviours associated with experiencing joy. Many physiological responses accompany the feeling of joy such as increased heart rate, either constant skin conductance level (SCL) or increased SCL as well as increased nSRR (Neumann & Waldstein, 2001).

2.4.3.4 Facial Muscles

Human faces are composed of approximately 42 muscles that share a complex dimensional structure with no cross-joints. These muscles originate from the bone or fascia of the skull and are inserted into the skin of the face (Goodmurphy & Ovalle, 1999). According to their functions, facial muscles are categorized into two groups involving mastication muscles and expression muscles (Rinn, 1984). Therefore, facial muscles possess two unique functions. One is to control the opening and the closing the sensory organs on the face: eye, nose and mouth. Another one is to contract the skin or fascia to form facial muscular movements, thus eventually producing meaningful facial expressions for social communicative behaviour (Goodmurphy & Ovalle, 1999; Rinn, 1984).

Nine facial muscles are particularly important for the expression of emotion (including M. frontalis, M. corrugator supercilii, M.orbicularis oculi, M. levator labii, M. zygomaticus major, M.risorius, Platysma, M.depressor anguli oris and M. mentalis) (Wolf et al., 2005). However, the EMG site "Atlas" hasn't been available for all facial musculature. The specific locations of EMG electrode placements relevant for emotion measurement are presented in Figure 2-5.

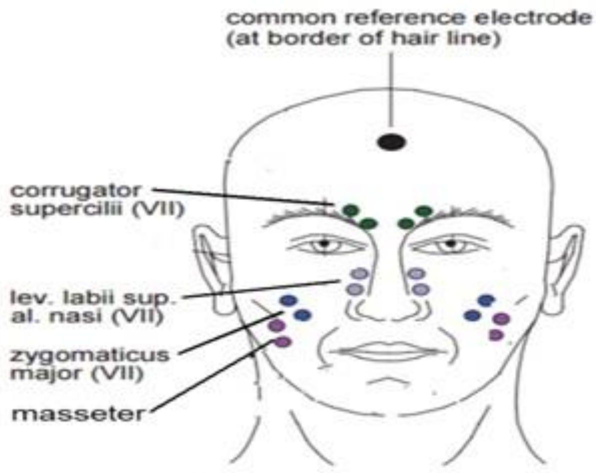


Figure 2-5 Facial EMG Muscles locations (Van Boxtel., 2010)

It was found that M. levator labii, M. zygomaticus and M. corrugator supercilii were commonly used facial muscles to reflect hedonic stimuli using facial EMG (Tassinary et al., 1989b; Vrana, 1993b).

Zygomaticus major (located in the cheek and close to buccinator, masseter and zygomaticus minor) is influenced by contralateral innervation (Rinn, 1984). Numerous researchers have illustrated that pleasant stimuli evoked muscle activity and elicited greater muscle activity over zygomaticus major (Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, 1997; Hu et al., 1999; Larsen et al., 2003; Rymarczyk, Biele, Grabowska, & Majczynski, 2011; Sato et al., 2008b). Lifting the lip corner and elevating the cheek are characteristics of generating a smile, which is a symbol of positive affect (Armstrong et al., 2007b; Jancke, 1996a; Sato et al., 2008b). Interestingly, some researchers still found that pleasant stimuli do not consistently evoke activity from zygomaticus major (Jancke & Kaufmann, 1994); whereas the contraction of zygomaticus major was sometimes the result of exposure to negative stimuli resulting in a grimace (Armstrong et al., 2007b; Burton et al., 2008).

However, increased muscle activities of M. corrugator supercilii and M. levator labii superioris are the main representatives of negative affect (anger and disgust) evoked by unpleasant stimuli (Dimberg, 1997; Jancke, 1996a; Rymarczyk et al., 2011). M. corrugator supercilii is located in the eyebrow region. Lowering, furrowing the brows and generating associated wrinkles are all typical characteristics of the facial display of anger (Armstrong et al., 2007b; Dimberg, 1982). On the other hand, the disgust expression is accompanied by lifting the middle of the upper lip and wrinkling the nose, which results from the movements of M. levator labii superioris located on the two sides of the nose (Armstrong et al., 2007b). However, in our study, as a functional muscle, masseter muscle is also included to assess dynamic acceptability because the movement of masseter muscle is always associated with food consumption. Chewing behaviour, chewing cycles and mastication were detected by masseter muscle (Grigoriadis, Johansson, & Trulsson, 2014); Miyaoka et al. (2014). Additionally, increased contraction of masseter muscles was found when tasting less preferable taste stimuli (Horio, 2003).

2.4.3.5 EMG Studies

The studies of facial EMG are mainly focused on social mimicry, emotion, and affective responses (Borg, Bosman, Engelhard, Olatunji, & de Jong, 2016; Cacioppo et al., 1988; Cannon, Schnall, & White, 2011; Kreibig et al., 2007; Vrana, 1993b; Wolf et al., 2005).

Facial muscle activity has previously been validated as a measure of emotion relating to subjective experiences. For example, EMG responses for corrugator supercilii, zygomaticus major, and levator labii superioris muscle were recorded by facial EMG from 50 participants asked to imagine situations eliciting disgust, anger, pleasure and joy using a tone-cued imagery procedure. At the same time, self-report emotions were also collected. The results of self-report emotions produced consistent results with the affective categorization of the imagery stimuli. Increased EMG activity in the levator muscles was found when experiencing disgust imagery rather than anger imagery. Corrugator supercilii muscle activity was found to increase for negative stimuli, whereas the emotion joy was represented by higher EMG activity at the zygomatic regions than other emotions (Vrana, 1993b). Later, the investigation of the facial muscle pattern of disgust in comparison to appetence and joy was conducted by recording nine facial muscle activities for 40 participants passively viewing pictures. One of the primary findings showed that disgust is distinguishable from the facial patterns of appetence and joy and involve a specific facial muscle pattern of M. corrugator and M.orbicularis oculi (Wolf et al., 2005). The affective responses of the corrugator supercilii, levator, and zygomaticus major muscles were detected using facial EMG to predict moral judgements. The results showed that moral judgements such as purity and fairness violations were correlated with facial disgust, harm correlated with corrugator activity and positive in group behaviours correlated zygomaticus major activity (Cannon et al., 2011).

Undoubtedly, these interesting previous findings demonstrate that EMG can distinguish negative and positive stimuli using specific facial muscle activities including corrugator, zygomaticus, and levator muscles. Of more relevance to this thesis is that facial EMG was found to correlate with hedonic responses to odour (Armstrong et al., 2007a; Jancke & Kaufmann, 1994) and taste (Epstein & Paluch, 1997) stimuli in the food industry.

The relationship between affective responses to odours and their hedonic evaluation in solitude and with an audience was studied by recording six muscle regions, including corrugator, procerus, nasalis, levator, orbicularis, and zygomaticus muscles. The results showed that in solitude, pleasant odours did not evoke smiles, whereas a facial display of disgust was found during the smelling of highly concentrated malodours (Jancke & Kaufmann, 1994). Negative and positive emotional food visual stimuli were presented to participants to investigate their affective responses by detecting the EMG activities in corrugator and zygomaticus muscles. The results showed that EMG activity in corrugator muscles increased when passively viewing the negative stimuli, whereas positive stimuli evoked more zygomaticus muscle activity (Dimberg, 1997). Two years later, only the levator labii superioris/alaeque nasi region was measured to assess the sensory hedonic responses to 1) real beverages, including apple juice, Gatorade, water, soybean milk, and pickle juice, and 2) solutions, including sugar solution, salt solution, and water. The results indicated that increased EMG activity in the levator labii muscle region was evoked by negative hedonic sensations, whereas reduced EMG activity in the same region was associated with positive hedonic sensory perception (Hu et al., 1999). Facial EMG was used as a clinical measurement to assess the affective responses to pleasant and unpleasant smell and taste stimuli (water, bitter, sweet, salt, and sour) of children by detecting levator and zygomaticus muscle activities. The results illustrate that EMG activity in zygomaticus was only able to discriminate between taste stimuli and water, whereas the levator muscle differentiated between sucrose and the other three taste stimuli and between all the taste stimuli and water control. Importantly, the levator muscle was also used to discriminate the pleasant and unpleasant stimuli, which was not able to be achieved by the EMG activity from the zygomaticus major muscle (Armstrong et al., 2007a). M. masseter and M. digastricus, as functional muscles, were found to assess the hedonic liking induced by different taste stimuli (sweet, salty, sour, bitter, umami, harsh, astringent, and pungent) with other facial expression muscles (M. corrugator supercilii, M. orbicularis oculi, M. risorius, M. depressor anguli oris, and M. orbicularis oris). The interesting results showed that not only muscles associated with facial expressions, but also chewing muscles displayed greater responses to less preferred taste stimuli.

In summary, the interesting findings from previous studies reveal the feasibility of facial EMG to discriminate negative and positive affect when tasting or smelling stimuli. However, the limited number of published papers indicates that this is a neglected research topic using facial EMG. Sometimes, levator muscles and corrugator muscles were used to discriminate negative and positive affect but there were some inconsistencies. Importantly, in these papers, conventional correlation analysis was used to determine the relationship between the psychophysiological data and the hedonic liking data. These research gaps provide us an opportunity to explore some new ideas such as using more advanced statistical analysis and co-activation of facial muscles in our study.

Therefore, in this thesis, a systematic study was conducted and more facial muscles, including expression (corrugator, levator, and zygomaticus) and chewing (masseter) were also used to explore the potential application of facial EMG to assess dynamic food acceptability and to predict the hedonic liking rating of stimuli.

2.5 Research Outline and Objectives

The studies of this thesis are both involved in assessing dynamic affective responses to food using facial EMG.

In this study, the overall H_0 and H_1 we set for the null hypothesis and alternative hypothesis are that:

H_0: there will be no relationship between hedonic liking and facial muscle activity.

H_1: Individual disliked stimuli will increase the facial muscle activity of the corrugator and levator muscle. Contrary, the increase of the zygomaticus muscle activity will result from the individual liked stimuli. As a functional muscle, the activity of the masseter muscle will also rise from the individual disliked stimuli because the study of Horio (2003) indicates that the movement of masseter muscle links to the unpleasant stimuli.

The impact of experimental design on type I errors included rigorous methods (avoiding experimenter influences and confounding effects) and statistical analyses:

In this study, the use of a controlled laboratory setting for the research minimized human social contact during the experiment. This reduced the impact of social influences on the participant during the experiment. All of the stimuli were pretested when they were prepared for the study. Food images were selected using a different participant group from the participants in the main experiment. The same for the liquid study. Participants with diverse cultural backgrounds were recruited to attend the experiments. Extreme bitter liquid ratings and muscle activity were avoided by only recruiting medium-bitter tasters. Lastly, a multi-level modelling (MLM) analysis strategy accounts for the variability within participants and stimuli and avoids the requirement for multiple tests on the same data (which inflates Type I error); this analysis also accounts for the repeated measures design of the experiments.

The impact of experimental design on type II errors is that:

1) The choice of statistical analysis multi-level modelling (MLM) decreased the quantity of data excluded for each participant (pairwise exclusion compared with listwise exclusion). It all allows individuals to have hedonic liking preferences (dependent variable) that are personal and not correlated with other participants' data. This analysis method is a good alternative to traditional analyses that are required to correct for multiple comparisons because testing of the model parameters does not require Bonferroni correction (which is conservative and can lead to inflated Type II error).

2) Using a controlled laboratory setting was valuable because it enhances the sensitivity of the experiments to find effects. Ensuring that the stimuli were pretested to avoid ceiling and floor effects increased the variance that could be explained during the analyses;

3) The processing of the EMG data maximized the sensitivity of the analyses. The calculation of the individual trial changescores removes any trends for muscle activity change over time (baseline shift). Excluding trials where there was pre-trial muscle activity ensured that the dataset was high quality.

The primary research questions of this overall study are that:

1) Can facial EMG detect emotion when assessing sensory attributes?

2) Can facial muscular activities predict hedonic liking ratings?

All the studies in this thesis are designed to answer these two primary research questions.

Figure 2-6 has listed the research outline of this study, which is composed of two main experimental studies and one advanced statistical analysis study.

Study 1 (see 3.2 and 3.3) will record facial muscle activities when participants passively view different kinds of food images using facial EMG to assess dynamic food appearance acceptability. This study will be without any food consumption, but relates to the main food sensory attributes. Two experiments, including food appearance survey (see 3.2) and facial EMG recording (see 3.3) both address this issue. Finally, a conventional statistical analysis, including t-test and ANOVA will be used to understand the correlation between facial muscle activity and hedonic liking rating data.

The two main research questions of Study 1 are that:

1. Is facial EMG able to detect dynamic emotion change when participants view different kinds of food images by recording facial muscular activities?

2. Is there a correlation between EMG activity (corrugator, levator, zygomaticus, masseter) and the hedonic liking rating of food images?

For Study 2 (see 4.2 and 4.3), it will record facial muscle activities when participants taste different concentrations of bitter and sweet stimuli to assess the dynamic acceptability of tastant stimuli, which requires minimal oral processing. There are three experiments in this study including the supertaster testing (see 4.1), acceptability testing (see 4.2), and facial EMG measurement (see 4.3). In this study, different dynamic phases, including emptying, swirling and thinking about the liquid stimulus, will be used to understand dynamic emotion patterns during EMG measurement. Finally, conventional statistical analyses, including t-tests and ANOVA, will be used to understand the dynamic emotion pattern and the relationship between facial muscle activities, different concentration levels of tastant stimuli and hedonic liking rating data.

Based on the findings of Study 1, the main research questions of Study 2 are that:

1. Is facial EMG able to detect dynamic emotion change when participants taste different concentration levels of sweet and bitter stimuli by recording facial muscle activity?

2. Are dynamic facial emotion patterns different when liquids are emptied, swirled, and after they are spat out of the mouth?

3. Will EMG activity show the same result when comparing tasting (tasting without a rating) and rating (tasting with a rating) blocks?

4. Is there a correlation between EMG activity and the rating of tastant stimuli during tasting and rating blocks?

Study 3 (see Chapter 5) will focus on using an advanced statistical analysis technique called multi-level modelling (MLM) to predict the hedonic liking rating and intensity rating using facial muscle activity. The psychophysiological and rating data will be both acquired in Study 1 and Study 2. Here, the predictive modelling of Study 1 and Study 2 will be established and analysed separately. Different models will be defined to predict the hedonic liking and intensity ratings. For each dependent variable, ***Models A*** and ***B*** are the checks of appropriateness of the use of multilevel modelling—that there is variability in the dependent variable for participants and for stimuli. ***Model C*** is the most important model and is the main focus of Chapter 5 because, in this model, facial muscle activity from corrugator supercilii, zygomaticus major, levator labii and masseter are continuous variables used to predict the hedonic liking and intensity rating dependent variables. Other important models including ***Model D***, ***Model E***, and ***Model F*** will be developed to interpret the data when including categorical variables, but the results for these will only be included in the appendix.

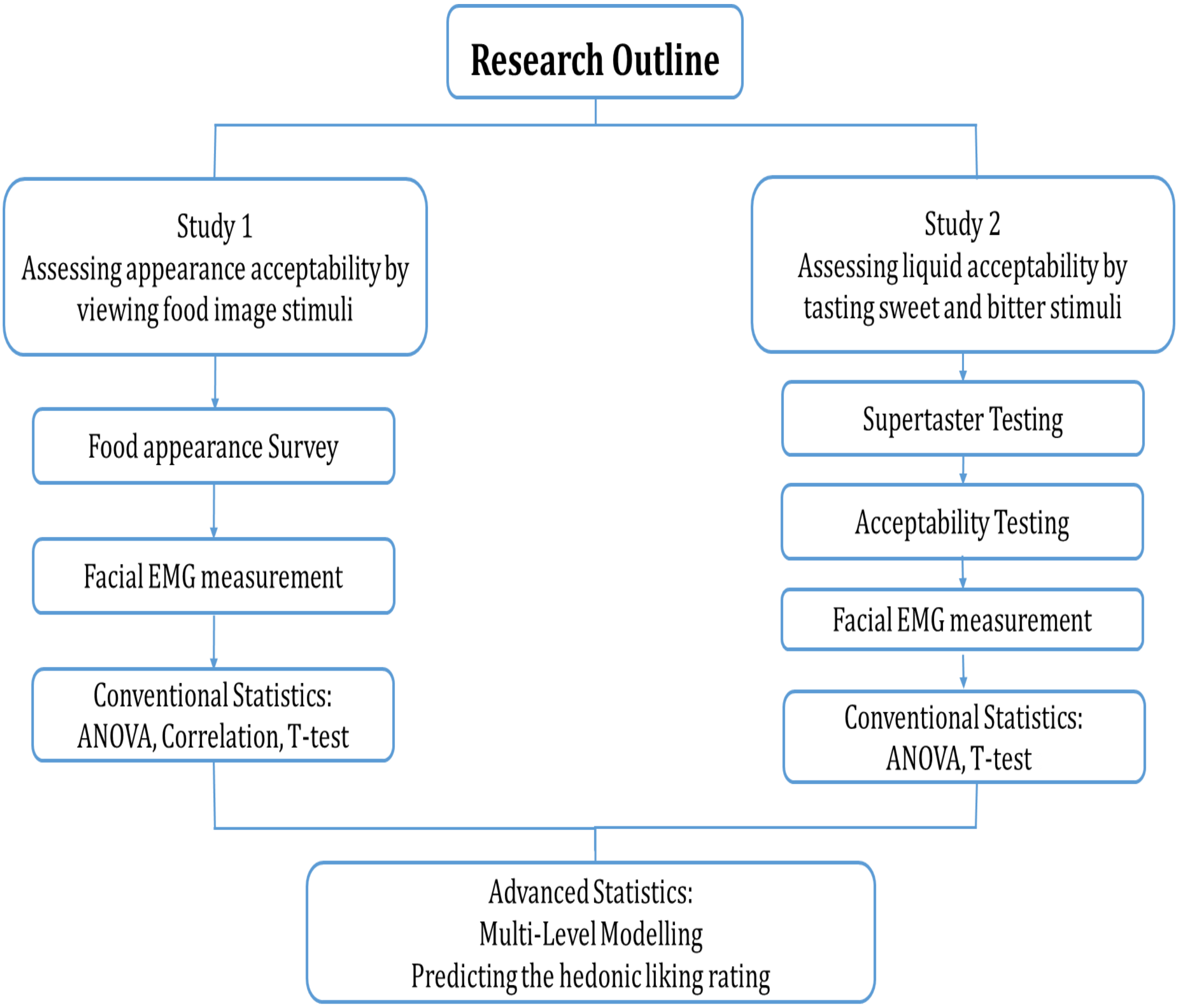


Figure 2-6 The flow chart of the research outline

3 Study 1: Assessing the dynamic appearance acceptability of different food image stimuli being viewed using facial EMG

3.1 Introduction

Visual, olfactory, gustatory, tactile, and trigeminal are sensory signals received by the human brain during food consumption, which can provide critical information when assessing food acceptability (Costell et al., 2010). Appearance as visual perception captured by the eyes is the easiest and most efficient approach for consumers acquiring information on food before other sensory attributes appear. Food appearance comprises two main components involved in the colour perception and physical factors such as size, shape, inherent characteristics or presentation ways (MacDougall, 2003).

Undoubtedly, food appearance as one of the principal sensory attributes has a determinate effect on food being accepted or rejected by consumers (MacDougall, 2003). Sometimes this influence even appears at the first sight of foods. For example, when first sights by consumers are focused on the green mould on cheese, the wrinkled skin of an apple and the rotten surface of a tomato, a negative effect will be laid on consumers' appetites, and even worse, rejection may occur (MacDougall, 2003). Therefore, there is a growing need to explore the relationship between food appearance and acceptability.

However, the limitations of using hedonic scales to assess acceptability have been listed such as overall hedonic liking rating, static rating and participant's subjective assessment (Moskowit & Sidel, 1971).

Therefore, the aim of this study is to assess dynamic appearance acceptability by facial EMG when participants view different kinds of food images. There are two main research questions in this study: 1) Is facial EMG able to detect different emotion changes when participants view different kinds of food image stimuli? 2) Is there any correlation between EMG activity and the hedonic rating of food pictures? Two experiments (food appearance survey and facial EMG measurement) are included in this study. The purpose of the food appearance survey is to screen out the food image stimuli, which will be used in further EMG measurement. 30 adults participated in this survey, and they were required to give their hedonic liking to the 30 different food images using the 9-point scale. The EMG measurement is to detect dynamic emotion change when each participant views different kinds of food images. In total 16 participants will be recruited for this measurement which is composed of three blocks, including practice, viewing and rating block.

The hypotheses of this study are addressed here again:

1) EMG activity in corrugator and levator muscles will increase for less liking image stimuli,

2) EMG activity in zygomaticus will increase for more liking stimuli,

3) A negative correlation will be found between EMG activity (corrugator and levator) and hedonic liking rating of less liking image stimuli

4) A positive correlation will be found between zygomaticus muscle activity and hedonic liking rating of more liking image stimuli.

3.2 Food appearance survey

3.2.1 Materials and methods

The food appearance survey is the first experiment of this study. The purpose of this survey was to select the optimum food images as stimuli in the later EMG measurement study. For this reason, these participants were required to rate these food images using a 9-point scale (See Figure 3-1). Finally, the five highest and lowest rated images and ten highest standard deviation images were selected as stimuli for the facial EMG experiment.

3.2.1.1 Participants

The participants were thirty adults aged 20-40 years (12 males and 18 females) with a mean age 27.8 years recruited from Massey University. All participants had normal or corrected-to-normal vision. The survey was deemed to be low risk, and a low-risk notification was submitted to the University of Massey Human Ethics Committee: Northern. All participants gave informed consent and were debriefed at the end of the experiment. The demographic data of participants is shown in Table 3-1.

Table 3-1 The Demographic data of 30 participants for food appearance survey

Demographics	**N**
Gender	
Male	12
Female	18
Age	27.8 (+/-9.2)
Nationality	
New Zealand	13
European	4
Asian	10
African	3

3.2.1.2 Food images

The food appearance survey was composed of 30 different kinds of food images in total. There is no perfect method to select what kinds of food images were most liked or disliked by participants. Therefore, the rationale for the choice of the food images in this survey is that these food images were able to cover as many aspects of different categories as possible, such as daily foods, and animal foods. Food images with high resolution and no water mark were chosen from the internet by selecting images covering the different intensity of hedonic ranging from "like extremely" to "disgust extremely" as far as possible using the experimenter's judgement. The images combined into a food appearance survey and were presented in Figure 3-2. The food appearance survey is shown in Appendix I.

3.2.1.3 9-Point Scale

A horizontal 9-point scale (see Figure 3-1) was used in this survey for participants to rate the food images. The extreme end-point anchors were 'Like Extremely' to 'Disgust Extremely' and are a modification of existing 9-point scales. Here, the word 'Disgust' was used because extreme responses were expected because of the animal food pictures in this survey were expected to arouse negative affect or disliking feelings from participants. It was important to use the anchor disgust because by using a milder term (e.g. dislike) there would be many responses at the floor level of the scale. The scale does not include an extreme positive anchor (e.g. love) because it was unlikely that the visual stimuli would evoke such an extreme response and this would result in compressed liking responses on the positive side of the scale.

However, we have to admit here this scale was not perfect because of the imbalance between the extreme anchors. It should be noted that the use of 'Disgust' is a stronger term than the other side of anchor 'Like'. We suggest that using uniaxial scales, for example 'Disgust' or 'Appealing' as separate scales using terms 'not at all' through to 'extremely', when similar studies are conducted. If a bimodal scale is used, then it is desirable to balance the terms whilst also attempting to achieve low sampling error.

3.2.1.4 Procedure

Each participant was required to complete the survey alone in a quiet office approximately 3 hours after eating a meal. The consent form and explanations such as how to use the 9-point scale were provided before the beginning of the survey. Then, the appearance survey composed of colourful images was presented to each participant in a random order. The participants were required to rate these thirty images using a horizontal 9-point scale ranging from 'disgust extremely' to 'like extremely' (See Figure 3-1).

3.2.1.5 Analysis

The length of this 9-point scale was 18cm. The hedonic liking rating of each food image was measured with a ruler. The average acceptability rating and a principal component analysis (PCA) was conducted using Minitab 16.

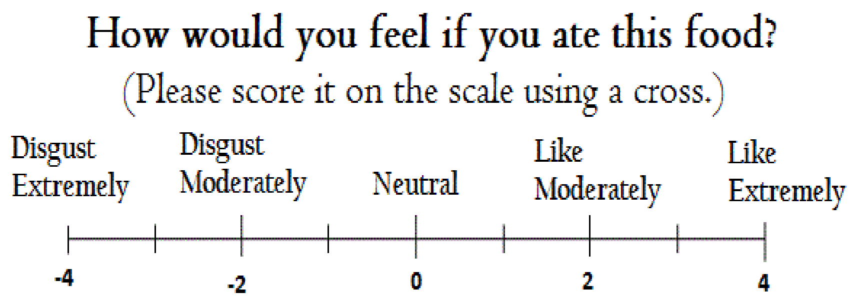


Figure 3-1 The 9-point scale used in food appearance survey

Figure 3-2 The selected images of food appearance survey

3.2.2 Results

3.2.2.1 The average acceptability ratings of 30 food images from a food appearance survey

Figure 3-3 shows the mean values of various food images rated by the participants and their corresponding standard deviations. The following trends were noted:

Images of Roast Chicken (M=3.21, SD=1.27), Chocolates (M=3.19, SD=1.17), Chocolate Cake (M=3.06, SD=1.36), Salad (M=3.04, SD=1.53) and Banana Split (M=3.00, SD=0.92) were the most acceptable for the participants. Images of Mouse Bread (M=-3.99, SD=0.05), Cockroaches (M=-3.83, SD=0.30), Little Mouse (M=-3.82, SD=0.57), Dog's Head (M=-3.76, SD=0.65) and Bird's Egg (M=-3.41, SD=1.16) were the most unacceptable images. The largest standard deviations were seen for images which were only slightly positively or negatively rated, including in Cat Lunch Box (SD=±2.50), Chilli (SD=±2.36), Chicken Heads (SD=±2.29), Broccoli Tree (SD=±2.22) and Beetle Bread (SD=±2.21), correspondingly.

The food image stimuli selected for use in the facial EMG measurement experiment are listed in Figure 3-4. From Figure 3-4, it can be seen that these 20 food images selected from the food appearance survey were divided into three different categories. Specifically, five most liked food images, five most disliked food images, and five food images with neutral ratings but high variability images. Positive images included: roast chicken, chocolates, chocolate cake, salad, and banana split, and were composed of positive images because these food image stimuli were expected to evoke positive affect from participants. Negative images included: mouse bread, little mouse, dog's head, cockroaches and bird's egg, the most unacceptable images being more likely to elicit a negative affect from participants. High variability images included food images with the highest standard deviation.

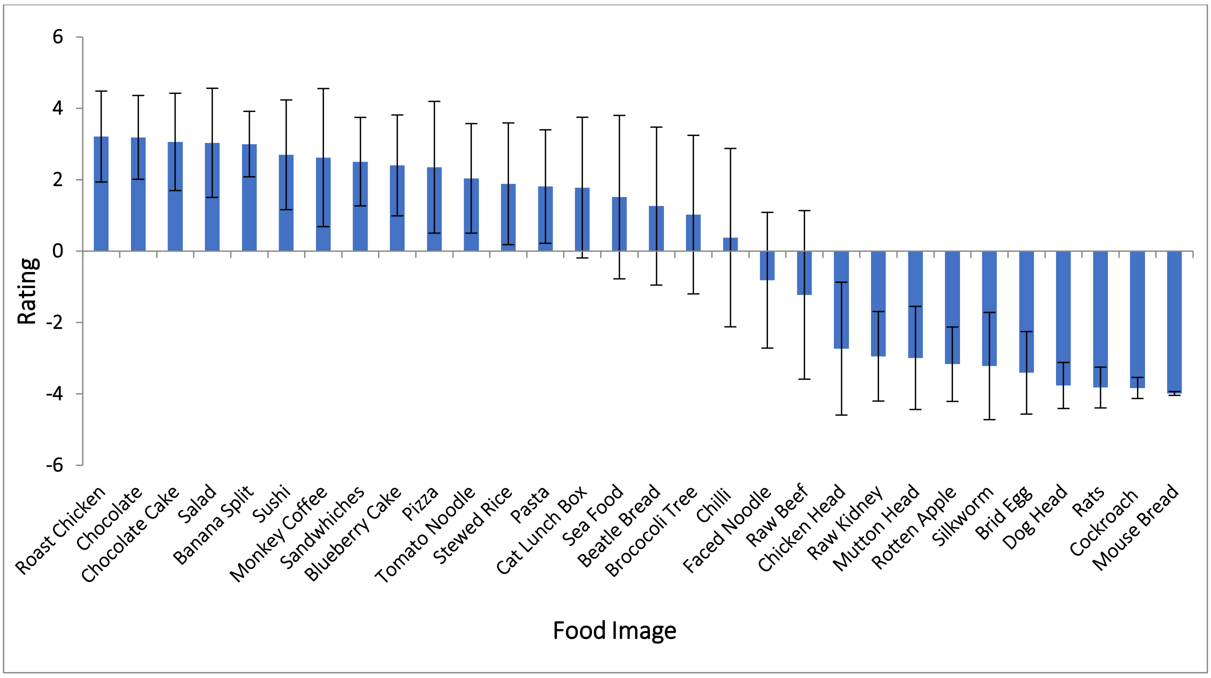


Figure 3-3 The acceptability ratings of 30 food images from food appearance survey. Images have been ordered from most positive to most negative (Error bars show -/+1 SD)

Figure 3-4 The food image stimuli used in Facial EMG measurement

3.2.2.2 The individual acceptability rating pattern of 30 food images from food appearance survey

The individual acceptability rating pattern of 30 food images addressed by each participant is presented in Figure 3-5.

The ratings of the food images were distributed across the rating scale by the participants. There was an obvious trend for positively ranked images being rated as positive on the scale, and unpleasant foods rated negatively. High variability images from the Food Appearance Survey, such as salad, monkey coffee, cat lunch box, seafood, and chilli ranged from positive to negative. There was a phenomenon in which a small number of the ratings given by the participants was focused on the upper limit such as +4.00 or nearly +4.00 given for positive rating images from roasted chicken to chilli. However, the opposite trend occurred for unacceptable food images. The majority of negative ratings were found on -4.00 or close to -4.00, indicating the presence of floor effect for a few images. Interestingly, seven food images which were expected to be rated positively, including salad, monkey coffee, sandwiches, cat lunch box, beetle bread, broccoli tree and chilli were also found to be rated extremely close to the lower limit of -4.00 by a few participants. Some extreme values were found in both positive and negative rating images. Roasted chicken, chocolate cake, salad, sushi, monkey coffee and blueberry cake consistently earned extreme positive values. Similarly, mutton head, silkworms, bird's egg, little mouse and cockroach noodles were consistently given extreme negative values. It was found that these very negative and positive images were always rated at the extreme ends of the scale by participants and had a low standard deviation.

The bold red line in Figure 3-5 represents the mean rating of the food images. Because the thin lines represent individuals, it can be deduced that images where the mean value is close to zero, result in high variability of ratings, and this generates high deviation in ratings for the food images.

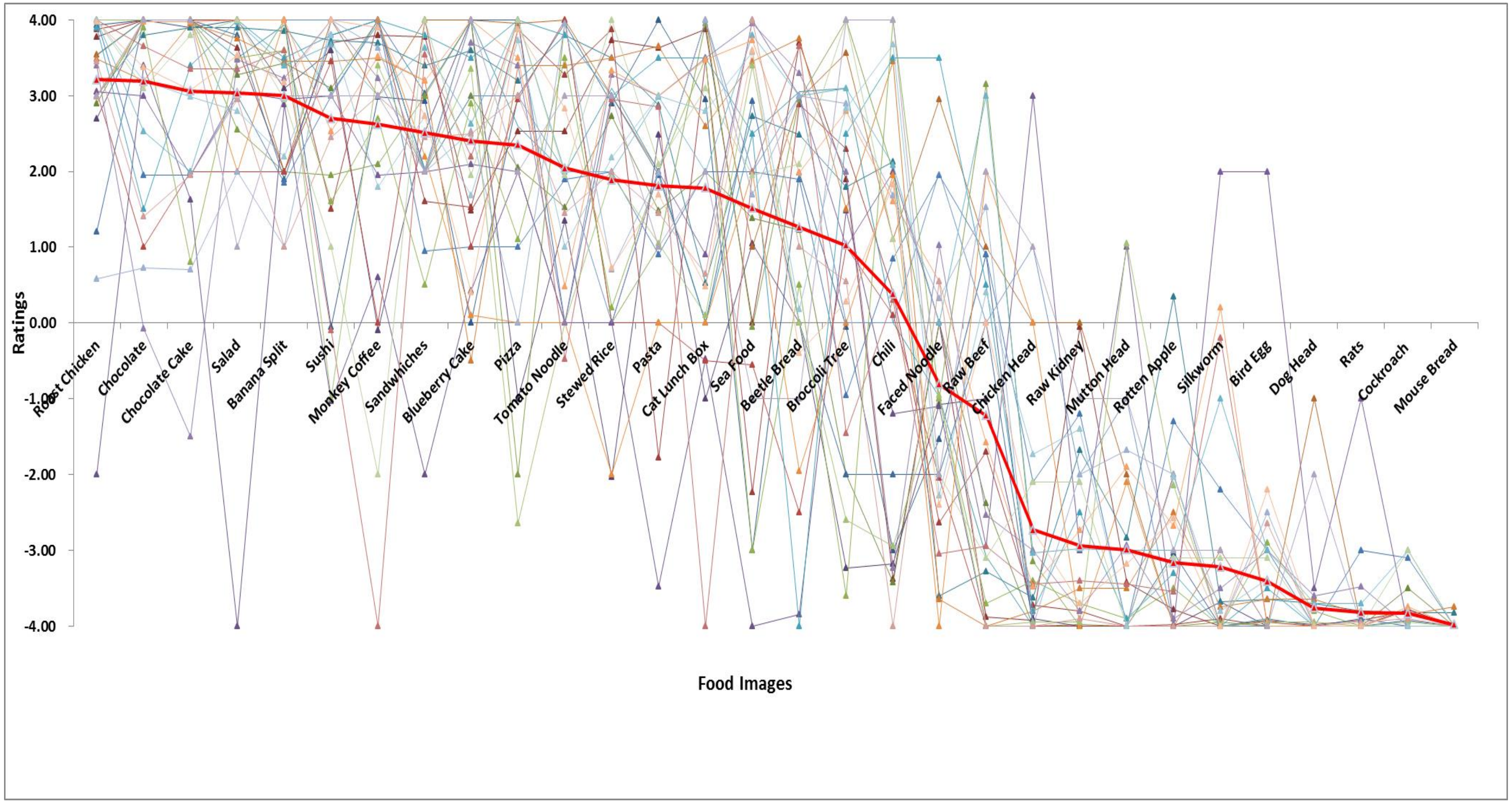


Figure 3-5 The individual acceptability rating pattern of 30 food images by each participant (Thick red line shows mean ratings for each food images. Thin lines show individual participants' responses.)

3.2.2.3 The influencing factor analysis of acceptability rating of 30 food images from the food appearance survey

Figure 3-6 illustrates the principal component analysis result of acceptability ratings. Here, there are two main influencing factors, including food image category and participants' ethnicity, which are taken into consideration.

Principal components 1 and 2 occupied 78.1% and 3.8%, respectively, representing the influence of images and ethnicity on final results, which illustrated that compared with ethnicity, different kinds of food images contributed the most significant influence on the final acceptability ratings. The most preferable images selected by the participants were roasted chicken, chocolates, chocolate cake, salad and banana split, whereas mouse bread, cockroaches, rats, dog's head and bird's egg were selected as the most unacceptable food images.

There was a high correlation between the hedonic liking ratings between most participants. However, three outliers including no. 28 (Male, China), no. 10 (Female, UK) and no. 16 (Female, China) participants were found in Figure 3-6.

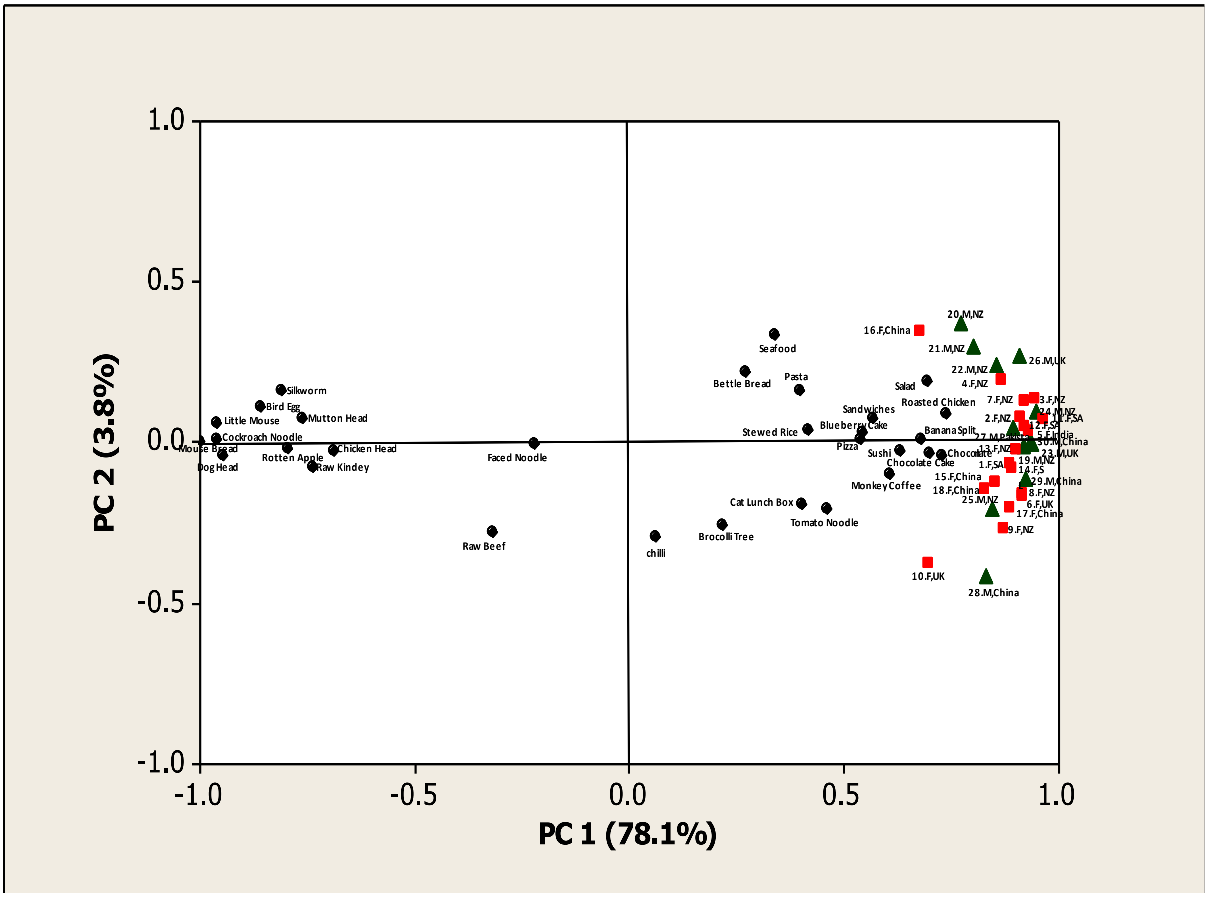


Figure 3-6 The principal component analysis of acceptability ratings from food appearance survey

(Black circles show correlations of food images. Red squares and green triangles represent the correlations of female and male participants' responses, respectively.)

3.3 Facial EMG measurement in assessing food appearance acceptability by viewing different kinds of food imagery stimuli

3.3.1 Materials and methods

This EMG measurement is the second part of Study 1. The purpose of this measurement is to detect dynamic emotion change when participants view food imagery stimuli passively by recording facial muscle activities (including corrugator, levator, masseter, and zygomaticus). There will be three blocks in this measurement, including practice, viewing images and viewing images with the rating. The more detailed testing procedure will be explained in the following sections.

3.3.1.1 Participants

A total of 16 participants (8 female) recruited from Student Job Search and Massey University with a mean age of 24.69 years (*SD=4.1*) volunteered and were each paid $20. Participants' ethnicity was variable (See Table 3-2). All participants were right-handed and did not suffer from colour-blindness.

Table 3-2 The Demographic data of 16 participants for facial EMG measurement

Demographics	**N**
Gender	
Male	8
Female	8
Age	24.69 (+/-4.1)
Nationality	
New Zealand	9
European	1
Asian	5
African	1

3.3.1.2 Facial EMG

EMG activity was recorded using BIOPAC MP150 physiological recording equipment (Biopac, California, USA) using three EMG100C electromyographic amplifiers, with silver/silver chloride reusable surface electrodes (4mm in diameter). The raw EMG signal from each facial muscle was amplified by 1000x and then hardware was filtered with a high pass 10 Hz and low pass 500Hz filters. After recording, EMG raw data was IIR filtered (high pass 20Hz, low pass 500Hz, notch 50Hz) and rectified. Filtered EMG data was time-locked to the E-Prime instruction screens and mouse responses then downsampled to 10Hz.

The muscles assessed were M. corrugator supercilii, M. levator labii, M. zygomaticus major and M. masseter. Before attaching the bipolar electrodes to the left side of the face, the face was cleaned with skin cleanser (Cetaphil, Johnson & Johnson) and the skin was rubbed with an alcohol-swab, and then electrode gel was rubbed into the recording site. The electrodes were positioned using the guidelines of Fridlund and Cacioppo (1986). The distance between electrodes was 1cm. The four electrodes' sites were the inside brow (corrugator supercilii: lowering the brow, furrowing and frowning), the nose (levator labii: generating nose wrinkles and lifting the middle upper lip) and the cheek (zygomaticus major: elevating the cheek and lifting the lip corner; masseter: chewing food) (see Figure 2-5). An unshielded ground electrode was placed on the upper forehead close to the hairline. However, at the commencement of a testing session, participants were asked to wrinkle their eyebrows (corrugator), wrinkle their nose (levator), smile (zygomaticus), and clench their jaw (masseter) to check that the electrodes were recording correctly.

3.3.1.3 Food imagery stimuli

Twenty food images (see Figure 3-4) covering a broad range of positive and negative food appearance were selected from the food appearance survey. These 20 food images were divided into three different categories including negative images, positive images and high variability images, indicating the five lowest rated images, five highest rated images and ten highest standard deviation images, correspondingly. The rationale for selecting stimuli was listed in 3.2.2.3 in detail.

3.3.1.4 Procedure

For each physiological testing session, participants were required to wash their faces using a facial cleanser (Cetaphil; Johnson & Johnson); electrode sites were then prepared using isopropyl alcohol swabs and electrode gel (Signagel, Parker Laboratories) to reduce impedance. EMG electrodes were attached, and each participant was seated in a testing booth to relax whilst the EMG recordings settled. Here, participants were only told that the study was detecting their facial muscular activities during while viewing different kinds of food images but without mentioning that the study was investigating emotional change.

Three blocks, Practice, Viewing only and Rating and Viewing was included in this psychophysiological measurement experiment. There was only one session and all participants were required to complete three blocks at one occasion. The first block was a practice block where participants viewed five high variability food images in a random order only once. The purpose of this block was for participants to familiarise themselves with all the instructions presented on the monitor, and to allow them to relax at the commencement of the two main blocks. The second block was a viewing block, which recorded facial muscle activities when participants viewed food imagery stimuli (three viewings for each picture randomised so that 60 images were viewed in this block). Here, food imagery stimuli were composed of five negative images, five positive images and five high variability images and presented in a random order. The last block was a rating block. During this block, participants viewed the same food imagery stimuli as Block 2 only once, but after viewing each imagery stimulus, the modified 9-point scale (the same as the food appearance survey) appeared on the monitor for participants to rate their hedonic liking. The stickers with numbering -4, -3, -2, -1, 0, +1, +2, +3 and +4 were attached to keys 'A', 'S', 'D','F', 'G', 'H', 'J', 'K' and 'L' on keyboard, representing the corresponding nine categories on the modified scale. Participants were free to press the corresponding key to give their hedonic liking of the imagery stimuli. The detailed procedure of each trial instruction is presented in Figure 3-7. During the experiment, blind-coded videos were used to record the changes on participants' faces.

Following the computer task, participants were required to answer simple questions such as eating habits and past eating experience. It is notable that no suspect thinking about the nature or purpose of this experiment was raised by participants.

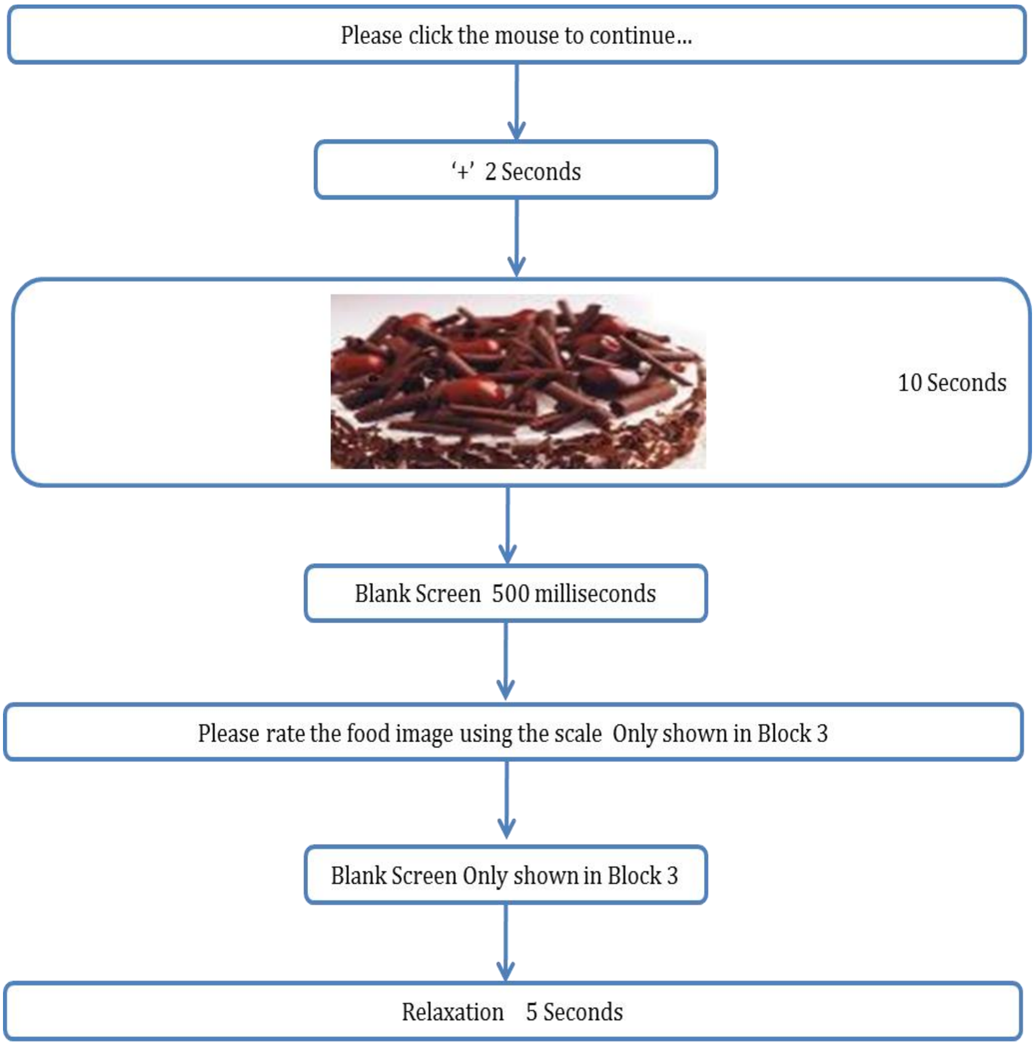


Figure 3-7 The flow chart of each trial instruction

3.3.1.5 Electromyographic Analysis

EMG activity was collected and exported from Acknowledge 4.2. The hedonic liking rating data was collected by E-prime. Changescores were calculated by subtracting the mean muscle activity level during the 500ms period prior to the presentation of each food image (when there was a "+" on the screen). After this process, positive values represent the increase in muscle activity in response to the food image (increased muscle contraction), and negative values represent the relaxation of muscle in response to the food image; zero represents no change from the baseline and no muscle response to the food image.

There were two main conventional techniques including ANOVA with repeated measures, correlation and paired-sample T-Test in statistical analysis. The statistical analysis was run using SPSS 23.

First, an ANOVA with repeated measures (Image Conditions: Positive, Negative, High variability) was conducted for each dependent variable (Corrugator, Zygomaticus, Levator, Masseter).

Second, the dynamic EMG change scores of four facial muscles with different kinds of food image stimuli were evaluated using an ANOVA with repeated measures. An ANOVA with repeated measures (Image Conditions: Positive, Negative, High Variability; Timing Course: every 500ms within 0~9500ms) was conducted for each dependent variable (Corrugator, Levator, Zygomaticus, Masseter).

Third, paired sample T-tests were used to discriminate the significance of EMG activity in corrugator, levator, zygomaticus, and masseter between three pairs including positive/negative images, positive/high variability images, and negative/high variability images.

Fourth, paired sample T-tests were also used to discriminate the EMG activity in corrugator, levator, zygomaticus, and masseter between three pairs including positive/negative images, positive/high variability images, and negative/high variability images at different dynamic time points from 0 to 9500ms.

Lastly, the correlation between the hedonic liking rating of each food imagery stimulus and EMG activity (corrugator, levator, zygomaticus, and masseter) was investigated.

3.3.2 Results

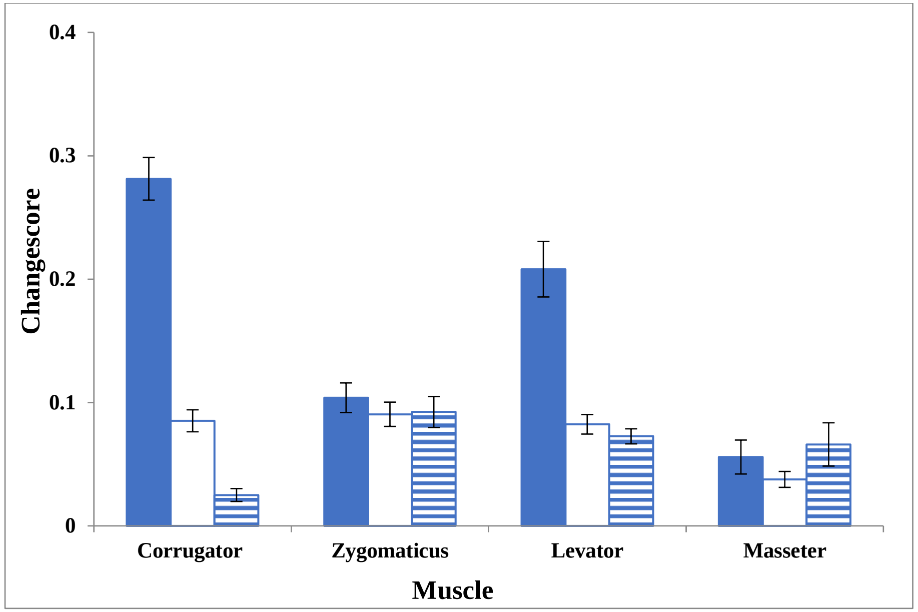
3.3.2.1 Comparison between facial muscle activities (corrugator, zygomaticus, levator, and masseter) and hedonic liking ratings for three food imagery stimuli groups (negative, positive, and high deviation images)

Figure 3-8 (a) and (b) show the average muscle activity and corresponding hedonic liking ratings for negative, high variability and positive images, respectively.

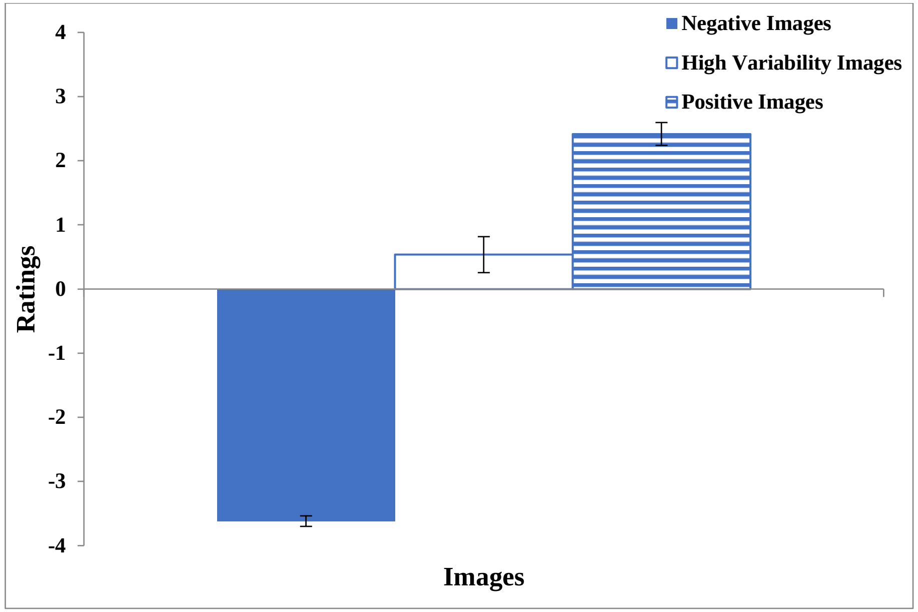
From Figure 3-8, there were significant changes from the baseline for corrugator (M= 0.28, SE= 0.02) and levator (M= 0.21, SE= 0.02) in response to negative food images. However, for positive images, corrugator muscle activity decreased significantly and displayed the smallest change (M = 0.025, SE = 0.005). Zygomaticus muscle presented the highest activity (M= 0.09, SE= 0.01) for positive images compared to other muscles. For viewing high variability imagery stimuli, corrugator, levator and zygomaticus muscles tended to present almost the same activities, whereas masseter activity decreased slightly. The ratings presented in Figure 3-8 (b) were ranked by negative (M= -3.58, SE=0.08), high variability (M=0.45; SE=0.25) and positive images (M=0.15; SE=0.15) from the lowest to the highest ones. It is noted that negative images showed the least standard error, suggesting minimal variability for unpleasant food images. High variability in muscle activity was also evoked by high variability images.

An analysis of variance with repeated measures was conducted between image conditions (positive, negative, and high variability) for each facial muscle (corrugator, levator, zygomaticus, and masseter) to investigate the influencing factor of the different stimuli group of EMG activity. According to Mauchly's test results, the assumption of sphericity had been violated, so the Greenhouse-Geisser estimate was used. The results revealed that different kinds of food imagery stimuli had a significant main effect on corrugator ($F_{\text{Corr}}(1.383,20.743) =12.180$, p=.001, η_p^2=0.448) activity, but it did not influence the response of levator ($F_{\text{Lev}}(1.085,16.270)$= 3.285, p= 0.086, η_p^2=0.180), zygomaticus ($F_{\text{Zygo}}(2,30)$= 0.190; p=0.727, η_p^2=0.013) and masseter ($F_{\text{Mass}}(2,30)$=1.102; p= 0.323, η_p^2=0.068)) activities.

In further T-test analysis to look for the differences between the paired samples, it was found that only corrugator muscles were able to discriminate from negative to high variability images (t (15) =3.471; p=0.003) and from negative to positive images (t (15) =3.811; p= 0.002), respectively. No distinct discrimination could be found for levator, masseter and zygomaticus muscles.



(a)



(b)

Figure 3-8 Average facial muscle activities (a) and hedonic liking ratings (b) of negative, high variability and positive food image stimuli for corrugators, zygomaticus, levator and masseter muscles (Error bar stands for +/-1 standard error)

3.3.2.2 Dynamic EMG activity (corrugator, levator, zygomaticus, and masseter) of different imagery stimuli (positive, negative and high variability images) during the presentation time

Figure 3-9 lists the dynamic EMG activity changes when participants viewed the different kinds of food imagery stimuli from 0~9500ms. 500ms EMG activity data of each trial was extracted as a baseline (see 3.3.15) to an analysis EMG activity so the present time in the chart only ranged from 0 ~9500ms. From Figure 3-9, it is evident that EMG activity in corrugator and levator muscles of negative, high variability and positive images presented a similar trend. Negative images aroused more negative responses from participants, so there were significant increases in muscle activity for corrugator and levator. Furthermore, overall muscle activity of the corrugator muscle was higher than that for levator. Specifically, the corrugator activity increased quickly from 0 to 2000ms and reached a peak (M= 0.40; SE=0.09) at that time. Then from 2500 to 4000ms, it dropped considerably and kept a stable trend after that. Similarly, a significantly increasing trend occurred to levator activity by negative images. Negative response grew quickly at the beginning and reached the peak at 2000ms (M= 0.28, SE=0.09). After that point, there was also a gradually decreasing trend, which was the same as the corrugator muscle. Concerning high variability images, corrugator muscle activity kept a stable trend after it reached a peak at 100ms (M=0.14, SE=0.06), whereas levator activity increased considerably from 0 to 1500ms, then decreased slightly until 4500ms. After 4500ms, its EMG activity slightly increased again then a stable trend occurred from 6500ms to the end. Interestingly, the activity of the levator muscle induced by positive images was higher than that of corrugator muscle. EMG activity in the corrugator muscle kept a stable trend except the beginning from 0 to 500ms with a slight decrease. However, EMG activity in the levator muscle increased slightly with the timing and reached a peak at 3000ms (M=0.11, SE=0.03). After that, it kept a gradual and decreasing trend until the end of the viewing time.

For zygomaticus and masseter muscles, no distinct pattern could be found. The activities of zygomaticus and masseter muscles evoked by negative images grew quickly from 0 to 2500ms, but after 2500ms, their activities decreased gradually and kept a stable trend until the end of the viewing time. However, their affective responses to positive images gradually increased and reached a peak at 5500ms. After that point, the EMG activities dropped significantly from 5500 to 7500ms, and then kept a stable trend until 9500ms. For viewing high variability imagery stimuli, EMG activity in the masseter muscle always kept a stable trend from 0 to 4500ms and then experienced a slight increase between 5000 and 6500ms. After 6500ms, it decreased within 500ms and then maintained a stable trend. By contrast, EMG activity in the zygomaticus muscle increased slightly from 0 to 1500ms and then it tended to present a stable trend until the end of the viewing time.

Interestingly, the error bars for negative images for corrugator, levator, zygomaticus, and masseter were all wider than that of positive images. Participants were more likely to experience more affective responses to negative images so that more facial muscle contractions were able to be found on viewing negative images. However, here positive images were not able to elicit all participants' hedonic responses, in other words, not all positive food images were liked by all participants.

An ANOVA with repeated measures (Image Categories: Negative, Positive, High Variability; Timing Course: 0~9500ms) was conducted for each dependent variable (Corrugator, Levator, Zygomaticus, Masseter) (see Table 3-3). According to Mauchly's test results, the assumption of sphericity had been violated, so the Greenhouse-Geisser estimate was used. Using an alpha level of 0.05, there was a significant main effect of time course of EMG activity in each facial muscle (F_{Corr} (3.901, 58.512) = 8.854, p<0.001, η_p^2=0.371; F_{Zygo} (3.518, 52.763) =7.259, p<0.001, η_p^2=0.326; F_{Lev} (3.191, 47.868) =9.818, p<0.001, η_p^2=0.396; F_{Mass} (2.589, 38.842)=3.860, p=0.021, η_p^2=0.205). Interestingly, the only EMG activity in the corrugator muscle varied with the different category of food imagery stimuli (F_{Corr} (1.382, 20.731) = 12.145, p<0.001, η_p^2=0.447). Furthermore, a significant interaction between time course and image categories was able to be found for corrugator muscle activity as well (F_{Corr} (4.976, 74.641) = 4.544, p=0.001, η_p^2=0.223).

No distinct patterns on the significance of image categories and interaction were able to be found for levator, zygomaticus, and masseter muscles.

Further analysis performed using paired sample t-tests are listed in Table 3-4. The data in Table 3-4 was not corrected for multiple comparisons, so it ran the high risk of Type I error. However, this table still reveals the dynamic EMG activity and affective response pattern to discriminate three food imagery stimuli. The corrugator muscle was reliable and able to discriminate between negative and high variability and between negative and positive images during 500 to 9500ms. Interestingly, only two short periods ranging from 500 to 2000ms for negative and positive images and from 3500 to 4500ms for negative and high variability images were able to be discriminated by the levator muscle. However, zygomaticus and masseter were not reliable muscles to differentiate any image category during 0 to 9500ms.

Table 3-3 ANOVA results for the facial muscles

Within subjects factors	Corrugator				Zygomaticus				Levator				Masseter			
	df	**F**	***P***	η_p^2	**df**	**F**	***p***	η_p^2	**df**	**F**	***p***	η_p^2	**df**	**F**	***p***	η_p^2
Image	1.38	12.15	<0.001	0.45	1.40	0.22	0.73	0.01	3.37	3.26	0.09	0.18	1.24	1.12	0.32	0.07
Timing	3.90	8.85	<0.001	0.37	3.52	7.26	<0.001	0.33	3.19	9.82	<0.001	0.40	2.59	3.87	0.02	0.21
Image*Timing	4.98	4.54	<0.001	0.22	5.20	0.68	0.64	0.04	2.95	1.74	0.17	0.10	3.54	1.33	0.27	0.08

Table 3-4 P values of T-test results for averaged time periods starting from stimulus onset

	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500
Corrugator																				
Positive/High Variability	0.119	0.231	0.100	0.050	0.055	0.108	0.136	0.122	0.088	0.053	0.123	0.105	0.078	0.054	0.121	0.212	0.140	0.307	0.151	0.120
Positive/Negative	0.588	0.009	0.004	0.002	0.001	0.001	0.001	0.003	0.004	0.003	0.005	0.003	0.002	0.001	0.001	0.003	0.006	0.006	0.005	0.006
Negative/High Variability	0.320	0.009	0.007	0.004	0.004	0.003	0.003	0.005	0.014	0.013	0.006	0.007	0.006	0.003	0.002	0.007	0.023	0.008	0.012	0.017
Zygomaticus																				
Positive/ High Variability	0.585	0.932	0.251	0.285	0.826	0.932	0.974	0.976	0.755	0.538	0.447	0.329	0.694	0.289	0.938	0.800	0.472	0.338	0.369	0.476
Positive/Negative	0.282	0.341	0.996	0.168	0.417	0.358	0.756	0.717	0.613	0.918	0.992	0.620	0.680	0.653	0.567	0.439	0.835	0.808	0.503	0.176
Negative/ High Variability	0.783	0.187	0.228	0.698	0.325	0.209	0.635	0.596	0.210	0.369	0.375	0.540	0.890	0.621	0.479	0.476	0.553	0.275	0.982	0.461
Levator																				
Positive/ High Variability	0.653	0.347	0.168	0.190	0.951	0.765	0.984	0.775	0.798	0.847	0.190	0.342	0.111	0.494	0.918	0.981	0.590	0.568	0.961	0.739
Positive/Negative	0.626	0.034	0.051	0.043	0.055	0.088	0.089	0.075	0.070	0.053	0.097	0.109	0.095	0.117	0.094	0.115	0.167	0.140	0.105	0.181
Negative/ High Variability	0.843	0.009	0.116	0.138	0.089	0.110	0.094	0.054	0.037	0.038	0.189	0.190	0.456	0.178	0.086	0.115	0.113	0.080	0.100	0.073
Masseter																				
Positive/ High Variability	0.650	0.387	0.742	0.989	0.099	0.312	0.115	0.158	0.272	0.189	0.281	0.076	0.197	0.647	0.165	0.069	0.063	0.062	0.317	0.354
Positive/Negative	0.211	0.989	0.975	0.145	0.299	0.386	0.959	0.619	0.655	0.527	0.692	0.289	0.168	0.768	0.688	0.508	0.126	0.172	0.473	0.979
Negative/ High Variability	0.280	0.415	0.664	0.065	0.064	0.155	0.194	0.166	0.056	0.110	0.570	0.674	0.814	0.435	0.395	0.149	0.683	0.029	0.861	0.175

Note: all df = 19, p-values have not been corrected for multiple comparisons and single time points should be treated with caution

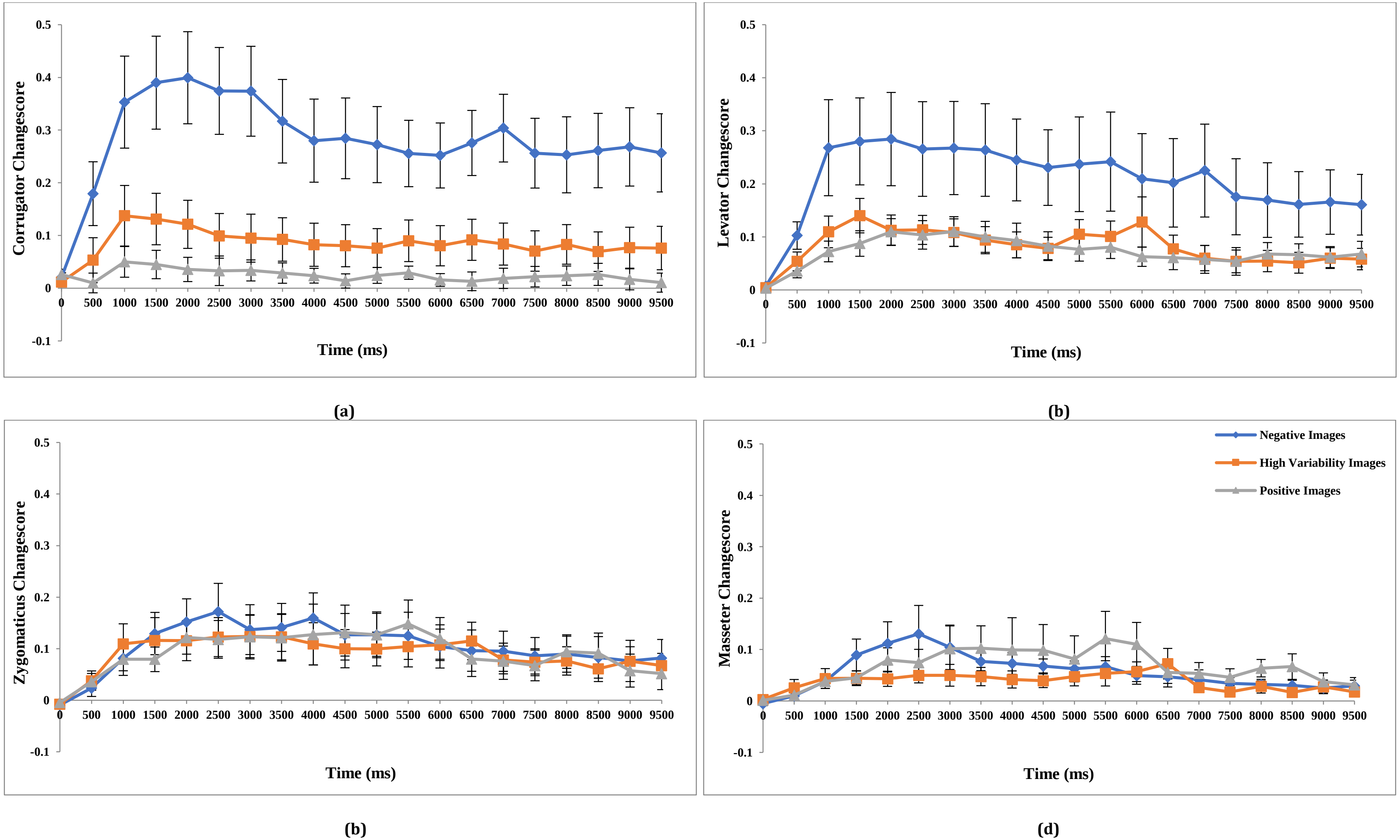


Figure 3-9 Average muscle activities of corrugator, zyogmaticus, levator and masseter for viewing negative, high variability and positive images from 0 to 9500ms (Error bar stands for +/-1 standard error)

3.3.2.3 Comparison between hedonic ratings and EMG activity for each food imagery item

The acceptability rating of each food image item has been presented in Figure 3-10. The result showed that acceptability ratings are almost the same as that of the food appearance survey in Figure 3-3. These different 16 participants were still consistent in their ratings of negative images such as ‘Mouse Bread’ (M=-4; SE=0), ‘Rats’ (M=-3.8; SE= 0.107), ‘Dog Head’ (M=-3.67; SE= 0.159), ‘Bird Egg’ (M= -3.33; SE=0.187) and ‘Cockroach’ (M= -3.07; SE=0.228). These were the most disgusting images from the initial survey and the EMG study. Similarly, sweet foods such as ‘Chocolates’ (M=2.81; SE= 0.279), ‘Chocolate Cake’ (M=2.75; SE= 0.284) and ‘Banana Split’ (M=2.69; SE= 0.312), ‘Roast Chicken’ (M=2.06, SE=0.569), and ‘Salad’ (M=2.00, SE=0.316) were still the favourite foods and got the highest ratings. . The high variability images such as ‘Chicken Heads’ (M=-2.33; SE=0.494), ‘Faced Noodle’ (M= -0.2; SE=0.545), ‘Cat Lunch Box’ (M=1.2; SE=0.459), ‘Seafood’ (M=1.47; SE=0.576) and ‘Monkey Coffee’ (M=1.98, SE=0.317) maintained the same trend and were rated in the middle part with high variability. Interestingly, from the standard error of each image item, it is confirmed that participants reached an agreement on such negative images as ‘Mouse Bread’ (SE=0), ‘Rats’ (SE= 0.107), ‘Dog Head’ (SE= 0.159), ‘Bird Egg’ (SE=0.187) and ‘Cockroach’ (SE=0.228). However, their opinions varied on positive and high variability images a lot, especially for ‘Roast Chicken’ (SE= 0.569), ‘Seafood’ (SE= 0.576), ‘Faced Noodle’ (SE= 0.545), and ‘Chicken Head’ (SE= 0.494) that are controversial ones.

Figure 3-11 shows the mean EMG activity in facial muscles (corrugator, levator, zygomaticus and masseter) for each food image stimuli. All negative images (including ‘Mouse Bread’, ‘Rats’, ‘Dog Head’, ‘Bird Egg’ and ‘Cockroach’) and ‘Chicken Head’ evoked the strong and negative affect, which resulted in an increase of EMG activity in corrugator and levator muscles. Furthermore, a certain increase of zygomaticus and masseter activity was also found in viewing negative image items. Interestingly, there was a high standard error for these image stimuli, indicating participants' facial muscles and expressions were more active when viewing these images. However, there was an opposite trend of EMG activity on viewing positive image items. Take 'Chocolate Cake' as an example, showing minimum EMG activity in the corrugator muscle, but certain zygomaticus and masseter muscle activity was found, because 'Chocolate Cake', the most positively rated image by participants, made participants emotionally aroused and evoked positive physiological responses reflecting states such as happiness and appetite arousal. Interestingly, the facial movement in the levator muscle was also involved in the viewing of some positive image items. It can be explained by high intensity smiles (lifting the upper lip to expose the teeth) which is likely to involve a little contraction of the levator muscle. Because the masseter muscle is located in the cheek region and closed to the jaw, it is also involved in smiling, where it holds the teeth clenched. It was observed in response to 'Chocolates', 'Banana Split', 'Roast Chicken' and 'Cat Lunch Box'. So the most extreme positive rated images also evoked a small amount of levator and masseter activity along with the expected zygomaticus activity; furthermore, low corrugator activity was presented. However, there was not a distinct pattern on most of the high variability food imagery stimuli such as 'Face Noodle', 'Seafood', 'Monkey Coffee' and 'Salad'.

Correlations between EMG activity and ratings for each image were calculated. This analysis used images as the unit of analysis rather than the traditional method of using participants as the unit of analysis. This analysis revealed strong negative correlations between EMG activity (corrugator and levator muscles) and image ratings (r_{Corr} (15) = -0.946, p<0.001; r_{Lev} (15) =-0.860, p<0.001). However, there was no correlation between zygomaticus and masseter muscle activity and ratings.

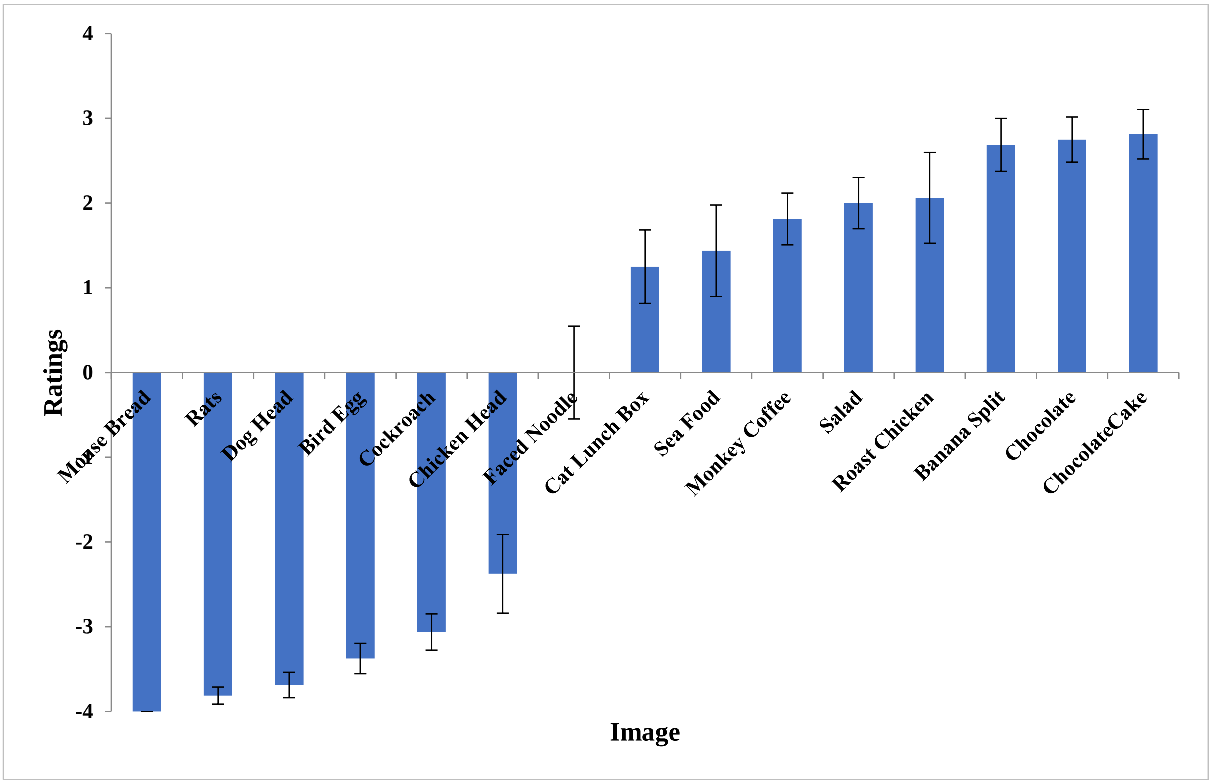


Figure 3-10 Mean acceptability ratings of each food image item in facial EMG measurement (Error bar stands for -/+1 standard error)

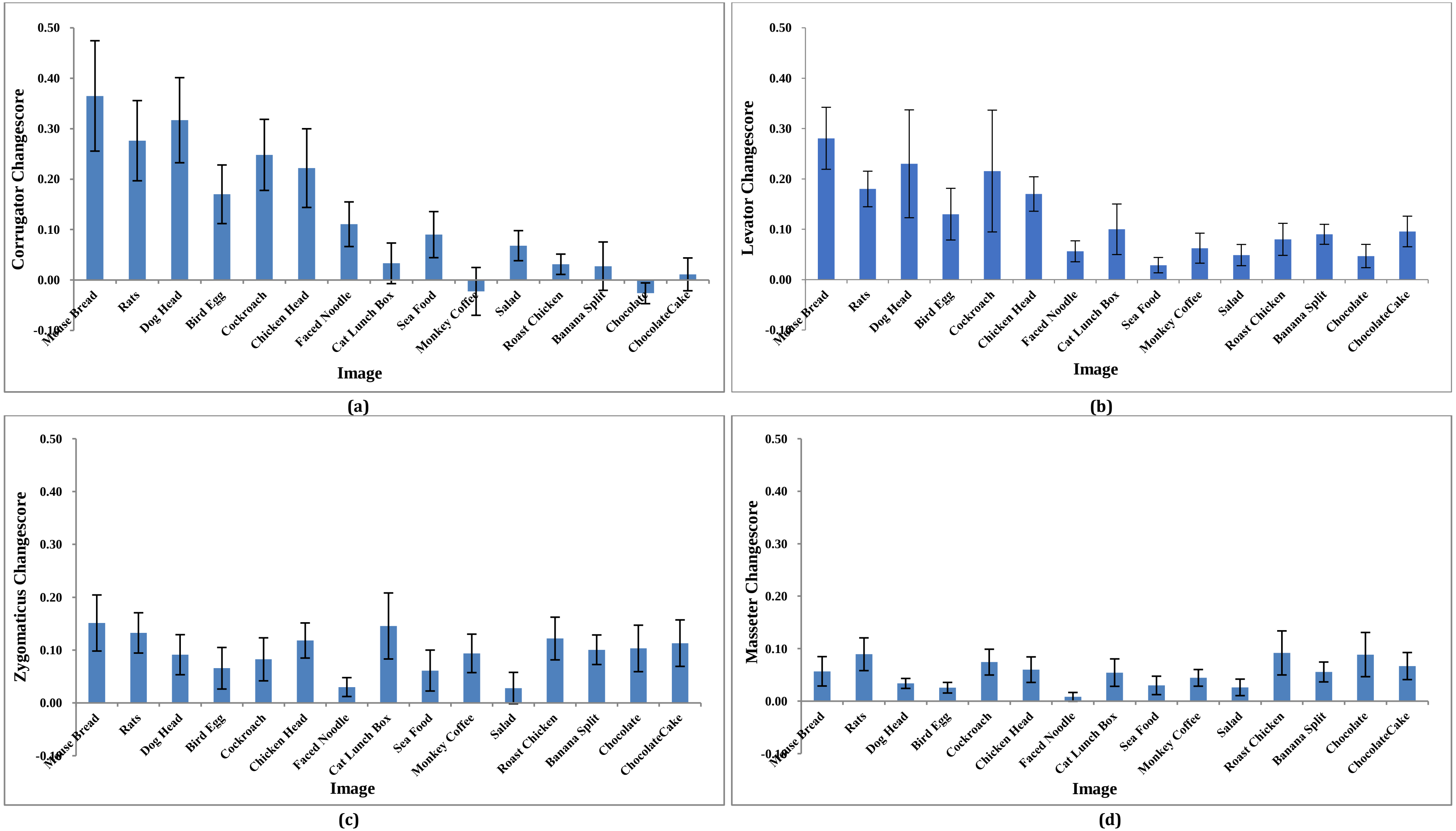


Figure 3-11 Average EMG activity in facial muscles (corrugator, levator, zygomaticus and masseter) for viewing each food image item (Error bar stands for -/+1standard error

Each participant rating pattern was shown in Figure 3-12. In these plots, the sequences of image stimuli were arranged from the most disgusting image to the most acceptable image. These participants rated images such as 'Mouse Bread', 'Rats', 'Dog's Head', 'Bird Egg' and 'Cockroach' negatively because all the participants experienced negative affect when they viewed these images. For positive images, most of the participants gave them the positive ratings except for 'Roast Chicken' which was rated a negative point by participant No. 9 (M=-4) and No. 10 (M=-2) because these two participants were vegetarians. Participants varied their opinions on the high variability images, including 'Cat Lunch Box' (M=1.2; SE=0.45), 'Faced Noodle' (M=-0.2; SE=0.54), 'Chicken Head' (M=-2.33; SE=0.49) and 'Seafood' (M=1.47; SE=0.57). Participant No.2 rated 'Chicken Head' a positive point (+2.0) because this participant had eaten chicken heads before and liked them. 'Seafood' also rated negatively by participant No. 8 (M=-1), No. 9 (M=-4) and No. 13 (M=-2). These different ratings by participants are mostly related to their eating habits (vegetarian), past eating experience and nationality.

Figure 3-13 shows facial muscle activity patterns for image stimuli of each participant. It can be seen that significant contraction of the corrugator muscle was present at negative images and also the 'chicken head' image. Here, it is noted that Participant No.13 did not show any change in corrugator activity while viewing these images because this participant used his hands to block his eyes and avoided viewing these scary images according to his comments and the video that recorded participants' faces during the experiment. Participants No. 5, No. 14 and No. 6 experienced stronger negative feelings than any other participants for these images. Positive images did not arouse changes in corrugator activity. However, Participant No. 7 still presented a stronger affect to 'Banana Split', and Participants No. 10 and No. 14 also showed more intense feelings to 'Monkey Coffee'. For high variability images, stronger affective responses were still exhibited by Participants No. 5 and No. 6 compared to other participants. A similar trend was present for the levator muscle activity. Negative images and 'Chicken Heads' aroused considerable changes in levator muscle activity, especially, participants No. 2 and No. 14 who were more reactive than other participants. However, levator activity was also observed in some positive images, which was related to the muscle position being close to the zygomaticus muscle and this muscle having a limited involvement in positive facial affect.

Interestingly, negative and high variability images also aroused considerable contraction of the zygomaticus muscle. This is because participants sometimes tightened their faces into a grimace when viewing negative and high variability images, which requires contraction of the zygomaticus muscle. However, EMG activity in the zygomaticus muscle evoked by some positive images was not as strong as negative or high variability images. This is because not all participants rated positive images as positively as they could have done. For example, some participants were vegetarians. For masseter muscle activity, subtle changes were present for all image stimuli except for participant No. 2, No. 9 and No. 5.

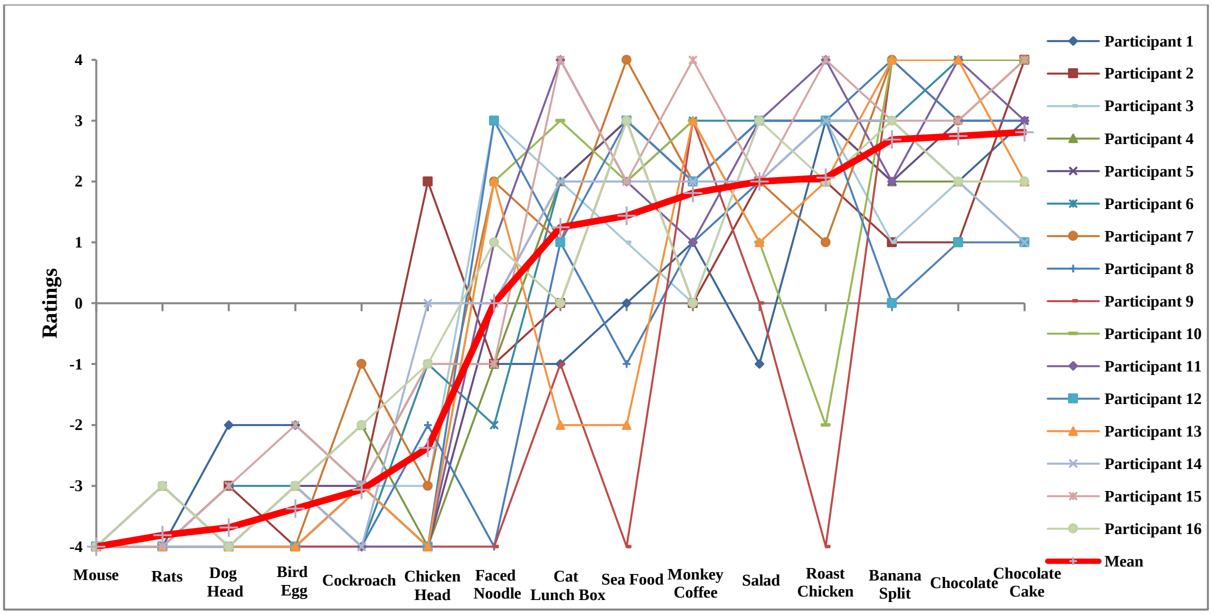


Figure 3-12 Acceptability image ratings for image stimuli of each participant

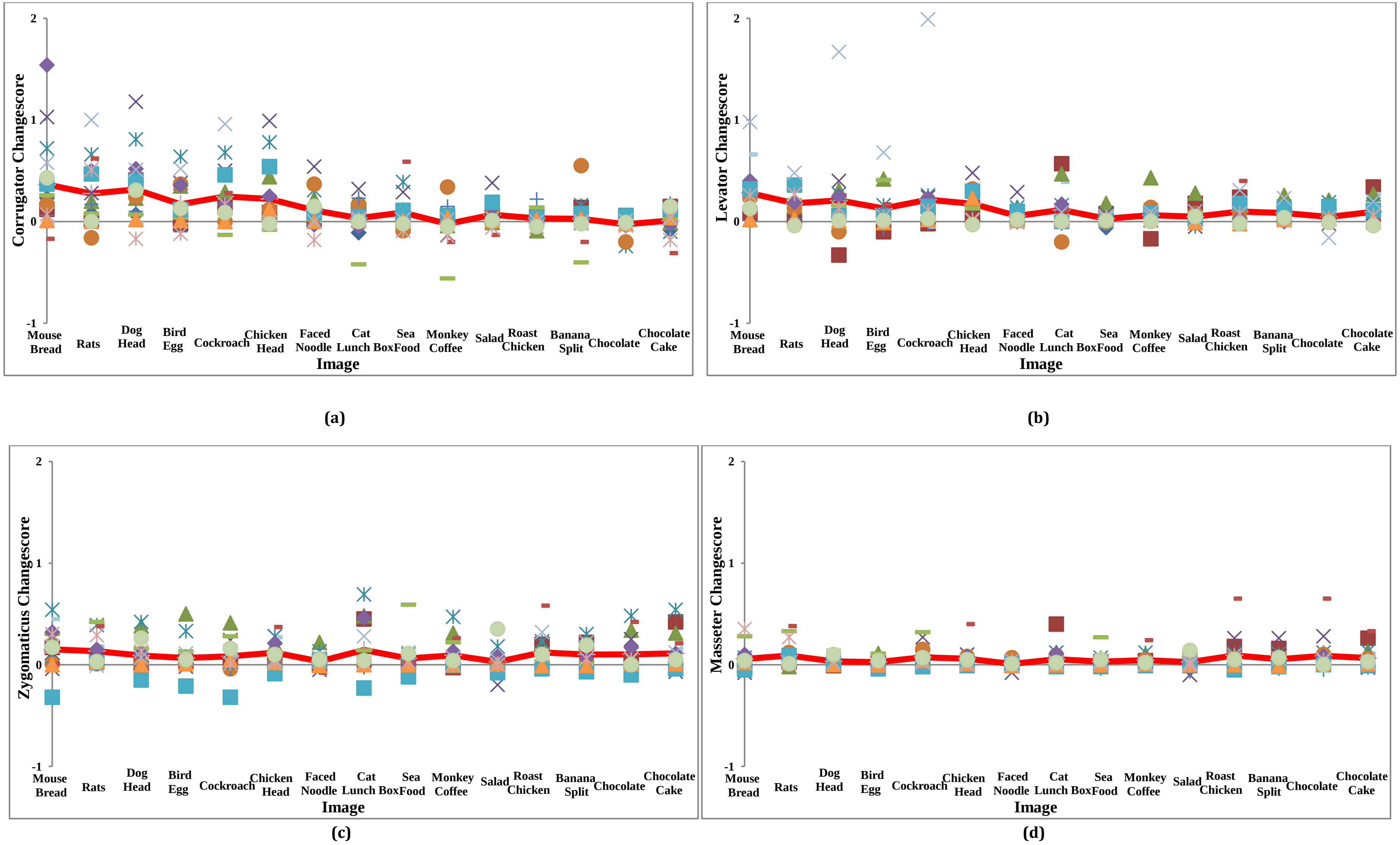


Figure 3-13 Average facial muscle activities for image stimuli by each participant

3.4 Discussion

3.4.1 The acceptability of food appearance images by the participants

Food image ratings by the participants demonstrate that food acceptability is affected by food appearance (MacDougall, 2003). The results showed mouse bread, cockroach, rats, dog head and bird egg were the most unacceptable food images; furthermore, they were considered to be the least preferable foods by a high number of participants (see Figure 3-3). It is the same result as Korsmeyer's research (Korsmeyer, 2002) who said that objects which were too alien from us in nature, such as cockroaches or too close to us such as dogs, were undoubtedly rejected by human beings. Similarly, Rozin and Fallon (1980) noted that objects of disgust have often been animals or animal products.

It is hard to make some conclusions on preferable food images because there are a lot of factors determining the acceptance of food by humans such as culture, individual experience and physiological status (Clark, 1998).

3.4.2 Ceiling and floor effect on rating results with selected food images

According to Figure 3-5, we can infer that ceiling and floor effects appeared in the final rating results. The reasons for these effects can be divided into three factors: the image sequence, the images themselves, and the test scale. Firstly, image sequence, as the main influencing factor, is more likely to arouse a contrast effect. Specifically, when the participants are confronted with a nice food image first and then a disgusting food image, an even lower rating will be obtained for the disgusting image, resulting from a contrast effect. Also, if a participant rates an unacceptable food image very close to the extreme end of the scale first, then even more unacceptable images appear after that, it is likely that a floor effect will appear. Because there is not sufficient anchor in the scale to express feelings beyond the first unacceptable food image, the following food image will be rated at the floor. Similarly, when an opposite sequence is presented involving a disgusting image being presented before a preferable image, a contrast effect also occurs (Kamenetzky, 1959).

A carry over effect is defined as the previous image having an influence on the next image (Ferris et al., 2003; Waters, Sayette,Franken, & Schwartz, 2005). If two preferable images were presented in order such as roast chicken first and chocolates next, the chocolates image was likely to be affected by the roast chicken image and might get a higher rating. It was said by Rozin and Fallon (1980) that disgust enhanced and aroused the floor effect. The properties and limitations of the 9-point scale can also result in the ceiling and floor effects (Keeley, English, Irons, & Henslee, 2013). Limited categories, lack of sufficient potential answers and the using of the scale improperly are all influencing factors in causing floor and ceiling effects (Moskowit & Sidel, 1971). These psychological influencing factors are unavoidable in this study because all the food imagery stimuli were presented in a random order. Allowing more time for participants to relax can reduce these effects.

3.4.3 Individual differences in acceptability ratings of the food appearance survey

It was reported by Clark (1998) that individual differences such as physiological status, cultural background and previous experience definitively affected the decisions about accepting or rejecting a food by humans.

From Figure 3-5, we found that images such as roast chicken, chocolate cake, salad, sushi, monkey coffee, blueberry cake, mutton head, silkworms, bird's egg, rats and cockroaches obtained some uncommon ratings. According to the comments from the participants, it is easier to get the answer that caused the extreme values. Take 'Roast Chicken' and 'Salad' for example, the participant who is a vegetarian rated them with a low score. Regarding 'Chocolate Cake' and 'Pasta', those who are trying to lose or maintain weight rejected them and gave them a low rating. There was an interesting finding concerning the silkworms and bird egg, considered to be disgusting images that were rated positively by a Chinese participant because the participant once ate these two kinds of food in China. The Seafood image was rejected by a participant who is allergic to shrimps. Lastly, chilli was preferred by Chinese participants, but was not popular with European participants owing to their previous food experiences. These are interesting observations that identify qualitative data about the participants' food preferences. For conventional analyses such as ANOVA these individual differences are a threat to the validity of the findings because they introduce a large amount of variability to the data - a solution to this issue that incorporates individual differences using multilevel modelling is developed later in the thesis.

The ratings from three participants (No. 28, No. 10 and No. 16) were outliers compared with other participants. Participant No. 10 was a UK female. Combined with Figure 3-5, we can infer that the participant does not like meat, seafood, rice, or noodles, which agrees with the comments she made to us. Concerning No. 16, a Chinese female, she gave uncommon ratings on images such as the chicken heads (+3.00), mutton head (+1.00), silkworms (+2.00), bird's egg (+2.00), and rats (-1.00) (see Figure 3-5). The reason why she gave such ratings is closely related to her past eating experiences. The information we obtained from her comments is that in China she had eaten these types of food. Lastly, Participant No. 28 was a Chinese male. The unusual ratings he gave were focused on unacceptable images as well, such as chilli (+4.00), chicken head (+1.00), mutton head (-1.00) and dog head (-2.00). His preference for chilli had a close relationship with his eating behaviour. When compared with Participant No. 16, he did not feel disgust towards these images, although he had never tried eating them.

3.4.4 EMG activity vs different food imagery stimuli

Levator, zygomaticus and corrugator are commonly used facial muscles to reflect hedonic responses to stimuli using facial EMG (Tassinary, Cacioppo, & Geen, 1989a; Vrana, 1993a). EMG activity in corrugator and levator muscles increased a lot when participants viewed negative food imagery stimuli, which is a similar result to Dimberg (1997) and Rymarczyk et al. (2011). These findings indicate that the increased muscle activity of corrugator and levator muscles are the main phenomenon of negative affect (anger and disgust) that accompany reduced liking. Interestingly, in this study, zygomaticus and masseter muscles, representing a positive affect and functional facial muscle, were also found to increase in activity while viewing negative food image stimuli. This is crucial because it indicates that frowning and nose wrinkling are not the only facial expressions used to express negative affect. The tightening of the face leading to the lifting of the lip corners and the tongue expulsion are also facial expressions associated with extreme feelings of disgust, which is more likely to involve the facial movements of zygomaticus and masseter muscles. Previous evidence for zygomaticus activity in disgust facial expressions was reported by Cannon, Schnall, and White (2011) in response to biological and spiritual disgust stories.

The zygomaticus muscle is usually discussed in terms of being a positive affect muscle, and was expected to evoke a strong positive affect when participants viewed pleasant/more liked visual stimuli, but no distinct pattern was found in this study (Armstrong, Hutchinson, Laing, & Jinks, 2007a; Jancke, 1996b; Sato, Fujimura, & Suzuki, 2008a). These positive imagery stimuli failed to evoke positive affect from participants because positive images such as 'Salad', 'Roast Chicken', 'Banana Split', 'Chocolates' and 'Chocolate Cake' screened by the food appearance survey was not rated as positive or pleasant by the 16 participants who attended the facial EMG measurement session. Therefore, only a small amount of the zygomaticus muscle increased. Interestingly, minimal activity in the corrugator muscle was found when viewing positive imagery stimuli, which was the expected result. This result also indicates that the contraction of the corrugator muscle represents negative responses to stimuli. Importantly, the locations of these three muscles, zygomaticus, masseter, and levator should be discussed further. Figure 2-5 shows that the electrode locations of levator, zygomaticus and masseter muscles are close to each other. Furthermore, zygomaticus and masseter muscles are located in the same cheek region, which indicates that each muscle contraction pulls the skin in the same direction and this means that there might be co-activation of these muscles depending on the intensity of emotional facial expressions. In high variability images, no common trend can be found, except for the 'Chicken Heads' image. It is noted that the data in Figure 3-11 indicates that a negative affect was elicited similar to the group of negative images when participants viewed this

‘Chicken Heads’ image. This is because unusual animal product such as spiders, animal heads, and animal feet are considered to be disgusting food, which are likely to evoking negative affects such as disgust or anger from humans (Korsmeyer, 2002).

Clearly, the findings of EMG activities for viewing different kinds of food image stimuli indicate that a negative affect is easy to be evoked, but it is more difficult to elicit a strong positive affect by presenting acceptable food stimuli. In other words, future research should investigate why there might be minimal positive emotional responses to acceptable foods. Additionally, the co-activation of facial muscles around the cheek region should be studied more closely because extreme negative stimuli also evoked certain EMG activity in zygomaticus and masseter muscles. Here, the corrugator muscle is a reliable muscle to discriminate negative and positive affect because it is located in the eyebrow region, which is not able to be influenced by other facial muscles. This question should be investigated in the following studies.

3.4.5 EMG activity vs hedonic liking rating

One hypothesis we had set before this study was that there would be a negative correlation between EMG activity (corrugator and levator) and hedonic liking ratings. However, there was also a positive correlation between EMG activity in the zygomaticus muscle and the hedonic liking rating. Interestingly, only strong and negative correlations were found between EMG activity in the corrugator and levator muscles and the hedonic liking rating of food imagery stimuli. But participants did not have a strong positive response towards the highest rated images, so no significant EMG activity in the zygomaticus muscle was present.

The low standard error seen in Figure 3-10 indicates that all 16 participants consistently gave the lowest ratings to the category of negative images selected from the image rating survey. However, it was found in Figure 3-11 that high standard errors of facial muscle activities occurred for negative images because participants experienced strong negative feelings and their facial muscle activities varied in intensity. It potentially highlights an advantage of facial EMG because it captured variability that was not possible using a simple rating scale.

Conversely, the majority of participants rated positive images positively on the scale, but variability still existed within these 16 participants so the positive food images were not at a maximal positive level, reflecting an asymmetry in negative vs positive food acceptability.

Both hedonic liking rating and affective responses to imagery stimuli revealed the participants' individual differences. For example, in this study, Participant No.13 did not express any facial responses to any image stimuli so that no muscle activity changes were found. However, when we checked the video recording for the whole experimental procedure, it was found that he used his hand to block his eyes and avoid viewing any disgusting images, which, although it was not how we operationalised disgust in this study, it is a qualitatively similar phenomenon. It is possible that this participant expressed facial muscle contractions before blocking his eyes; this was not investigated in this analysis.

In summary, facial EMG reveals intriguing individual differences and is a promising avenue for future research. Additionally, the negative correlation between EMG activity in corrugator and levator muscles and the hedonic liking rating provides us with another interesting question that facial muscular activities can predict hedonic liking rating or not.

3.4.6 The implication of dynamic emotion change by facial EMG

The dynamic emotional change while viewing food imagery stimuli provides an important clue for discriminating negative and positive affect. The negative affect elicited by the corrugator and levator muscles reached a peak at 2000ms to negative imagery stimuli, which indicates that the negative affect exhibit strongly and quickly at the beginning of viewing less liked visual stimuli. After the peak, their EMG activity showed a gradual decreasing trend until the end of the viewing time, suggesting that facial displays of negative affect are transient and do not last for a long time after the initial peak. The same conclusion cannot be drawn from zygomaticus and masseter muscle data. Positive affect is likely to present a relatively long, slow development and stable trend. These differences between negative and positive affect patterns indicate the dynamic emotional pattern of stimuli, implicating that accepting or rejecting food is more likely to being decided at the beginning of exposure, which provides a new angle for further study.

3.5 Summary of key findings from Study 1

Study 1 was composed of the two main experiments, a food appearance survey and a facial EMG experiment assessing food appearance acceptability, and did not extend to food consumption. The key findings of this study have answered the primary research questions 1) Is facial EMG able to detect the dynamic emotional change in viewing different kinds of food images? and 2) Is there any correlation between EMG activity in corrugator, levator, zygomaticus, and masseter muscles and hedonic liking rating of each food image stimuli?

The key findings from Study are as follows:

1. From the food appearance survey, it can be seen that participants were consistent in giving negative ratings to unappetizing, unpleasant, negative images, but for some positive and expected (by the research team) acceptable food image stimuli, their opinions varied a lot. This was likely to result from their usual eating habits, past eating experiences, and cultural background. This finding is meaningful for us to screen out the samples in further sensory or EMG studies because it is easy to find unpleasant stimuli, whereas positive and acceptable stimuli are more difficult to find.

2. Increased EMG activity for corrugator and levator muscles was found when viewing less liked image stimuli, but the zygomaticus and masseter muscles were still active. Interestingly, when viewing liked food image stimuli, only slight EMG activity in the zygomaticus muscle was found. Additionally, there was minimal corrugator muscle activity when viewing liked images.

3. An interesting and obvious difference between negative and positive affect was found here. Negative affect increased very quickly and sharply at the beginning of viewing less liked image stimuli, but after the peak activity, it there was a stable and decreasing pattern of relaxation of the muscle. However, there was a long, slow developing and stable pattern for positive affect. The difference indicates that for future research negative and positive affect is more likely to be discriminated at the beginning of exposure.

4. The strong negative correlation between EMG activity in negative affect muscles and the hedonic liking rating of food image stimuli was able to be detected. There was no distinct pattern for the zygomaticus and masseter muscles.

Based on these findings, the conclusion is that facial EMG is useful in determining food acceptability from visual food stimuli. The commercial application of this technique could be used to assess food packaging in the industry. Some opportunities for further study and statistical analysis are as follows:

1) During oral processing, the dynamic emotion pattern should be different during oral processing, such as emptying, after swallowing, and mastication;

2) It is unclear which stages will be the ideal ones to discriminate the negative and positive affect;

3) Can psychophysiological data predict hedonic liking ratings beyond simple categorisation?

To demonstrate these indications, Study 2 will be designed to assess dynamic tastant acceptability when tasting different concentration levels of sweet and bitter solutions.

4 Study 2: Assessing dynamic taste acceptability by tasting different concentration levels of sucrose and quinine solutions using facial EMG

4.1 Introduction

Taste is a chemical sense and enables human beings to ensure that they acquire sufficient nutritional content and to avoid the intake of toxic substances from daily diets (Drewnowski, 2001; Lemon, 2015; Reed, Tanaka, & McDaniel, 2006). The tasting process always starts from the tongue and soft palate. There are two main factors influencing taste perception, which are the proportion of taste buds and the food stimuli processing method, swallowed or not (Drewnowski, 2001; Reed et al., 2006). Facing varieties of food choices, humans are more likely to choose foods that encompass both good flavour and varied texture, which can create and increase hedonic flavour experiences during oral processing. Therefore, the taste perception of food has a dominant influence on its acceptability and choices.

Sweet and bitter are two opposite modalities of taste. Humans usually consider sweet as a good taste and dislike bitter tastes. However, according to Reed (2006), the liking for specific tastes is largely influenced by consuming context and concentration. Although sweet was perceived as a good taste, an unpleasant experience leading to rejection was still reported when very high concentrations were presented. On the contrary, not all bitter tastes result in rejection by consumers because in certain beverages, adding a limited degree of bitter taste can increase the flavour and increase enjoyment (Drewnowski, 2001). Furthermore, Reed (2006) mentioned that in Asia, the behaviour of eating bitter melon indicates that bitter might be a pleasurable taste. Interestingly, sweet perception shares several similarities with bitter perception (Drewnowski, 2001; Reed et al., 2006). The sensitivity to sweet and bitter perception is largely decided by the number of taste papillae and taste reception cells on specialized epithelial cells including Type I, II or III (Reed et al., 2006).

It is possible to segment the population by their sensitivity to bitter and sweet preferences. Supertaster testing can discriminate the taster status from 'non-taster' to 'taster', which represents a different perception level to bitter tastes. Early studies indicated that the sensitivity to bitter-tasting compounds such as 6-n-propylthiouracil (PROP)/ phenylthiocarbamide (PTC) is able to identify taste blindness and define the taster into 'non-taster', 'medium taster', and 'super taster' (Bartoshuk, Duffy, & Miller, 1994; Zhao, Kirkmeyer, & Tepper, 2003). It is because of the chemical moiety N-C=S that PROP (6-n-propylthiouracil)/PTC is perceived as a bitter taste (Zhao et al., 2003). However, PROP was suggested to substitute PTC by Lawless (1980) because of it has no sulphurous taste and reduced toxicity issue. A growing number of studies showed that the tasters with high sensitivity to PROP are also more sensitive to oral sensations including sweet, irritant, and fat (Delwiche, Buletic, & Breslin, 2001; Tepper, Christensen, & Cao, 2001; Zhao et al., 2003). There are a variety of methods to establish an individual's taster-status, such as the three-solution testing, one-solution testing, and counting papillae (Tepper et al., 2001; Zhao et al., 2003). Drewnowski, Henderson, Shore, and BarrattFornell (1997) investigated the relationship between taster status and hedonic responses to sweet and bitter tastes, but the results showed that a weak link existed between the sensitivity to PROP and the intensity of sweet taste. Furthermore, the PROP-taster status did not predict hedonic responses to sweet taste (Drewnowski, Henderson, & Shore, 1997).

Although a variety of studies have focused on sweet and bitter tastes, a neglected topic is using dynamic measurement to assess the hedonic responses to liquid stimuli. Recent studies on EMG activities and taste stimuli have been conducted by Horio (2003) and Armstrong et al. (2007b). It was found that optimum pleasant stimuli produced higher activity in the zygomaticus muscle and no activity on the levator muscle. On the other hand, the activities of zygomaticus and levator muscles represented higher activity optimally unpleasant stimuli (Armstrong et al., 2007b). Furthermore, more specific results for corrugator and masseter muscles showed that corrugator and masseter muscles experienced higher activities when tasting quinine than sucrose (Horio, 2003). However, these published papers only provide the EMG activity pattern in facial muscle during tasting liquid samples rather than focusing on the dynamic emotion change at different time points such as emptying the liquid, swirling the liquid, or after spitting the liquid. Additionally, based on findings of Study 1, facial EMG, this technique has been demonstrated to be a reliable tool to distinguish negative affect from positive affect for visual stimuli. Importantly, positive and negative affects presented different dynamic patterns of muscle activity and this indicated that affective responses are more likely to be decided at the beginning of an experience.

Therefore, the second study is focused on detecting dynamic emotion change when participants taste different concentration levels of sucrose and quinine solutions, and includes different phases: emptying, swirling and spitting the liquids.

The primary research questions of Study 2 are:

1) The different dynamic emotion pattern will be able to be detected when sweet and bitter stimuli are tasted: emptying into the mouth, swirling and spitting out the solutions,

2) Different concentration levels of sweet and bitter stimuli will be discriminated by facial muscle activity,

3) There will be a relationship between facial muscle activity and hedonic liking rating of stimuli,

3) Facial muscle activity will predict the hedonic liking rating and intensity rating (this research question will be solved in Chapter 5 using multi-modelling analysis to predict the hedonic liking and intensity rating, but Study 2 will collect the basic psychophysiological and rating data).

There are three experiments in this study, including supertaster testing, acceptability testing and facial EMG measurement. The purpose of the supertaster testing is to screen and select medium-tasters to attend the acceptability testing and facial EMG measurement. Then, the optimum concentrations of sweet and bitter solutions selected for the acceptability testing will be used as taste stimuli to detect participants' dynamic emotion change during facial EMG measurement.

Based on findings from Study 1 and previous research, the hypotheses, we set here are that:

1) EMG activity in corrugator and levator muscles will increase when tasting bitter stimuli; additionally, facial muscle activity will increase as the concentrations of bitter solutions increases;

2) Increased EMG activity in the zygomaticus muscle will be found when tasting sweet stimuli, whereas minimal corrugator muscle activity will also be present;

3) Different dynamic facial emotion patterns will be found when participants empty, swirl and spit out the liquids;

4) Negative affect will increase and grow very quickly and sharply at the beginning of tasting liquids as illustrated by an increase in the activity of the corrugator and levator muscles;

5) Facial muscle activity will predict hedonic liking and intensity ratings using multi-level modelling analyses (addressed in Chapter 5).

4.2 Supertaster Testing

4.2.1 Materials and methods

The supertaster testing was the first experiment in Study 2, and its purpose was to screen out super-tasters and non-tasters to select 30 medium-taster participants to attend further acceptability (10 medium tasters) and facial EMG testing (20 medium tasters) using a three-solution test. A three-solution test was used to identify taster status (super-, medium- and non-) by tasting and rating the intensities of three different levels of PROP and sodium chloride (NaCl) by a labelled magnitude scale (LMS) (Li, 2012; Tepper et al., 2001). Then, different PROP/NaCl ratio equations were used in this study to exclude the super-and non-tasters (Li, 2012; Tepper et al., 2001).

The reason for only considering medium tasters as participants is that owing to the difference of sensitivity to bitter stimuli, recruiting medium-tasters ensured that their sensitivity to bitter stimuli was almost the same. Currently, there is no evidence of any relationship between taster status and the perception of sweet stimuli.

4.2.1.1 Participants

Fifty-three participants (30 women and 23 men; mean age, 26.94±5.13) were recruited for this study from notice board advertisements and flyers at Massey University, Auckland. All were healthy, non-smokers, not pregnant, free from oral and nasal disease and stated that they were not taking medicines that interfered with taste and odour sensations at least one month before the session. Furthermore, they were required not to consume strong beverages and food such as coffee and garlic 1 hour before the testing. Informed consent was obtained from all participants. This study was approved by the Human Ethics Committee (Massey University) MUHECN 14/040. The demographic data of all participants is shown in Table 4-1. Only nationality data was collected.

Table 4-1 The Demographic data of 53 participants for supertaster testing

Demographics	N
Gender	
Male	23
Female	30
Age	26.94(+/-5.13)
Nationality	
New Zealand	14
European	5
Asian	33
African	1

4.2.1.2 Taste Stimuli

The taste stimuli were composed of two solutions, PROP and NaCl, which were dissolved in reverse osmosis (RO) water. The PROP solutions were prepared by dissolving by stirring the powder in the RO water on a hot plate under mild heat. All solutions were prepared prior to the testing day and stored in a refrigerator at 4°C. They were brought to room temperature before tasting.

Three different intensities of PROP (0.032, 0.32, and 3.2mmol/l) and NaCl (0.01, 0.1, and 1.0mol/l) solutions were used in this three-solution test, which represented the lowest, middle and highest intensities used in previous studies (Drewnowski, Henderson, & Shore, 1997; Tepper & Nurse, 1997).

4.2.1.3 Rating Scale

The LMS (see Appendix II), a quasi-logarithmic scale with label descriptors, is particularly useful to evaluate strong or lingering oral sensations such as bitterness or irritation (Green, Shaffer, & Gilmore, 1993; Prutkin et al., 2000), which was used to evaluate the sample liquids in this test. The LMS consists of numbers on the left side of 0 to 90 and phrases (anchors) on the other side from 'barely detectable' to 'strongest imaginable', which provides participants with the freedom to rate the intensities according to their relevant experiences in everyday life. However, just because the scale can tell the difference in subtle intensity changes of the stimuli from participants, training in how to use this scale is essential before the test. According to Green et al. (1993), instructions should be given as follows:

> "You will rate the intensity of each solution by placing a mark on the labelled scale that best describes what you are experiencing. You can use any part of the line scale that seems appropriate for judging intensity. In making your judgments of intensity, you should rate the solution relative to the strength of all sensations you have experienced in referring to the most intense sensation you have experienced putting food and non-food items in your mouth. This includes such varied taste and mouthfeel sensations that come from hot and cold foods and beverages, spices and spicy foods, toothpaste, mouthwash, medicines etc."

4.2.1.4 Procedure:

Sample presentations were randomized within solution type. Two replications occurred for each sample during the test sessions. Participants were required to rinse their mouths with RO water before they began and between each sample to reduce the carryover effect. They were asked to place the whole sample liquid (10ml) into their mouth, swirl it for a few seconds, expectorate it and rate its intensity by making a cross mark on the rating sheet (Appendix II). There were 45 seconds rest time between each sample.

4.2.1.5 Data Analyses

For three solutions test, the mean intensity rating of the two replicates was calculated for each participant. To identify PROP status, visual observation was used first after results for the three-solution test were plotted for each subject. According to the previous study (Li, 2012; Tepper et al., 2001), participants who rated NaCl higher in intensity than PROP were non-tasters. Contrarily, those whose intensity ratings of PROP were higher than that of NaCl were supertasters. For medium-tasters, they always gave similar ratings between NaCl and PROP. However, owing to the similar ratings between NaCl and PROP, it is more difficult to identify the status classification accurately. Therefore, based on visual observations, two different equations and corresponding cut-off scores were used to screen out the taster status more accurately.

First, cut-off scores ranged from 0.7 to 1.7 which is portrayed here to classify the uncertain taster group (Li, 2012). The equation used to be:

$$PROP_{ratio} = (PROP_2/NaCl_2 + PROP_3/NaCl_3)/2 \qquad \textbf{(Equation 4-1)}$$

where $PROP_2$ and $NaCl_2$ represent the perceived intensities of the second level of PROP and NaCl solutions. Similarity, $PROP_3$ and $NaCl_3$ represent the highest perceived intensities of these two solutions.

Secondly, external validity was established to confirm the groupings obtained from using 0.7-1.7 cut-off line (Prescott & Swain-Campbell, 2000). The equation used to be:

$$PROP_{ratio} = (PROP_1/NaCl_1 + PROP_2/NaCl_2 + PROP_3/NaCl_3)/3 \qquad \textbf{(Equation 4-2)}$$

where $PROP_{1\text{-}3}$ and $NaCl_{1\text{-}3}$ corresponded to the intensity ration for the three solutions of PROP and NaCl, respectively. The cut-off score for the supertasters here was ≥ 2.5.

4.2.2 Results

4.2.2.1 PROP status classification

Figure 4-1 lists typical non-taster and super-taster responses, respectively. The results were the same as those reported by Bartoshuk et al. (1994). The ratings of NaCl intensity by non-tasters were higher than that of PROP. However, super-tasters rated the PROP intensities more strongly than NaCl. Apart from typical non-tasters and super-tasters, the visual observation method is difficult to classify for some participants who rated intensities of NaCl and PROP very closely (see Figure 4-2).

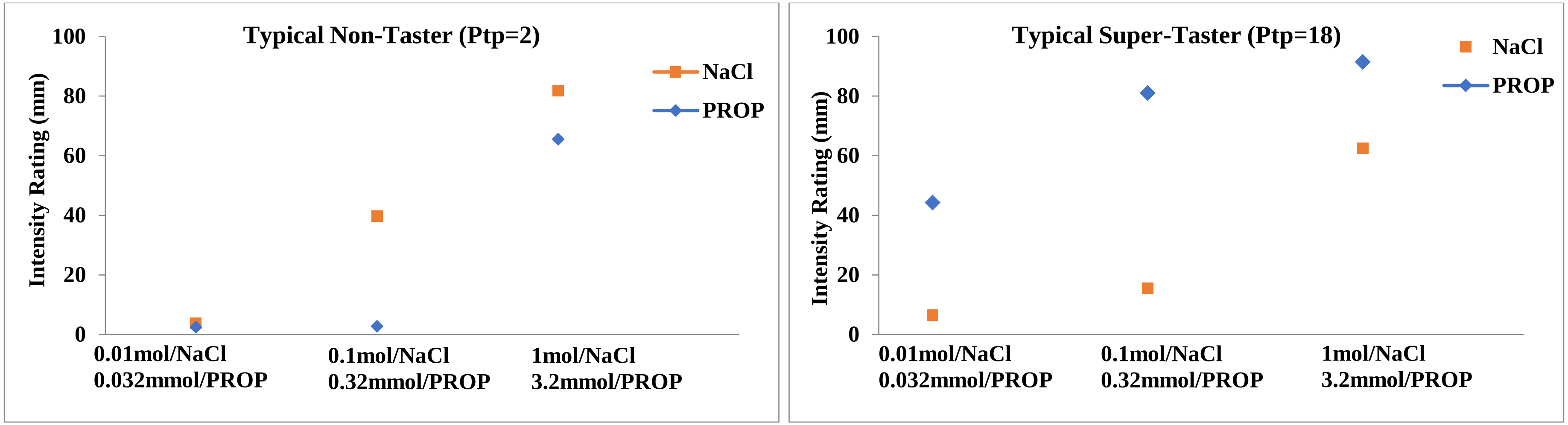


Figure 4-1 Intensity ratings of NaCl and PROP for a typical non-taster (left) and a typical supertaster (right)

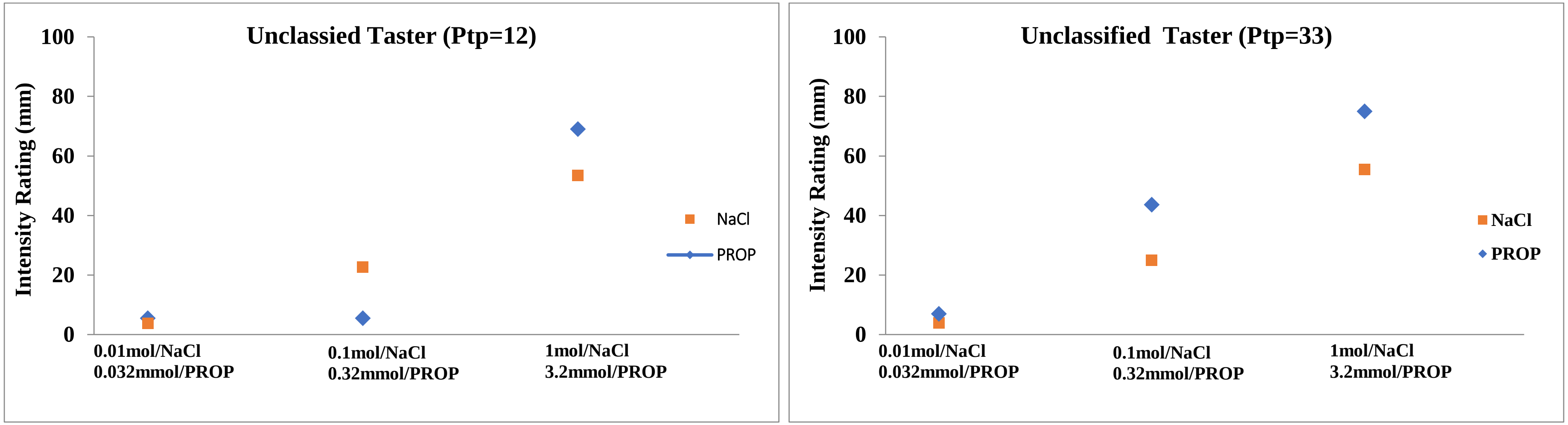


Figure 4-2 Intensity ratings of NaCl and PROP for unclassified Participant A (left) and Participant B (right)

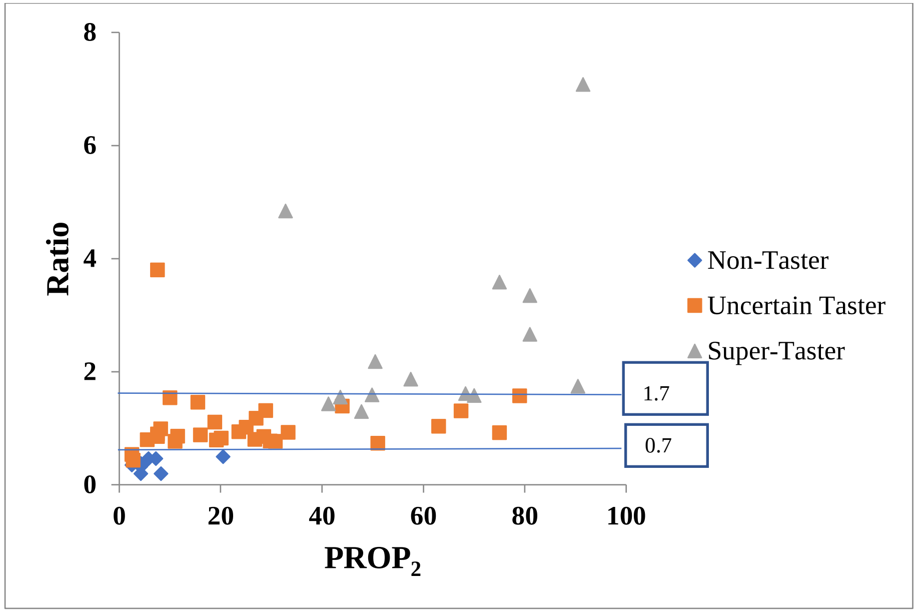
As shown in Figure 4-2, it is clear that using visual observation, it is not possible to discriminate the taster status for these uncertain groups. Participant A taster status was uncertain because of the overlapping of the first point. Similarly, sometimes NaCl and PROP rating lines crossed each other. For this reason it was difficult to discriminate between Participants A and B. Therefore, at this moment, three practical groups, typical NT, typical ST and an uncertain taster group were classified based on visual observation.

The 'PROP ratio' was proposed by Bartoshuk et al. (1994) to subdivide uncertain tasters into MTs and STs. There are two equations used to calculate the ratio:

$$PROP_{ratio} = (PROP_2/NaCl_2 + PROP_3/NaCl_3)/2 \qquad \text{(see Equation 4-1)}$$

$$PROP_{ratio} = (PROP_1/NaCl_1 + PROP_2/NaCl_2 + PROP_3/NaCl_3)/3 \qquad \text{(see Equation 4-2)}$$

where $PROP_{1\text{-}3}$ and $NaCl_{1\text{-}3}$ corresponded to the intensity ratings for the three solutions of PROP and NaCl, respectively. According to Bartoshuk et al. (1994), the lowest concentrations were not used to calculate because a few subjects gave zero ratings for NaCl concentrations in Equation 4-1. Therefore, the cutoff line score was slightly different to discriminate the STs from the MTs when using Equation 4-1 and 4-2. According to Li (2012), a cutoff score 1.7 was used to divide medium tasters from supertasters for Equation 4-1. To confirm the results of taster groups, a PROP ratio ≥ 2.5 was used in Equation 4-2 when the intensity ratings of the lowest PROP and NaCl solution were used.



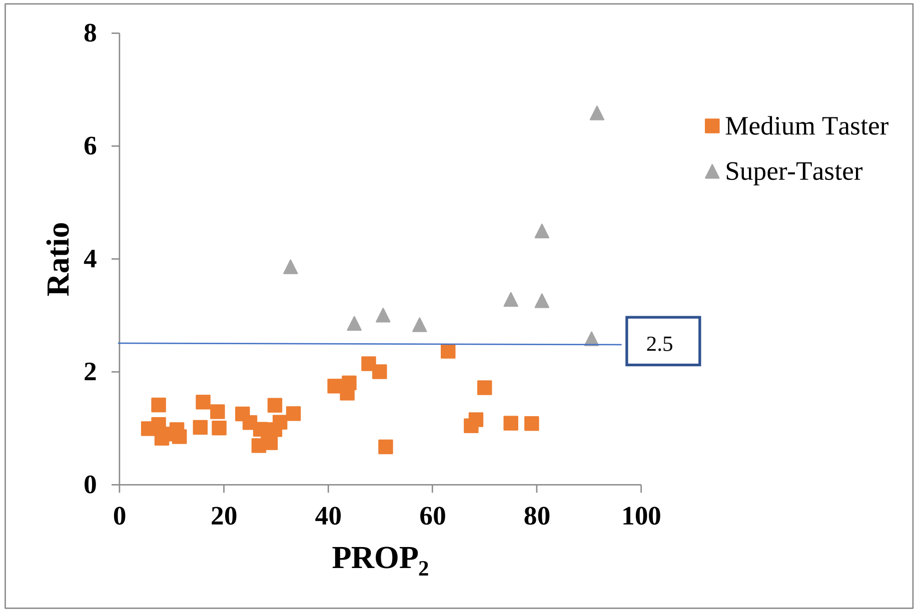


Figure 4-3 Scatter Plot of PROP ratio vs level 2 PROP intensity ratings for Equation 4-1calculation (Left) and Equation 4-2 calculation (Right)

Figure 4-3 shows that the 0.7 cutoff line had divided all the typical NTs into the non-taster group, including two uncertain tasters with relatively high PROP intensity ratings. Similarly, supertaster tasters and the uncertain taster group were classified by the 1.7 cutoff line. Six typical ST-pattern participants were categorized into medium-tasters even though their PROP intensity ratings were slightly higher than NaCl ratings. To confirm the medium-taster and super-taster status again, the PROP ratio ≥ 2.5 (Equation 4-2) was used to discriminate the taster groups (see Figure 4-3, right chart). The result indicates that the distribution of medium- and super-tasters was the same as those who were divided by the 1.7 cutoff line.

Using the above method, all the participants were classified as non-tasters (n=11), medium-tasters (n=33) and super-tasters (n=9) (see Table 4-2). Figure 4-4 lists three charts for the average intensity ratings of NaCl and PROP for the three taster groups. It can be seen that non-tasters (20.75%) gave higher intensity ratings for NaCl solutions whereas extremely high PROP intensity values were rated by super-tasters (17%). The percentage of medium-tasters in this study was 62%. Over half of the participants rated NaCl and PROP closely with their three different concentration levels.

Table 4-2 The number and proportion of non-, medium-, and supertasters

Taster Status	Female N	Male N	%
Non-taster	5	6	20.75
Medium-taster	17	16	62.26
Super-taster	8	1	16.98
Total (N=53)	30	23	100

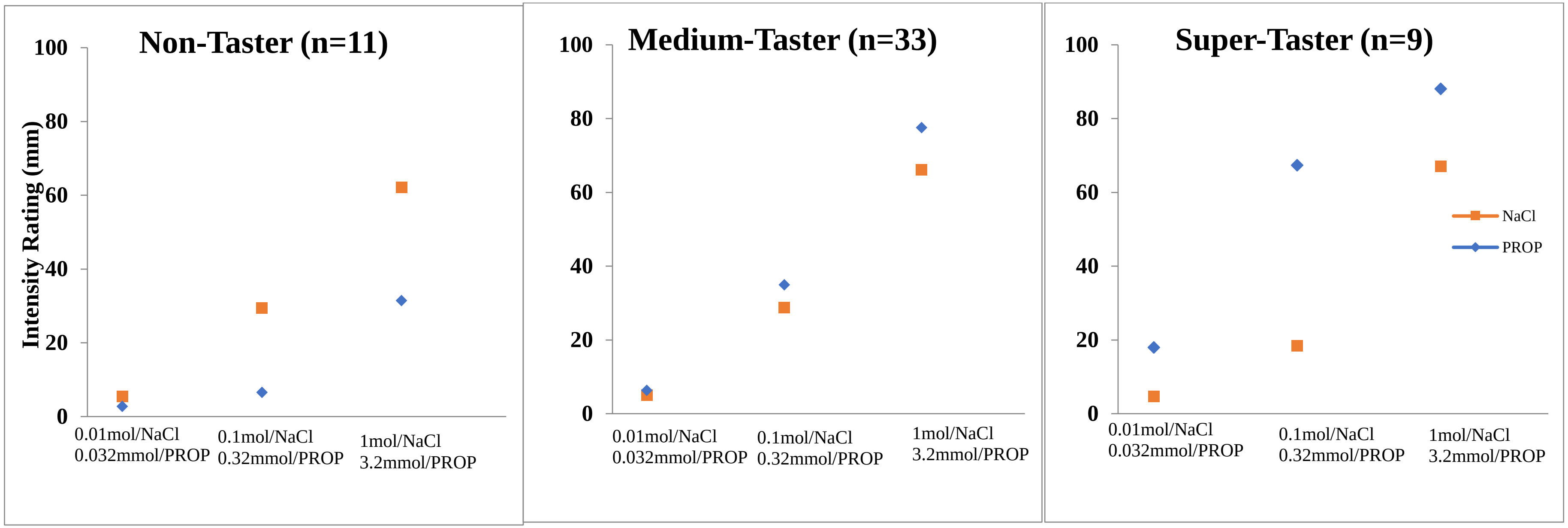


Figure 4-4 PROP and NaCl average intensity ratings for non-, medium-, super-tasters

4.3 Acceptability test

4.3.1 Materials and methods

The purpose of this acceptability test was to screen for the optimal concentrations of sucrose and quinine solutions that would be used in the following facial EMG measurement as taste stimuli. Ten medium-tasters screened by 4.2.1 were invited to taste sucrose and quinine solutions with five different concentration levels, respectively. Labelled magnitude scales (LMS) and labelled affective scales (LAM) were provided for them to give their intensity and hedonic liking ratings, respectively. Half of the participants attended the sweet session first. Sweet and bitter stimuli were conducted on different days.

4.3.1.1 Participants

Ten medium-tasters screened by supertaster testing (see 4.2.1) participated in this study. They were required to not consume strong food and beverages such as coffee and garlic at least one hour before the test.

4.3.1.2 Taste Stimuli

Sweet and bitter solutions were made by dissolving sucrose and quinine at room temperature (22 ºC) in RO water.

Sucrose concentrations used were 0.09, 0.18, 0.36, 0.72 and 1.44M

Quinine concentrations used were $0.005*10^{-4}$, $0.005*10^{-3}$, $0.005*10^{-2}$, $0.005*10^{-1}$ and 0.005M.

These different concentrations of sweet and bitter solutions were screened out by the pilot study (one medium taster, one non-taster, and one super-taster). The sweet and bitter sessions were conducted on different days.

4.3.1.3 Rating Scale

Two scales, including LMS (see Appendix II) and LAM (see Appendix III) were provided for participants to give their intensity and hedonic liking ratings to stimuli, respectively. In this study there was no modification of the rating scale; furthermore, these scales were presented in the same format as Lim (2011) and Green et al. (1993).

Before the acceptability testing, proper training on how to use LAM and LMS was provided. Participants were instructed to make a mark anywhere on the scale to represent their hedonic responses and intensity perceptions to each solution stimuli. The hedonic and intensity scales were produced on a separate sheet of paper; additionally, the hedonic liking rating sheet was presented before the intensity rating sheet. Each solution stimuli was presented on a new, separate rating sheet.

4.3.1.4 Procedure

Participants were requested to come to each session with no strong food intake at least one hour before the testing. Half of the participants tasted sucrose solutions first, while quinine solutions were presented first for another five participants. Each participant was tested alone, and each testing sample cup containing about 20ml of sucrose and of quinine solutions were served one-by-one. The cups were numbered in random order. Participants were required to rinse their mouths using RO water before they started the formal testing. They were then instructed to empty all the liquid into their mouths, swirl it around their mouth for a while and spit it out. A large plastic jug was provided for spitting. Rating sheets were provided for each taster to rate the hedonic liking and the intensity value of the taste stimuli before participants rinsed their mouths. Here, participants were required to rinse their mouths using RO water at least twice in order to reduce the carry over effect. Then one minute relaxing time was given before they proceeded to the next solution sample. Participants were not permitted to swallow any testing solutions, or to taste any solution more than once.

4.3.1.5 Data Analysis

The intensity ratings were scored by measuring the distance to the mark on the scale, from 0 to 95. The Hedonic ratings were measured from the neutral point to the extreme liking, ranging from 0 to +50, and to the extreme disliking, ranging from 0 to -50. Each participant's intensity and hedonic liking ratings were averaged over the three replications of each sucrose and quinine stimulus. The mean hedonic liking rating and intensity rating were made using the same chart to find out the relationship between intensity perception and hedonic liking of these sweet and bitter stimuli, to help select the optimal concentrations of taste stimuli for the EMG measurement study.

4.3.2 Results

4.3.2.1 Average hedonic liking rating and intensity rating for different concentration levels of sucrose and quinine solutions

The intensity and hedonic liking ratings of sucrose solutions by ten medium-tasters are shown in Figure 4-5. For these sweet liquids, 0.36M (M=15.53, SE=5.422) was rated the most liked concentration, whereas the least liked concentration was 1.14M (M=-0.733, SE=7.363). Participants' hedonic liking ratings increased slightly at the low concentrations (water, 0.09M, and 0.18M) and reached the highest value when the concentration was 0.36M. After that, there was a decreasing trend for the relatively high concentrations (0.72M and 1.14M). However, it was noted that water control was rated slightly negatively. However, for intensity ratings, participants rated 1.14M (M=57.78, SE=5.15) and 0.72M (M=45.12, SE=4.31) sucrose solutions sweeter than other concentration levels. The intensity ratings for water control (M=4.68, SE=2.68) and 0.09M (M=6.47, SE=1.5) sucrose solution were very close. The perception of sweetness in sucrose solutions increased gradually with the increase of concentrations.

Bitterness intensity and hedonic liking ratings are shown in Figure 4-6. Participants gave similar intensity ratings for the water control (M=10.87, SE=2.98), $0.005*10^{-4}$M (M=14.70, SE=4.48) and $0.005*10^{-3}$M (M=14.35, SE=3.67), whereas the intensity ratings increased dramatically for $0.005*10^{-2}$M, 0.0005, and 0.005M quinine solutions. However, hedonic liking ratings presented an opposite trend. More negative ratings of quinine solutions were rated by participants as the concentration levels increased. In other words, 0.005M (M=-43.17, SE= 1.54) was the least liked concentration selected by participants. Interestingly, there was no significant difference between the hedonic ratings for water control (M=-6.60, SE=2.98), 0.005*10^{-4} (M=-8.74, SE=2.08) and 0.005*10^{-3}M (M=-8.64, SE=2.15). Importantly, short standard error bars for quinine solutions shows that participants were consistent in their dislike for bitter solutions.

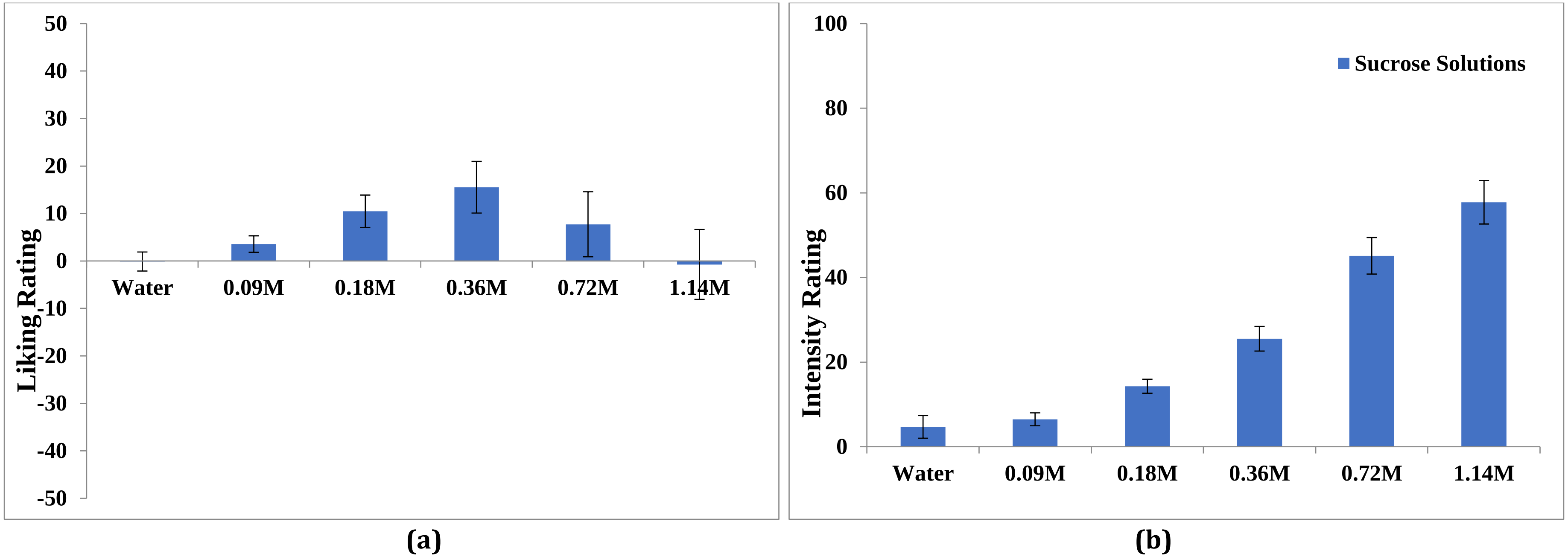
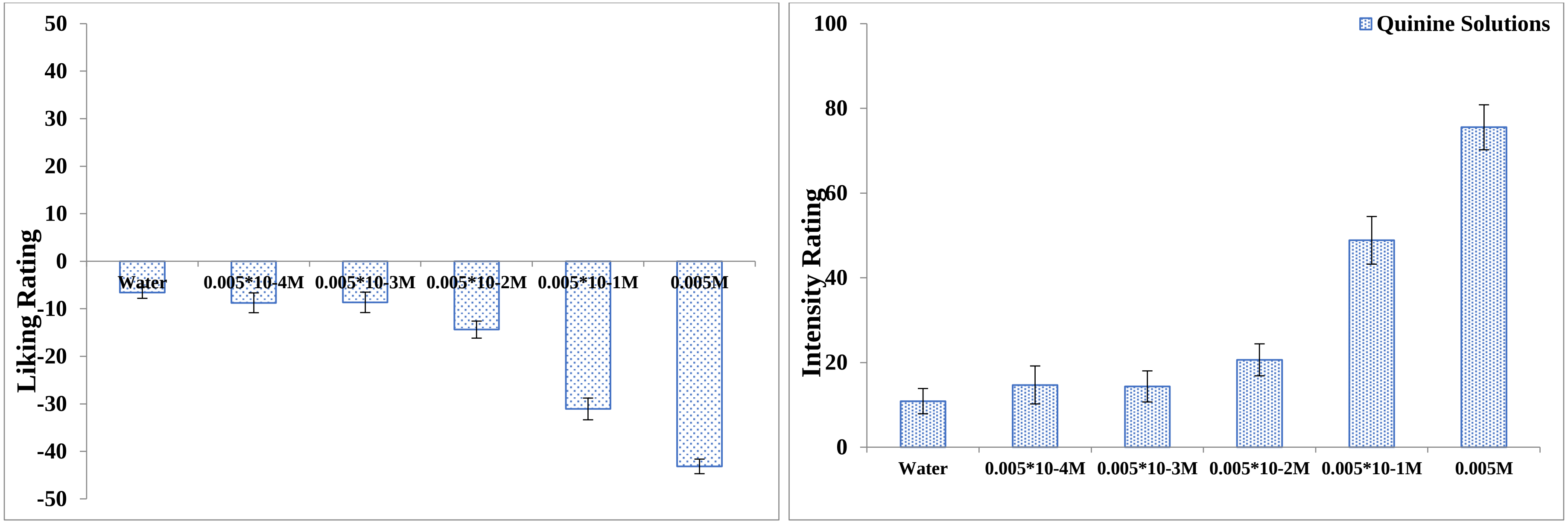


Figure 4-5 Acceptability (a) and intensity (b) ratings for sucrose solutions with different concentrations (Error bar stands for -/+1 standard error)



(a) (b)

Figure 4-6 Acceptability (a) and intensity (b) ratings for quinine solutions with different concentrations (Error bar stands for -/+1 standard error)

Table 4-3 lists the different concentration levels of sucrose solutions and quinine solutions, which would be used in the facial EMG measurement as sweet and bitter stimuli. For sucrose solutions, the concentrations selected were 0.09, 0.36 and 1.14M because participants presented the most and least liking for these three concentrations, respectively. Despite the water control, 0.09M was the second least liked concentration rated by participants. Therefore, these three concentrations were selected to be low, medium, and high concentrations of sucrose solution as sweet taste stimuli. Regarding bitterness, because participants rated all quinine solutions negatively, the two most disliked concentrations of 0.0005 and 0.005M were selected for the medium and high concentration stimuli. For the low concentration, water control, $0.005*10^{-4}$ and $0.005*10^{-3}$M, all presented similar hedonic liking and intensity ratings, which indicated that medium-tasters are not sensitive enough to discriminate the low concentration of quinine solutions. However, two extremely high concentrations of quinine solutions were selected as high and medium concentration levels of bitter stimuli. The lowest concentration level $0.005*10^{-4}$M of quinine solution was considered to be the low concentration level of bitter stimuli.

Table 4-3 Concentrations selected as taste stimuli for facial EMG measurement

Solution Type	**Sweet Taste Stimuli**		**Bitter Taste Stimuli**	
	Material	**Concentration (M)**	**Material**	**Concentration (M)**
Low		0.09		$0.005*10^{-4}$
Medium	Sucrose Solution	0.36	Quinine Solution	0.0005
High		1.14		0.005

4.3.2.2 Individual participant intensity and hedonic liking rating patterns of different concentration levels of sucrose and quinine solutions

Figure 4-7(a) and (b) show the individual participant hedonic liking rating patterns of sucrose and quinine solutions, respectively. These medium-taster participants all gave their hedonic liking negatively to bitter solutions and water control. The hedonic liking rating for water control (bitter session) ranged from -13.5 to -4.5. Similar negative ratings were given for quinine solutions of $0.005*10^{-4}$ and $0.005*10^{-3}$M by participants, whereas their hedonic liking ratings decreased significantly compared with the bitter solution of 0.0005 and 0.005M. Few participants (Ptp=2, 4, 6) rated extreme values (-48.67, -49.17, and -47.17, respectively) for 0.005M quinine solution. Regarding sucrose solutions, the participants' liking varied significantly. Four medium-tasters rated sucrose solutions of 1.14M as their most disliked concentration. However, another two participants gave their highest hedonic liking ratings to this concentration. Water control was rated the lowest value by four participants especially for Participants 3 and 8, where negative values (-2.83 and -16) were given by them. 0.36M of sucrose solution was selected by four participants to be the most liked concentration.

Intensity ratings of sucrose and of quinine solutions are shown in Figure 4-7 (c) and (d), respectively. It can be seen from sucrose solutions that participants' intensity ratings increased correspondingly with the increase in sweet concentrations, except for Participant 8 who rated water control more intensively (M=28.33) compared to sucrose solutions with 0.09 (M=18.67) and 0.18M (M=23.833). The intensity ratings for the sucrose solution of 1.14M ranged from 34.33 (by Ptp 7) to 86.67 (by Ptp 8) owing to the different acceptability. Regarding intensity ratings of bitter solutions (see Figure 4-7 (d)), participants did not give a neutral rating for water control. The highest intensity rating for water control was 34.5 by Participant 8. Interestingly, Participants 4 and 5 rated the quinine solution $0.005*10^{-4}$M more intensively than $0.005*10^{-3}$M. The same situation also happened to Participants 6 and 9 when they rated the intensity of $0.005*10^{-3}$M and $0.005*10^{-2}$M for quinine solutions. There was no doubt that 0.005M of quinine solution was rated the most intense concentration by all the participants. Interestingly, Participant 7 also gave the lowest intensity rating (M=44.83) for 1.14M quinine solution, while 93.99, 91.67, and 90 extreme values were rated by Participants 4, 6 and 8, respectively.

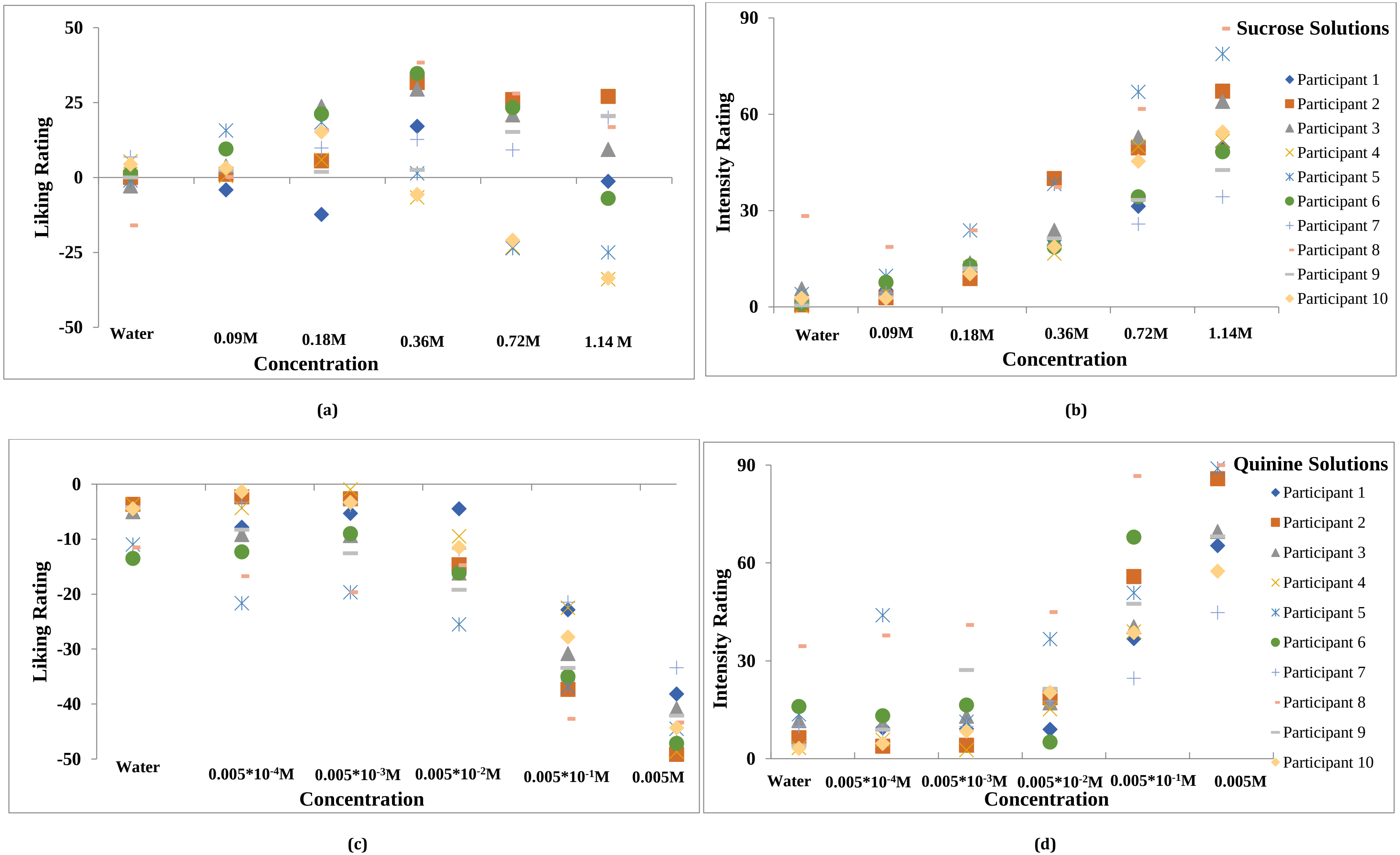


Figure 4-7 Individual liking and intensity rating patterns of sucrose (a) (b) and of quinine (c) (d) solutions with different levels of concentration

4.4 Facial EMG measurement in assessing the taste acceptability by tasting sweet and bitter taste stimuli

4.4.1 Materials and methods

This EMG measurement is the third part of Study 2. The purpose of this experiment is to detect dynamic emotion change when participants taste low, medium and high concentration levels of sweet and bitter stimuli by recording facial muscle activities (corrugator, levator, zygomaticus, and masseter).

Again, the primary research questions of Study 2 are:

1) Different dynamic emotion changes will be detected when tasting sweet and bitter stimuli;

2) The relationship between hedonic liking and intensity ratings and facial muscle activities will be investigated. It is anticipated that muscle activity will predict ratings.

There are three blocks in this EMG measurement, including the training block, tasting block, and rating block. Here, to understand the dynamic emotion better, three phases, including emptying the liquid into the mouth, swirling the liquid, and thinking about the taste after spitting out the liquid was defined to detect dynamic EMG activity. Furthermore, this experiment collected psychophysiological and rating data for further statistical analysis using multi-level modelling to predict the hedonic liking rating and the intensity rating (see Chapter 5). This is the reason why the tasting and rating blocks were conducted separately for the purposes of collecting data. All detailed procedure and research design have been listed in 4.4.1.4.

4.4.1.1 Participants

Twenty medium-tasters screened by supertaster testing (see 4.2.2) participated in this study. They were required to refrain from strong food and beverages such as coffee and garlic at least 1 hour before the test.

4.4.1.2 Facial EMG

See 3.3.1.2 Facial EMG.

4.4.1.3 Chemosensory Stimuli

Liquid stimuli were produced using food grade white sugar (sweet; Chelsea, New Zealand) and analytical quinine hydrochloride (bitter; Sensient Technology, New Zealand) representing the sweet and bitter taste stimuli. Solutions of quinine ($0.005*10^{-4}$, $0.005*10^{-1}$ and 0.005M) and sucrose (0.09, 0.36 and 1.44M) were used as the low, medium and high concentrations of bitter and sweet stimuli, respectively. Solution concentrations were chosen based on the acceptability testing described earlier (see Table 4-3). The sweet and bitter solutions were made by dissolving the sucrose and the quinine at room temperature (22ºC) in RO water. RO water was also introduced here as a control for facial EMG measurement. The sweet and bitter sessions were designed to be run on separate days.

4.4.1.4 Procedure

At the commencement of each session, the purpose of this study and general procedure was described before the consent form was signed. After that, each participant was asked to wash their face using a facial cleanser (Cetaphil, Johnson & Johnson) and electrode sites were wiped with an alcohol swab and electrode gel (Signagel, Parker Laboratories) to reduce impedance. EMG electrodes were attached (specific location see Figure 2-5). Participants had the right to stop the experiment at any time if they felt discomfort. After that, the participant was seated in a testing booth to relax while the EMG recordings settled.

Sweet and bitter solution testing sessions were conducted on separate days. The sucrose testing session was conducted first and one week later, participants were required to come back to continue the bitter testing session. Each session was composed of three blocks: training, tasting and rating block. For the training block, an RO water sample was served so that participants could become familiar with the instructions to avoid mistakes later. In the tasting block, participants tasted all of the liquid samples in a random order while their facial EMG activity was recorded. However, the rating block was identical to the tasting block due to the additional requirement that participants rated the hedonic liking and intensity of each of the liquid samples using the LAM and LMS scales. During the tasting and rating blocks, three concentrations (low, medium and high) of the bitter or sweet solutions and water control were replicated three times in a random order.

It should be noted that using facial muscular activities to predict hedonic liking and intensity ratings was one of the primary research questions. The purpose of conducting the tasting block was to collect and record pure psychophysiological data without participants thinking about evaluating the samples and rating them. The reason why tasting and rating blocks were conducted separately was that two further research questions need to be investigated, including 1) whether pure EMG activity was able to predict the hedonic liking rating or intensity rating and 2) whether there was any difference between pure EMG activity and interruptive EMG activity that might predict rating data. These research questions were answered in Chapter 5 by using advanced statistical analysis multi-level modelling.

Trials began with participants reading the instructions while they rested quietly. Instructions were presented to participants using E-prime to minimise contact with the experimenter, and are listed in Figure 4-8. Some of the instructions were time controlled, but the rest of the instructions were operated by the participant clicking a mouse button. This is the reason why there was a training block prior to the formal experiment. A short 'Blank Phase' was used to prevent participants from skipping stages of the testing trials by clicking the mouse twice mistakenly.

Each participant was instructed to pick up, hold the sample cup and get ready to empty the liquid into their mouth. Then the *emptying screen* appeared, indicating that the participant should empty the liquid sample into their mouth and click the mouse button. Then the *swirling screen* instructed each participant to swirl the liquid in their mouth for five seconds, but actually, eight seconds was provided to record facial muscle activity. After swirling, an instruction was given to spit out the solution and click the mouse button. Participants were then instructed to think about the taste of the liquid for ten seconds (*thinking screen*). Finally, participants rinsed their mouths with RO water and then were asked to take a five second break before the next sample instruction started. For the rating block, the rating scales were presented sequentially on the monitor after the thinking screen before rinsing the mouth so that participants could give their hedonic liking and intensity ratings to each taste stimulus. Participants would click on the scale, and they would receive visual feedback from the brief presentation of a horizontal line across the scale where they clicked. For the purposes of statistical analyses these screens are referred to as *emptying phase*, *swirling phase*, and *thinking phase*.

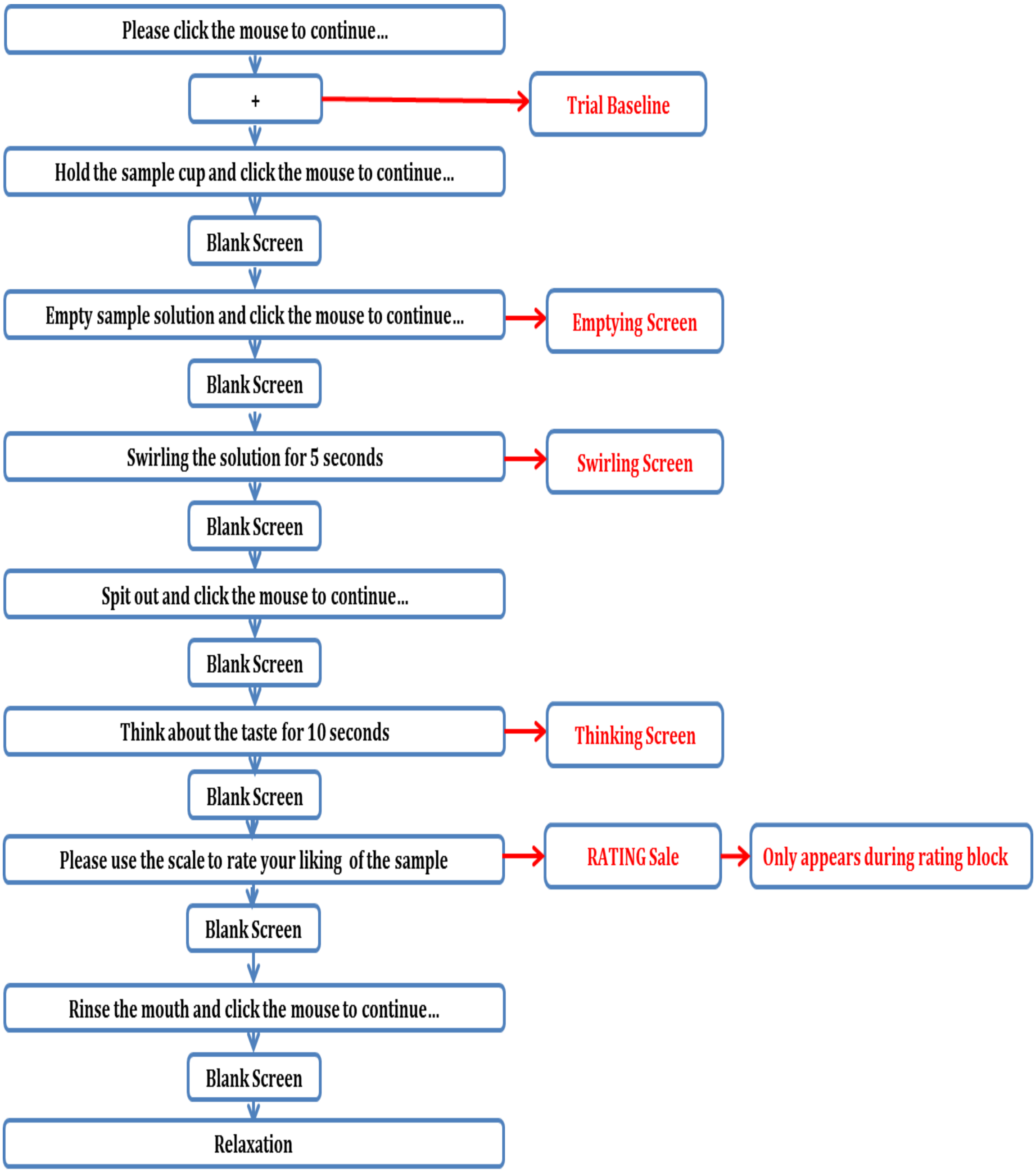


Figure 4-8 The E-prime instructions for EMG measurement. An additional pair of phases for rating were displayed after the "thinking" phase in the rating block

4.4.1.5 EMG analysis

Hedonic liking rating and intensity ratings by LAM and LMS were collected by E-prime. EMG data was collected using Acknowledge 4.2. A 20Hz high-pass and 500Hz low-pass filter were applied to the EMG data to reduce high and low-frequency noise. 50Hz band stop was used to remove mains current interference. Data was rectified.

The mean of the last 500ms of fixation data from each data point for the trials was extracted to act as the baseline for that trial. Once the mean (500ms) fixation data was subtracted, the mean value of the final 500ms of fixation should be centred on 0mV, which suggests there is no change in muscle activity immediately before the trial data. Otherwise, the trial was rejected if the fixation data deviated from 0mV (visual check).

Charts were generated to investigate for problematic fixation data. Twenty medium participants attended the facial EMG measurement, but the data of one participant had EMG data consistent with sniffing relating to illness and unusual extreme data so was excluded. The total trial number of the sweet and bitter session was 456 (24 samples/per person*19 person). Table 4-4 shows the percentage of usage data.

Table 4-4 The percentage of used psychophysiological data in each session

Muscle	Sweet Session		Bitter Session	
	Used data N	%	Used data N	%
Corrugator	417	91.45	416	91.23
Zygomaticus	394	86.40	412	90.35
Levator	409	89.69	406	89.04
Masseter	413	90.57	416	91.23

The training block was excluded from analysing data. Changescores were calculated using the fixation phase for 'Empty sample solution' (*Emptying Phase*) 'Swirl the solution for 5 seconds'

(*Swirling Phase*) and 'Think about the taste for 10 seconds' (*Thinking Phase*). Tasting and rating blocks were analysed separately. Each block was composed of three replications of RO water and different concentration levels of taste stimuli. As with Study 1, positive changescores represent increased muscle activity (contraction) of the muscles versus the 500ms pretrial fixation phase; zero changescores represent no change in activity from pre-trial, and negative changescores represent the relaxation of the muscle.

In this chapter, conventional statistical methods such as ANOVA, and paired sample t-tests were used to analyse the EMG data and rating data. Here, three different phases (emptying, swirling and thinking phases) and two different blocks (tasting and rating block) were run separately for analysing the data using ANOVA and t-tests. Furthermore, the bitter and sweet session analyses were conducted separately. Water, low, medium and high referred to water control, low concentration stimuli, medium concentration stimuli and high concentration stimuli, respectively.

First, mean EMG activity in facial muscles with different concentration levels of sweet/bitter sample stimuli was evaluated using an ANOVA with repeated measures. An ANOVA with repeated measures (Concentration: Water, Low, Medium and High) was conducted for each dependent variable (Corrugator, Zygomaticus, Levator, Masseter).

Second, the dynamic EMG changescores of four facial muscles with different concentration levels of taste stimuli were evaluated using an ANOVA with repeated measures. An ANOVA with repeated measures (Concentration: Water, Low, Medium and High; Timing Course: every 500ms during each emptying, swirling and thinking phase) was conducted for each dependent variable (Corrugator, Levator, Zygomaticus, Masseter).

Third, paired sample T-tests were used to discriminate the significance of EMG activity in corrugator, levator, zygomaticus, and masseter muscles between six solution pairs including water/low, water/medium, water/high, low/medium, low/high, and medium/high.

Fourth, paired sample T-tests were also used to discriminate dynamic EMG activity in corrugator, levator, zygomaticus, and masseter muscles between six solution pairs including water/low, water/medium, water/high, low/medium, low/high, and medium/high during the emptying, swirling and thinking phases for the tasting and rating blocks.

4.4.2 Results

4.4.2.1 Mean EMG activity in facial muscles (corrugator, zygomaticus, levator and masseter) of the bitter session for the tasting and rating blocks

Figure 4-9 and Figure 4-10 show the mean EMG activity for corrugator, zygomaticus, levator and masseter muscles during different time points, including *emptying, swirling* and *thinking* phases for the tasting and rating blocks. Again, emptying, swirling, and thinking phases represented the different time points when participants emptied the solutions into their mouths, swirled the liquid in their mouths, and thought about the liquid after spitting out the liquid, respectively. The difference between tasting and rating blocks is that during the tasting block, EMG recorded pure facial muscular activities, whereas, for the rating block, participants were required to rate the hedonic liking rating and intensity rating after they tasted each taste stimulus. A more detailed description is given in 4.4.1.4.

Corrugator (tasting block): The results of the tasting block will be discussed first. From Figure 4-9, it can be seen that bitter-low solutions evoked EMG activity in the corrugator muscle from emptying, swirling to thinking phase ($M_{Corr\text{-}Low\text{-}Emptying}$= 0.27, SE= 0.17; $M_{Corr\text{-}Low\text{-}Swirling}$= 0.22, SE= 0.06; $M_{Corr\text{-}Low\text{-}Thinking}$= 0.25, SE= 0.08). When emptied, more negative responses were elicited by bitter-high solutions ($M_{Corr\text{-}High\text{-}Emptying}$= 1.06, SE=0.27) than by bitter-medium solutions ($M_{Corr\text{-}Medium\text{-}Emptying}$= 0.59, SE=0.18). Swirling resulted in greater contraction of the corrugator muscle in bitter-medium ($M_{Corr\text{-}Medium\text{-}Swirling}$= 1.26, SE=0.33) and bitter-high ($M_{Corr\text{-}High\text{-}Swirling}$= 2.55, SE=0.60) solution. After spitting out the liquids, there was a considerable decrease in EMG activity for the corrugator muscle when tasting medium ($M_{Corr\text{-}Medium\text{-}thinking}$= 0.95, SE=0.23) and high concentration ($M_{Corr\text{-}High\text{-}thinking}$= 2.02, SE=0.59) solutions. According to the t-test results (see Table 4-6), the corrugator muscle was found to discriminate bitter-low solution from bitter-medium solution and bitter-medium solution from bitter-high solution from the emptying to the thinking phase, but no distinct pattern could be found in water control and bitter-low solutions.

Levator (Tasting block): The Levator muscle presented similar EMG activity patterns to the corrugator muscle. Specifically, ignoring water control, there was a gradual increase pattern of levator muscle activity from the bitter-low ($M_{Lev\text{-}Low\text{-}Emptying}$= 1.93, SE=0.34), bitter-medium ($M_{Lev\text{-}Medium\text{-}Emptying}$= 2.36, SE=0.34) to bitter-high ($M_{Lev\text{-}High\text{-}Emptying}$= 2.83, SE=0.36) solutions during the emptying phase. The same pattern was found in the swirling phase, but the increased levator muscle contraction was found for bitter-medium ($M_{Lev\text{-}Medium\text{-}swirling}$= 2.85, SE=0.43) and bitter-high ($M_{Lev\text{-}high\text{-}swirling}$= 4.25, SE=0.53) solutions during the swirling period than at the emptying point. After spitting out, in contrast to the emptying and swirling phases, the corresponding EMG activity in the levator muscle of bitter-low, bitter-medium to bitter-high solutions decreased to 0.40, 1.18 and 2.23 during the thinking phase, respectively. Interestingly, water control presented similar levator muscle activity to bitter-low solution from the emptying to the thinking phases. It was found in Table 4-6 that the levator muscle presented the same result as the corrugator muscle, which indicated that it was able to discriminate bitter low to medium concentrations and medium to high concentrations consistently while emptying the solution, swirling the solution in the mouth, to spitting out. No discrimination was found between water control and bitter-low solution throughout the whole experiment.

Zygomaticus (Tasting block): The Zygomaticus muscle, reported to be a positive affect muscle, presented a different EMG pattern for bitter stimuli during the tasting block. When emptying the solution, a slight increase in EMG activity was found for water control ($M_{Zygo\text{-}water\text{-}emptying}$= 0.47, SE=0.18) to bitter-high solution ($M_{Zygo\text{-}High\text{-}emptying}$= 0.79, SE=0.16), which indicated that no more contractions were made on the zygomaticus muscle at that time point. Interestingly, water control was reported to evoke the strongest EMG activity in the zygomaticus muscle than other different concentrations of bitter stimuli during both swirling ($M_{Zygo\text{-}water\text{-}swirling}$= 1.97, SE=0.42) and thinking ($M_{Zygo\text{-}water\text{-}thinking}$= 1.15, SE=0.34) periods. Besides that, during the swirling and thinking phases, the zygomaticus muscle still presented a similar activity pattern on bitter solutions, which showed that bitter-low solution ($M_{Zygo\text{-}Low\text{-}Swirling}$= 1.19, SE=0.24; $M_{Zygo\text{-}Low\text{-}Thinking}$= 0.55, SE=0.14) evoked more zygomaticus activity than others. Furthermore, the least

EMG activity was able to be found in bitter-medium solution ($M_{Zygo\text{-}Medium\text{-}Swirling}$= 0.89, SE=0.17; $M_{Zygo\text{-}Medium\text{-}Thinking}$= 0.31, SE=0.10). T-test results illustrated that the zygomaticus muscle was a reliable muscle to discriminate bitter-low solution from bitter-medium solution during the thinking period; furthermore medium and high concentration levels of bitter stimuli were able to be identified at the moment the solutions were emptied.

Masseter (Tasting Block): The chewing muscle, Masseter, did not reveal a distinct pattern when solutions were emptied, which could be explained by the fact that the function of masseter at that moment was to open and close the jaw. The strongest masseter muscle contraction was evoked by bitter-high solution ($M_{Mass\text{-}High\text{-}Emptying}$= 1.08, SE=0.71) whereas the lowest EMG activity was found for bitter-medium solution ($M_{Mass\text{-}Medium\text{-}Emptying}$= 0.41, SE=0.20). More EMG activity in the masseter muscle was found in more concentrated bitter solution stimuli during the swirling and thinking phases, which indicated that water control ($M_{Mass\text{-}Water\text{-}Swirling}$= 0.42, SE=0.14; $M_{Mass\text{-}Water\text{-}Thinking}$= 0.12, SE=0.07) presented the least EMG activity, whereas the strongest EMG activity was elicited by bitter-high solution ($M_{Mass\text{-}High\text{-}Swirling}$= 1.22, SE=0.33; $M_{Mass\text{-}Water\text{-}Thinking}$= 0.80, SE=0.21), correspondingly. The t-test results (see Table 4-6) showed that bitter-low and bitter-medium solutions were only able to be discriminated during the thinking phase, whereas the masseter muscle could discriminate medium to high concentration levels of bitter stimuli during both swirling and thinking periods.

A repeated measure ANOVA was used to investigate the relationship between solution samples (including water control and three different concentration levels of bitter stimuli) and EMG activity. The result of Table 4-5 illustrated that the concentration levels of bitter stimuli influenced the EMG activity in corrugator and levator muscles significantly from emptying to thinking phases of the tasting block. When participants swirled and thought about the taste, the only weak effect was able to be found on the zygomaticus muscle activity, whereas there was a significant influence on the masseter muscle EMG activity of the different concentration levels of bitter stimuli.

Figure 4-10 presents the EMG activity of bitter stimuli for the rating block. The difference between rating and tasting blocks is that rating the solution sample was required using the scale after the thinking phase. The rest of the trial procedure was identical.

Corrugator (Rating block): Corrugator, the negative affect muscle, generally presented the same pattern in all three phases (emptying, swirling and thinking) with more corrugator contraction being generated when more concentrated bitter stimuli was tasted. When solutions were emptied into the mouth, there was a gradual and slight increase in corrugator muscle activity from the bitter-low ($M_{Corr\text{-}Low\text{-}Emptying}$= 0.63, SE=0.31) to bitter-high ($M_{Corr\text{-}High\text{-}Emptying}$= 1.12, SE=0.27) solutions. Additionally, similar EMG activity was able to be found in water control ($M_{Corr\text{-}Water\text{-}Emptying}$= 0.62, SE=0.35) and bitter-low ($M_{Corr\text{-}Low\text{-}Emptying}$= 0.63, SE=0.31) solution. Compared with the emptying phase, a significant increase in EMG activity in the corrugator muscle evoked by bitter-medium and bitter-high liquids was able to be found during the swirling phase ($M_{Corr\text{-}Medium\text{-}Swirling}$= 1.56, SE=0.53; $M_{Corr\text{-}Medium\text{-}Swirling}$= 3.13, SE=0.77), whereas EMG activity in the corrugator muscle for water control and bitter-low solution decreased to 0.33 and 0.36, respectively. During the 10 second thinking period, there was no doubt that bitter-high solution still evoked the strongest negative affect among the four solution samples ($M_{Corr\text{-}High\text{-}Thinking}$= 2.53, SE=0.69). Interestingly, bitter-low ($M_{Corr\text{-}Low\text{-}Thinking}$= 0.32, SE=0.11) solution presented the least EMG activity rather than water control ($M_{Corr\text{-}Water\text{-}Thinking}$= 0.47, SE=0.11). Table 4-7 illustrates the T-test results for the rating block. The corrugator muscle was able to discriminate from low to medium concentration levels and from medium to the high concentration levels of bitter stimuli during the swirling and thinking phases.

Levator (Rating block): EMG activity in the levator muscle was reported to present an increasing trend with the increase of solution concentration. In other words, water control presented the least EMG activity in the levator muscle, whereas bitter-high solution evoked the strongest negative affect during the whole emptying, swirling and thinking phases. Specifically, EMG activity in the levator muscle for water control with emptying, swirling and thinking phases was

2.24, 1.95, and 0.44, respectively, whereas a significant increase in EMG activity for bitter-high solution was 3.30, 4.56, and 2.61 for corresponding phases. It is noted that the more EMG activity for bitter-high solution for the emptying and swirling phases was due to the levator muscle acting as a functional muscle when emptying and swirling the solutions. Levator was a reliable muscle to discriminate bitter-low and bitter-medium solution stimuli for both swirling and thinking phases. Additionally, the medium and high concentration level of bitter stimuli was able to be discriminated by the levator muscle for all three phases. No distinct pattern could be found in water control and bitter-low concentration levels.

Zygomaticus (Rating block): From Figure 4-10, it can be seen that zygomaticus as a positive muscle, was not able to be found in any distinct pattern during these three phases for the rating block. However, the swirling phase was found to evoke more zygomaticus activity by all sample solutions than the emptying and thinking phase. When liquids were emptied into the mouth, bitter-medium solution evoked the least EMG activity in the zygomaticus muscle ($M_{Zygo\text{-}Medium\text{-}Emptying}$= 0.38, SE=0.23). However, the other stimuli (water, low, and high concentration levels) presented similar EMG activity, which was 0.60 for water control, 0.61 for bitter-low solution, and 0.70 for bitter-high stimuli, respectively. However, during the swirling phase, what was interesting was the maximum EMG activity in the zygomaticus muscle evoked by water control ($M_{Zygo\text{-}Water\text{-}Swirling}$= 1.80, SE=0.39) rather than by other bitter stimuli; furthermore, bitter-medium solutions still presented the least zygomaticus muscle activity ($M_{Zygo\text{-}Medium\text{-}Swirling}$= 1.00, SE=0.17). Similarly EMG activity was able to be found in bitter-low and bitter-high solutions. During the thinking phase, water control still presented the strongest EMG activity in the zygomaticus muscle ($M_{Zygo\text{-}Water\text{-}Thinking}$= 1.12, SE=0.26), although zygomaticus muscle activity decreased a lot compared to the swirling phase. Apart from water control, EMG activity in the zygomaticus muscle decreased with the increase of concentration levels of bitter solutions, which indicated that bitter-low solutions ($M_{Zygo\text{-}Low\text{-}Thinking}$= 0.48, SE=0.23) generated more zygomaticus contraction than the bitter-high ($M_{Zygo\text{-}High\text{-}Thinking}$= 0.32, SE=0.09) solutions. The results in Table 4-6 showed that both water control and the bitter-low solution were able to be discriminated by the zygomaticus muscle during the swirling and thinking phases.

Masseter (Rating block): The chewing muscle, Masseter, was not able to produce a distinct pattern during the emptying phase for the rating block. During the emptying phase, EMG activity in the masseter muscle evoked by solution samples was ranked the bitter-medium solution ($M_{Mass\text{-}Medium\text{-}Emptying}$= 0.55, SE=0.27), water control ($M_{Mass\text{-}Low\text{-}Emptying}$= 0.42, SE=0.24), the bitter-high solution ($M_{Mass\text{-}High\text{-}Emptying}$= 0.37, SE=0.22), and the bitter-low solution ($M_{Mass\text{-}Low\text{-}Emptying}$= 0.19, SE=0.16). More masseter muscle activity was evoked by all solution stimuli during the swirling phase than by the emptying phase. Except for water control, more masseter muscle contraction was able to be found when swirling more concentrated bitter stimuli, which indicated that bitter-high solution ($M_{Mass\text{-}High\text{-}Swirling}$= 1.42, SE=0.48) evoked the strongest EMG activity in the masseter muscle whereas the low concentration of bitter solutions ($M_{Mass\text{-}Low\text{-}Swirling}$= 0.47, SE=0.14) made the least contraction. Interestingly, EMG activity in the masseter muscle evoked by water control ($M_{Mass\text{-}Water\text{-}Swirling}$= 0.52, SE=0.10) was slightly higher than by bitter-low solution. During the thinking phase, the masseter muscle presented the same EMG activity pattern as the swirling phase, but its masseter muscle activity decreased noticeably. From Table 4-7, the masseter muscle was able to discriminate water control from the bitter-low solution during the emptying phase. Furthermore, the bitter-low and the bitter-medium solution was able to be differentiated by masseter muscles during all three phases. Table 4-5 illustrates the ANOVA result with repeated measures. (Concentration: Water, Low, Medium, High; Dependent variable: Corrugator, Zygomaticus, Levator, and Masseter). The result shows that there was a significant main effect of the concentration levels on corrugator muscle activity during the swirling and thinking phases. The levator was reported to be influenced significantly by different concentration levels as well during all three phases. However, zygomaticus and masseter activity was found to have a medium correlation with the concentration level of bitter stimuli during the thinking phase. Additionally, the concentration level of bitter stimuli influenced masseter muscle activity weakly during the swirling period.

Table 4-5 Repeated Measures ANOVA results of bitter session

Bitter Session								
	Tasting Block				Rating Block			
	df	F	P	η_p^2	df	F	p	η_p^2
Corrugator								
Emptying	1.513	13.181	<0.001	0.423	1.668	2.945	0.076	0.141
Swirling	1.17	14.464	0.001	0.446	1.199	11.549	0.002	0.391
Thinking	1.07	9.646	0.005	0.349	1.142	10.024	0.004	0.358
Levator								
Emptying	1.521	11.921	0.001	0.398	2.017	11.935	<0.001	0.399
Swirling	1.532	16.653	<0.001	0.481	1.513	14.866	<0.001	0.452
Thinking	1.263	20.505	<0.001	0.533	1.427	22.205	<0.001	0.552
Zygomaticus								
Emptying	1.879	3.377	0.049	0.166	1.715	2.432	0.111	0.119
Swirling	1.346	4.658	0.032	0.215	1.86	3.113	0.061	0.147
Thinking	1.283	3.506	0.066	0.171	1.745	5.671	0.01	0.24
Masseter								
Emptying	1.119	1.656	0.215	0.084	1.875	2.439	0.106	0.119
Swirling	1.47	6.592	0.009	0.268	1.145	4.313	0.046	0.193
Thinking	1.345	8.761	0.004	0.327	1.467	5.595	0.016	0.237

Table 4-6 T-test results for bitter stimuli of the emptying, swirling and thinking phases for the taste block

Bitter Session - Tasting Block								
			Emptying		Swirling		Thinking	
	N	df	T	p	T	Sig.	T	p
Corrugator								
Water/Low	19	18	-0.105	0.917	-1.265	0.222	-1.31	0.207
Low/Medium	19	18	-3.184	0.005	-3.114	0.006	-3.297	0.004
Medium/High	19	18	-2.771	0.013	-3.721	0.002	-2.8	0.012
Levator								
Water/Low	19	18	0.69	0.499	-1.316	0.205	0.23	0.82
Low/Medium	19	18	-3.077	0.006	-2.694	0.015	-3.343	0.004
Medium/High	19	18	-3.082	0.006	-3.725	0.002	-4.995	0
Zygomaticus								
Water/Low	18	17	-0.612	0.549	1.639	0.12	1.516	0.148
Low/Medium	19	18	-1.473	0.158	1.874	0.077	2.207	0.041
Medium/High	19	18	-2.547	0.02	-0.546	0.592	-1.113	0.28
Masseter								
Water/Low	19	18	-1.011	0.325	-1.837	0.083	-1.389	0.182
Low/Medium	19	18	0.853	0.405	-1.445	0.166	-2.108	0.049
Medium/High	19	18	-1.277	0.218	-2.359	0.03	-3.017	0.007

*p<0.05

Table 4-7 T-test results for bitter stimuli of the emptying, swirling and thinking phases for the rating block

Bitter Session - Rating Block								
			Emptying		Swirling		Thinking	
	N	df	T	P	T	p	T	p
Corrugator								
Water/Low	19	18	-0.0983	0.9228	-0.4658	0.6470	1.7740	0.0930
Low/Medium	19	18	-0.8297	0.4176	-2.3172	0.0325	-2.6528	0.0162
Medium/High	19	18	-1.7179	0.1030	-4.1881	0.0006	-3.2439	0.0045
Levator								
Water/Low	19	18	-0.7553	0.4598	-1.1372	0.2704	-0.8971	0.3815
Low/Medium	19	18	-1.4463	0.1653	-2.3076	0.0331	-3.3761	0.0034
Medium/High	19	18	-3.6610	0.0018	-3.9125	0.0010	-4.3554	0.0004
Zygomaticus								
Water/Low	19	18	-0.0945	0.9257	2.3460	0.0306	2.0577	0.0544
Low/Medium	19	18	1.7285	0.1010	0.4061	0.6895	0.7134	0.4848
Medium/High	19	18	-1.8738	0.0773	-1.1832	0.2521	0.1181	0.9073
Masseter								
Water/Low	19	18	2.2635	0.0362	0.7682	0.4523	0.5579	0.5838
Low/Medium	19	18	-2.3951	0.0277	-2.1292	0.0473	-2.2311	0.0386
Medium/High	19	18	0.9791	0.3405	-1.8853	0.0756	-1.9478	0.0672

*p<0.05

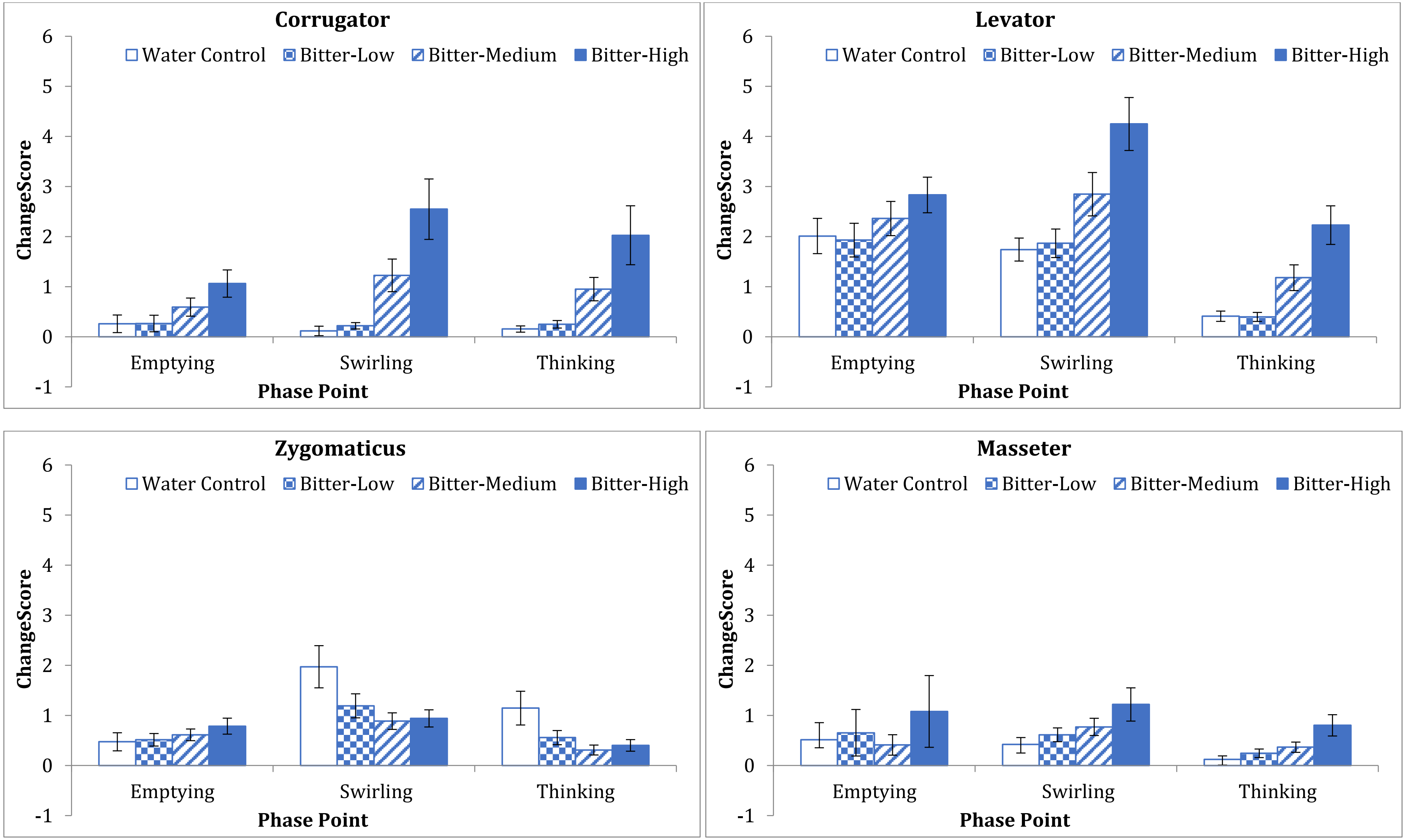


Figure 4-9 Mean muscle changescore of corrugator, zygomaticus, levator and masseter of bitter stimuli for the tasting block

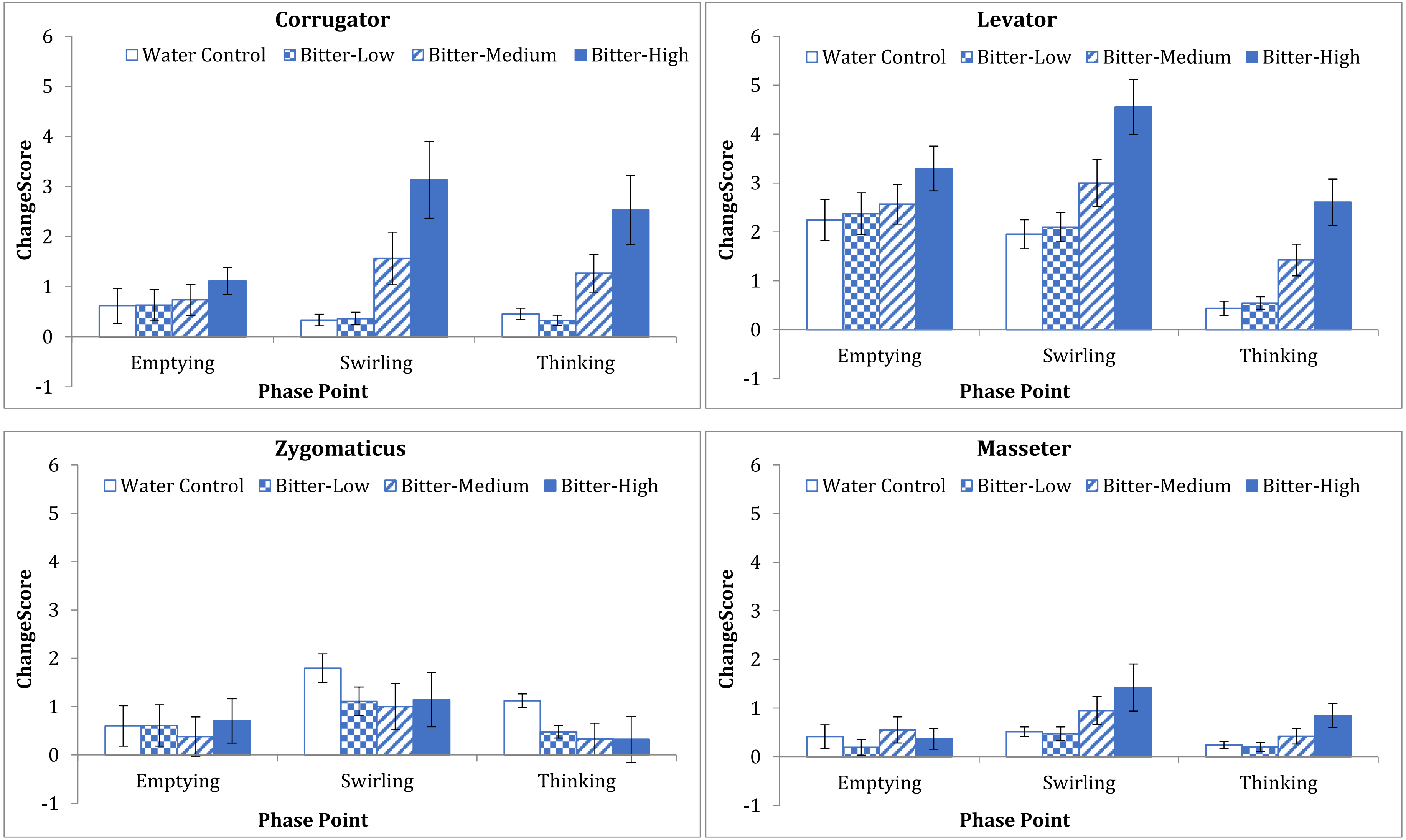


Figure 4-10 Mean muscle changescore of corrugator, zygomaticus, levator and masseter of bitter stimuli for the rating block

4.4.2.2 Mean EMG activity in facial muscles (corrugator, zygomaticus, levator and masseter) of the sweet session for the tasting and rating blocks

Figure 4-11 and Figure 4-12 shows the mean EMG activity in facial muscles of water control and different concentration levels of sweet stimuli during three phases (emptying, swirling, and thinking phases) for the tasting and rating blocks. The solution stimuli were composed of water control, sweet-low, sweet-medium, and sweet-high solutions.

Corrugator (Tasting block): It can be seen from Figure 4-11 that in contrast to the bitter session, corrugator muscle activity evoked by sweet stimuli decreased noticeably and presented a stable pattern during emptying, swirling and thinking phases. Specifically, similar EMG activity in the corrugator muscle was seen between water control, sweet-low liquid and sweet-medium solutions during all three phases. Interestingly, the corrugator muscle was showed more contraction on tasting sweet-high solutions than other solution types; furthermore, its muscle activity increased slightly from the emptying to the swirling phase ($M_{Corr\text{-}High\text{-}Emptying}$=0.37, SE=0.12; $M_{Corr\text{-}High\text{-}Swirling}$=0.77, SE=0.27) and then after spitting out, while less corrugator contraction was found ($M_{Corr\text{-}High\text{-}Thinking}$=0.58, SE=0.21). The result of Table 4-9 illustrated that for the sweet session, only medium and high concentration levels of sweet stimuli was able to be discriminated by the corrugator muscle during the emptying phase.

Levator (Tasting block): Levator is a negative muscle, but in this study, it is more likely to be used as a functional muscle to empty and swirl the solution sample. This is the reason why more EMG activity in the levator muscle was always found during the emptying and swirling phases than during the thinking period. As shown in Figure 4-11, the levator muscle presented the same EMG activity trend during the emptying and swirling phases. Except for water control, there was a slight increase in EMG activity of the levator muscle with the increase of the concentration level of sweet stimuli, but more EMG activity was evoked by water control than was found with the sweet-low solution. Specifically, during the emptying and swirling phases, the sweet-high liquid evoked the strongest EMG activity in the levator muscle ($M_{Lev\text{-}High\text{-}}$

$_{Emptying}$=1.95, SE=0.34; $M_{Lev-High-Swirling}$=2.28, SE=0.31), whereas the least levator activity was found in the sweet-low liquid ($M_{Lev-Low-Emptying}$=1.50, SE=0.32; $M_{Lev-Low-Swirling}$=1.32, SE=0.17). After spitting out, the same EMG activity pattern was presented as the emptying and swirling period, but it should be noted that levator muscle activity dropped dramatically. During the thinking phase, sweet-high and sweet-low solutions still evoked the strongest and the least EMG activity in the levator muscle, but activity dropped significantly from 2.28 and 1.21 (swirling phase) to 0.49 and 0.25 (thinking phase), respectively. The result of paired sample T-tests (see Table 4-9) shows that the medium concentration level of sweet stimuli was discriminated by the levator muscle from sweet-low liquid and sweet-high liquid respectively during the swirling and thinking phases.

Zygomaticus (Tasting block): The same EMG activity pattern of the zygomaticus muscle (see Figure 4-11) evoked by sweet stimuli was able to be found during all emptying, swirling and thinking phases, indicating that, except for water control, more zygomaticus muscle activity was generated when the high concentration sweet solution was tasted. There was an increasing trend in zygomaticus activity of sweet stimuli from emptying to swirling phases, but after spitting out, their zygomaticus EMG activity dropped quickly. Specifically, the strongest EMG activity in the zygomaticus muscle was evoked by sweet-high solution ($M_{Zygo-High-Emptying}$=0.67, SE=0.14; $M_{Zygo-High-Swirling}$=1.25, SE=0.24; $M_{Zygo-High-Thinking}$=0.67, SE=0.13) whereas sweet-low solution elicited the least zygomaticus muscle activity ($M_{Zygo-Low-Emptying}$=1.50, SE=0.32; $M_{Zygo-Low-Swirling}$=1.32, SE=0.17; $M_{Zygo-Low-Thinking}$=0.25, SE=0.12). No distinct pattern of zygomaticus muscle activity could be found in water control. Only sweet-low and sweet-high solutions were able to be discriminated by the zygomaticus muscle during the thinking phase (see Table 4-9).

Masseter (Tasting block): From Figure 4-11, during the emptying phase, the masseter muscle presented similar EMG activity within low, medium and high concentration levels of sweet solutions, but the least masseter activity was found on water control. During the swirling and thinking phases, EMG activity in the masseter muscle presented a gradual and slight increase in pattern with the increase in sweet concentration level. However, the strongest EMG activity was evoked by sweet-high solutions ($M_{Mass\text{-}High\text{-}Swirling}$=0.58, SE=0.09; $M_{Mass\text{-}High\text{-}Thinking}$=0.33, SE=0.07), whereas sweet-low solution was found to evoke the least activity ($M_{Mass\text{-}Low\text{-}Swirling}$=0.36, SE=0.07; $M_{Mass\text{-}Low\text{-}Thinking}$=0.17, SE=0.07). Water control was found to elicit more EMG activity than sweet-low solution during these two phases. It can be seen from Table 4-9 that for the tasting block, the sweet-medium solution was able to be discriminated by the masseter muscle from sweet-low solution and sweet-high solution during the thinking and swirling phases, respectively.

The result of an ANOVA with repeated measures is presented in Table 4-8. The concentration level of sample solution stimuli, including water control, sweet-low, sweet-medium and sweet-high solutions were used to investigate their main influence on EMG activity in facial muscles during three different phases for the tasting block. The concentration level of sweet stimuli was only reported to influence corrugator muscle activity during the swirling phase for the tasting block. The levator muscle was influenced by concentration levels of sweet solutions significantly during all three phases. Masseter and zygomaticus muscles were both reported to be influenced by different concentration levels of sweet stimuli during the swirling and thinking phases for the tasting block.

Figure 4-12 shows the EMG activity in corrugator, levator, zygomaticus, and masseter muscles of the sweet session for the rating block.

Corrugator (Rating block): During the emptying phase, more EMG activity in the corrugator muscle was evoked by sweet-high ($M_{Corr\text{-}High\text{-}Emptying}$=0.37, SE=0.12) solution than other solution types. Interestingly, participants even showed relaxation of the corrugator muscle when tasting water ($M_{Corr\text{-}Water\text{-}Emptying}$=-0.07, SE=0.15). Similar activity was present in the corrugator muscle for sweet-low ($M_{Corr\text{-}Low\text{-}Emptying}$=0.12, SE=0.045) and sweet-medium ($M_{Corr\text{-}Low\text{-}Emptying}$=0.12, SE=0.08) solution. Turning to the swirling phase, EMG activity in the corrugator muscle presented the same pattern on the emptying phase, but more corrugator muscle activity was found during the swirling phase. Specifically, during the swirling phase, the strongest EMG activity in the corrugator muscle was still evoked by sweet-high solution ($M_{Corr-High-swirling}$=0.58, SE=0.16), while water control aroused the least corrugator muscle contraction ($M_{Corr-Water-swirling}$=0.20, SE=0.17). The same EMG activity was evoked by sweet-low and sweet-medium solutions. After spitting out, there were 10 seconds to think about the taste of the solutions. EMG activity in the corrugator muscle evoked by sweet-high solution dropped slightly from 0.58 to 0.51 during this phase. The least corrugator contraction was found for sweet-medium liquid ($M_{Corr-Medium-Thinking}$=0.25, SE=0.10). More corrugator muscle activity evoked by sweet-low liquid was found than water control. Table 4-10 reveals that the sweet-medium liquid and the sweet-high liquid could only be discriminated by corrugator muscles at the moment when liquids were emptied into the mouth.

Levator (Rating block): More EMG activity in the levator muscle was found during the three phases than other facial muscles (see Figure 4-12). When emptying the liquids, similar EMG activity in the levator muscle was evoked by all solution types, with 2.20 for sweet-high solution, 2.15 for sweet-low solution, 2.04 for sweet-medium solution, and 1.90 for water control, respectively. However, during the swirling phase, EMG activity in the levator muscle evoked by sweet-high liquid increased slightly to 2.32 whereas water control ($M_{Lev-Water-Swirling}$=1.62, SE=0.22) resulted in the least levator muscle contraction. Similar EMG activity in the levator muscle was evoked by sweet-low and sweet medium solution ($M_{Lev-Low-Swirling}$=1.86, SE=0.24; $M_{Lev-Medium-Swirling}$=1.87, SE=0.26). Lastly, the levator muscle activity realised from all solution types was found to decrease dramatically during the thinking phase; furthermore, more levator contraction was generated when the more concentrated level of solution stimuli was tasted. Specifically, the strongest levator muscle activity was able to be evoked by sweet-high liquid ($M_{Lev-High-Thinking}$=0.96, SE=0.23) whereas water control still aroused the least levator contraction ($M_{Lev-Water-Thinking}$=0.35, SE=0.11). T-test (see Table 4-10) results demonstrate that the levator muscle was able to differentiate between the sweet-low solution from the sweet-medium solution of the thinking phase and the sweet-medium solution from the sweet-high solution during the swirling phase.

Zygomaticus (Rating block): A distinct pattern was that EMG activity in zygomaticus muscle increased as the increase of the concentration level of sample stimuli during all three phases (emptying, swirling, and thinking). However, it should be noted that less EMG activity in zygomaticus muscle was presented within the thinking period than that within the emptying and swirling phases. Sweet-high liquid presented the strongest EMG activity during emptying ($M_{Zygo\text{-}High\text{-}Emptying}$=0.77, SE=0.22), swirling ($M_{Zygo\text{-}High\text{-}swirling}$=1.12, SE=0.20) and thinking ($M_{Zygo\text{-}High\text{-}Thinking}$=0.66, SE=0.16) phase. However, the least EMG activity was evoked by water control during three phases, and its corresponding zygomaticus activity tended to increase from 0.65 within the emptying period to 0.91 during the swirling period, but then drop dramatically in 0.66 after spitting out. The thinking phase was the only ten second period which was able to discriminate the sweet-low solution from the sweet-medium solution using the zygomaticus muscle (see Table 4-10).

Masseter (Rating block): Similar to zygomaticus muscle, there was a distinct EMG activity pattern of the masseter muscle within all three phases, which indicated that, except for water control, more EMG activity in the masseter muscle was evoked by more concentrated sweet solution samples, but more masseter contraction was found on water control than the sweet-low solution (see Figure 4-12). Specifically, the strongest EMG activity was elicited by the sweet-high liquid during the emptying ($M_{Mass\text{-}HIgh\text{-}Emptying}$=0.31, SE=0.08), the swirling ($M_{Mass\text{-}HIgh\text{-}Swirling}$=0.57, SE=0.09), and the thinking ($M_{Mass\text{-}HIgh\text{-}Thinking}$=0.44, SE=0.15) phases, whereas the least masseter muscle activity was evoked by sweet-low solution. From Table 4-10, the t-test result shows that no distinct pattern could be found for the masseter muscle distinguishing the different concentration levels of sweet solutions and water control at any time.

The result of Table 4-8 illustrates the effect of the different concentration levels of sweet stimuli on EMG activity during emptying, swirling and thinking phases of the rating block using repeated measures of ANOVA. Different concentration levels of sweet stimuli influenced levator muscle activity significantly during the swirling and thinking phases, but zygomaticus and masseter muscle activities were slightly influenced by concentrations.

Table 4-8 Repeated measures ANOVA results for sweet session

Sweet Session								
	Tasting Block				Rating Block			
	df	F	p	η_p^2	df	F	p	η_p^2
Corrugator								
Emptying	1.964	2.998	0.064	0.143	1.5	3.398	0.06	0.159
Swirling	1.359	3.649	0.056	0.169	1.839	2.238	0.126	0.111
Thinking	1.345	2.886	0.092	0.138	1.725	0.665	0.5	0.036
Levator								
Emptying	3	3.395	0.024	0.159	1.926	1.162	0.323	0.061
Swirling	1.557	9.666	0.001	0.349	2.006	6.193	0.05	0.256
Thinking	1.399	8.125	0.004	0.313	1.477	4.197	0.036	0.189
Zygomaticus								
Emptying	2.231	1.646	0.203	0.084	2.426	1.37	0.265	0.071
Swirling	2.288	5.789	0.004	0.243	2.628	2.898	0.051	0.139
Thinking	1.606	7.978	0.003	0.307	2.171	3.991	0.024	0.181
Masseter								
Emptying	1.147	0.899	0.368	0.048	1.719	1.152	0.322	0.06
Swirling	3	6.629	0.002	0.269	1.795	0.785	0.452	0.042
Thinking	3	5.18	0.003	0.223	4.634	4.316	0.033	0.187

Table 4-9 T-test results for sweet session of the emptying, swirling and thinking phases for the tasting block

Sweet Session - Tasting Block								
			Emptying		Swirling		Thinking	
	N	df	T	p	T	p	T	p
Corrugator								
Water/Low	19	18	0.114	0.911	0.116	0.909	0.851	0.406
Low/Medium	19	18	0.119	0.906	-0.692	0.498	-0.216	0.832
Medium/High	19	18	-2.141	0.046	-1.977	0.064	-2.043	0.056
Levator								
Water/Low	19	18	0.49	0.63	0.649	0.525	0.385	0.705
Low/Medium	19	18	-0.971	0.345	-2.298	0.034	-2.139	0.046
Medium/High	19	18	-1.959	0.066	-3.75	0.001	-3.001	0.008
Zygomaticus								
Water/Low	19	18	1.141	0.269	-0.084	0.934	-0.483	0.635
Low/Medium	19	18	-1.848	0.081	-2.07	0.053	-3.525	0.002
Medium/High	19	18	-0.523	0.607	-0.865	0.399	-1.651	0.116
Masseter								
Water/Low	19	18	-0.908	0.376	0.843	0.41	0.28	0.782
Low/Medium	19	18	0.062	0.951	-1.929	0.07	-2.792	0.012
Medium/High	19	18	0.287	0.777	-2.203	0.041	-1.412	0.175

*p<0.05

Table 4-10 T-test results for sweet session of the emptying, swirling and thinking phase for the rating block

Sweet Session - Rating Block								
			Emptying		Swirling		Thinking	
	N	df	T	p	T	p	T	p
Corrugator								
Water/Low	19	18	-1.3270	0.2010	-0.8540	0.4050	-0.4380	0.6670
Low/Medium	19	18	0.0780	0.9390	-0.0400	0.9690	1.5160	0.1470
Medium/High	19	18	-2.9960	0.0080	-1.6880	0.1090	-1.4890	0.1540
Levator								
Water/Low	19	18	-1.6080	0.1250	-1.9700	0.0640	-1.5450	0.1400
Low/Medium	19	18	0.9040	0.3780	-0.0810	0.9370	-2.2410	0.0380
Medium/High	19	18	-0.7310	0.4740	-2.5200	0.0210	-1.1210	0.2770
Zygomaticus								
Water/Low	19	18	-0.1140	0.9100	-0.6620	0.5160	-0.6670	0.5140
Low/Medium	19	18	-1.7190	0.1030	-1.4310	0.1690	-2.3860	0.0280
Medium/High	19	18	-0.3370	0.7400	-0.8310	0.4170	-1.0160	0.3230
Masseter								
Water/Low	19	18	1.4540	0.1630	0.7610	0.4570	0.6500	0.5240
Low/Medium	19	18	-1.1060	0.2830	-1.0080	0.3270	-0.9810	0.3390
Medium/High	19	18	-0.7220	0.4790	-0.5940	0.5600	-1.7510	0.0970

*$p<0.05$

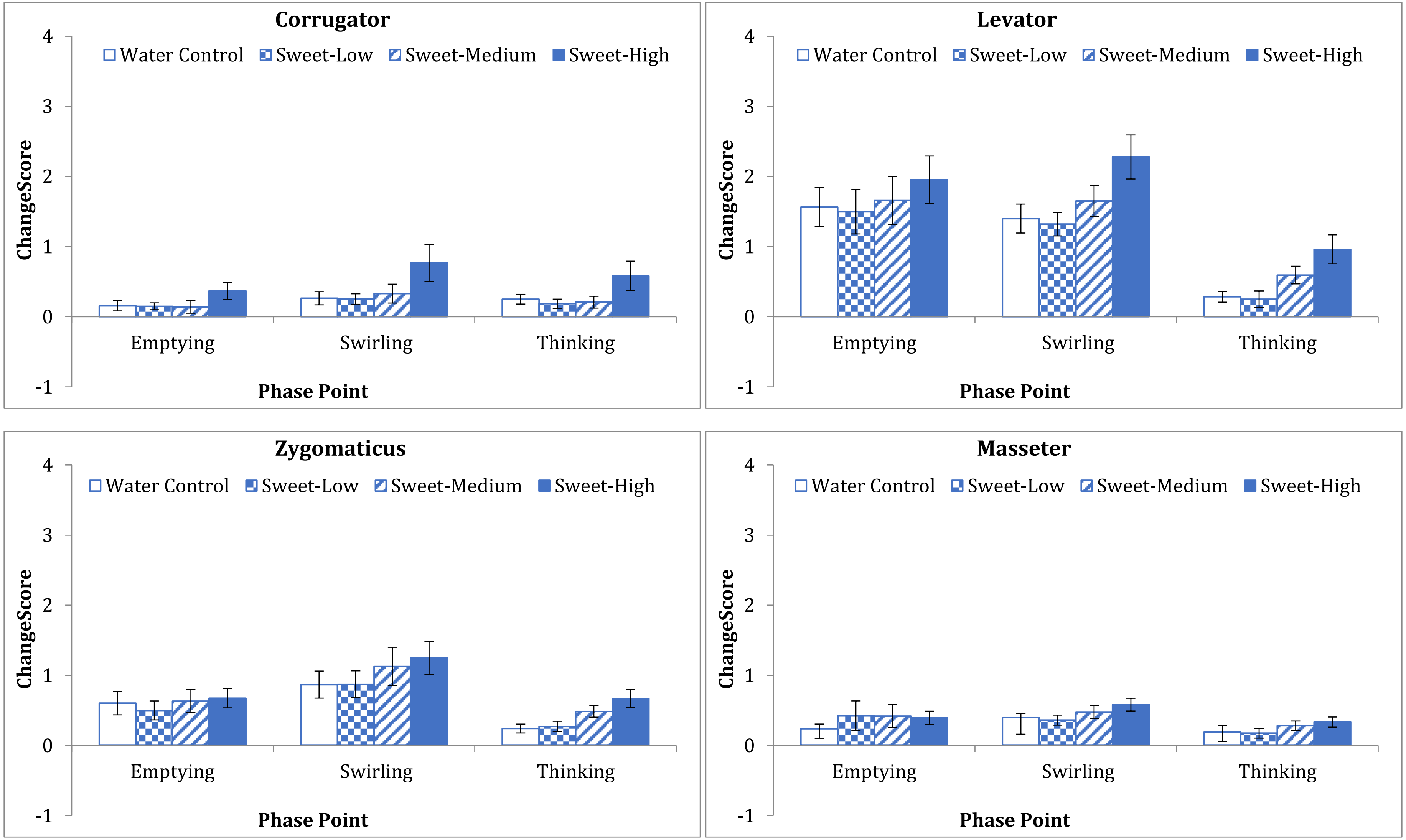


Figure 4-11 Mean muscle changescore of corrugator, zygomaticus, levator and masseter of sweet stimuli for the tasting block

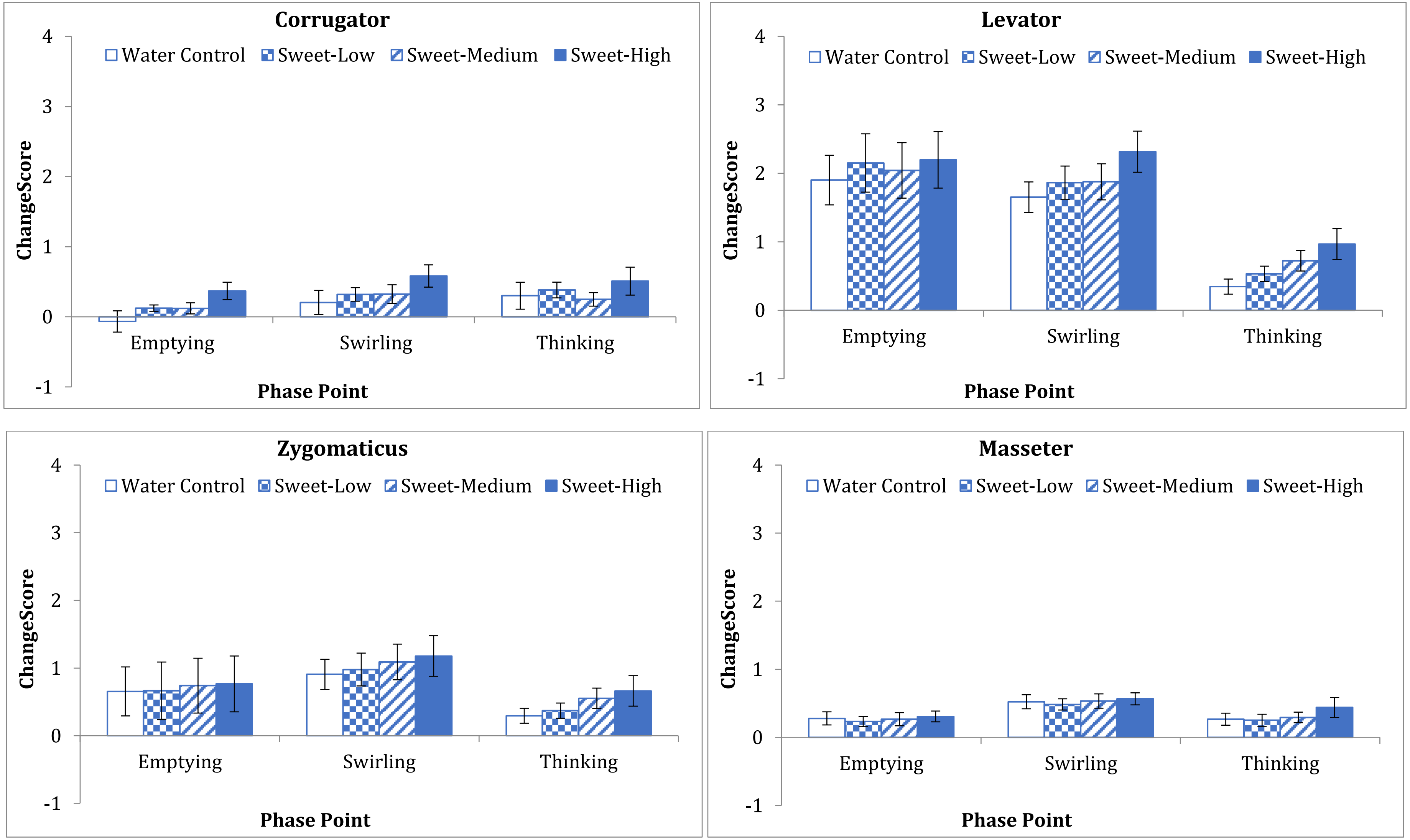


Figure 4-12 Mean muscle changescore of corrugator, zygomaticus, levator and masseter of sweet stimuli for the rating block

4.4.2.3 Dynamic EMG activity responses to bitter stimuli for the tasting and rating blocks

Figures 4-13 - 4-20 list the dynamic EMG activity of four muscles (corrugator, zygomaticus, levator and masseter) with the timing for the tasting and rating blocks. Figures (a), (b) and (c) represent the dynamic EMG activity during the emptying, swirling, and thinking phases for the bitter session. Figures (d), (e), and (f) illustrate the results of paired sample T-tests during the emptying, swirling and thinking phases. The T-test compared the dynamic facial muscle activity during each phase of two different concentration levels of solution samples, including water/low, water/medium, water/high, low/medium, low/high, and medium/high. In these charts, the timing for the emptying phase is in reference to when the participants clicked the mouse button after they had emptied the sample into their mouths. The Swirling phase required participants to swirl the solutions in their mouths for 8 seconds. During the Thinking phase (10s), participants were instructed to think about the taste of sample solutions after they had spat out the sample. For the solution sample, water, low, medium, and high, are in reference to water control, bitter-low concentration, bitter-medium concentration, and bitter-high concentration, respectively. The *p*-values of T-tests are not corrected for multiple comparisons and single time points should be treated with caution. Although running the high risk of Type I error, dynamic and discriminative patterns were also able to be identified.

An ANOVA with repeated measures was used to analyse the relationship between facial muscle activity, different concentration levels of bitter/sweet stimuli and the timing course, which will describe the dynamic activity of the muscles in response to bitter solutions from corrugator, levator, zygomaticus, and masseter muscles. This differs from the previous section in which a single mean value was presented for each muscle (corrugator, levator, zygomaticus, masseter), phase (every 500ms during emptying, swirling and thinking phases), and sample type (water, low, medium, high concentration levels), which will therefore present a dynamic and developing pattern of muscle activity.

The charts reveal that there was a predictable trend for all muscles to increase in activity for all solutions. Muscle activity increased when the sample was emptied into the mouth, stayed higher than baseline during swirling, and then in some cases began to return to baseline during the thinking phase. These results using conventional statistical analysis tools also provide a basic scope to predict the rating data using advanced statistical tool multi-modelling analysis, which will be discussed in Chapter 5. Therefore, the exact patterns of responses for each muscle will be described in full.

4.4.2.3.1 Dynamic EMG activity in the corrugator muscle for the tasting and rating blocks of the bitter session

The dynamic corrugator muscle activity of the bitter session in the tasting block is shown in Figure 4-13 (a), (b), and (c). EMG activity in the corrugator muscle was found to present the same pattern for the tasting and rating blocks, which showed that bitter-high solution evoked the strongest EMG activity in the corrugator muscle compared with other solution types, whereas the least similar corrugator muscle activity was found in the bitter-low solution and water control from the emptying to the thinking phases.

During the emptying phase (Figure 4-13 (a)), there was an increase in corrugator muscle activity for all solution types from -2500 to 0ms, which indicates that negative affect grew quickly when the solution was emptied into the mouth. The results of Figure 4-13(d) illustrated that most of the solution types were able to be discriminated when the solution samples were emptied into the mouth, and the mouse button was clicked. Specifically, the pairs of water control and the bitter-medium solution, water control and the bitter-high solution, the bitter-low and bitter-medium solutions, the bitter-low and bitter-high solutions, and the bitter medium and bitter-high solutions were differentiated by the corrugator muscle during the period -500 to 0ms, -2000 to 0ms, -1000 to 0ms, -2500 to 0ms, and -1500 to 0ms, respectively (all $p<.05$).

The negative affect evoked by bitter-high liquids continued developing at the beginning of the swirling of the liquid and reached a peak at 500ms, but after that time point, corrugator activity decreased gradually over time. However, for the bitter-medium liquid, the bitter-low liquid and water control, their EMG activities in the corrugator muscle always kept a stable trend when liquids were swirled. Interestingly, water control and the bitter-low liquid was only able to be discriminated for a very short time from 7000 to 7500ms (t_{7000ms} (18) =-2.588, p=0.019; t_{7500ms} (18) =-3.358, p=0.004). The rest of five solution pairs were all able to be differentiated from 0~7500ms (p<.05) (see Figure 4-13 (b) and (e)).

For the thinking phase (see Figure 4-13(c)), a gradually decreasing trend was found in corrugator muscle activity for all liquid types over time. It was found by Figure 4-13(f) that water control and the bitter-low solution were not able to be discriminated whereas the pairs of water control and the bitter-medium solution, water control and the bitter-high solution, and the bitter-low and bitter-high solutions were able to be differentiated by corrugator muscle activity from 0 to 9500ms(all p<.05). The other two solution pairs were the bitter-low and bitter-medium solutions, and the bitter-medium and bitter-high solutions, which were able to be discriminated for most of the time period.

Figure 4-14 (a), (b) and (c) present the dynamic EMG activity in the corrugator muscle of the bitter session for the rating block. Clearly, EMG activity in the corrugator muscle for the rating block presented the same pattern as the tasting block (see Figure 4-13). However, the T-test results were slightly different. Figure 4-14 (d) presents the p value of paired comparisons for the emptying phase, which illustrated that four pairs of the solution samples (including water control and the bitter-medium solution, water control and the bitter-high solution, the bitter-low and bitter-medium solutions, and the bitter-low and bitter-high solutions) were able to be discriminated by the corrugator muscle very quickly but briefly when these solutions were emptied into the mouth. During the swirling phase, the bitter-medium solution was easy to be discriminated by the corrugator muscle from the water control and the bitter-low liquid within

0 to 4500ms, whereas the bitter-high liquid can be differentiated from the water control, the bitter-low liquid and the bitter-medium liquid during the whole swirling period (see Figure 4-14 (e)). It is shown in Figure 4-14 (f) that water control and the bitter-low liquid was only able to be discriminated at two time points for 0 and 6500ms during the thinking phase. The bitter-medium liquid was still discriminated from the water control (0~500ms and 3000~9500ms), the bitter-low liquid (0~500ms and 2500~9500ms) and the bitter-high liquid (1000~5000ms and 6500~9500ms) by the corrugator muscle. The bitter-high liquid can be discriminated from the water control and the bitter-low solution during the whole thinking phase.

Table 4-11 presents the ANOVA results using Concentration (Water, Low, Medium, and High) * Timing (every 500ms during each phase) and the results were split into different phases and blocks. For the tasting block, the emptying and thinking phases were both found to be influenced not only by the different concentration levels of bitter stimuli but also by the timing. Additionally, the dynamic corrugator muscle activity with different time points significantly varied with different concentration levels of bitter stimuli. However, during the swirling phase, different concentration levels of bitter stimuli and timing placed the main effect on corrugator muscle activity, respectively. Turning to the rating block, no distinct pattern was able to be found in the corrugator muscle during the emptying phase. The different concentration levels of bitter stimuli influenced the dynamic corrugator muscle activity during both swirling and thinking phases. Additionally, time was another main effect influencing corrugator muscle activity during the thinking phase.

Corrugator Activity - Bitter Session – Tasting Block

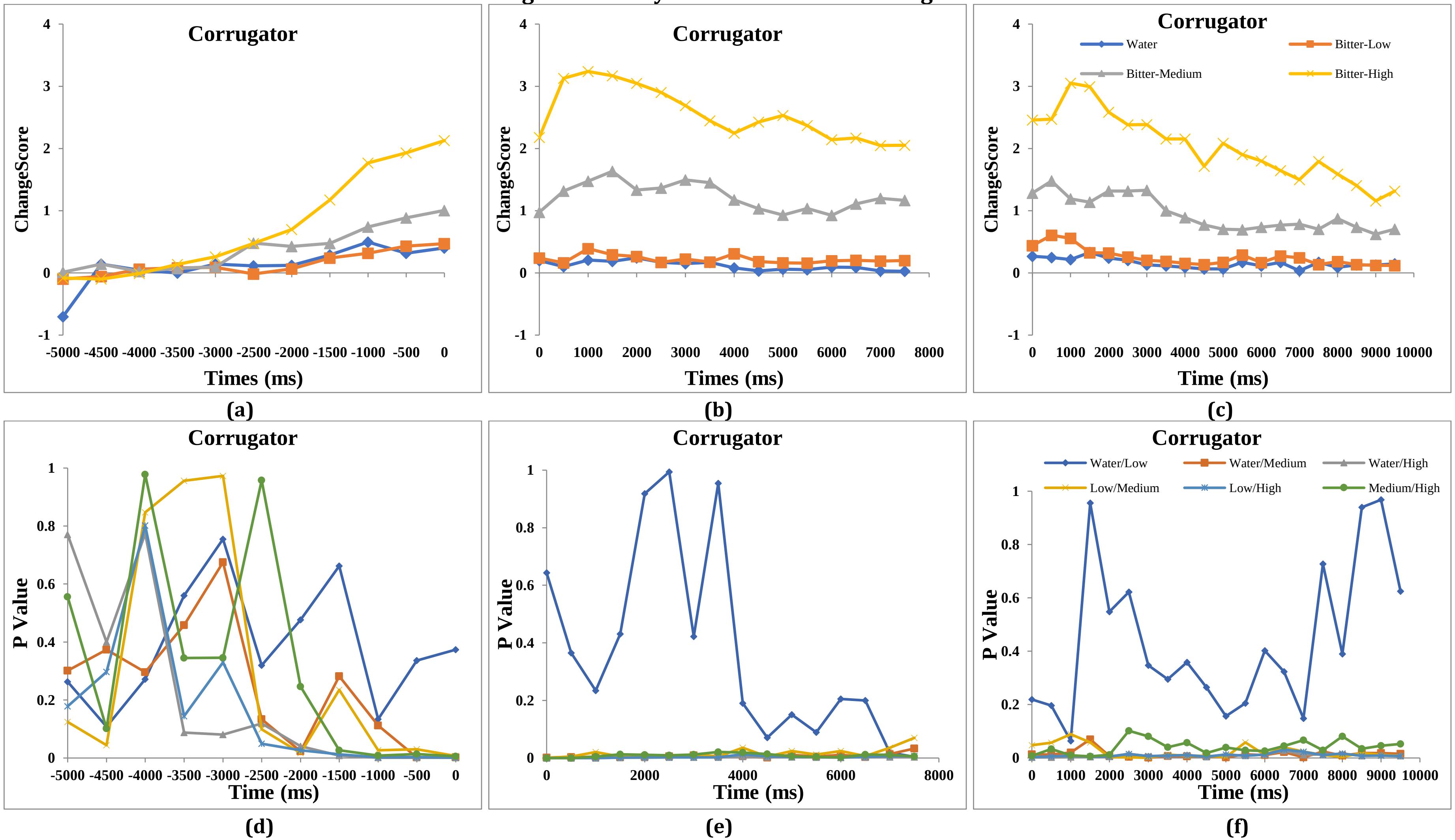


Figure 4-13 Dynamic corrugator activity and P value of T-test result of emptying (a)(d), swirling(b)(e) and thinking (c)(f) phases for the tasting block

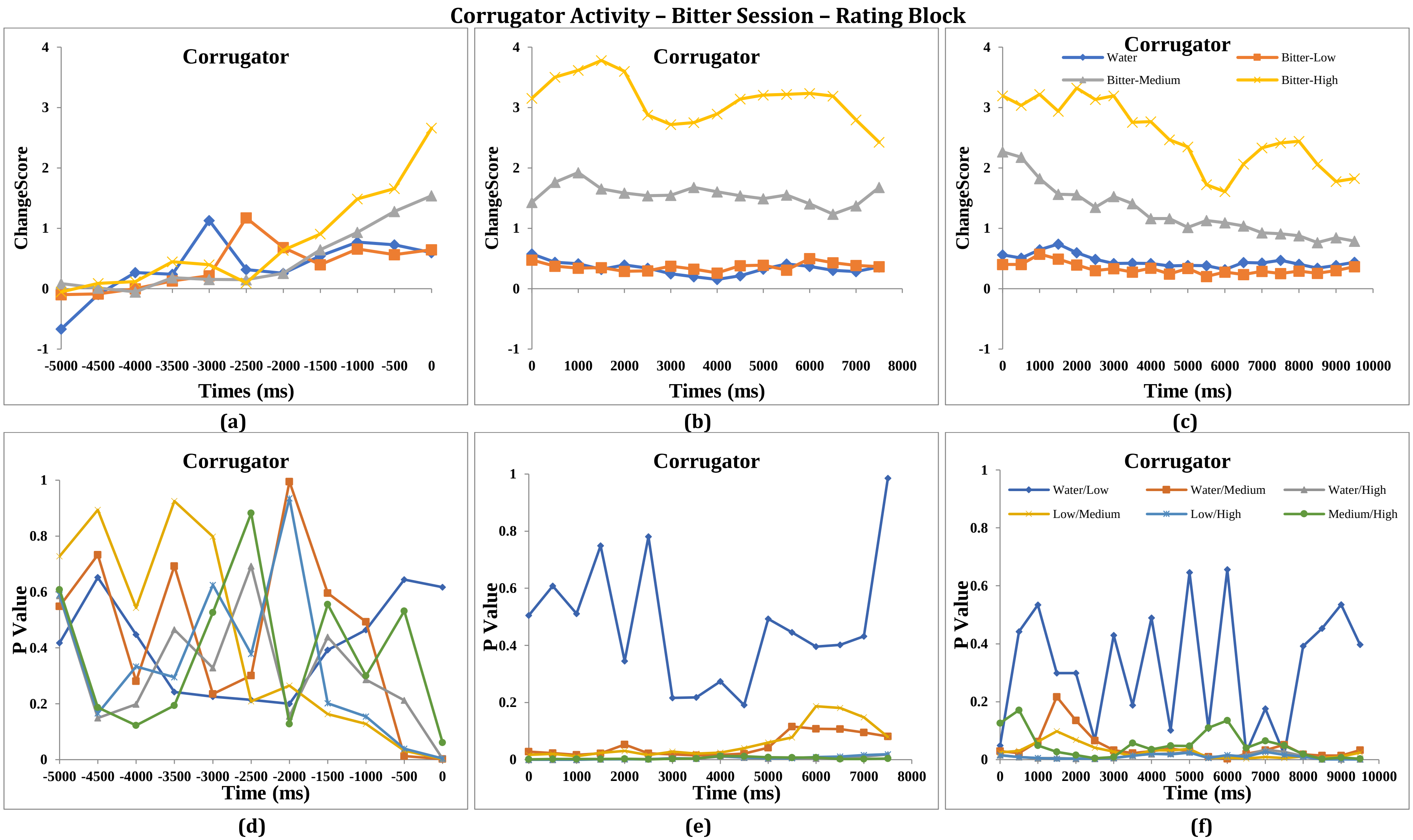


Figure 4-14 Dynamic corrugator activity and P value of T-test result of emptying (a)(d), swirling(b)(e) and thinking (c)(f) phases for the rating block

4.4.2.3.2 Dynamic EMG activity in the levator muscle for the tasting and rating blocks of the bitter session

Figure 4-15 and Figure 4-16 (a), (b), (c) present the dynamic EMG activity in the levator muscle in the bitter sessions for the tasting and rating blocks, respectively. Because it is a negative affect muscle, the levator muscle was reported to present the same pattern of EMG activity as the corrugator muscle for both the tasting and rating blocks. The bitter-high solution still evoked the strongest EMG activity in the levator muscle than any other solution types, whereas the least and similar levator muscle activity was found in water control and bitter-low liquids. It is noted that more EMG activity in the levator muscle was evoked by all solution types than corrugator, zygomaticus and masseter muscles because the levator muscle was not only a negative affect muscle but it was also used as a functional muscle when emptying and swirling the liquid sample (see Figure 4-15 and Figure 4-16 Y-axis scale value).

From Figure 4-15 and Figure 4-16(a), during the emptying phase, EMG activity in the levator muscle evoked by four solution types was reported to increase gradually after -2500ms. For the tasting block, their levator muscle activity reached a peak at -1000ms and then dropped again. For the rating block, EMG activity in the levator muscle evoked by water control and the bitter-low solution reached a peak at -1500ms. -1000ms was the EMG activity peak for the bitter-medium liquid and the bitter-high solution. After those time points, a decreasing trend was found. At the beginning of the swirling phase for both the tasting and rating blocks (Figure 4-15 and Figure 4-16(b)), EMG activity in the levator muscle evoked by all solution types increased slightly and then kept a stable decreasing trend. Specifically, for the tasting block, the levator muscle evoked by water control, bitter-low, bitter-medium and bitter-high solutions were found to present the maximum contraction on 2000, 1500, 2000, and 2500ms, respectively. After that, their levator activities dropped slightly, and all kept a stable trend. As with the tasting block, after maximum levator muscle contraction being presented on 1500ms for water control, 1000ms for the bitter-low liquid, 3000ms for the bitter-medium liquid and 1000ms for the bitter-high liquid, a stable and decreasing trend appeared in the rating block. After spitting out the liquid samples, a gradual decreasing EMG activity pattern in the levator muscle was able to be found by four solution types for the both rating and tasting blocks during the thinking phase (see Figure 4-15 and Figure 4-16 (c)).

The paired comparison result for the tasting block will be discussed first (see Figure 4-15 (d), (e), and (f)). This data is all based on df =18, and a critical t value to give a cutoff at p <.05. No distinct pattern was able to be found between water control and the bitter low liquid during three phases. The bitter-high solution was able to be discriminated by the levator muscle from water control, bitter-low and bitter-high liquids after -500ms of the emptying phase (emptying and clicking the mouse) until the end of the thinking phase. The bitter-medium solution can be differentiated from water control and bitter-low solution at some time periods, such as -500~0ms for the emptying phase, 0~5500ms for the swirling phase and 2500~9500 for the thinking phase, respectively.

The result of paired comparison of the rating block is listed in Figure 4-16(d), (e), and (f). During the emptying phase, water control was able to be discriminated by the levator muscle from bitter-medium and bitter-high liquids from -1000 to 0ms. Additionally, the bitter-high solution was able to be discriminated by the levator muscle from bitter-low solution and from bitter-medium solution even earlier (-1500ms~0ms), which indicates that these liquids can be differentiated when they are emptied into the mouth. During the swirling phase (see Figure 4-16 (e)), the bitter-high liquid was still able to be discriminated from water control and bitter-low liquids for eight swirling seconds. Additionally, the bitter-medium concentration level was able to be discriminated from water control (0~1000ms, 3000~400ms, and 6500ms), bitter-low liquids (0~500ms, 1500, 3000, 4000, and 5000~5500ms) and bitter-high liquids (0~2500ms and 4000~7500ms) at some time points. There was no doubt that bitter-high liquids were still able to be differentiated from water control and bitter-low liquids during the whole thinking phase (see Figure 4-16 (f)). Bitter-medium liquids can be differentiated from water control, bitter-low liquids, and bitter-high liquids for most of the thinking phase.

The same ANOVA results were able to be found on both the tasting and rating blocks (see Table 4-11). Different concentration levels of bitter stimuli, timing course and concentration*timing all placed main effects on dynamic levator muscle activity during the emptying phase, whereas bitter stimuli concentration levels and timing were two influencing factors of levator muscle activity during the swirling and thinking phases.

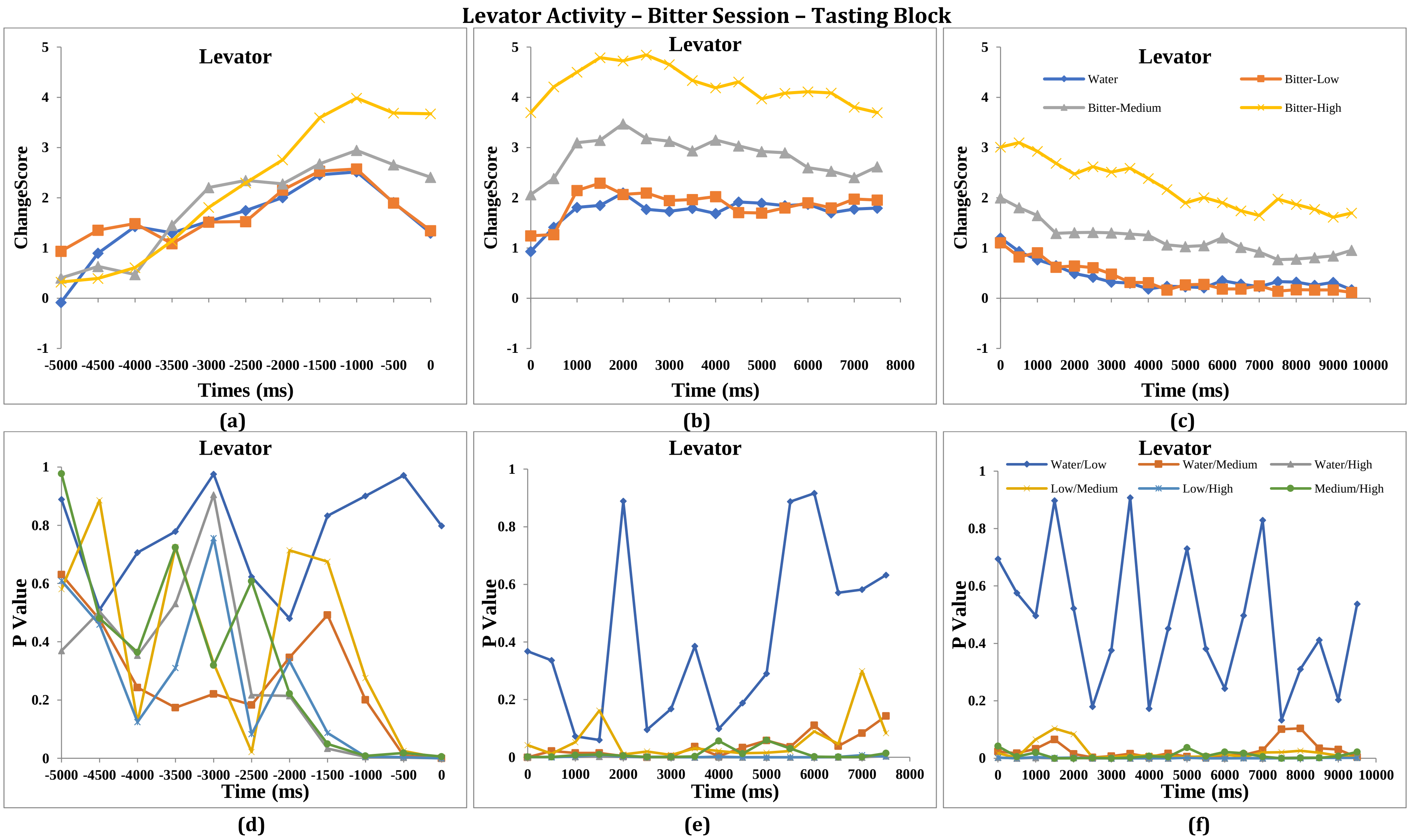


Figure 4-15 Dynamic levator activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

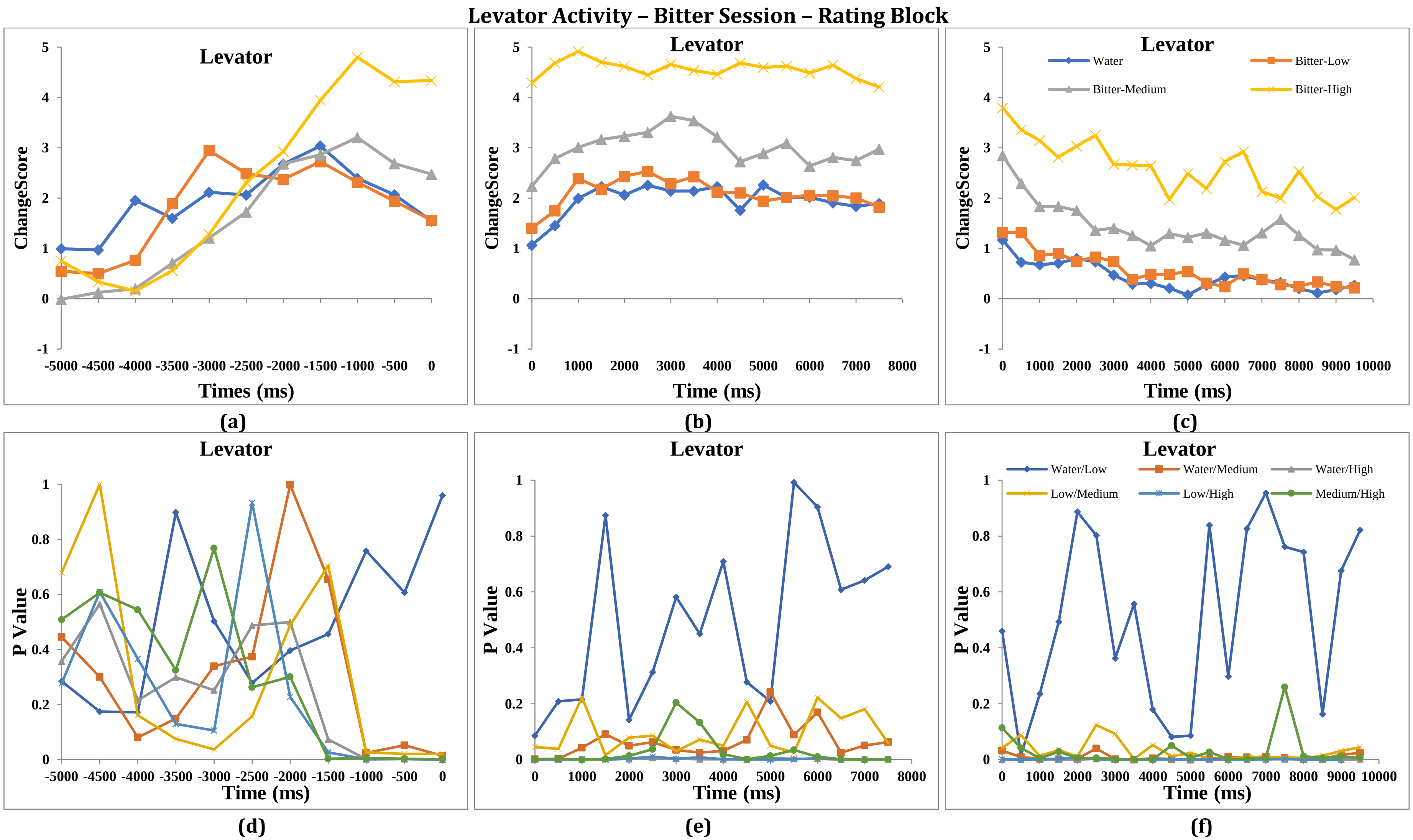


Figure 4-16 Dynamic levator activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

4.4.2.3.3 Dynamic EMG activity in the zygomaticus muscle for the tasting and rating blocks of the bitter session

Figure 4-17 (a), (b) and (c) show the dynamic EMG activity in the zygomaticus muscle for the tasting block. There is no doubt that the bitter-high solutions still evoked the strongest EMG activity in the zygomaticus muscle, whereas the least zygomaticus muscle activity was found in the water controls. More zygomaticus muscle contractions were made when tasting the bitter-medium solutions than the bitter-low solutions.

Specifically, from Figure 4-17 (a), it can be seen that after -2500ms, EMG activity in the zygomaticus muscle increased with the timing. Furthermore, at 0ms (when the mouse was clicked), more zygomaticus muscle contractions were found on the bitter-medium and bitter-high liquids than water control and the bitter-low liquids. At the beginning of the swirling phase (Figure 4-17 (b)), a slight and brief increasing trend was able to be found in all liquid samples, and their EMG activity in the zygomaticus muscle reached a peak at 2000ms for the bitter-high liquids and 1000ms for the other solutions. After that, the EMG activity in the zygomaticus muscle kept a stable and decreasing trend until the end of the swirling phase. During the thinking phase (see Figure 4-17(c)), EMG activity in the zygomaticus muscle evoked by all solution types tended to decrease slightly and gradually within 10 seconds.

According to Figure 4-17 (d), (e) and (f) for the tasting block, the bitter-high solution was able to be discriminated from the water control, the bitter-low liquid, and the bitter-medium liquid by the zygomaticus muscle during most of the time in all three phases. The other solution type pairs were only able to be differentiated by zygomaticus muscle activity at some time points.

The result of ANOVA (Table 4-11) illustrates that for the tasting block, during the swirling and thinking phases, different concentration levels of bitter stimuli and timing course were two main influences on the zygomaticus muscle activity($p<.05$). No distinct pattern was able to be found during the emptying phase.

Dynamic EMG activity in the zygomaticus muscle for the rating block is shown in Figure 4-18 (a), (b), and (c). The strongest EMG activity was still evoked by the bitter-high solution, but water control, the bitter-low and bitter-medium solutions were found to present similar EMG activity in the zygomaticus muscle during the emptying, swirling and thinking phases for the rating block.

During the emptying phase (Figure 4-18 (a)), the EMG activity in the zygomaticus muscle increased with timing after -1500ms and zygomaticus activities ranked from high to low with the bitter-high solution, bitter-medium solution, bitter-low solution and water control at 0ms. The result of Figure 4-18 (d) illustrates that zygomaticus muscle activity can differentiate the bitter-high liquid from water control, the bitter-low liquid and the bitter-medium liquids for 0ms, 0ms, and -1500~0ms, respectively (p<.05). There were main influencing factors, including the different concentration levels of bitter stimuli ($F_{\text{Concentration}}$ (3, 15) =7.78, p<0.001, η_p^2 =0.66) and timing course (F_{Timing} (10, 50) =6.68, p<0.001, η_p^2 =0.63) of zygomaticus muscle activity during the emptying phase (see Table 4-11).

When the liquids were swirled in the mouth (Figure 4-18(b)), EMG activity in the zygomaticus muscle evoked by the bitter-high liquid increased significantly from 0 to 1500ms, and reached a peak at 1500ms. However, after 1500ms, zygomaticus activity showed a decreasing trend. Zygomaticus muscle activity evoked by water control, the bitter-low and bitter-medium liquids also increased gradually at the beginning of the swirling period, but after 2000ms for water control, 1000ms for the bitter-low liquid, and 1500ms for the bitter-medium liquid, their muscle activities all maintained stability until the end of swirling. It was found by Figure 4-18(e) that the bitter-high solution was able to be discriminated by the zygomaticus muscle from water control within 0~1500ms and 3500~7000ms, from the bitter-low liquid within 0~7500ms, and from the bitter-medium liquid within 0~5500ms and 6500~7000ms. However, water control and the bitter-low liquid were only able to be differentiated at 5000ms. No distinct pattern could be found in other paired samples. The results in Table 4-11 illustrate that only different concentration levels of bitter stimuli influenced zygomaticus muscle activity significantly ($F_{Concentration}$ (1.79,32.16)=7.23, p<0.001, η_p^2 =0.29).

During the thinking phase (Figure 4-18(c)), there was a gradually decreasing pattern of zygomaticus muscle activity for all solution types. More zygomaticus muscle contraction was found in the bitter-high solution and the other solution types presented the same activity. During the thinking period, zygomaticus muscle activity was able to discriminate the bitter-high liquid from the water control (within 0~6000ms and 7000~9500ms), from the bitter-low liquid (within 1000~3500ms and 5000 ~9500ms) and the bitter-medium liquid (within 1500~7000ms and 8000~9500ms) (see Figure 4-18 (f)). The result of Table 4-11 illustrates that during the thinking phase, different concentration levels of bitter stimuli ($F_{Concentration}$ (4.19, 75.42) =6.62, p<0.001, η_p^2=0.27) and timing course (F_{Timing} (1.84, 33.07) =7.32, p<0.001, η_p^2=0.29) were two significant influencing factors on EMG activity in the zygomaticus muscle.

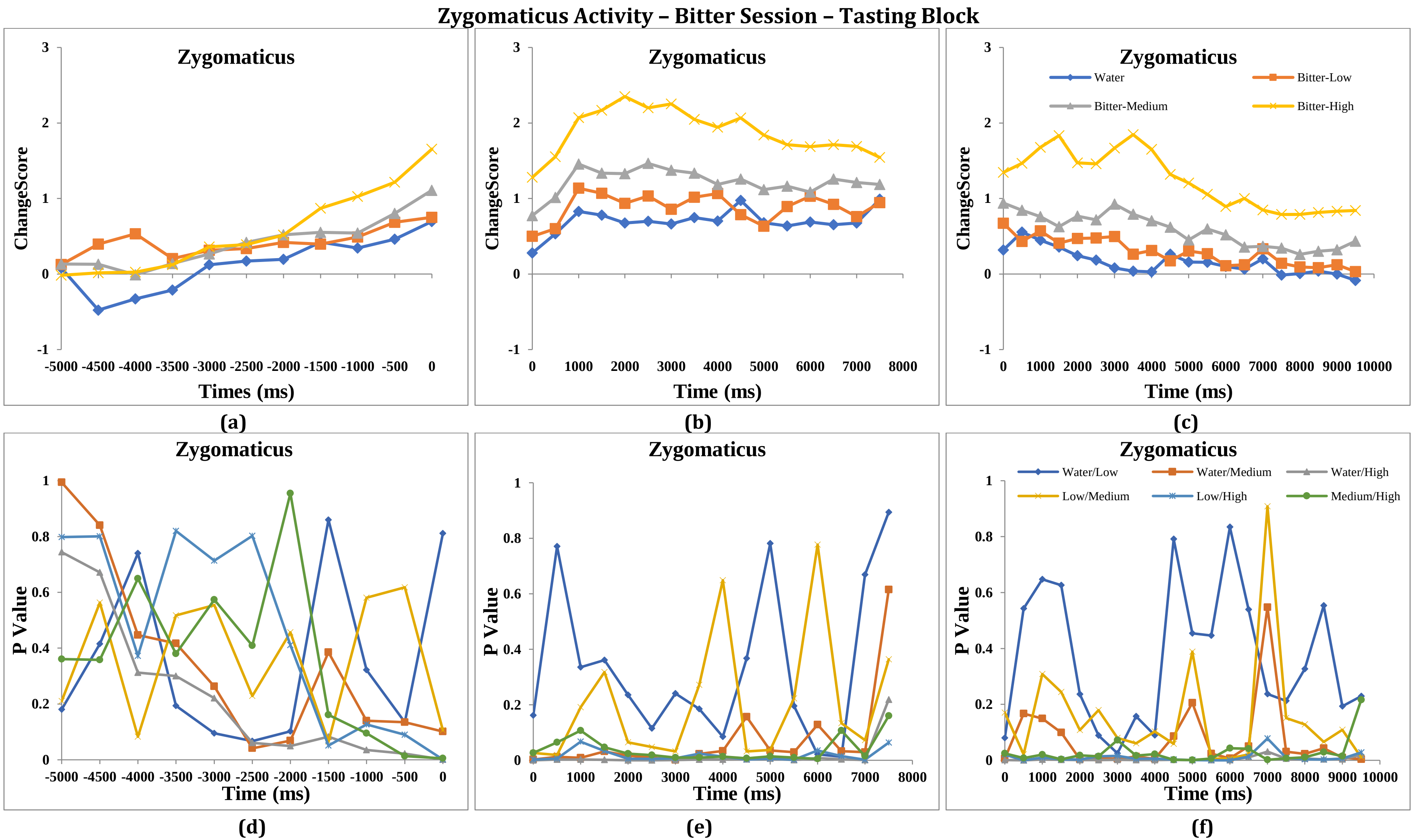


Figure 4-17 Dynamic Zygomaticus activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

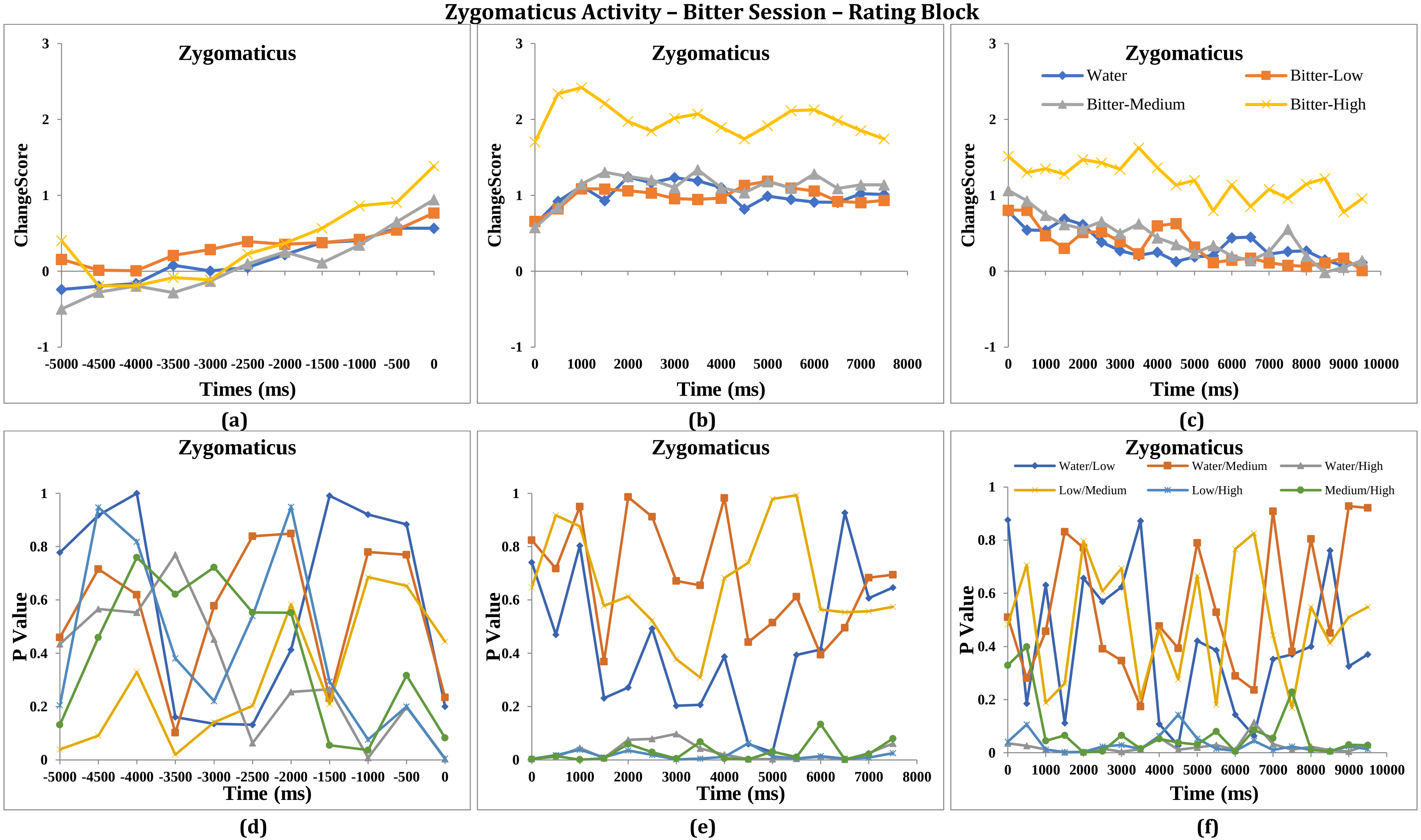


Figure 4-18 Dynamic Zygomaticus activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

4.4.2.3.4 Dynamic EMG activity in the masseter muscle for the tasting and rating blocks of the bitter session

Figure 4-19 (a), (b), and (c) presents the dynamic masseter muscle activity of the bitter session for the tasting block.

It can be seen from Figure 4-19 (a) that masseter muscle activity evoked by the bitter-high and bitter-low liquids reached a peak at -1000ms during the emptying phase, which indicated that participants opened their jaws to empty the liquid sample. However, no distinct pattern could be found on the bitter-medium liquid and water control. At 0ms (the moment of clicking the mouse), more EMG activity in the masseter muscle was reported with the increase of concentration levels of bitter stimuli, however water control still presented the least masseter muscle activity. During the emptying phase (Figure 4-19 (d)), the bitter-high liquid was found to be discriminated by the masseter muscle from the bitter-low and bitter-medium liquids at 0ms ($t_{\text{Low-High}}(18)= -2.274$, $p=0.035$; $t_{\text{Medium-High}}(18)=-2.448$, $p=0.025$). The ANOVA result (see Table 4-11) shows that ignoring other factors, masseter muscle activity only varied with timing ($F_{\text{Timing}}(10,50)=3.02$, $p=0.01$, $\eta_p^2=0.38$).

During the swirling period (see Figure 4-19 (b)), more masseter muscle contraction was found with the more concentrated bitter stimuli, whereas the least EMG activity was still presented by water control. The EMG activity in the masseter muscle evoked by four solution types displayed the same pattern, which showed that their masseter muscle activity increased at the beginning of the swirling period and reached a peak at 2000ms for the bitter-high liquid, 1500ms for the bitter-medium and bitter-low liquids, and 1000ms for water control. However, after their peak time points, there was a gradual decrease of their masseter muscle activities until the end of swirling phase. The result of Figure 4-19 (e) shows that water control and the bitter-low liquid was able to be differentiated by the masseter muscle very quickly from 6000 ($t(18)=-2.324$, $p=0.032$) to 6500ms ($t(18)=-2.773$, $p=0.013$). Water control and the bitter-medium liquid can be discriminated at some time points, including 0~1500, 3000~3500, and 6000~7000ms

(p<.05). The bitter-high liquid was able to be differentiated by the masseter muscle from water control (during the whole swirling phase), from the bitter-low liquid (0~500ms and 2000~7000ms), and from the bitter-medium liquid (0ms, 3000~5500ms, and 6500ms). Different concentration levels of bitter stimuli and timing course both influenced the masseter muscle activity significantly ($F_{Concentration}$ (1.47, 26.45) =6.59, p=0.01, η_p^2=0.27; F_{Timing} (2.78, 50.08) =4.36, p=0.01, η_p^2=0.20), which was the same result as in the emptying phase (see Table 4-11).

After spitting out, 10 seconds were provided to think about the taste of the liquid (see Figure 4-19 (c)). More masseter muscle contraction was found for bitter-high liquid than other solution types, but no distinct pattern was found in water control, the bitter-low and bitter-medium liquids because they all evoked similar EMG activity in the masseter muscle. Generally, the masseter muscle activity presented a stable and gradually decreasing trend from 0 to 9500ms. According to the T-test result (see Figure 4-19 (f)), during the thinking phase the bitter-medium liquid was able to be discriminated by the masseter muscle from water control within 2000~4500ms and from the bitter-high liquid within 500~1500, 4500~5000ms and 6500~7000ms (p<0.05). The bitter-high solution can be differentiated from the bitter-low liquid and water control during most of the thinking time except for some time points. The concentration levels of bitter stimuli ($F_{Concentration}$ (1.35, 24.21) =8.76, p<0.001, η_p^2=0.33) and timing ($F_{Concentration}$ (3.77, 67.81) =8.17, p<0.001, η_p^2=0.31) were also the main effects influencing the masseter muscle activity for the tasting block (see Table 4-11).

The dynamic masseter muscle activity for the rating block of the bitter session is presented in Figure 4-20(a), (b), and (c).

It was found from Figure 4-20 (a) that during the emptying phase, EMG activity in the masseter muscle was found to peak at -1000ms for the bitter-high solution, bitter-medium solution and water control, indicating that the masseter muscle was used to open the jaws and empty the solutions, but no distinct pattern was able to be found in the bitter-low liquid. At 0ms (emptying the mouth and clicking the mouse), the strongest EMG activity in the masseter muscle was evoked by the bitter-high liquid, whereas both water control and the bitter-low liquid presented the least masseter muscle activity. During the emptying phase (Figure 4-20 (d)), the bitter-low liquid and bitter-medium solutions were only able to be discriminated by the masseter muscle very briefly from -500 ($t(18) = -2.07$, $p=0.050$) to 0ms ($t(18)=-2.381$, $p=0.029$). The timing course ($F_{Timing}(10, 40) = 6.18$, $p<0.001$, $\eta_p^2=0.61$) and different concentration levels of bitter stimuli ($F_{Concentration}(3, 12)=5.91$, p=0.01, $\eta_p^2=0.60$) were two significant influencing factors on EMG activity in the masseter muscle (see Table 4-11).

During the swirling phase (see Figure 4-20 (b)), more masseter muscle contraction was able to be found with the bitter-high and bitter-medium solutions. Their EMG activities increased from the beginning of the swirling phase and reached peaks at 1500ms and 2000ms, respectively. After that, a gradually decreasing trend was found in both of them. However, for water control and bitter-low solution, they always presented a stable trend during the swirling phase. The result of Figure 4-20 (b) illustrates that water control and the bitter-low liquid was only able to be differentiated at 2500ms ($t(18) = 2.779$, $p=0.012$). Both the bitter-medium and bitter-high liquids can be discriminated by the masseter muscle from water control and the bitter-low liquid at some time points ($p<0.05$). The masseter muscle can distinguish the difference between the bitter-medium and bitter-high liquids only at 0ms ($t(18)=-2.538$, p=0.019). Only different concentration levels of bitter stimuli were found to influence the masseter muscle activity slightly ($F_{Concentration}(1.15, 20.60) = 4.31$, $p=0.05$, $\eta_p^2=0.19$) (see Table 4-11).

The EMG activity in the masseter muscle during the thinking phase is shown in Figure 4-20 (c). Generally, a stable and gradually decreasing pattern of EMG activity in the masseter muscle was able to be found in all solution types. The bitter-high solution still evoked the strongest masseter muscle activity during 10 seconds, whereas no distinct pattern was able to be found with the other solution types (water, bitter-low liquid and bitter-medium liquid) owing to their similarity of EMG activity in the masseter muscle. The result of T-test (Figure 4-20 (f)) illustrates that during the thinking phase, the masseter muscle was not able to discriminate the difference between water control, the bitter-low liquid and the bitter-medium liquids continuously other than at some time points. However, the bitter-high solution was able to be differentiated by the masseter muscle from the bitter-low solution (500~2000ms, 3000~3500ms, and 8000~9500ms) and bitter-medium solution (8000~9000ms) continuously. Different concentration levels of bitter stimuli ($F_{\text{Concentration}}(1.46, 26.30)=5.70$, $p=0.02$, $\eta_p^2=0.24$) and the timing course, ($F_{\text{Timing}}(3.80, 68.32)=4.49$, $p<0.001$, $\eta_p^2=0.20$) both influenced EMG activity in the masseter muscle significantly during the thinking phase (see Table 4-11).

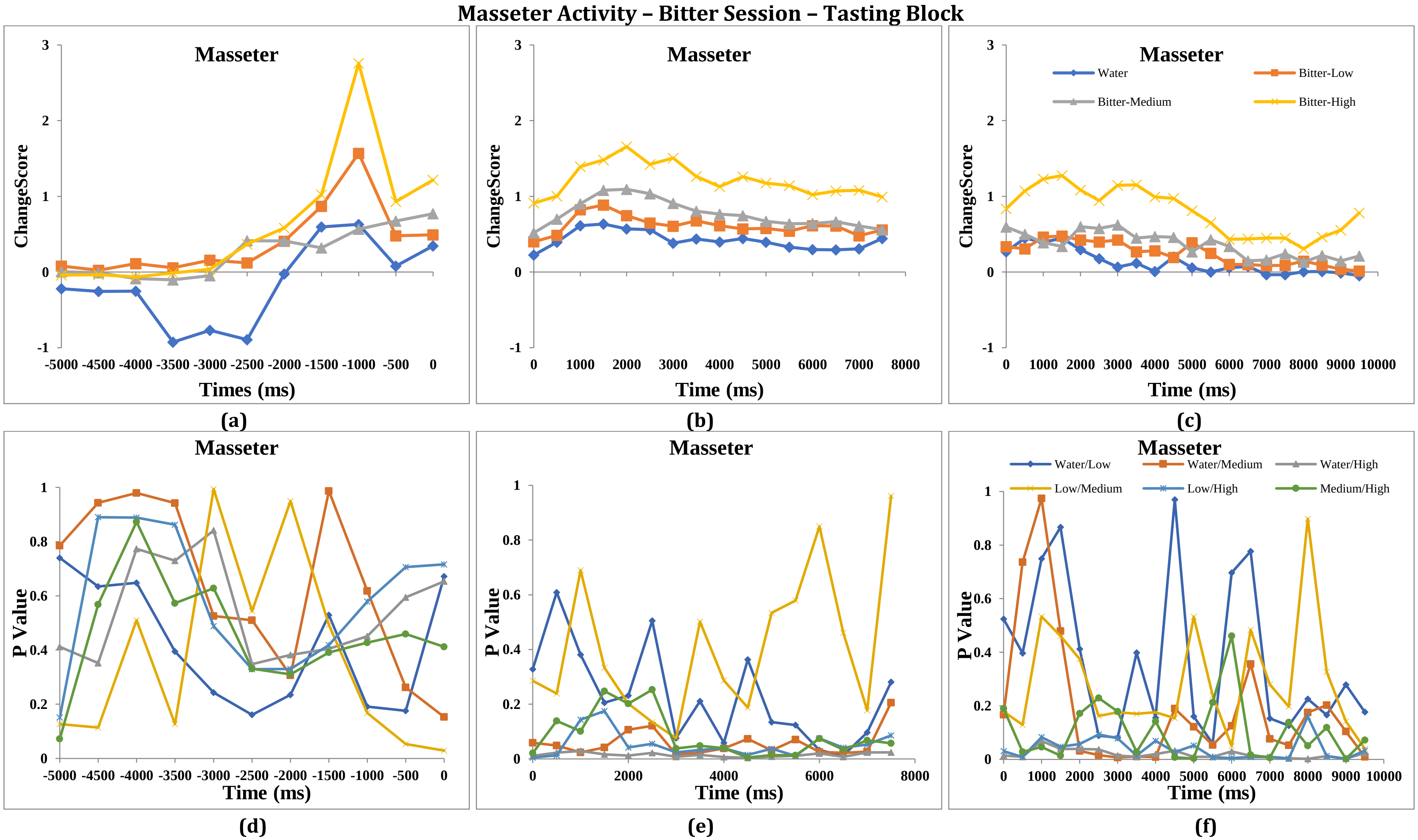


Figure 4-19 Dynamic Masseter activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

Figure 4-20 Dynamic Masseter activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

Table 4-11 Repeated measures ANOVA results of bitter session for the tasting and rating blocks

Within subjects factor	Bitter Session																							
	Tasting Block												Rating Block											
	Emptying Phase				Swirling Phase				Thinking Phase				Emptying Phase				Swirling Phase				Thinking Phase			
	Df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2
Corrugator																								
Concentration	1.47	7.03	0.00	0.58	1.17	14.46	0.00	0.45	1.07	9.65	0.01	0.35	1.08	3.36	0.14	0.46	1.20	11.55	0.00	0.39	1.14	10.02	0.00	0.36
Timing	2.05	6.47	<0.001	0.56	3.11	3.06	0.03	0.15	2.85	6.84	0.00	0.28	1.14	0.10	0.10	0.51	3.14	1.08	0.37	0.06	2.00	4.56	0.02	0.20
Concentration*Timing	2.08	3.21	<0.001	0.39	5.08	1.71	0.14	0.09	3.95	2.37	0.06	0.12	1.31	2.58	0.17	0.39	4.75	1.02	0.41	0.05	3.33	1.48	0.23	0.08
Zygomaticus																								
Concentration	1.18	2.95	0.14	0.37	1.63	9.97	0.00	0.37	1.63	15.44	<0.001	0.48	3.00	7.78	0.00	0.66	1.79	7.23	0.00	0.29	1.84	7.32	0.00	0.29
Timing	1.25	3.07	0.13	0.38	3.94	5.52	0.00	0.25	4.95	8.07	<0.001	0.32	10.00	6.68	<0.001	0.63	3.36	1.50	0.22	0.08	4.19	6.62	<0.001	0.27
Concentration*Timing	1.19	1.67	0.25	0.25	4.62	1.35	0.25	0.07	5.45	1.56	0.18	0.08	30.00	1.18	0.26	0.23	4.79	0.84	0.52	0.05	4.65	1.13	0.35	0.06
Levator																								
Concentration	3.00	9.42	0.00	0.65	1.53	16.65	<0.001	0.48	1.26	20.51	<0.001	0.55	3.00	5.72	0.01	0.59	1.51	14.87	<0.001	0.45	1.43	21.90	<0.001	0.55
Timing	10.00	4.11	<0.001	0.45	3.14	6.58	0.00	0.27	2.41	10.04	<0.001	0.31	10.00	5.87	<0.001	0.59	4.06	3.13	0.02	0.15	3.01	8.38	<0.001	0.32
Concentration*Timing	30.00	1.91	0.01	0.28	7.04	1.18	0.32	0.06	6.92	1.08	0.38	0.06	30.00	2.48	<0.001	0.38	6.69	0.70	0.62	0.04	4.62	1.25	0.30	0.07
Masseter																								
Concentration	3.00	0.88	0.48	0.15	1.47	6.59	0.01	0.27	1.35	8.76	0.00	0.33	3.00	5.91	0.01	0.60	1.15	4.31	0.05	0.19	1.46	5.70	0.02	0.24
Timing	10.00	3.02	0.01	0.38	2.78	4.36	0.01	0.20	3.77	8.17	<0.001	0.31	10.00	6.18	<0.001	0.61	2.73	1.86	0.15	0.09	3.80	4.49	0.00	0.20
Concentration*Timing	30.00	0.83	0.72	0.41	5.25	0.71	0.62	0.04	5.33	1.27	0.28	0.07	30.00	0.58	0.96	0.13	3.06	1.55	0.21	0.08	3.09	1.09	0.37	0.58

4.4.2.4 Dynamic EMG activity responses to the sweet stimuli for the tasting and rating blocks

4.4.2.4.1 Dynamic EMG activity in the corrugator muscle for the tasting and rating blocks of the sweet session

Figure 4-21 (a), (b) and (c) present the dynamic corrugator muscle activity of the sweet session for the tasting block. Generally, in contrast to the bitter session, less corrugator muscle contraction was made by the sweet stimuli. The sweet-high solution exhibited the strongest corrugator muscle activity from the emptying to the thinking phases, whereas the other solution types including water control, the sweet-low solution and the sweet-medium solution presented similar EMG activity in the corrugator muscle.

It can be seen from Figure 4-21 (a) that during the emptying phase, the strongest corrugator muscle activity was evoked by the sweet-high liquid, which increased gradually to a peak at 0s (clicking the mouse after emptying the sample into the mouth). The other solution types presented a stable trend in EMG activity in the corrugator muscle. Interestingly, more corrugator muscle activity was found on the water control at 0s than the sweet-low liquid and the sweet-medium liquid. The results of paired comparisons (Figure 4-21 (d)) illustrate that the water control was able to be discriminated by the corrugator muscle from the sweet-medium liquid and sweet-high liquids only at 0ms ($t_{\text{Water-Medium}}(18)=2.245$, $p=0.038$) and -500ms ($t_{\text{Water-High}}(18)=-2.242$, $p=0.038$), respectively. However, the corrugator muscle can differentiate the sweet-high liquid from the sweet-low liquid and sweet-medium liquids very quickly from -500~0ms ($p<.05$). No distinct pattern was able to be found in the relationship between concentration levels of sweet stimuli, timing and muscle activity (Table 4-12).

During the swirling phase (Figure 4-21 (b)), more EMG activity in the corrugator muscle evoked by the sweet-high liquid was able to be found than by the other solution types, whereas similar EMG activity of the corrugator muscle was reported on water control, the sweet-low liquid and sweet-medium liquid. Additionally, their corrugator muscle activity all tended to be stable. Only the sweet-high liquid was able to be discriminated by the corrugator muscle from water control (within 1000~2500ms and 7500ms), the sweet-low liquid (within 2000, 2500, and 6000ms) and the sweet-medium liquid (at 2500ms) (p<.05). No distinct pattern was found on the other solution types (see Figure 4-21 (e)).

During the period of thinking about the taste (see Figure 4-21 (c)), corrugator muscle activity presented a stable and then gradual decreasing trend for the sweet-high liquid, whereas the other solution types exhibited similar EMG activity in the corrugator muscle by keeping a stable trend from 0 to 9500ms. It can be seen from Figure 4-21 (f) that the sweet-high liquid was only able to be discriminated by the corrugator muscle from the sweet-low liquid and sweet-medium liquid at some time points (2500~3000ms for sweet low liquid and 2500~3500ms for sweet medium liquid). No distinct pattern was able to be found in the relationship between sweet stimuli concentration, timing and corrugator muscle activity during the whole tasting block (Table 4-12).

Figure 4-22 (a), (b), and (c) show the EMG activity in the corrugator muscle for the sweet session of the rating block. It can be seen from Figure 4-22 (a) that the sweet-high liquid evoked the strongest corrugator muscle activity during the emptying phase, furthermore its muscle activity increased slightly over the time. However, similar EMG activity in the corrugator muscle was found for water control, the sweet-low liquid and the sweet-medium liquid, also presenting a stable trend when these liquids were emptied. Similar corrugator activity directly resulted in the indiscrimination between liquid samples (see Figure 4-22 (d)). Only the sweet-high liquid was able to be discriminated by the corrugator muscle from water control (-1000~0ms), the sweet-low liquid (-1000~0ms) and the sweet-medium liquid (-3000ms and -2000~0ms) (p<.05).

During the swirling phase (see Figure 4-22 (b)), more corrugator muscle contraction was found for the sweet-high liquid than the other solution types; furthermore, similar EMG activity in the corrugator muscle was found for water control, the sweet-low liquid, and sweet-medium liquids. Regardless of the solution types, corrugator muscle activity always kept a stable pattern. Fewer time points were discriminated by the corrugator muscle during the swirling phase (see Figure 4-22 (e)). Specifically, the corrugator muscle was only able to distinguish the sweet-high liquid from water control at 0, 500, 4500, 6500~7000ms, the sweet-low liquid at 500 and 1500ms, and the sweet-medium liquid at 0 and 7000ms (p<.05).

For the thinking phase (Figure 4-22 (c)), similar EMG activity in the corrugator muscle was presented by all solution types. No distinct pattern was able to be found. From Figure 4-22 (f), it can be seen that the p value looks messy. Only the time period 9000~9500ms was able to be discriminated by the corrugator muscle from the sweet-medium liquid to the sweet-high liquid (t_{9000} (18)=-2.817, p=0.042; t_{9500}(18)=-2.627, p=0.017).

The result of ANOVA (see Table 4-12) shows that no significant relationship was found between the concentration levels of sweet stimuli, timing and the corrugator muscle activity in the rating block.

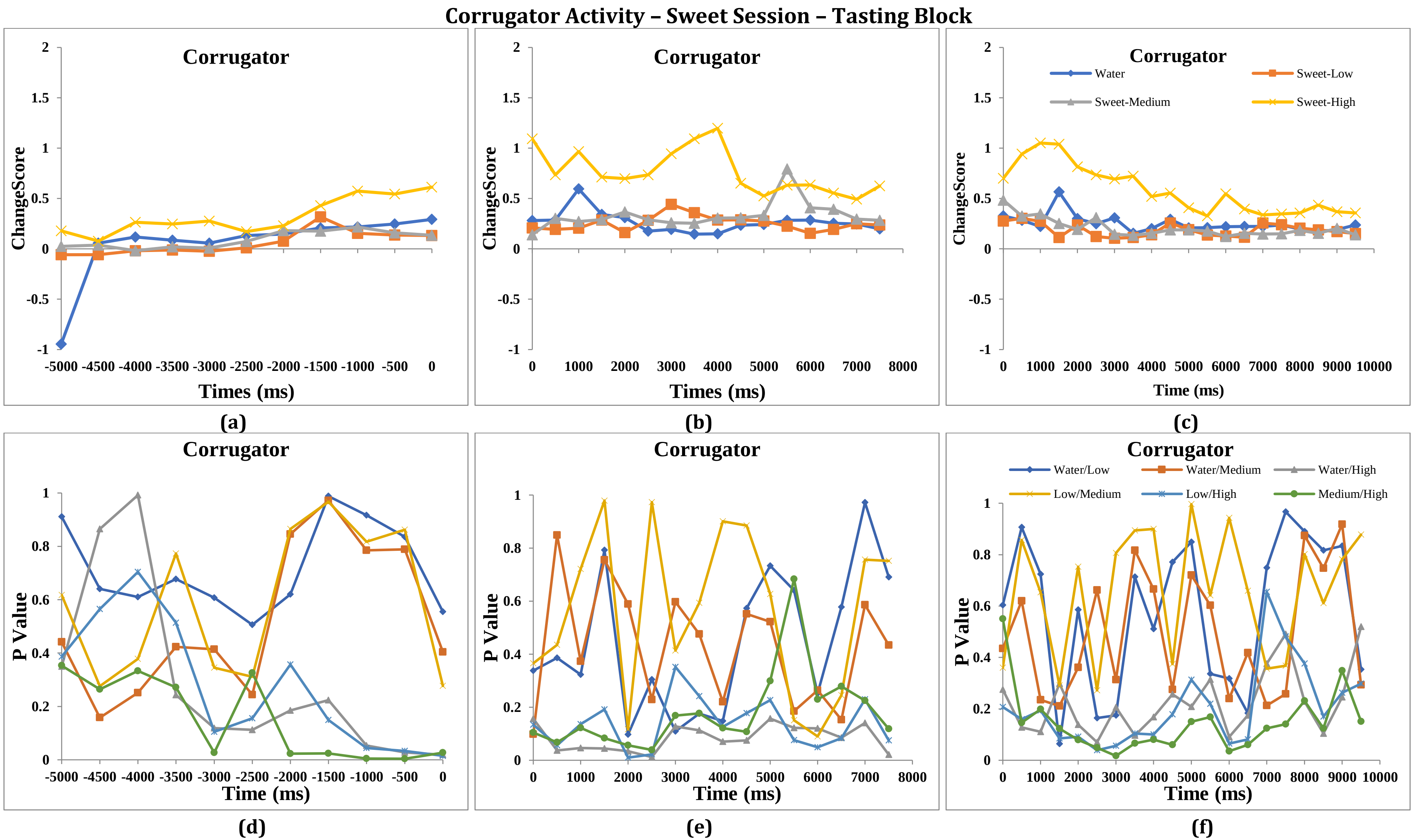


Figure 4-21 Dynamic corrugator activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

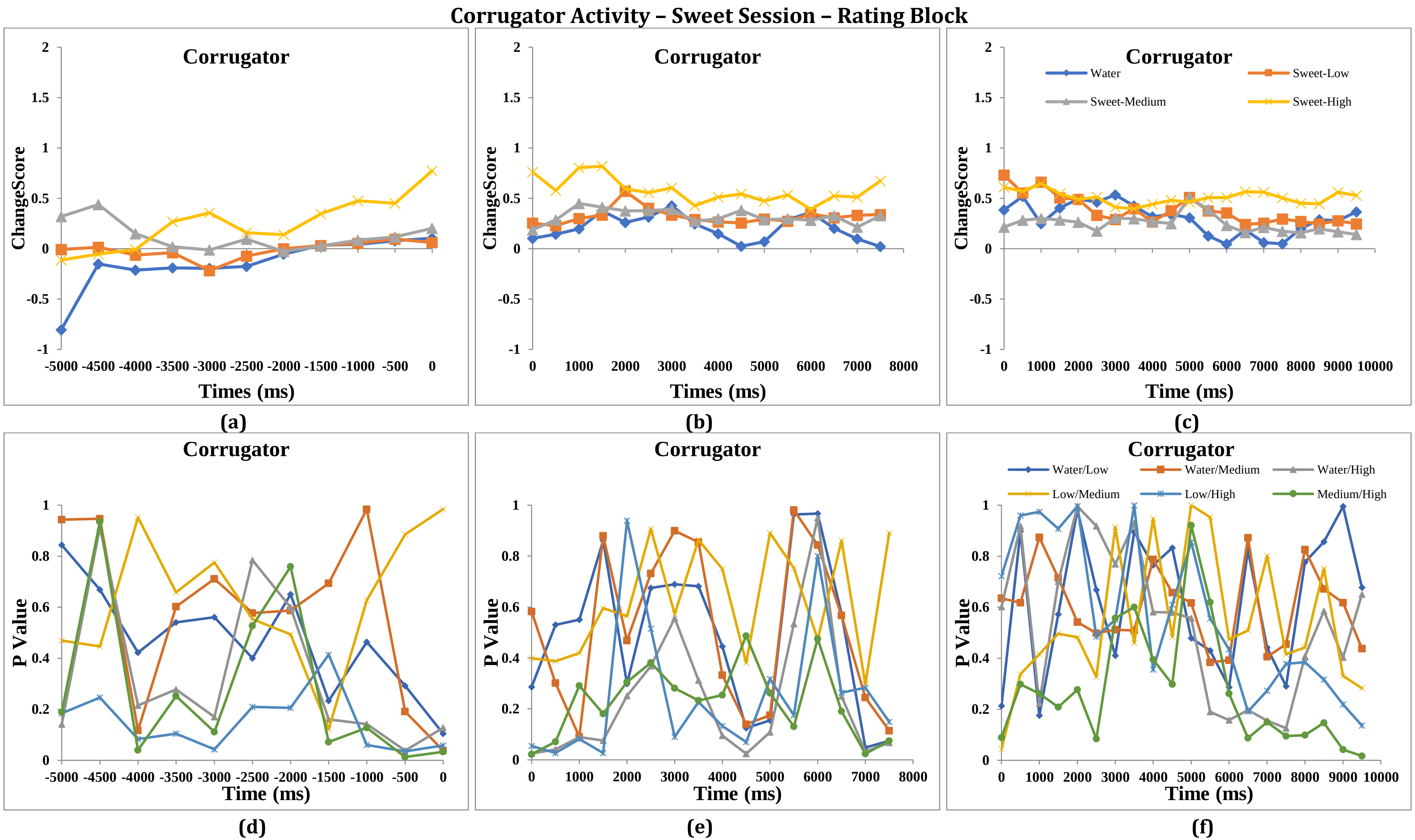


Figure 4-22 Dynamic corrugator activity and *p* value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

4.4.2.4.2 Dynamic EMG activity in the levator muscle for the tasting and rating blocks of the sweet session

Figure 4-23 and Figure 4-24 (a), (b), and (c) show dynamic EMG activity in the levator muscle for the sweet session during the emptying, swirling, and thinking phases for the tasting and rating blocks. It is noted that more EMG activity in the levator muscle was found in the sweet session for both the tasting and rating blocks than for the corrugator, zygomaticus and masseter muscles.

It can be seen from Figure 4-23 (a), (b), and (c) that during the three different phases, the strongest levator muscle activity was still evoked by the sweet-high liquid, whereas the least EMG activity in the levator muscle was found for water control and the sweet-low liquid.

During the emptying phase (see Figure 4-23 (a)), EMG activity in the levator muscle evoked by all solution types increased gradually over time and reached a peak at -2000ms for the sweet-medium liquid, and -1500ms for the other solution types, indicating that the levator muscle was used as a functional muscle at that time point. However, after their peak time points, their levator muscle activities all decreased over time. At 0ms (clicking the mouse after emptying the mouth), more levator activity was found in the sweet-high liquid, while the other solution types presented similar EMG activity. According to a set of paired comparisons (see Figure 4-23 (d)), during the emptying phase, the sweet-high liquid was able to be discriminated by the levator muscle from water control (within -1000~-1500ms), the sweet-low liquid (within -4000~-3500, -1000~-500ms), and the sweet-medium liquid (at -4000, -3500, and -1000ms). Table 4-12 shows that levator muscle activity over the time during the emptying phase varied for different concentration levels of sweet stimuli ($F_{\text{Concentration*Timing}}$ (30, 39.64)=1.68, p=0.02, η_p^2=0.16). Additionally, the main influencing factor was timing on levator muscle activity (F_{Timing} (10, 90) =2.39, p=0.02, η_p^2=0.21).

When liquids were being swirled in the mouth (see Figure 4-23 (b)), EMG activity in the levator muscle was found to increase with timing and reach a peak at 1000ms for water control and the sweet-medium liquid, at 1500ms for the sweet-low liquid and at 3000ms for the sweet-high liquid, respectively. After the peak time points, levator muscle activity evoked by all solution types presented a stable trend until 7500ms. The results of paired comparisons (Figure 4-23 (e)) illustrate that more time periods were able to be discriminated during the swirling phase. Specifically, the sweet-high liquid was able to be differentiated by the levator muscle from water control (within 0~7500ms except for 1000 and 6000ms), the sweet-low liquid (within 0~7500ms), and the sweet-medium liquid (0~7500ms except for 4000, 6000, and 7500ms). Besides that, the levator muscle can tell the difference between the sweet-medium liquid and sweet-low liquids at 0ms, 2500~3000ms, and 4000~4500ms. These T-test results were all based on df=18, and $p<.05$. Interestingly, different concentration levels of sweet stimuli ($F_{Concentration}$ (1.56, 28.02) =9.67, p=0.001, η_p^2=0.35) and timing (F_{Timing} (3.19, 57.34) =7.17, p<0.001, η_p^2=0.83) were the two significant factors in influencing levator muscle activity during the swirling phase (see Table 4-12).

During the thinking phase (see Figure 4-23 (c)), EMG activity in the levator muscle decreased over time gradually. The strongest levator muscle activity was found in the sweet-high liquid whereas water control and the sweet-low liquid presented not only the least but also very similar EMG activity. Figure 4-23 (f) shows that during the thinking phase, not only the sweet-high liquid, but also the sweet-medium liquid was able to be distinguished from the other liquids. Specifically, the levator muscle was able to differentiate the sweet-medium liquid from the water control (during 0~500, 1500, 3000, 4000~5000, 9000ms) and the sweet-low liquid (during 0~2000ms). The sweet-high liquid was able to be discriminated easily from the water control, the sweet-low liquid and sweet-medium liquids most of the time during the thinking phase. It can be seen from Table 4-12 that levator muscle activity was influenced significantly both by different concentration levels of sweet stimuli ($F_{Concentration}$(1.40, 25.18)=8.22, p=0.004, η_p^2=0.31) and timing (F_{Timing}(2.19,39.45)=9.09, p<0.001, η_p^2=0.34) during the thinking phase.

Figure 4-24(a), (b), and (c) show the dynamic change of levator muscle activity for the rating block of the sweet session. It can be seen from Figure 4-24 (a), during the emptying phase, similar EMG activity in the levator muscle was presented by all four solution types. Their levator activity tended to increase over the time, then reached a peak at -1500ms, and after that point, a decreasing trend lasted until 0ms. The T-test and ANOVA results (Figure 4-24 (d) and Table 4-12) illustrate that no discrimination pattern to the levator muscle was found for any solution type; furthermore, no significant relationship can be found between timing, levator muscle activity and concentration levels of sweet stimuli during the emptying phase.

During the swirling phase (Figure 4-24 (b)), the sweet-high liquid evoked slightly more EMG activity in the levator muscle than other solution types. Generally, their levator muscle activity tended to increase with time and then kept a stable trend after the peak time points (1500ms for water control and the sweet-high liquid, 1000ms for the sweet-low liquid, and 3000ms for the sweet-medium liquid). The result of the paired comparison (Figure 4-24 (e)) shows that only the sweet-high liquid was able to be discriminated by the levator muscle from water control, the sweet-low liquid and sweet-medium liquid during most of the swirling phase (p<.05). Timing (F_{Timing} (4.99, 89.76) =5.88, p<0.001, η_p^2=0.25) and different concentration levels of sweet stimuli ($F_{\text{Concentration}}$ (2.01, 36.10) =6.19, p=0.001, η_p^2=0.26) were found to influence levator muscle activity significantly during the swirling phase (see Table 4-12).

Figure 4-24 (c) indicates that during the thinking phase, EMG activity in levator muscle evoked by four solution types tended to decrease gradually over time. More levator muscle activity was found in the sweet-high liquid than the other solution types, whereas the other solution types exhibited similar EMG activity of the levator muscle. Both the sweet-medium and sweet-high liquids were found to be discriminated by the levator muscle from water control (during 4000~6500ms) and the sweet-low liquid (during 7500~8500ms for the sweet-medium liquid and during 5500~6500ms for the sweet-high liquid) (see Figure 4-24 (f)). It was found in Table 4-12 that during the thinking phase, levator muscle activity was influenced slightly by the concentration levels of sweet stimuli ($F_{Concentration}(1.48, 26.59)=4.20$, $p=0.04$, $\eta_p^2=0.19$), but significantly with the timing ($F_{Timing}(2.45, 44.78)=8.06$, $p<0.001$, $\eta_p^2=0.31$).

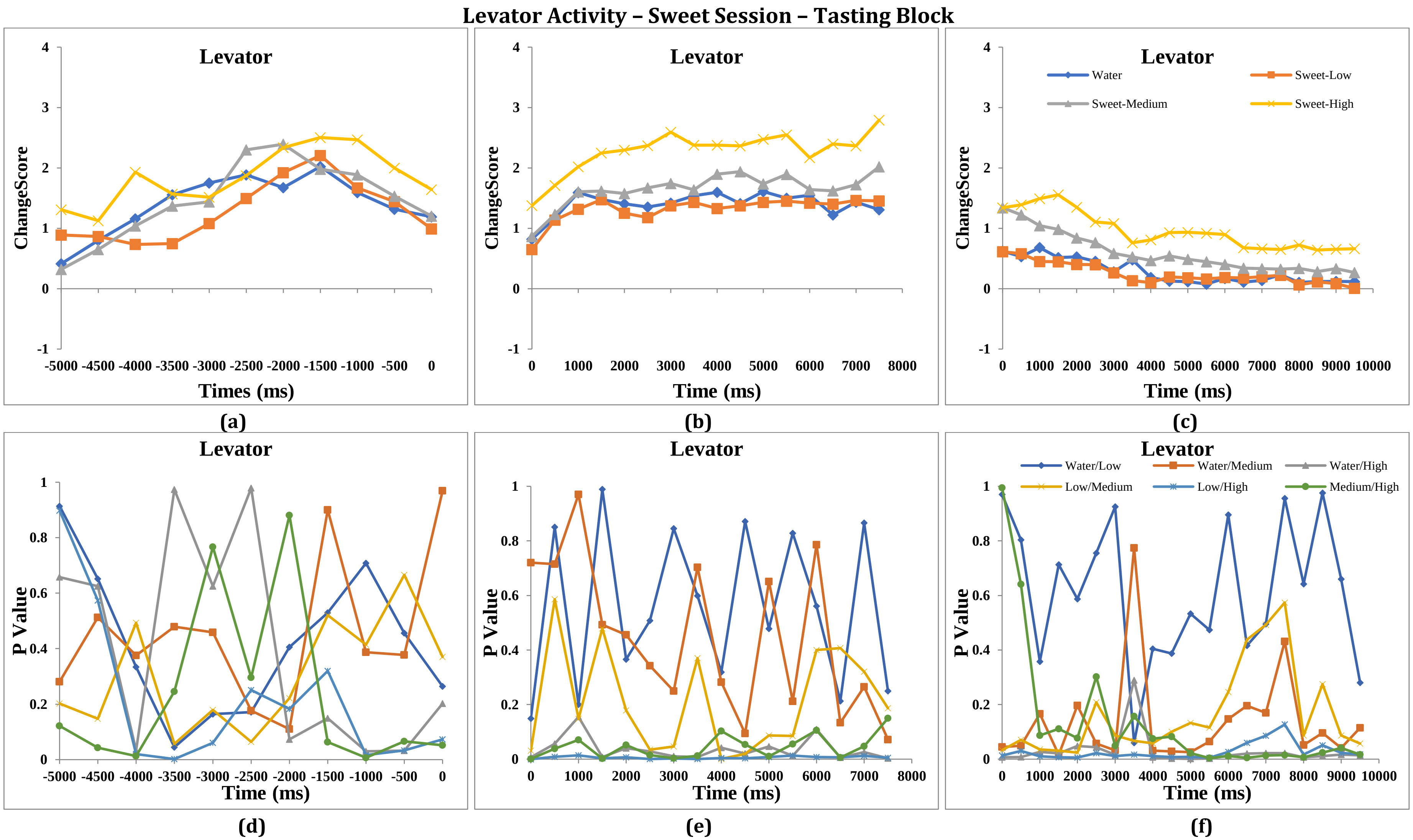


Figure 4-23 Dynamic levator activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

Levator Activity – Sweet Session – Rating Block

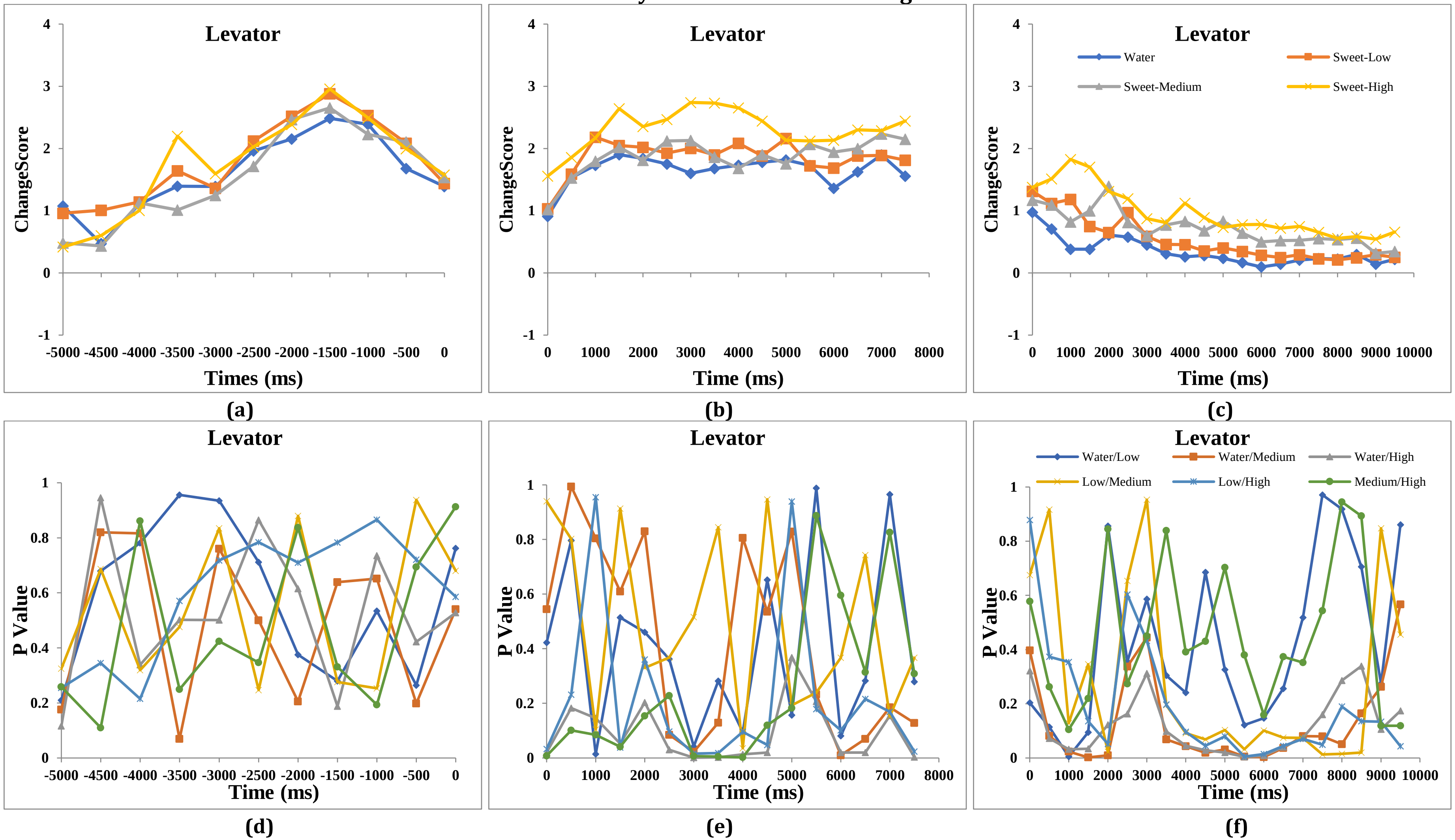


Figure 4-24 Dynamic levator activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

4.4.2.4.3 Dynamic EMG activity in the zygomaticus muscle for the tasting and rating blocks of the sweet session

Figure 4-25 and Figure 4-26 (a), (b), and (c) present dynamic EMG activity in the zygomaticus muscle of the sweet session for the tasting and rating blocks.

It can be seen from Figure 4-25 (a), (b), and (c) that generally, during three different phases, slightly more EMG activity in the zygomaticus muscle was found in the sweet-high liquid and sweet-medium liquid than water control and the sweet-low liquid. Furthermore, similar zygomaticus muscle activity was presented by water control and the sweet-low liquid.

Specifically, during the emptying phase (Figure 4-25 (a)), EMG activity in the zygomaticus muscle increased over time. At 0ms (the moment of emptying the liquid and clicking the mouse), the strongest to the least EMG activity in the zygomaticus muscle was evoked by the sweet-high liquid, the sweet-medium liquid, water control and the sweet-low liquid. The result of paired comparisons (Figure 4-25 (d)) illustrate that the zygomaticus muscle was able to differentiate the sweet-medium liquid from water control only at -1000ms and the sweet-low liquid within -3500~-500ms. Additionally, the sweet-high liquid was able to be discriminated by the zygomaticus muscle from water control within -1000~-500ms and the sweet-low liquid within -4000~-500ms (p<.05). No distinct pattern was able to be found in the relationship between different concentration levels of sweet stimuli, timing and zygomaticus muscle activity (see Table 4-12).

During the swirling phase (see Figure 4-25 (b)), more zygomaticus muscle contractions were made for the sweet-high solution and the sweet-medium solution; furthermore, water control and the sweet-low liquid evoked similar activity. EMG activity in the zygomaticus muscle slightly increased at the beginning of the swirling period. Specifically, zygomaticus muscle activity reached a peak at 2000ms for sweet-high liquid and 1500ms for the other solution types. After the peak time points, EMG activity in the zygomaticus muscle kept a stable trend for all solution samples. However, the sweet-low, sweet-medium and sweet-high liquids were found to present a decreasing pattern after 5500ms, 5500ms, and 5000ms, respectively. The T-test result (see Figure 4-25 (e)) illustrates that during the swirling phase, the sweet-medium liquid was only able to be discriminated by the zygomaticus muscle from water control and the sweet-low liquid at some time points. However, the zygomaticus muscle can discriminate the sweet-high liquid from water control (most of the time, except 1000 and 6000ms) and the sweet-low liquid (within 2500~3000ms, 4000~5000ms and 6500~7000ms) (p<.05). As shown in Table 4-12, different concentration levels of sweet stimuli ($F_{Concentration}$ (2.29, 41.19) =5.79, p=0.004, η_p^2=0.24) and timing (F_{Timing} (3.55, 63.81)=3.16, p=0.02, η_p^2=0.15)both influenced zygomaticus muscle activity significantly.

During the thinking phase (see Figure 4-25 (c)), EMG activity in the zygomaticus muscle for all solution types tended to keep a stable and the gradually decreasing pattern. The t-test result of the thinking phase presented the same result as the swirling phase (see Figure 4-25 (f)). Both the sweet-medium liquid and sweet-high liquid were able to be discriminated from water control (within 4000~5000ms, 7500~9500ms for the sweet-medium liquid and within 4000~9500ms for the sweet-high liquid) and the sweet-low liquid (within 0~1500ms, 3500~4000ms, 6000ms and 9000~9500ms for the sweet-medium liquid and within 500~1500ms, 3000~4500ms, 5500~7000ms and 9000~9500ms for the sweet-high liquid) by the zygomaticus muscle. From Table 4-12, it can be seen that different concentration levels of sweet stimuli ($F_{Concentration}$ (1.61, 28.92) =7.98, p=0.003, η_p^2=0.31) and timing (F_{Timing}(3.72, 66.99)=7.40, p<0.001, η_p^2=0.29) both had a significant influence on zygomaticus muscle activity, which presented the same result as in the swirling phase.

By contrast to the tasting block, a different EMG activity pattern for the zygomaticus muscle was present for the rating block (see Figure 4-26 (a), (b), and (c)). Generally, similar zygomaticus muscle activity was evoked by all solution types from the emptying, swirling to the thinking phases.

A continuously increasing pattern of zygomaticus muscle activity was found during the emptying phase (see Figure 4-26 (a)); furthermore, slightly more zygomaticus muscle activity was evoked by the sweet-high liquid than the other solution types at 0ms. According to T-test results (see Figure 4-26 (d)), the sweet-high liquid was only able to be discriminated by the zygomaticus muscle from the sweet-low liquid ($t_{0ms}(18)=2.51$, $p=0.022$) and sweet-medium liquid ($t_{0ms}(18)=2.459$, $p=0.024$) both at 0ms. No clear result was able to be found from ANOVA analysis (see Table 4-12).

When swirling the liquids (Figure 4-26 (b)), no distinct pattern was able to be found, which was likely to result from the zygomaticus muscle being involved in swirling the liquid. However, similar zygomaticus muscle activity was presented by all solution types. It was found by Figure 4-26 (e) that the sweet-medium liquid was able to be discriminated from water control only at 7000ms ($t(18)=-2.618$, $p=0.017$) during the swirling phase. More timing periods, including 0ms, 2500~4500ms, 6000~6500ms and 7500ms were found to discriminate water control from the sweet-high liquid by the zygomaticus muscle ($p<.05$). The result of Table 4-12 shows that different concentration levels of sweet stimuli were the only effect influencing zygomaticus muscle activity slightly ($F_{Concentration}(2.63, 47.30)=2.90$, $p=0.05$, $\eta_p^2=0.14$).

During the thinking phase (see Figure 4-26 (c)), EMG activity in the zygomaticus muscle tended to present a gradual decreasing pattern for all solution types. The zygomaticus muscle could discriminate only a few time points during the thinking phase. Specifically, it was found in Figure 4-26 (f) that both the sweet-medium liquid and sweet–high liquid were able to be differentiated by the zygomaticus muscle from water control and the sweet-low liquid only at a few points ($p<.05$). During the thinking phase, no distinct pattern was reported from the ANOVA result in Table 4-12.

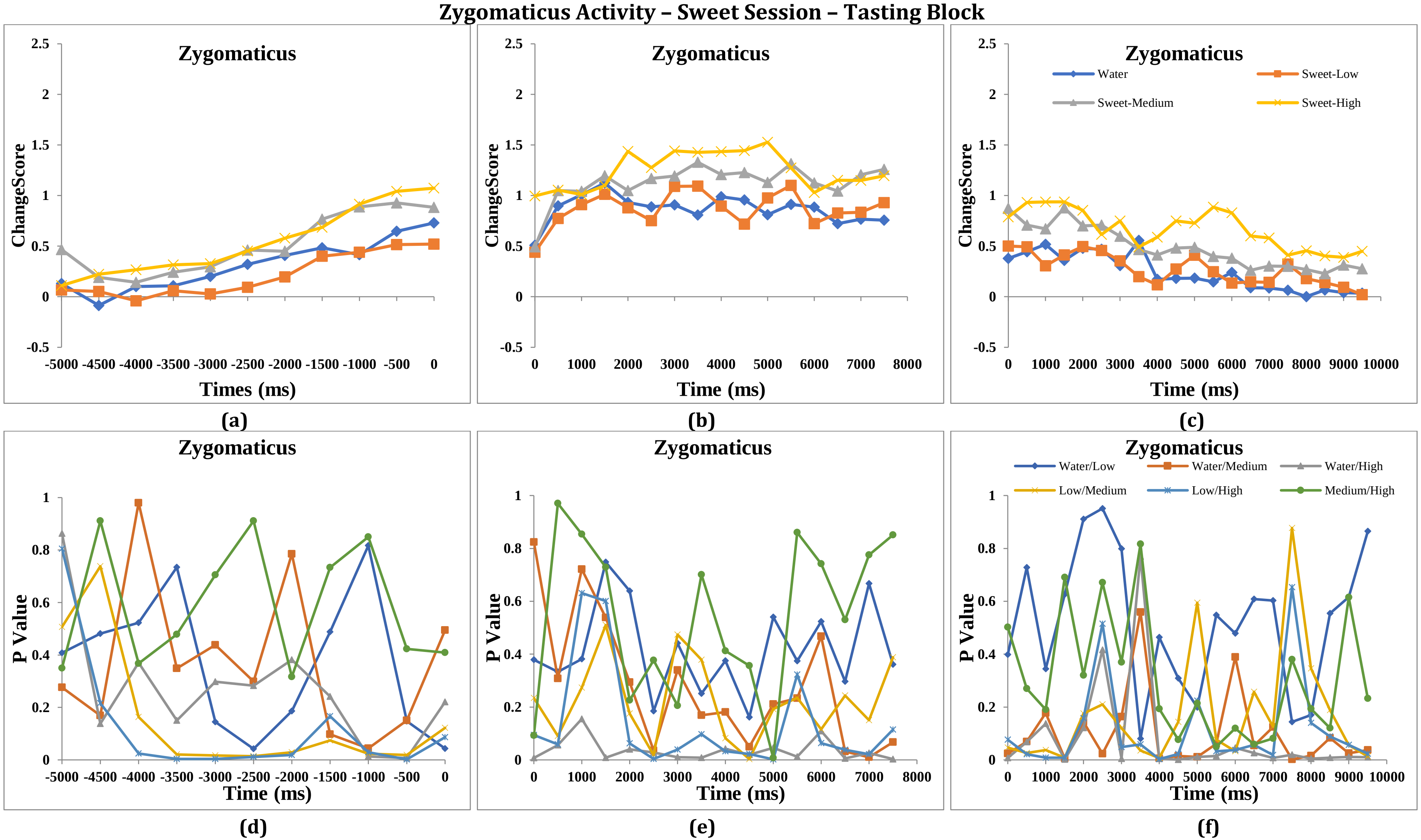


Figure 4-25 Dynamic zygomaticus activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

Zygomaticus Activity – Sweet Session – Rating Block

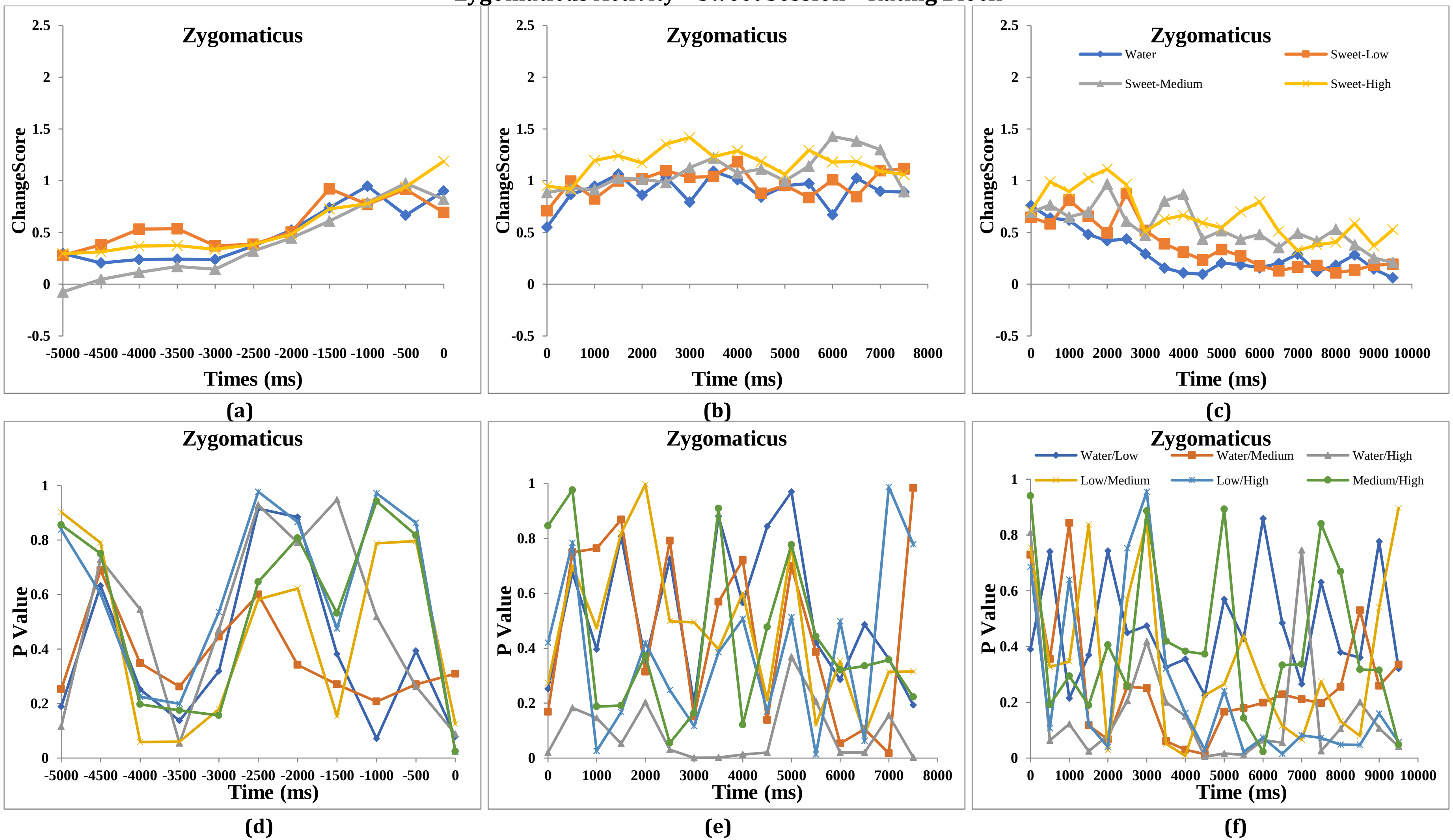


Figure 4-26 Dynamic zygomaticus activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

4.4.2.4.4 Dynamic EMG activity in the masseter muscle for the tasting and rating blocks of the sweet session

Figure 4-27 and Figure 4-28(a), (b), and (c) present dynamic EMG activity in the masseter muscle of the sweet session for the tasting and rating blocks. Generally, similar masseter activity was found in all the solution types for both the tasting and the rating blocks.

From Figure 4-27 (a), it can be seen that for the tasting block, during the emptying phase, there were lots of peaks after -2000ms, which indicates that masseter, a functional muscle, is used to open and close the jaw to empty the liquid. At 0ms, more masseter muscle activity was found on tasting the sweet-low liquid than the other solution types. The sweet-low liquid and sweet-medium liquid were only discriminated by the masseter muscle at -2500ms ($t_{2500\text{ms}}$(18)=-2.615, p=0.018). No distinct pattern was found for the influencing factors of EMG activity in the masseter muscle for the tasting block (Table 4-12).

The EMG activity in the masseter muscle was found to increase gradually at the beginning of the swirling phase (Figure 4-27 (b)) and reached a peak at 3000ms for water control and the sweet-high liquid, 1000ms for the sweet-low liquid, and 2500ms for the sweet-medium liquid, respectively. After that, there was a stable pattern of masseter muscle activity for all solution types until the end of the swirling period. It can be seen from Figure 4-27 (e) that the sweet-high liquid was able to be discriminated by the masseter muscle from water control (within 3500~6500ms) and the sweet-low liquid (within 0 ~6000ms excluding 1500ms). Additionally, the masseter muscle was able to differentiate the sweet-medium liquid from water control, the sweet-low liquid and the sweet-high liquid at fewer time points (p<0.05). The result of ANOVA (see Table 4-12) illustrates that different concentration levels of sweet stimuli ($F_{\text{Concentration}}$(3, 54) =6.63, p=0.001, η_p^2=27) and timing (F_{Timing}(2.74, 49.27) =3.48, p=0.03, η_p^2=0.16) both influenced EMG activity in the masseter muscle significantly during the swirling phase for the tasting block.

During the thinking phase (Figure 4-27 (c)), no distinct pattern was found in masseter muscle activity on four solution types, but generally their EMG activity in the masseter muscle all tended to present a gradually decreasing trend. According to T-test results (Figure 4-27 (f)), the sweet-medium liquid was discriminated by the masseter muscle from water control (within 7500~9500ms), the sweet-low liquid (within 500~3000ms), and the sweet-high liquid (only at 4000ms) (p<.05). Similarly, the masseter muscle was able to differentiate the sweet-high liquid from water control (within 4000~4000ms and 7000~9500ms) and the sweet-low liquid (within 500~2000, 3000, and 650~7000ms). Only different concentration levels of sweet stimuli ($F_{Concentration}$ (3, 54) =5.18, p=0.003, η_p^2=22) were reported to influence the masseter muscle activity significantly (Table 4-12).

Dynamic EMG activity patterns in the masseter muscle of the sweet session for the rating block are presented in Figure 4-28 (a), (b) and (c). During the emptying phase (Figure 4-28 (a)), masseter muscle activity increased over the time, and more masseter contraction was found in the sweet-high liquid and water control at 0ms, which presented a different pattern compared with the tasting block. The result of paired comparisons (Figure 4-28 (d)) indicates that the masseter muscle was not able to discriminate these solution types most of the time during the emptying phase. Specifically, water control was able to be discriminated by the masseter muscle from the sweet-low liquid at 0ms and the sweet-high liquid at -5000ms. Additionally, the sweet-medium liquid was able to be differentiated from the sweet-high liquid at -3000 and -1000ms by the masseter muscle (p<.05). It can be seen from Table 4-12 that, during the emptying phase, masseter muscle activity varied with timing significantly (F_{Timing} (10, 40) =3.22, p=0.004, η_p^2=0.45).

Similar masseter muscle activity was found with water control, the sweet-low, sweet-medium and sweet-high liquids during the whole swirling period (Figure 4-28 (b)). Specifically, EMG activity in the masseter muscle evoked by the four solution types tended to increase at the beginning of the swirling phase, indicating that the activity peaks at 1500ms for both water control and the sweet-medium liquid, and 2000ms for both the sweet-low liquid and sweet-high liquid, respectively. After those peak points, they all presented a stable and slightly dropping trend until 7500ms. It can be seen from Figure 4-28 (e) and Table 4-12 that no discrimination was found in the masseter muscle during the swirling phase; furthermore, no influencing effect was found on masseter muscle activity.

During the thinking phase (Figure 4-28 (c)), slightly more EMG activity in the masseter muscle was evoked by the sweet-high liquid than the other solution types, which presented the same stable trend within 10 seconds. The result of paired comparisons (Figure 4-28 (f)) illustrate that only the sweet-high liquid was able to be discriminated by the masseter muscle from water control, the sweet-low liquid, and the sweet-medium liquid at some time points. Only the different concentration levels of sweet stimuli were shown to influence masseter muscle activity slightly during the thinking phase ($F_{Concentration}$ (1.63, 29.42) =4.14, p=0.03, η_p^2=0.19).

Masseter Activity – Sweet Session – Tasting Block

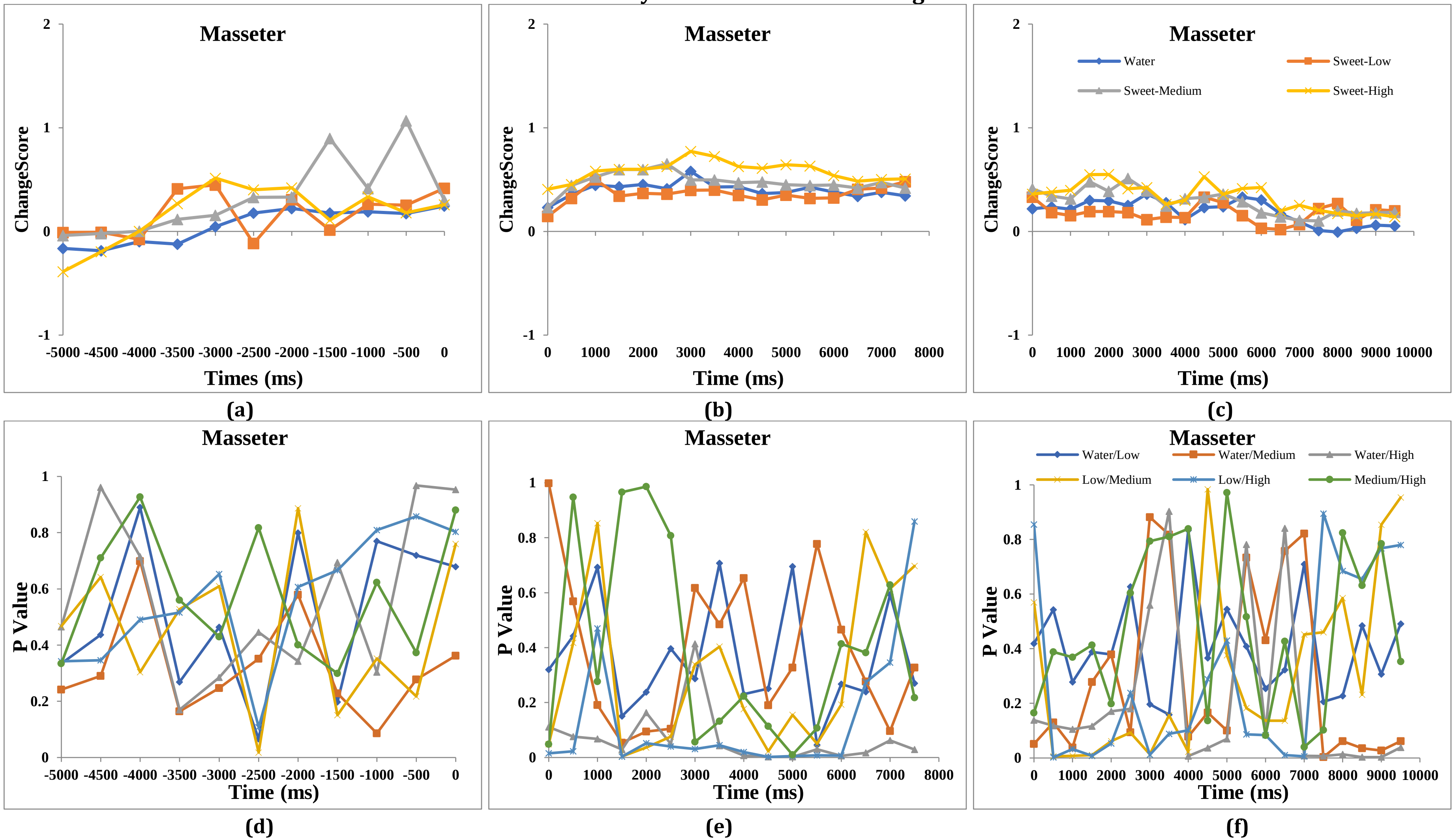


Figure 4-27 Dynamic masseter activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the tasting block

Masseter Activity – Sweet Session – Rating Block

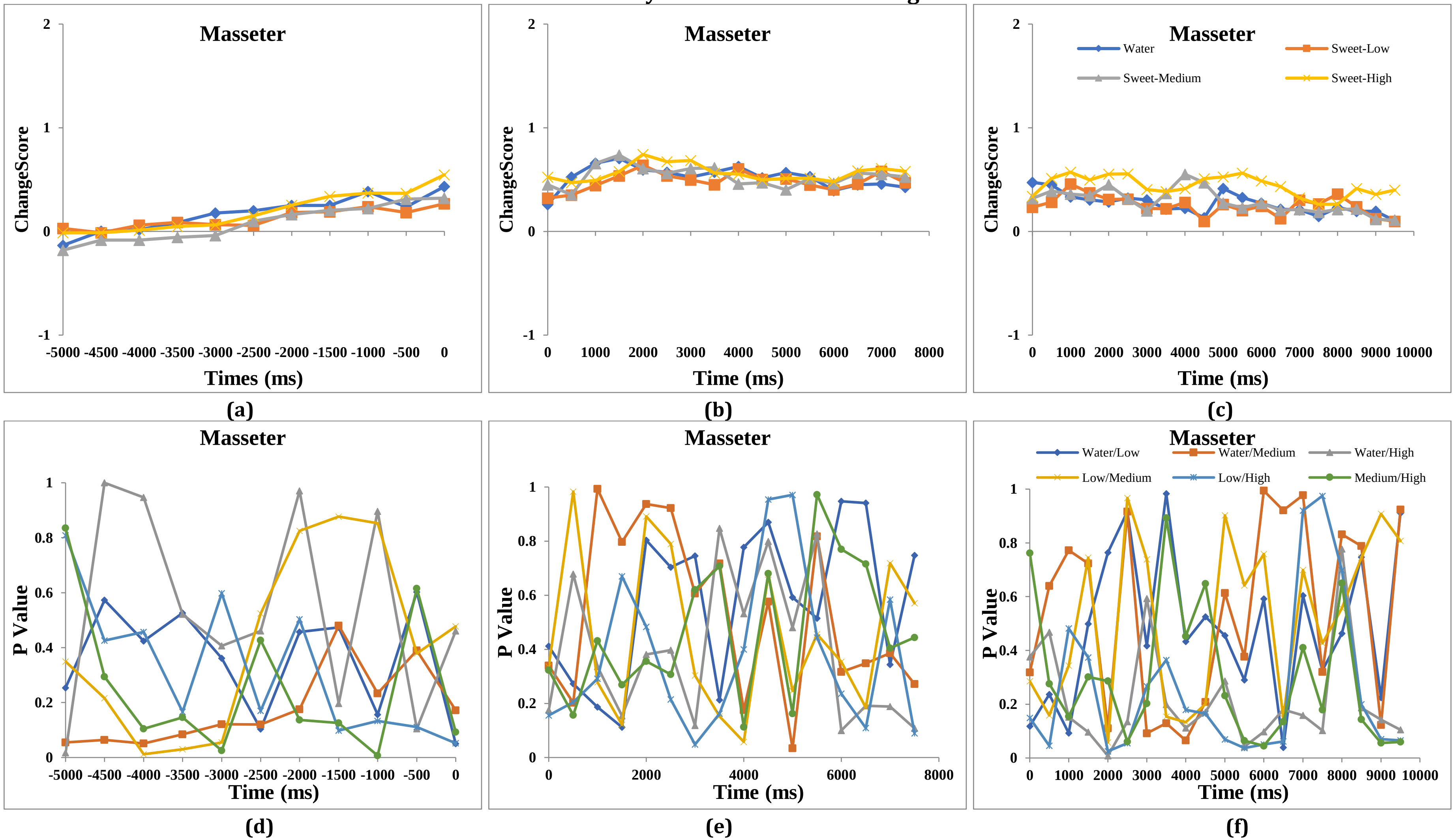


Figure 4-28 Dynamic masseter activity and P value of T-test results of emptying (a)(d), swirling(b)(e) and thinking (c)(f) for the rating block

Table 4-12 Repeated measures ANOVA results of sweet session for the tasting and rating blocks

Within subjects factor	Sweet Session																							
	Tasting Block												Rating Block											
	Emptying Phase				Swirling Phase				Thinking Phase				Emptying Phase				Swirling Phase				Thinking Phase			
	df	F	p	η_p^2	Df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2	df	F	p	η_p^2
Corrugator																								
Concentration	3.00	1.25	0.31	0.12	1.36	3.65	0.06	0.17	1.35	2.89	0.09	0.14	3.00	1.39	0.29	0.26	1.84	2.24	0.13	0.11	1.73	0.67	0.50	0.04
Timing	10.00	0.83	0.60	0.09	1.84	0.62	0.53	0.03	1.79	2.36	0.12	0.12	10.00	1.55	0.16	0.28	2.49	1.46	0.24	0.08	1.81	1.19	0.32	0.06
Concentration*Timing	30.00	0.81	0.75	0.08	1.53	1.14	0.32	0.06	2.55	1.33	0.28	0.07	30.00	1.48	0.07	0.27	2.33	0.75	0.50	0.04	2.25	0.64	0.55	0.04
Zygomaticus																								
Concentration	1.57	1.92	0.18	0.18	2.29	5.79	0.00	0.24	1.61	7.98	0.00	0.31	3.00	1.26	0.33	0.29	2.63	2.90	0.05	0.14	3.00	3.99	0.01	0.18
Timing	1.79	1.36	0.28	0.13	3.55	3.16	0.02	0.15	3.72	7.40	<0.001	0.29	10.00	1.96	0.07	0.33	4.75	1.41	0.23	0.07	2.32	5.60	<0.001	0.24
Concentration*Timing	2.44	0.76	0.51	0.08	3.66	0.88	0.47	0.05	6.58	1.20	0.31	0.06	30.00	1.44	0.09	0.27	4.26	0.90	0.48	0.05	2.68	1.10	0.29	0.06
Levator																								
Concentration	3.00	6.05	0.23	0.15	1.56	9.67	0.00	0.35	1.40	8.22	0.00	0.31	3.00	0.86	0.49	0.18	2.01	6.19	0.01	0.26	1.48	4.20	0.04	0.19
Timing	10.00	2.39	0.02	0.21	3.19	7.17	<0.001	0.83	2.19	9.09	<0.001	0.34	10.00	1.97	0.06	0.33	4.99	5.88	<0.001	0.25	2.45	8.06	<0.001	0.31
Concentration*Timing	30.00	1.68	0.02	0.16	8.31	0.90	0.52	0.03	6.65	1.01	0.37	0.06	30.00	1.62	0.13	0.52	9.26	1.16	0.32	0.06	5.17	1.18	0.32	0.06
Masseter																								
Concentration	1.29	0.85	0.40	0.09	3.00	6.63	0.00	0.27	3.00	5.18	0.00	0.22	3.00	0.39	0.76	0.09	1.80	0.79	0.45	0.04	1.63	4.14	0.03	0.19
Timing	1.06	1.38	0.27	0.13	2.74	3.48	0.03	0.16	1.81	2.24	0.13	0.11	10.00	3.22	0.00	0.45	3.21	1.44	0.24	0.07	1.52	1.13	0.32	0.06
Concentration*Timing	1.08	0..924	0.37	0.09	4.28	0.96	0.44	0.05	3.35	1.02	0.40	0.05	30.00	1.07	0.39	0.21	5.20	1.02	0.42	0.05	2.56	0.96	0.41	0.05

4.4.2.5 Mean hedonic liking rating and intensity rating of sweet and bitter stimuli during the rating block

Figure 4-29 presents the hedonic liking rating and the intensity rating by LAM and LMS scales collected in the rating block. Ranking the hedonic liking rating of sweet solutions made by participants from most liked to most disliked: sweet-medium concentration liquid (M=10.06, SE=2.44)> sweet-high concentration liquid (M=8.780, SE=3.23)> sweet-low concentration liquid (M=3.43, SE=1.34)> water control-sweet session (M=-0.895, SE=0.956). Interestingly, the standard error of sweet-medium concentration and sweet-high concentration liquids were higher than that of water control and sweet-low concentration liquid, which indicated that increased accuracy of the LAM rating prediction of sweet-medium and sweet-high liquids from these medium taster participants was found.

The hedonic liking ratings for bitter sample stimuli were all negative. Participants gave the most negative rating to the bitter-high concentration solution (M=-39.66, SE=1.34). Similarly, negative ratings were also made for the bitter-medium solutions by participants (M=-20.57, SE=1.87). The hedonic liking rating increased dramatically for bitter-low concentration liquid and water control (bitter session). Their mean ratings were -3.89 for water control and -3.69 for the bitter-low solution. The considerable overlap in standard error between these samples suggested that during the bitter session, participants were not able to discriminate the water control and low concentration of the bitter solution.

The intensity rating of sample stimuli in the sweet session rose moderately with the increase of concentration levels of sucrose solutions. Specifically, the intensity rating of liquid stimuli in the sweet session was ranked as sweet-high concentration liquid > sweet-medium concentration liquid > sweet-low concentration liquid > water control (sweet session). The standard errors of the sweet-medium and sweet-high solutions were relatively high, suggesting high variability of the intensity ratings for these samples.

The participants all rated the intensity of the bitter-high liquid extreme negatively. The bitter-medium solution was rated less intensely than the bitter-high solution. Interestingly, the intensity rating of water control was rated more negatively than the bitter-low solution, which is related to the participants' taster status. The high standard error for the bitter-high liquid, the bitter-medium liquid and water control (bitter session) indicated that there was substantial variability in subjective judgement that might be because of differences in the taster status of participants.

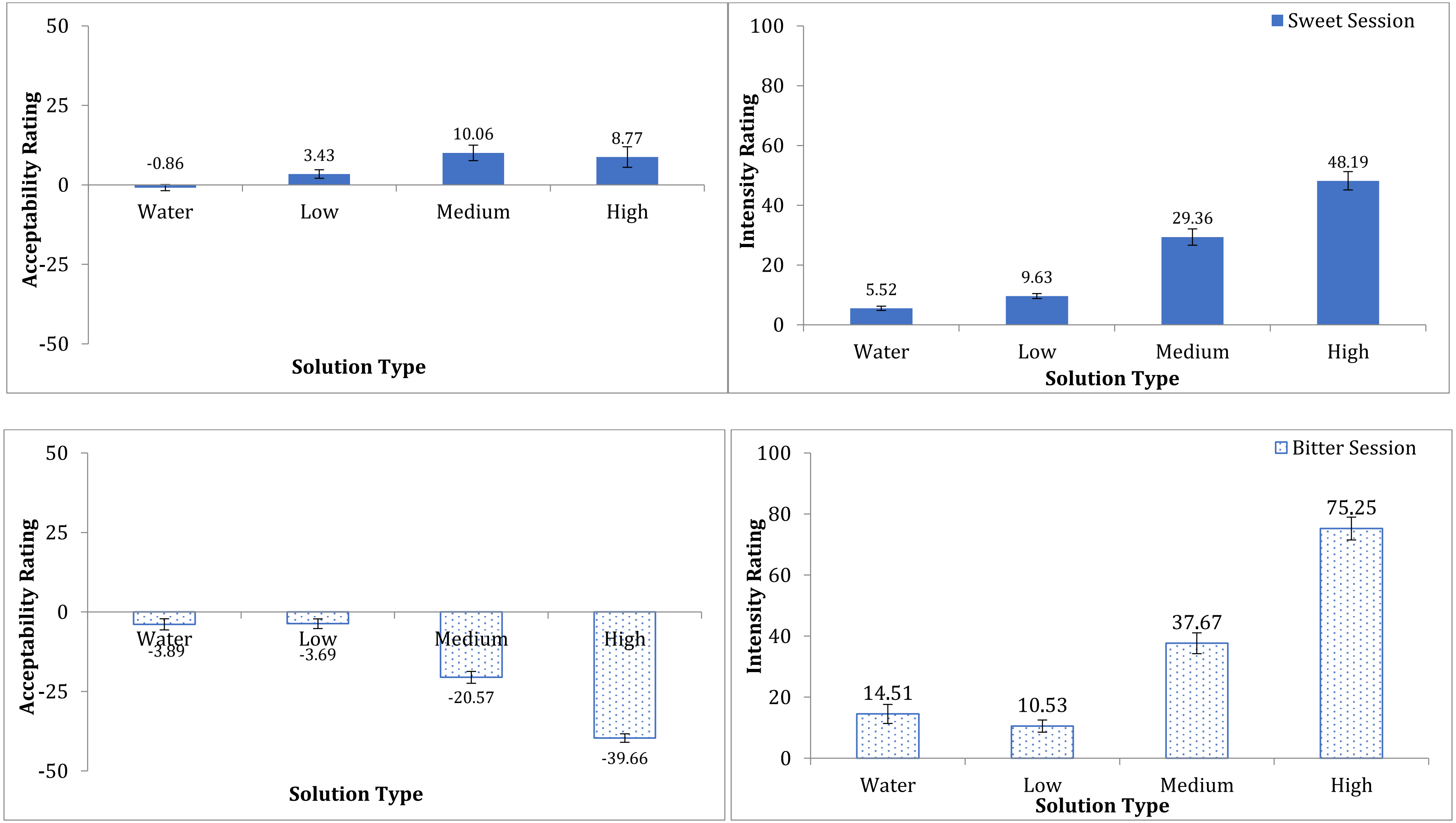


Figure 4-29 Acceptability and intensity ratings of sweet and bitter sessions during the rating block (Error bars stands for -/+1 standard error)

4.5 Discussion

4.5.1 PROP status

Table 4-2 reveals that the proportions of non-tasters, medium-tasters and super-tasters in our study were 20.75%, 62.26% and 16.98%, respectively.

As expected, non-tasters, medium-tasters and super-tasters differed in their intensity ratings of NaCl and PROP solutions. The result of Figure 4-4 illustrated that non-tasters always give lower intensity ratings to the two highest concentrations of PROP as compared to the two highest concentrations of NaCl, respectively. However, super-tasters show the reverse pattern. Medium-tasters tended to provide similar intensity ratings of PROP and NaCl solutions. These results are the same as (Tepper et al., 2001).

Interestingly, the saltiness of NaCl is still being discussed. The PROP ratio (see Equation 4-1) used by Bartoshuk et al. (1994) is only based on the two highest concentrations of PROP and NaCl solutions because participants always give the lowest NaCl solution rating, such as 0, which can be ignored in the calculation. However, Tepper et al. (2001) used the classic PROP ratio (see Equation 4-2) in their publication, which takes all three concentrations into consideration. The exact relationship between an individual's PROP sensitivity and NaCl sensitivity is still unclear. If the three solution test was used, there was not a stable intensity rating of NaCl across PROP tasters groups (Prutkin et al., 2000). Therefore, to make sure of the final results, two PROP ratios have been used in this analysis. Furthermore, the two different PROP ratios allocated individuals to identical PROP taster groups in this study.

Previous studies have shown that sex, genetics and fungiform papillae density all influence PROP taste sensitivity. Investigations into genetics and taster status reveal that individuals with two recessive alleles (tt) are non-tasters, whereas individuals with one dominant allele (Tt) as well as those with two dominant alleles (TT) are tasters (Bartoshuk et al., 1994). In our study, more female super-tasters were able to be found (see Table 4-2), which indicates that females tend to have both more fungiform papillae and more taste pores than males (Bartoshuk et al., 1994). However, the association between taste papillae density and PROP taste sensitivity needs to be investigated in greater details in future studies. Some findings showed that supertasters not only have more papillae at the tip of the tongue, but also have a greater density of taste pores (Tepper et al., 2001). However, these findings are not enough to illustrate the relationship between papillae density and taster status. In particular, distributions of papillae densities for three taster status groups always greatly overlapped (Tepper et al., 2001). Therefore, counting papillae is not an ideal approach to confirm taster classifications.

4.5.2 PROP sensitivity vs hedonic and intensity responses to sweet taste

Previous studies investigated the relationship between the sensitivity to PROP and hedonic and perception responses to sweet solutions and found that neither intensity ratings nor hedonic liking for sweet solutions was influenced by sensitivity to PROP (Drewnowski, Henderson, & Shore, 1997; Drewnowski, Henderson, Shore, et al., 1997). There was no relationship between the perception and hedonic response between sucrose solutions and taster status (Looy & Weingarten, 1992).

The intensity rating of sucrose solutions increased with the concentration of sucrose levels (see Figure 4-5 (b) and Figure 4-7 (d)), which indicated that these medium-taster participants were able to discriminate the different concentration levels successfully. However, only Participant No. 8 was found to rate the water control as more intense than 0.09M sucrose solution, which resulted from either the individual difference or the sample presentation sequence. For example, if Participant 8 tasted the highest concentration before tasting the water control, the rating of the water would be influenced by the previous sample.

In this study, the hedonic liking by medium-taster participants presented a bliss point indicating the optimized palatability of sucrose solutions. Their preference liking was ranked as 0.36M, 0.18M, 0.72M, 0.09M, water (0M), 1.14M (see Figure 4-5 (a)). Specifically, 0.36M sucrose solution had the optimial palatability of these sucrose solutions so this sucrose concentration was selected as the sweet-medium liquid used as for the EMG measurement. However, the acceptability of sucrose solutions varied among participants. For example, Participant No. 1 considered 0.72M sucrose solution to be the most preferred concentration. However, Participant No. 4, No. 5 and No. 10 rated 0.18M sucrose solution as their most preferred. The highest concentration 1.14M was ranked the least liked by most medium-taster participants. This is likely because stimulus concentration is an important determinant factor in influencing hedonic liking (Kocher & Fisher, 1969). Very high concentrations are perceived as unpleasant (Reed et al., 2006) and are beyond the individual's sucrose bliss-point. Combined with Figure 4-7 (a), half of the participants gave a positive rating to 1.14M sucrose solution, and the rest of the participants rated it negatively: especially Participants No. 4, No. 5, and No. 10. A similar pattern was observed for the 0.72M sucrose solution which Participants No. 10 and No. 5 reported a strong disliking for. Therefore, it can be seen that in this study the sweet liking was not decided by the PROP taster status, so the sample included both sweet-likers and sweet-dislikers.

Apart from that, gender and age also influenced the hedonic responses to sweet stimuli. Several studies reported that women presented reduced preferences for sweetness; people with ages ranging from 9 to 15 years old preferred greater sweetness than did adults aged 18 to 64 years old (Murphy & Withee, 1986). In our research, only medium tasters were invited to participate in the acceptability and EMG measurement. Furthermore, these participants were recruited by selecting half males and half females whose mean age was approximately 27 years old to ensure having a consistent age group and balanced gender in order to reduce variability during the experiment.

4.5.3 PROP sensitivity vs hedonic and intensity responses to bitter taste

Unlike sucrose solutions, previous studies have been in agreement that sensitivity to PROP correlates with the taste for quinine (Chang, Chung, Kim, Chung, & Kho, 2006). Because only medium tasters were used in this study, no comparison could be made to discriminate the difference between taster status and quinine sensitivity. However, from Figure 4-6 (b) it can be seen that the intensity rating of quinine solutions rose with the increase of the concentration of solutions except in the concentration of $0.005*10^{-4}$M. Furthermore, similar ratings were given by participants in water, $0.005*10^{-4}$M and $0.005*10^{-3}$M quinine solutions. This result indicates that the recruited medium tasters were not able to discriminate the low concentration bitter solutions and water. This can be explained by the taster status and the sequence of presentation order. The result of Figure 4-7 (d) illustrated the difference of medium-taster status. In this study, the medium-taster cutoff line ranged from 0.7 to 1.7. Specifically, the sensitivity to quinine solutions between low PROP ratio (low-medium tasters) and high PROP ratio (high-medium tasters) is different because high-medium tasters are close to super-taster status whereas if the PROP ratio is close to 0.7, participants' behaviours are more similar to non-tasters. For example, Participant No. 8 always presented high sensitivity to quinine solutions and water because this participant is a high-medium taster. However, Participant No. 7 gave the relatively low rating to 0.0005M and 0.005M quinine solutions, indicating he is a low-medium taster. Furthermore, the sequence of sample presentation order has a strong influence on the bitter perception. For example, Participant No. 5 gave a higher intensity rating for $0.005*10^{-4}$M while Participant No. 9 rated $0.005*10^{-3}$M quinine solution highly. If participants met the strongest concentration 0.005M quinine solutions before water, then they experienced a strong negative affect, and there might have been the residual solution in the mouth, and both these influenced the perception of water intensity.

In this study, participants all reported a negative affect for quinine solutions (even water) because bitterness is the opposite of sweetness and was always considered to be bad at all concentrations (Reed et al., 2006). Although it can be observed that many people choose bitter solutions in their everyday behaviour (black coffee, hopped beer, black tea, tonic water), these everyday bitter solutions are usually balanced by also having sweet, salty, fatty and sour tastes. Super tasters were able to perceive bitterer tastes than non-tasters from most of the compounds when dissolved in aqueous solutions rather than real foods in everyday life. Furthermore, PROP status did not influence the acceptability of these foods (Tepper et al., 2009). An investigation of the relationship between PROP status and food preferences was conducted among 139 college students and the results illustrated no significant group differences between PROP taster status and the rating of how much they liked brussel sprouts, raw broccoli, cabbage, spinach, black coffee, dark chocolate, crushed red pepper, jalapenos, chilli peppers, red wine, beer, creamy salad dressing or mayonnaise (Catanzaro, Chesbro, & Velkey, 2013). Later, the relationship between food preferences (brussel sprouts, broccoli, spinach, black coffee, soy milk, and soybean tofu) and PROP taster status was investigated again using 63 female participants. The results showed that PROP tasters are more sensitive to bitter stimuli than non-tasters on samples such as brussel sprouts. Furthermore, foods were perceived more bitter and rated less pleasant and less acceptable by participants. Taste preferences and food preferences were linked (Kaminski, Henderson, & Drewnowski, 2000).

It can be seen from Figure 4-6(a) that the liking rating decreased with the increase of concentration level. The highest concentration of quinine solutions 0.005M elicited food rejection from participants (Reed et al., 2006), so its liking rating was assessed as negative by participants. No more difference between liking ratings was found in water and quinine solutions ($0.005*10^{-4}$ and $0.005*10^{-3}$M) which is unsurprising because their corresponding intensity rating was not able to be discriminated by participants, suggesting that participants perceived these solutions to be the same concentration. Also, in certain circumstances, bitter solutions may be pleasing, especially low concentrations (Reed et al., 2006). This is a potential reason why a few participants gave liking ratings close to 0 when tasting the quinine solutions ($0.005*10^{-4}$ and $0.005*10^{-3}$M). Previous studies also illustrate that compared to the perception of sweet and sour, the perception of a very low concentration of bitter tastes (including PROP/PTC, quinine, and caffeine) declines with age, which is more likely to influence the hedonic liking for the bitter taste in beverages and food. However, older women were found to express an increased liking for bitter cruciferous vegetables and salad greens (Drewnowski, 2001).

4.5.4 EMG activity in the corrugator muscle during the emptying, swirling and thinking phases for the tasting and rating blocks of sweet and bitter sessions

In this study, different instruction phases were presented to participants in order to record their dynamic facial muscle activity for each taste stimulus because, from Study 1 findings, the different emotional pattern was found at the beginning and end of viewing visual stimuli. Figure 4-8 lists the detailed EMG instruction. The emptying, swirling, and thinking phases were chosen as actions to guide participants in this study because they represented interesting time points when tasting liquids. Crucially, the analyses were time locked to the onset and offset of the instruction screens so that the different behaviours could be statistically investigated. The Emptying phase was used to record facial muscle activity when participants first emptied the liquid into their mouths. When they completed emptying the liquid into their mouths, they were required to click the mouse button and wait for the next instruction screen. The Swirling phase provided 8 seconds for participants to swirl the liquids in their mouths, so as to record the dynamic facial muscle activity during swirling. The Thinking phase followed swirling and was after participants had spat out the liquids into the waste jar to detect the change of facial muscle activity without any liquids in participants' mouths but immediately after tasting. These three phases were used to delimit points of interest in the facial muscle activity recordings. Both the tasting without the rating block (Tasting Block) and tasting with the rating block (Rating Block) used the same phase instructions, but for the rating block, participants were required to rate the acceptability and intensity of liquid stimuli after the thinking phases.

Corrugator supercilii is a negative affect muscle and is typically evoked by anger, where the typical facial expression is lowering the eyebrows and generating wrinkles around the inner brow. Based on the findings from Study 1, more EMG activity in the corrugator muscle was found when viewing less liked imagery stimuli. Similarly, in this study, regardless of whether it was the tasting or rating block, bitter taste as an unpleasant stimulus was able to evoke strong and negative affective responses from participants. It followed that more EMG activity in the corrugator muscle was found when tasting different concentration levels of bitter liquids, especially bitter-high liquid and bitter-medium liquid. Horio (2003) and Armstrong et al. (2007b) both found that bitter taste stimuli generated negative affective responses in their studies and the typical facial expressions were gaping and nose wrinkling, which demonstrates the same result as in this study. It should be noted that the bitter-high liquid and bitter-medium liquid evoked strong negative affective responses from participants as expected, however, similar EMG activity in the corrugator muscle was always found in water control and the bitter-low liquid. Additionally, combined with the dynamic corrugator muscle activity pattern, bitter-low liquid and water control always elicited similar EMG activity in the corrugator muscle, which indicates that extreme concentration levels of bitter stimuli are easy to discriminate, but it is difficult to discriminate lower concentration levels of liquid stimuli. However, in our daily life, some beverages such as beer and tonic water taste bitter. Is facial EMG able to detect dynamic emotion change if beer or tonic water is tasted? Is the corrugator muscle activity able to predict the hedonic liking rating or intensity rating regardless of whatever stimuli is being tasted? The results of EMG activity in the corrugator muscle provide us with some useful implications in further work. There is no doubt that the medium-taster status was one of the reasons that explained why different emotion patterns were caused by different concentration levels of bitter stimuli.

Another interesting phenomenon is that the corrugator muscle activity during the emptying phase was lower than that of the swirling and thinking phases. This is because the emptying phase is short and participants' affective reactions were short and quick as well (and the mean will be reduced because the time points were averaged and started close to a changescore of 0mV). However, the dynamic corrugator muscle activity pattern reveals that negative affects evoked by the bitter-high and bitter-medium liquids increased quickly and sharply at the end of the emptying phase and the beginning of the swirling phase. After reaching the peaks during the swirling phases, their corrugator muscle activity tended to present a stable and gradually decreasing trend until the end of thinking phase.

This interesting pattern indicated two possibilities, 1) although emotion is dynamic during the tasting of liquid, which time point will be the ideal one to predict the hedonic liking rating? and 2) owing to a decreasing trend after spitting out the liquid, the corrugator muscle is still a reliable one to predict the hedonic liking of the after taste mouth feel. These questions will be answered in Chapter 5. The typical pattern of negative affect also implicates the locations of these four facial muscles.

For the sweet session, no distinct pattern was found on EMG activity in the corrugator muscle. However, minimal EMG activity in the corrugator muscle was found when tasting sweet liquids, positive stimuli, which presented the same result in Study 1. This result provides another assumption that a liking or a disliking to the food stimuli can be relied on to recording corrugator muscle activity, and there will be no need to take other facial muscles into consideration. Additionally, sweet-high solutions evoked a relatively high activity for the corrugator muscle because sweetness can be perceived as unpleasant at very high concentrations (Reed et al., 2006). There is no doubt that this phenomenon reflects two problems. Firstly, how to select food stimuli to best evoke positive affect. By contrast to the bitter session, it was more difficult to select stimuli that all participants liked because hedonic liking behaviour is a personal attribute and it is influenced by eating experience, culture and physical status. Facial EMG provides more potential to interpret psychophysiological data better than hedonic scales because it records dynamic emotion change. Secondly, in this study, sweet-likers and sweet-dislikers were not taken into consideration, which created some barriers to better interpretation of the EMG data of the sweet session. However, more potential research topics such as using EMG to assess the dynamic emotion change with homogenous products should receive more attention.

Compared to the tasting block, a similar trend was also present for the rating block, but the result from the rating block was stronger than from the tasting block. This is because the rating block was the third part of this study; furthermore, participants were more relaxed and were comfortable with the procedure.

4.5.5 EMG activity in the zygomaticus muscle during the emptying, swirling and thinking phases for the tasting and rating blocks of the sweet and bitter sessions

The zygomaticus muscle is always active when smiling and laughing and is considered to be a positive affect muscle.

Owing to the sweet taste stimuli used in this study, the results were expected to produce positive responses and be active during tongue protrusion, lip smacking and smiling (Armstrong et al., 2007b). It can be seen from Figure 4-9, Figure 4-10, Figure 4-11, and Figure 4-12 that although the activity of the zygomaticus muscle was evoked by sucrose solutions, there were also strong responses to quinine solutions. Generally, EMG activity in the zygomaticus muscle increased with the increase of the concentration level of sucrose solutions. However, the activity of the zygomaticus muscle decreased during the three phases for the tasting and rating blocks. During the emptying phase for the tasting block, the activity of the zygomaticus muscle was similar for sucrose and quinine solutions. For the swirling phase, the zygomaticus muscle changescore for bitter and sweet solutions was higher when emptying the cup into the mouth phase because, during the swirling phase, participants were required to swirl the liquids in their mouths. At this point, zygomaticus was more likely to be used as a functional muscle to swirl the liquid. However, especially for the medium and high concentration levels, zygomaticus activity for sweet solutions was only slightly higher than for bitter solutions. The same trend was also present during the thinking phase. The activity of zygomaticus during the thinking phase decreased, which could illustrate the comparative high zygomaticus activity resulted from swirling the liquids. Therefore, zygomaticus muscle did not differentiate between sucrose and quinine solutions, which was the same result as Armstrong et al. (2007b). Furthermore, it is difficult to discriminate the increase in EMG activity for the zygomaticus muscle that resulted from swirling or the emotional responses to the liquid. The dynamic activity change in timing should be taken into consideration to enhance the discrimination of sweet and bitter stimuli. Undoubtedly, EMG activity in the zygomaticus muscle for the emptying and the thinking phases was evoked by affective responses if participants followed the instructions for the experiment. The results also revealed that a high concentration of bitter solutions also increased EMG activity recorded from the zygomaticus muscle because grimacing is another facial expression used to convey negative affect, which activates the zygomaticus muscle. The reason that the zygomaticus muscle is such a useful marker of positive affect is that it is responsible for lifting the corners of the mouth during a smile while opening the mouth can also occur in disgust expressions in preparation for ejecting food from the mouth. Concerning sweet taste stimuli, the reason why EMG activity in the zygomaticus muscle was not able to be confirmed was that positive and negative affect is more likely to evoke the activity of the zygomaticus muscle. This is supported by Lang et al. (1997), who found that zygomaticus muscle activity has a U-shaped function, with increased activity for very negative and positive stimuli, and no activity for neutral stimuli. However, by observing that corrugator activity was evoked from high concentration sweet solutions, it is assumed that increasing EMG activity for the zygomaticus muscle was due to negative facial expressions such as grimacing.

In summary, sweet stimuli evoked similar EMG activity in the zygomaticus muscle, whereas strong zygomaticus muscle activity was found on tasting the bitter-high liquid, which indicates that the contraction of the zygomaticus muscle does not simply mean happiness and positive affect. Solely detecting the activity of the zygomaticus muscle prevents the ability to discriminate positive and negative affect. Alternatively, positive affect is harder to be discriminated and detected. When differentiating positive affect, other facial muscles should be taken into consideration together with the zygomaticus muscle. Additionally, the zygomaticus muscle is in the cheek region and therefore more likely to be involved in oral processing of food or swirling of liquid during food consumption. That should be taken into consideration when designing the further experiments on chewing solid food.

The Rating block always presented a similar trend to the tasting block for both the sweet and bitter sessions.

4.5.6 EMG activity in the levator muscle during the emptying, swirling and thinking phases for the tasting and rating blocks of the sweet and bitter sessions

As with the corrugator muscle, the levator is considered a negative affect muscle; furthermore, its typical expression is disgust because it lifts the upper lip and generates wrinkles around the nose.

During the tasting block, it was found (see Figure 4-9, Figure 4-10, Figure 4-11, and Figure 4-12) that the EMG activity in the levator muscle was greatest for the emptying and swirling phases compared with the thinking phase. That is because participants always held and swirled the liquid around the vestibule corresponding with the philtrum, which increased levator muscle activity. Undoubtedly, dynamic affective responses were happening at the same time. For the emptying phase, the increase of levator activity evoked by the medium and high concentration levels of bitter and sweet solutions indicated that the oral nasal rejection of aversive chemosensory stimuli appeared quickly. During the swirling phase, there was no obvious increase in levator activity evoked by the water control and low concentration solutions, suggesting participants did not make oral rejection or disgust expressions to these solutions. However, the significant increase in EMG activity in the levator muscle evoked by bitter-medium, bitter-high and sweet-high solutions illustrated that bitter tastes, and high concentrations of sucrose (beyond an individual's bliss point) are unpleasant (Reed et al., 2006). After spitting out, a distinct pattern was found between the sweet and bitter sessions. Compared to the sweet session, EMG activity for the levator muscle was higher for the bitter session, which indicated that levator activity was greater when discriminating the bitter stimuli, and sweet taste stimuli with high concentration. These results are comparable with other studies (Armstrong et al., 2007b; Chapman et al., 2009; Horio, 2003).

Compared to the tasting block, the overall trend of EMG activity for the levator muscle was the same as for the rating block (see Figure 4-9, Figure 4-10, Figure 4-11, and Figure 4-12), except for low concentrations during the emptying phase of the sweet session. The overall change score in levator activity for the rating block was higher than for the tasting block.

In summary, levator muscle, as a negative affect muscle, basically presented the same EMG activity pattern as the corrugator muscle. However, in this EMG measurement, more EMG activity in the levator muscle was found for both sweet and bitter sessions, which indicates that when emptying and swirling liquid, the levator muscle is also used as a functional muscle. Therefore, whether the levator muscle is still a reliable muscle to predict the hedonic liking rating during the emptying and swirling phases or not should receive more attention. This issue will be addressed in Chapter 5.

4.5.7 EMG activity in the masseter muscle during the emptying, swirling and thinking phases for the tasting and rating blocks of the sweet and bitter sessions

Masseter muscle is a functional muscle rather than an affective muscle, which is involved in chewing during the consumption of solid and semi-solid foods. In this study, the result of masseter activity is listed in Figure 4-9, Figure 4-10, Figure 4-11, and Figure 4-12. More activity in the masseter muscle was observed for the sweet solutions rather than the bitter solutions during the emptying phase except for the high concentration level, which may be explained by the participants opening and closing their jaws to empty the liquid into their mouths. For sweet solutions, participants expected to have a pleasant experience, so they opened their mouths widely to receive the solutions. However, during the bitter session, participants were less willing to empty the solutions into their mouths and functional muscle activity was suppressed. Furthermore, for the highest concentration, masseter had high activity because the participants were grimacing. During swirling, EMG activity in the masseter muscle for bitter solutions was higher than for sweet solutions, which illustrated that more activity of the masseter muscle was found in less preferred solutions (Horio, 2003). Regarding the thinking phase, there was a similar activity in the masseter muscle when thinking about sweet solutions. Moreover, increased activity for the masseter muscle when thinking about bitter-high concentration solutions illustrated that chewing or clenching muscles were found to have more activity when the participants disliked the taste of the solution (Horio, 2003).

In summary, the activity of the masseter muscle was not as strong as the other facial muscles, because the masseter muscle is a functional muscle active when clenching the jaw or involved in chewing solid food. However, this chewing muscle still had more activity for less preferred liquid stimuli, which indicated the potential of this function muscle to predict the hedonic liking rating. The EMG activity in the masseter muscle resulting from the negative affect or individual swirling behaviour is a crucial issue when considering the application of EMG in assessing hedonic liking during mastication. Taking another facial muscle such as the temporalis into consideration is essential to detect the chewing behaviour and benefit in understanding the masseter muscle better.

Masseter activity during the rating block presented the same trend as the tasting block apart from the emptying phase. No distinct pattern was found in the emptying phase for both sessions.

4.5.8 Dynamic facial muscle activities during the emptying, swirling and thinking phases for the tasting and rating blocks

As mentioned in 4.4.1, the primary research of this study is to find out the different dynamic affective responses when the participant emptied, swirled and spat out the liquid. It is the reason why emptying, swirling and thinking phases were set in Facial EMG measurement. Again, the difference between the tasting and the rating blocks was that during the rating block, participants not only tasted the same sample stimuli as the tasting block, but also after spitting out each stimulus, the hedonic liking and intensity ratings were both provided by them. The tasting block recorded pure EMG activity, whereas the interruptive EMG data were recorded during the rating block because participants were required to rate the stimuli. Different psychophysiological data was collected for further advanced statistical analysis to predict the hedonic liking and intensity rating data, which will be discussed in Chapter 5.

The facial muscle activity during the sweet session tasting block will be discussed first (see Figure 4-21,Figure 4-23,Figure 4-25,Figure 4-27(a)-(c)). The results show that the EMG activity of the corrugator and levator muscles for sweet-high solutions were always higher than for the other concentrated solutions from the emptying to the thinking phase; this indicates that the high concentration sweet solution aroused a negative affect from participants (Chapman et al., 2009). A distinct pattern was found in the swirling phase for the zygomaticus and masseter muscles because the swirling pattern was able to be distinguished. For the thinking phase, there was no distinct pattern of EMG activity over the masseter muscle, but its stable trend after 3000ms supported the theory that the masseter muscle is a functional muscle for oral processing and is not used to display facial emotion. Similar EMG activity over corrugator, levator and zygomaticus muscles for sweet-low solutions and water control represent weak affective responses evoked by these solutions. According to Figure 4-29, the sweet-medium and sweet-high solutions were rated the most liked solutions by participants. However, high EMG activity for corrugator and levator muscles were in contrast to these positive ratings because only disliking or disgust tends to evoke negative affect muscle movements. More attention should be paid to the rating values and error bars of the acceptability rating for sweet-high solutions. The large error bars represent variability in liking ratings across participants to these sweet-high solutions. Maybe some sweet-likers gave a high acceptability rating for the highest concentration level, so there was also greater muscle activity in the zygomaticus muscle for these participants (see Figure 4-25 (c)). However, an increase in levator and corrugator activity was more likely to result from participants who rated higher concentration sweet solutions negatively. For the sweet-medium solution, low EMG activity in the corrugator muscle is supported by previous research that found that the higher the recorded responses from the corrugator muscle, the lower the preference for the solution (Horio, 2003). Similarly, high activity in the zygomaticus muscle was evidence of liking for this concentration level.

The results for bitter solutions are the opposite of the results for sweet solutions, as participants all rated the solutions negatively; furthermore, the bitter-high solution was the least liked by participants (see Figure 4-29). This is because bitterness is assumed to be a bad taste at all concentrations (Reed et al., 2006). Focusing on the -500 to 0ms during the emptying screen (with 0ms being the point at which participants clicked the mouse button to confirm that they had emptied the cup into their mouths), the huge increase of activity in the corrugator, zygomaticus, levator and masseter muscles for bitter-high solutions all indicated that when this liquid was emptied into the mouth, a negative affect was evoked briefly, quickly and strongly. Increased activity in levator and corrugator muscles revealed strong negative affects were evoked whereas this grimace was so strong that it also led to an increase in zygomaticus and masseter activity. According to Horio (2003), an increase in the masseter muscle activity was evoked by the lower preference of tasted solutions. Similarly, bitter-medium solutions evoked activity in these facial muscles, but not as strongly as for bitter-high solutions. This is the same results as shown by Reed et al. (2006) and Kocher and Fisher (1969) that the concentration was the important factor when determining liking or disliking. Interestingly, during the swirling phase, the dynamic facial muscle activity illustrated that there was reduced swirling behaviour for the bitter session because EMG activity in zygomaticus, levator and masseter muscles looked smooth. That meant participants stopped swirling these bitter solutions which had evoked their negative, disgusted feelings. Undoubtedly, these four facial muscle activities all presented high activity for bitter-high solutions because participants were making an extreme facial expression of disgust. A similar pattern was observed in bitter-medium solutions, but owing to the reduced concentration, it was not as strong as for the bitter-high solutions. In terms of bitter-low solutions and water control, activity for the corrugator muscle presented the least change compared with other solutions, indicating that we might expect increased liking ratings to these two kinds of solutions, which was confirmed by the acceptability rating shown in Figure 4-29.

Interestingly, small, slow swirling behaviours were found in the zygomaticus muscle because its activity fluctuated from 0 to 7000ms with no linear increase or decrease in activity. The stable activity of the levator and masseter muscles was more likely to result from holding solutions within the mouth and making little swirling movements. After spitting out the solutions, the activity of all facial muscles was highest for the bitter-high solutions. It is easy to understand the increase in corrugator and levator activity because they are negative affect muscles; furthermore frowning and disgust are typical expressions of anger and dislike. However, the increased activity in masseter and zygomaticus muscles was most likely because of the extreme disgust facial expression which occurred because participants were asked to swirl a bitter solution in their mouths. Usually, such an unpleasant solution would immediately be rejected and spat out; but in this unusual experimental setting, participants were asked to swirl the solution. Instead of simply being disgusted by the unpleasant liquid and spitting it, they grimaced and minimally swirled the liquid in their mouths (as instructed). This was supported by the increase of both zygomaticus and masseter muscle activity from 1500 to 3500ms. The same trend happened for bitter-medium solutions. The minimal activity of the levator and corrugator muscles evoked by water control and bitter-low solutions indicated an increased preference to them, which was the same result as for the acceptability ratings (Figure 4-29). There was no distinct pattern of zygomaticus and masseter muscle activity for water control and bitter-low solutions, but the fluctuations of their activity were likely to result from the residual solutions left (after spitting out) in the participants' mouths. Specifically, participants might have opened their mouth and made some movements to remove the residue.

The same EMG activity trend of the corrugator, zygomaticus, levator and masseter muscles was present during the rating block because participants tasted the same solutions during the rating and tasting blocks. It suggests that rating the solutions after the three phases did not change the participants' functional or affective facial muscle activity. Additionally, no obvious difference in EMG activity in corrugator, zygomaticus, levator and masseter muscles between the rating and the tasting blocks implicated any particular one and assumes that if EMG is used in any future study, recording only pure EMG activity is able to discriminate the liking or disliking of the stimuli. This assumption will be demonstrated in Chapter 5 using multi-level modelling to predict the hedonic liking rating.

In summary, there was a similar EMG activity pattern of the corrugator, levator, zygomaticus, and masseter muscles on tasting water control, the bitter-low, bitter-medium and bitter-high liquids during the emptying, swirling and thinking phases. Negative affects grew sharply when the liquid was emptied into the mouth. There was still a quick increase in EMG activity at the beginning of swirling phase, but after reaching the peak points, their EMG activities all kept a gradually decreasing trend until the end of thinking phases. Concerning tasting sweet stimuli, not very strong positive affect was found; furthermore, three dynamic phases, including the emptying, swirling and thinking phases all presented a long and stable pattern of EMG activity in facial muscles. Since the emotion pattern was dynamic when emptying, swirling and thinking about the liquid, the liking or disliking of food stimuli has been determined when the food is placed in the mouth, which attracts our attention. These findings are also very beneficial to food innovation and mastication because aftertaste mouth feel could be detected. Some future research work can be done on aftertaste mouth feel which has a dominant role in determining hedonic liking, while enhancing the flavour perception after swallowing will also increase the hedonic liking to any new foods.

4.6 Summary of key findings from Study 2

Study 2 involved tasting different concentrations of sweet and bitter stimuli. The purpose of Study 2 was to detect dynamic emotion change when participants tasted these different concentrations. Study 2 was composed of three experiments, including supertaster testing, acceptability testing to select the stimuli for the final experiment, and tasting liquids while there was facial EMG measurement.

There were several key findings from Study 2:

1. Strong negative affective responses were found when tasting bitter-medium and bitter-high concentration liquids. Activity of the corrugator and levator muscles increased significantly for these liquids. Additionally, activity of the masseter and zygomaticus muscles was evoked by these stimuli. For tasting sweet stimuli, positive affect did not elicit strong activity for the zygomaticus muscle, which was the same finding as in Study 1. Interestingly, sweet-high concentration liquids evoked negative affect and this likely depended on individual differences in liking for sweet tastes relating to individual's sweetness bliss-point.

These findings provide a range of insights about the topic:

1) Screening pleasant stimuli to discover whether they will evoke positive affect in future studies is important. Potentially it will be important to select medium sweet likers or select sweet concentrations based on participants' sweet liking status.

2) Given that there is no perfect method that can select food stimuli that all participant will be guaranteed to like; is there a statistical analysis method that can be relied on to predict the hedonic liking rating without requiring that the acceptability of the food stimuli was predetermined?

3) The pattern of activity for the zygomaticus muscle should be investigated further because when tasting sweet stimuli, no strong affective responses were found, but some muscle contractions were made when tasting high concentration bitter liquids.

2. The dynamic emotional change for the emptying, swirling and thinking phases varied throughout the experiment. For the bitter liquids, negative affect increased rapidly when the liquid stimulus was placed in the mouth. At the beginning of the swirling phase, negative affect tended to quickly increase to a maximum peak. However, after reaching the peak activity, negative affect decreased gradually and this continued until the end of the thinking phase. In contrast, although positive affect increased gradually at the end of the emptying phase, generally it remained stable until the end of the thinking phase. These dynamic patterns provide new ways to think about affective responses during oral processing or swirling of liquids. For example, when is the best time to try and correlate muscle activity with hedonic responses after food is placed in the mouth? If the liking or disliking of food is decided at the beginning of the tasting, which muscles will be the best ones to discriminate affect and predict hedonic liking ratings?

3. The highest magnitude EMG activity was for the levator muscle compared to the other facial muscles. This suggested that the levator muscle was active when swirling liquids. In studies using solid foods, oral processing these solid foods will likely result in activity of the masseter muscle (jaw clenching). This study has provided evidence to assist in choosing the best muscles to discriminate affect and predict hedonic liking ratings for different stimuli.

Multi-level modelling will be used to explore the predictive relationship between facial muscle activity and hedonic liking ratings and intensity ratings. Chapter 5 will introduce this tool and then use it to analyse the data from Study 1 and Study 2.

5 Multi-Level Modelling Analysis

5.1 Introduction

In Study 1 and Study 2, conventional statistical analysis methods such as ANOVA and T-Test were used to explore the relationship between activity of facial muscles and the hedonic liking rating of stimuli. However, no conclusions can be made for positive stimuli such as pleasant food pictures or sweet solutions because liking and preferences varies with individual differences. Currently, there is no perfect method to screen out stimuli to evoke positive ratings from all human beings. Therefore, an advanced statistical tool should be used to mitigate these limitations instead of relying on conventional statistical techniques. Here, multi-level modelling (MLM) will be used as a statistical tool to predict hedonic liking ratings using facial muscle activity.

Multi-level or hierarchical structures are normal in social, medical and biological research. For example, lots of social studies involve individuals nested within geographical areas or institutions such as their class, school, or country. However, standard statistical techniques such as analysis of variance (ANOVA) or regression are not able to meet the requirements of analysing this data because these techniques only allow the inclusion of variables at one level, which means that it is difficult to study contextual factors in conjunction with individual variables. Jones, Jones and Jorgensen (2003) tried to use dummy variables representing contextual settings, but when large numbers of observations are involved, dummy variables are not recommended.

Recently, multilevel models (Goldstein, 2003) provided new opportunities to study the relationship between individual variables and their contextual settings. Specifically, the investigation of the nature of between-group variability and the effects of group-level characteristics on individual outcomes can be done using multilevel models. Multilevel modelling provides the flexibility to run complex models, but crucially, because they are both based on the general linear model, a simple regression model will generate the same outcome when run using a multilevel modelling approach.

There are advantages when using multilevel models compared with regression (including ANOVA). First, in this study, different levels of observed data can be nested within each participant. Second, in a standard statistical tool, the whole data of the participant might be excluded if there is missing data for this participant. However, multilevel models can overcome the problem of missing data and offers a relatively easy solution to deal with the missing data using parameters to estimate the available data. Third, this modelling allows for individual difference in participants without compromising the analysis or adding unexplained variability to the data. Fourth, variable regression slopes can be generated using different models such as intercept models, randomized models or randomized-intercept models. However, standard techniques such as regression are only able to provide the same slope for all groups. Fifth, standard statistical techniques fail to meet the assumption of dependence within errors, which leads them to underestimates of standard errors and result in narrow confidence intervals. However, in multilevel models, relationships between residuals can be explored and can explain variations in the outcome variable.

The purpose of this chapter is to use multi-level modelling to predict the hedonic liking ratings and intensity ratings by using psychophysiological data. The rating and psychophysiological data were both collected in Study 1 and Study 2.

Owing to prediction being the focus of this chapter, the primary research questions are:

1) For Study 1, can facial muscle activity predict hedonic liking ratings on a 9-point scale?

2) For Study 2, which stage of the emptying, swirling, and thinking phases will be the best for predicting the hedonic liking rating using the LAM scale?

3) For Study 2, can the intensity rating of liquid stimuli be predicted using facial muscle activity? Additionally, which stage will be the best for predicting the intensity rating?

4) For Study 2, will the pattern of results be the same when tasting alone versus tasting and then rating?

Therefore, the hypotheses will be:

1) The corrugator and levator muscles will predict decreased hedonic liking ratings whereas the zygomaticus muscle will predict increased liking ratings.

2) There3 will be a positive relationship between Intensity ratings and corrugator and levator muscle activity, but a negative relationship between Intensity ratings and the zygomaticus muscle activity.

3) The masseter muscle will not predict hedonic liking or intensity ratings.

4) The emptying and thinking phases will be the best stages to predict hedonic liking and intensity ratings for Study 2.

5) The predicted results of the models for the tasting only and the tasting and rating blocks will be the same.

To demonstrate these hypotheses, different models including ***Model A***, ***Model B***, ***Model C***, ***Model D***, ***Model E*** and ***Model F*** are established to explore the feasibility of predicting the rating data using different variables. However, ***Model D*** is the most important model for predicting the rating data in this study because, in this model, only psychophysiological data is used to predict the rating data. This model will be explained in full and discussed in detail. The results of other models are in Appendix IV.

5.2 Methodology

5.2.1 Assessing and comparing multi-level models

All modelling was run using SPSS version 23.

Minus twice the log-likelihood *(-2LL*): SPSS uses *-2LL* to report the overall fit of a multilevel model. Specifically, when the value of the log-likelihood is smaller, the better the model fits the data. *-2LL* can be used to compare different models, furthermore, models with lower *-2LL* value will be more favourable.

Akaike's information criterion (*AIC*): This statistic value belongs to a goodness-of-fit measure. The value is corrected for model complexity and takes into consideration how many parameters have been estimated. Models with more parameters are penalized.

Schwarz's Bayesian criterion (*BIC*): This has a more conservative statistic value compared to AIC because *BIC*'s correcting is harsher. When sample sizes are large, and the number of parameters is small, *BIC* should be considered.

5.2.2 Types of covariance structures

Covariance structure describes the form of the variance-covariance matrix and the relationship between the variables within the model. Variance Components and Unstructured are two different structures which were taken into account in our dataset because different covariance structures are suggested to run the models to compare the goodness-of-fit indices to see if changing the covariance structure would improve the fit of the model or not.

Variance Components (VC) means that all random effects are independent and the covariance in the matrix is 0. VC is likely to be a reasonable pattern when the variables are completely independent of each other, or they are measured on different scales.

Unstructured (UN) is a general pattern which means there is no pattern at all. Each variance is different, and each covariance is unpredictable. Furthermore, they have no relation to the others and don't conform to a systematic pattern.

Other covariance structures are available, but with the minimally sufficient sample size in the study, these were not suitable for the models that were fitted. Modelling using a Bayesian MC, MC approach suggested that there would be a minimal gain in using other variance covariance structures; additionally, SPSS was unable to consistently find convergence for several of the models using more restrictive covariance structures.

5.2.3 Estimation methods

Two methods for estimating the parameters are provided by SPSS. These are maximum likelihood (ML) and restricted maximum likelihood (REML). Under most circumstances, ML and REML will produce only slight differences in the parameter estimates. ML always makes the estimates of fixed regression parameters more accurate, whereas REML focuses on estimating more accurate random variances (Twisk, 2006). However, comparison between models is only able to be made by ML. Therefore, ML was used for estimating the parameters in our analysis.

5.2.4 Dependent variables

Study 1: the 9-point scale rating (hedonic liking ratings for imagery stimuli).

Study 2: The dataset was used to fit two different multi-level models. The dependent variable of the first set of models was the LAM (acceptability ratings for liquids) and for the second set of models was the LMS (intensity ratings for liquid stimuli) ratings (see 4.2.3).

5.2.5 Independent variables

Independent variables are composed of categorical variables and continuous variables. Separate prediction using multi-level modelling is conducted for Study 1 and Study 2. Therefore, their corresponding independent variable is listed in the following.

Study 1: Categorical variables were the different category of imagery stimuli, including positive, negative, and high variability stimuli. Facial muscular activities were used as continuous variables to predict the hedonic liking rating.

Study 2: The prediction analysis was more complicated than Study 1. The categorical variables were different concentration levels of sweet and bitter stimuli, including taste stimuli (sweet/bitter) and stimuli concentration (water, low, medium, and high). Continuous variables were EMG activity in the corrugator, levator, zygomaticus, and masseter muscles. The interaction variables between categorical and continuous variables were also referred to as Concentration (water, low, medium, high) * Muscle (corrugator, zygomaticus, levator, masseter).

5.2.6 Multilevel Model Building

Model A. "*Model A*", the "null model" was specified as the simplest multilevel model which allows for the participant effect on LAM/LMS ratings, without any explanatory variables. This 'null' model may be written

$$\mathbf{Y = B_0 + \sigma^{2\mu} + \sigma^{2e}} \qquad \textbf{(Equation 5-1)}$$

Where Y is the dependent variable, the LAM/LMS rating by the participant, B_0 is the overall intercept or LAM/LMS rating across participants, $\sigma^{2\mu}$ is the effect of the participant on LAM/LMS rating, which will refer to level 2 residuals. σ^{2e} is a participant level residual, which means the residual within participants.

Model B. "*Model* B" was the null multilevel model with a null single-level model. In order to test the significance of participant effects, this model was introduced here. The difference from Model A was that random between-participant effect was removed.

Model C. "*Model C*" was specified to include categorical predictor variables in the model. This modelling was only used in Study 2 to investigate the concentration influence on LAM/MS ratings by the participants. Different levels of concentration (high, medium, low and water control) with sweet and bitter solutions were introduced as the only categorical variables to predict the ratings.

Model D. "*Model D*" was specified to include continuous predictor variables only in the model. This model is of particular interest because it will establish whether facial muscle activity alone is a good predictor of subjective ratings without considering the category of stimuli. Study 1 and Study 2 both used this model for predicting the rating data, separately. Four facial muscles, including corrugator, zygomaticus, levator and masseter were included as explanatory variables for predicting the LAM/LMS ratings by this model.

The equation was formulated as follows:

$$\textbf{Rating} = B_0 + B_2 * \textbf{Muscle} + E \qquad \textbf{(Equation 5-2)}$$

Model E. "*Model E*" was used only to predict LAM/LMS ratings from Study 2. Two independent variables were used, including categorical variables (Concentration: water, low, medium, high) and continuous variables (Muscle: corrugator, levator, zygomaticus, masseter) to investigate their influence on predicting LAM/LMS ratings.

The equation was formulated as follows:

$$\textbf{Rating} = B_0 + B_1 * \textbf{Concentration} + B_2 * \textbf{Muscle} + E \qquad \textbf{(Equation 5-3)}$$

Of the variables in the model, the rating is the outcome predictor including LAM and LMS rating. Concentration and Muscle are predictor variables, which represent the concentration level and facial muscle activity in this analysis. E is the residual error which is an unmeasured variable. The parameters in the models are B_0, B_1 and B_2, which mean response variable's intercept, Concentration-intercept and Muscle-intercept, respectively.

Model F. "*Model F*", was adding an interaction term to the model in which the two predictor variables are multiplied. In this model, there would be three terms, including categorical variables (Concentration: water, low, medium, high), continuous variables (Muscle: corrugator, levator, zygomaticus, masseter) and the interaction term between categorical and continuous variables (Concentration*Muscle). This model is still used to predict the rating data from Study 2.

The equation will look like the following:

$$\textbf{Rating} = B_0 + B_1 * \textbf{Concentration} + B_2 * \textbf{Muscle} + B_3 * \textbf{Concentration*Muscle} + E \qquad \textbf{(Equation 5-4)}$$

At this point, the interaction term means the effect of concentration levels is not limited to B_1 but also depends on the values of B_3 and muscle activity. Therefore, this model could provide more specific interpretation for predicting LAM/LMS rating. The parameters in the models are B_0, B_1, B_2 and B_3, which mean response variable's intercept, Concentration-intercept, Muscle-intercept, and Muscle*Concentration-intercept, correspondingly.

In summary, ***Model A*** and ***Model B*** are essential to check the fitness of using *MLM*. Only ***Model D*** was conducted to predict the rating data for both Study 1 and Study 2. The detailed results and explanations are listed in the following. However, ***Model C***, ***Model E*** and ***Model F*** were not the primary focus of this study, the results of these models from Study 2 are listed in Appendix IV. The basic and simple explanation of these models is included in the Results session to help readers to understand the models better.

5.3 Study 1 Result: using *Model D* to predict the hedonic liking rating of the 9-point scale

5.3.1 Estimation methods and types of covariance structure

Two estimation methods (including ML and REML) and two types of covariance structure (including VC and UN) were compared using ***Model A***. The results have been presented in Table 5-1. It can be seen that the types of covariance structure produced the same parameter values when the same estimation method was used, but the UN is used in the unsystematic system, which is likely to fit our model better. However, taking goodness-of-fit into consideration, the parameter values, including -2LL, *AIC* and *BIC* analysed by ML were slighter lower than REML, therefore in this analysis for Study 1, ML and UN were applied as the estimation method and types of covariance structure.

Table 5-1 Comparing *Model A* using two estimation methods and covariance structures

		Parameter	ML-VC	ML-UN	REML-VC	REML-UN
Model A						
Fixed Effects						
	Intercept	Γ^{00}	-0.233	-0.233	-0.233	-0.233
Variance Components						
Level 1	Within-Participants	σ^{2e}	9.004***	9.004***	9.023***	9.023***
Level 2	Between-Participants	$\sigma^{2\mu}$	3.579**	3.579**	3.602**	3.602**
Goodness-of-fit						
	-2LL		2417.056	2417.056	2419.193	2419.193
	AIC		2423.056	2423.056	2423.193	2423.193
	BIC		2435.578	2435.578	2431.537	2431.537

Note: *p<.05; **p<.01; ***p<.001

5.3.2 Checking the goodness of the model and testing participant effects

Table 5-2 presents the result of checking model fitness and testing participant effects for predicting the hedonic liking of the 9-point scale. From Table 5-2, it was found that the overall mean hedonic liking was estimated at -0.233. The variance partition coefficient (VPC) is calculated using variance components, whose formula is

VPC = Level 2 Variance / (Level 1 Residual + Level 2 Variance) (Equation 5-5)

Therefore, the VPC value of ***Model A*** is 29.83% which indicates that 29.83% of the variance in hedonic liking rating can be attributed to differences between participants.

The purpose of ***Model B*** is to test the significance of participant effects, so a likelihood ratio was used. The likelihood ratio is calculated as the difference in the -2LL for the two models:

LR = -2LL (Model B) - -2LL (Model A) (Equation 5-6)

The LR value of this model is 158.768 on 1 d.f. (number of parameter difference between models), respectively. According to the chi-squared distribution with 1 d.f., the 5% point critical value is 3.84. This is strong evidence of participant effects of the hedonic liking rating; therefore, this is the reason why the multilevel model was fitted with participant effects modelled as a random effect.

Table 5-2 Null model and null multilevel model with a null single–level model for predicting the hedonic liking rating of the 9-point scale

Hedonic liking rating				
		Parameter	***Model A***	***Model B***
	Fixed Effects			
	Intercept	Γ^{00}	-0.233	-0.233
	Variance Components			
Level 1	Within-Participants	σ^{2e}	9.004***	34.799***
Level 2	Between-Participants	$\sigma^{2\mu}$	3.598***	-
	Goodness-of-fit			
	-2LL		2417.056	2575.824
	AIC		2423.056	2583.824
	BIC		2435.578	2609.765

Note: *p<.05; **p<.01; ***p<.001

5.3.3 *Model D* to predict the 9-point scale rating for Study 1

In ***Model D***, muscle activity of four facial muscles, corrugator, levator, zygomaticus, and masseter, all continuous variables, were entered into a multi-level model as the only predictors to explain the dependent variable, hedonic liking rating using a 9-point scale. Table 5-3 shows the predictive relationship between facial muscles and hedonic liking of the 9-point scale and can be interpreted as follows:

Fixed effects

Equation 5-7 **9-point scale Rating = B_0 + B_2* Corr+B_3*Lev+B_4*Zygo+B_5*Mass +E**

The model intercept (B_0) was 0.627 with low significance, which indicates that the average 9-point scale rating was expected to be 0.627 if facial muscle activity remained unchanged. E is the residual error which is an unmeasured variable.

Since 'Muscle' is a continuous variable, B_2, B_3, B_4 and B_5 represent the difference in the predicted value of the 9-point scale rating for each one-unit difference in corrugator, levator, zygomaticus, masseter muscle activities, respectively. Therefore, when EMG activity in the corrugator and levator muscles doubled, their corresponding hedonic liking rating would be expected to decrease by 5.93 and 3.060 respectively, which indicates that the corrugator and levator muscles had a negative and significant influence on predicting the hedonic liking rating of any stimuli. On the other hand, a minimum and positive effect was found in the masseter and zygomaticus muscles, but this effect was not statistically different from zero (the null hypothesis for these comparisons).

Variance Components

There are two levels of variance components, including within-participants and between-participants. The 'Within-Participants' component represents the consistency of the liking response to stimuli within the participant's data. The 'Between-Participants' component reflects the individual differences between each participant's responses.

The variance within-participants of ***Model D*** was 6.568 and this effect was significant. However, there were no obvious individual differences between each participant owing to the minimum level 2 variance value. Taking VPC into consideration, only 6.73% of the variance in the 9-point scale rating can be attributed to the differences between participants.

Goodness-of-fit

In this model, the values of ***-2LL***, ***AIC*** and ***BIC*** were 1144.567, 1158.567 and 1182.931, respectively.

Table 5-3 *Model D*: Facial muscle activity predicting 9-point scale rating for Study 1

Study 1 - Model D- 9-point scale rating			
		Parameter	
	Fixed Effects		
	Intercept	r^{00}	0.627*
Muscle	Corrugator		-5.293***
	Zygomaticus		1.205
	Levator		-3.060**
	Masseter		0.030
	Variance Components		
Level 1	Within-Participants	σ^{2e}	6.568***
Level 2	Between-Participants	$\sigma^{2\mu}$	0.474
	Goodness-of-fit		
	-2LL		1144.567
	AIC		1158.567
	BIC		1182.931

Note: *p<.05; **p<.01; ***p<.001

5.4 Study 2 Results: using *Model D* to predict the hedonic liking rating and the intensity rating of LAM/LMS scales

5.4.1 Estimation methods and types of covariance structure

As with 5.3.1, the estimation methods and types of covariance structure were compared using ***Model A*** first. Types of covariance structure produced the same parameter values when the same estimation method was used, but the UN is used in the unsystematic system, which is more likely to fit our model better. However, taking goodness-of-fit into consideration, the parameter values, including **-*2LL***, ***AIC*** and ***BIC*** analysed by ML, were slighter higher than REML, but in the later analysis, comparative modelling is included. Therefore, ML and UN were applied as the estimation method and types of covariance structure to predict the rating in Study 2.

Table 5-4 Comparing *Model A* using two estimation methods and covariance structures

		Parameter	ML-VC	ML-UN	REML-VC	REML-UN
Model A						
Fixed Effects						
	Intercept	Γ^{00}	3.541	3.541	3.541	3.541
Variance Components						
Level 1	Within-Participants	σ^{2e}	142.809***	142.809***	142.809***	142.809***
Level 2	Between-Participants	$\sigma^{2\mu}$	71.278**	71.278**	75.569**	75.569**
Goodness-of-fit						
	-2LL		3605.222	3605.222	3601.955	3601.955
	AIC		3611.222	3611.222	3605.955	3605.955
	BIC		3623.589	3623.589	3614.195	3614.195

Note: *p<.05; **p<.01; ***p<.001

5.4.2 Checking the goodness of the model and testing participant effects

Table 5-5 and Table 5-6 present the results of checking model fitness and testing participant effects for predicting LAM and LMS rating from the sweet and bitter sessions, respectively. The interpretation of this model was the same as in Study 1 (see 5.3.2). From Table 5-5, it was found that the overall mean LAM rating of the sweet and bitter models was estimated at 3.541 and -16.413, respectively. The VPC value of Sweet and Bitter ***Model A*** is 33.29% and 11.24%, which indicates that 33.29% and 11.24% of the variance in LAM rating can be attributed to differences between participants during the sweet and bitter sessions, respectively.

The purpose of ***Model B*** is to test the significance of participant effects, so a likelihood ratio was used. The LR value of the sweet and bitter models is 135.920 and 27.852 on 1 d.f., respectively. According to a chi-squared distribution on 1 d.f., the value of 5%-point critical value is 3.84. It is strong evidence of participant effects of the LAM rating; therefore this is the reason why the multi-level model was selected that included participant effects.

The null model of the LMS rating is listed in Table 5-6. The mean intensity rating of the sweet and bitter sessions was estimated at 22.622 and 33.296, respectively. The VPC value of the sweet and bitter sessions was quite similar, which was 14.86% and 15.42%, correspondingly. That means around 15% of the variance in LMS rating can be attributed to differences between participants for both testing sessions. Considering the LR ratio, 42.630 and 44.419 was the LR ration on 1 d.f. for the sweet and bitter models, which indicated that participant effects influenced the LMS rating.

Table 5-5 Null model and null multilevel model with a null single–level model for predicting LAM rating with sweet and bitter sessions

		Parameter	Sweet Model A	Sweet Model B	Bitter Model A	Bitter Model B
			LAM			
			Fixed Effects			
	Intercept	Γ^{00}	3.541	3.541***	-16.413***	-16.413***
			Variance Components			
Level 1	Within-Participants	σ^{2e}	142.809***	214.087***	270.494***	304.754***
Level 2	Between-Participants	$\sigma^{2\mu}$	71.278**	-	34.259*	-
			Goodness-of-fit			
	-2LL		3605.222	3741.142	3874.314	3902.166
	AIC		3611.222	3745.142	3880.314	3906.166
	BIC		3623.589	3753.387	3892.681	3914.411

Note: *p<.05; **p<.01; ***p<.001

Table 5-6 Null model and null multilevel model with a null single–level model for predicting LMS rating with sweet and bitter sessions

		Parameter	Sweet Model A	Sweet Model B	Bitter Model A	Bitter Model B
LMS						
Fixed Effects						
	Intercept	Γ^{00}	22.622***	22.622***	33.296***	33.296***
Variance Components						
Level 1	Within-Participants	σ^{2e}	407.748***	479.669***	850.909***	1006.058***
Level 2	Between-Participants	$\sigma^{2\mu}$	71.920**	-	155.149**	-
Goodness-of-fit						
	-2LL		4066.374	4109.004	4402.344	4446.763
	AIC		4072.374	4113.004	4408.344	4450.763
	BIC		4084.374	4121.249	4420.711	4459.007

Note: *p<.05; **p<.01; ***p<.001

5.4.3 Model D to predict LAM rating during the emptying, swirling, and thinking phases for the tasting and the rating blocks

As with 5.3.3, muscle activity of the four facial muscles, all continuous variables, were used as the only predictors to explain the LAM rating using ***Model D***. Separate models were calculated for the tasting and the rating blocks, which have been presented in Table 5-7and Table 5-8.

5.4.3.1 Model D to predict the LAM rating for the tasting block

Table 5-7 presents the predictive relationship between facial muscle activity and the hedonic liking rating for the tasting block. The interpretation of the result was the same as 5.3.3.

Fixed effects

The three different model intercepts (B_0) for the emptying, swirling and thinking phases was 2.512, 1.891, and -0.695 respectively, which indicated that the average LAM rating was expected to be 2.512, 1.891 and -0.695 if facial muscle activity remained unchanged.

During the emptying phase, the corrugator and levator muscles were found to influence the hedonic liking rating negatively and significantly. When EMG activity in the corrugator and levator muscles doubled, their corresponding LAM ratings would expect to decrease by 12.095 and 5.007, respectively. However, the zygomaticus muscle activity influenced the hedonic liking prediction positively, indicating that as its activity doubled, its corresponding hedonic liking would expect to increase by 8.282 significantly. All three of these muscles were statistically significant predictors, which means that they reliably predicted a change in LAM ratings more than zero, and this is supported by a confidence interval that does not include zero. No distinct pattern was able to be found in the masseter muscle.

In the swirling phase, only the zygomaticus and levator muscles were found to predict the hedonic liking with any significance. Specifically, when EMG activity in the zygomaticus and levator muscles doubled (versus the trial baseline), their corresponding hedonic liking would be expected to increase and decrease by 2.867 and -3.718 respectively.

However, during the thinking phase, only the levator muscle was reported to influence the value of the LAM rating negatively with its coefficient being -6.589. Corrugator and masseter muscle activity influenced the prediction of hedonic liking negatively whereas the positive effect was found in the zygomaticus muscle, but this effect was not statistically different from zero.

Interestingly, the corrugator and levator muscles influenced the prediction of the hedonic liking rating negatively whereas the positive effect was always found in the zygomaticus muscle. The influence of corrugator muscle activity on predicting the hedonic liking rating decreased with timing, although it presented the strongest predictive effect during the emptying phase. A similar pattern was found in the zygomaticus muscle. On the other hand, although the predictive influence of the levator muscle on the hedonic liking rating decreased a lot from the emptying to the swirling phase, during the thinking phase its coefficient increased a lot, and the levator muscle was the only reliable muscle to predict the hedonic liking rating. There was no significant effect on the masseter muscle, but an increasing pattern of its predictive influence was found from the emptying to the thinking phase.

Variance Components

The variance within-participants of ***Model D*** during all three phases were close to each other with a strong significance. However, for level-2 variance, the parameter value of the emptying phase was around two times higher than for the swirling and the thinking phases. 12.76% of the variance in LAM rating during the emptying phase can be attributed to differences between participants. However, during the swirling and the thinking phases, their VPC decreased significantly, with only 5.13% and 5.52% respectively. The decreasing trend indicates that more variance could be explained by facial muscle activity rather than by the individual difference between each participant.

Goodness-of-fit

The smallest ***-2LL***, ***AIC*** and ***BIC*** values of the swirling and the thinking phases demonstrates that ***Model D*** provided better model fit for these two phases than for the emptying phase.

Table 5-7 Model D: Facial muscle activity predicting LAM rating for the tasting block

Model D-LAM-Tasting Block					
		Parameter	**Tasting-Emptying**	**Tasting-Swirling**	**Tasting-Thinking**
			<u>Fixed Effects</u>		
	Intercept	r^{00}	2.512	1.891	-0.695
Muscle	Corrugator		-12.095***	-2.042	-1.998
	Zygomaticus		8.282**	2.867*	2.355
	Levator		-5.007**	-3.718**	-6.598**
	Masseter		0.636	-3.657	-2.239
			<u>Variance Components</u>		
Level 1	Within-Participants	σ^{2e}	257.238***	261.299***	262.036***
Level 2	Between-Participants	$\sigma^{2\mu}$	37.613	14.128	15.321
			<u>Goodness-of-fit</u>		
	-2LL		1281.218	1275.726	1276.611
	AIC		1295.218	1289.726	1290.611
	BIC		1316.330	1310.847	1311.731

Note: *p<.05; **p<.01; ***p<.001

5.4.3.2 Model D to predict LAM rating for the rating block

Table 5-8 presents the predictive results of the LAM rating by facial muscle activity during the rating block. The interpretation of this table was the same as 5.3.3 and has been identified in the following:

Fixed effects

For the rating block, the intercept (B_0) for the emptying, swirling and thinking phases was 2.395, 3.898, and 0.343, respectively, which indicated that the average LAM rating was expected to be 2.395, 3.898 and 0.343 if facial muscle activity remained unchanged.

For the rating block, during the emptying phase, zygomaticus muscle activity influenced the estimation of the hedonic liking rating positively and significantly. Specifically, when zygomaticus muscle activity doubled to twice the resting activity, its corresponding hedonic liking increased by 9.986 which was a statistically significant effect. As shown in the previous models, corrugator and levator muscle activity still predicted a negative influence on the estimation of the LAM rating with their coefficients being -5.636 and -5.222, which indicated that when there was increased EMG activity for the corrugator and levator muscles, there was a decreased hedonic liking rating. The masseter muscle still did not predict hedonic liking.

When participants swirled the liquid samples, the levator and corrugator muscles influenced the estimation of hedonic liking strongly and negatively, which indicated that when their muscle activity doubled their corresponding hedonic liking would be expected to drop by 3.874 and 2.364 respectively.

During the thinking phase, the levator muscle still showed the strongest contribution to predicting the LAM rating, which was the same result as in the tasting block. Additionally, its effect was negative. No significant association was found for the other muscles.

In summary, the same predictive result of the emptying and thinking phases was found for both the tasting and the rating blocks. However, the corrugator and levator muscles influenced the prediction of hedonic liking rating negatively and significantly during the swirling phases, which presented the slightly different result of the tasting block. Additionally, the predictive power during the swirling phase decreased a lot compared with the emptying and thinking phases.

Variance Components

There was no obvious difference between the variance within-participants during the emptying, swirling and thinking phases, which indicates that participants were more likely to show consistency to the stimuli during the three phases. However, compared to the level-1 variance, participants' individual differences decreased a lot. Additionally, the parameter value for the emptying and thinking phases was found to be around three times higher than for the swirling phase.

Taking VPC into consideration, 9.81% and 7.74% of the variance in the LAM rating during the thinking and the emptying phases can be attributed to differences between participants. However, during the swirling phase, VPC decreased significantly, reducing to only 3.28%. This suggests that there was much more consistency between and within subjects during the swirling phase. It is likely that the increased VPC during the emptying and thinking phases reflects the impact of individual differences in response to the liquids. This highlights the importance of using a mixed model approach during the emptying and thinking phases, but that there is less gained from using this approach in the swirling phase.

Goodness-of-fit

The parameter values of ***-2LL***, ***AIC*** and ***BIC*** for the rating block presented the same result as for the tasting block. The swirling phase was still the best model fit within three different phases because the smallest assessing values were found.

Table 5-8 *Model D*: Facial muscle activity predicting LAM rating for the rating block

Model D-LAM-Rating Block					
		Parameter	Rating-Emptying	Rating-Swirling	Rating-Thinking
Fixed Effects					
	Intercept	Γ^{00}	2.395	3.898	0.343
Muscle	Corrugator		-5.636**	-2.346**	-2.286
	Zygomaticus		9.986***	1.684	2.311
	Levator		-5.224***	-3.874***	-6.742***
	Masseter		-1.504	-1.512	1.294
Variance Components					
Level 1	Within-Participants	σ^{2e}	259.004***	246.803***	239.553***
Level 2	Between-Participants	$\sigma^{2\mu}$	21.733	8.377	26.046
Goodness-of-fit					
	-2LL		1285.756	1273.228	1276.022
	AIC		1299.756	1287.228	1290.022
	BIC		1320.923	1308.395	1311.189

Note: *p<.05; **p<.01; ***p<.001

5.4.4 *Model D* to predict LMS rating during the emptying, swirling and thinking phases for the tasting and the rating blocks

Table 5-9 and Table 5-10 present the relationship between facial muscle activity and LMS ratings (intensity rating) using ***Model D*** during the emptying, swirling and thinking phases for the tasting and the rating blocks.

5.4.4.1 Model D to predict LMS rating for the tasting block

Table 5-9 shows the predictive relationship between facial muscle activity and LMS rating during the tasting block using ***Model D***, which is interpreted as follows:

Fixed effects

Equation 5-8 $$\text{LMS Rating} = B_0 + B_2{*}\text{Corr}+B_3{*}\text{Lev}+B_4{*}\text{Zygo}+B_5{*}\text{Mass} + E$$

The interpretation is the same as 5.3.3, but the only difference is the outcome response. Here, the intensity rating by the LMS scale was the outcome responses in this model. The intercept of emptying, swirling and thinking phases could be interpreted that the overall average LMS rating was expected to be 17.625, 13.288 and 15.711 of strong significance if their facial muscle activity remained unchanged.

During the emptying phase, the strongest and negative effect was for corrugator muscle activity as a predictor of the intensity rating, which indicated that when corrugator muscle activity doubled, the corresponding LMS rating would be expected to increase 20.408 with high significance. Additionally, as a negative affect muscle, levator muscle activity influenced the prediction positively as well, but with no significance in the presence of the strong corrugator muscle effect.

On the other hand, both increased zygomaticus and masseter activity resulted in a reduction in intensity LMS rating, indicating that if more zygomaticus and masseter muscle activity was evoked, then lower intensity ratings were made by participants, although neither of these muscles were reliable predictors of intensity ratings because their coefficients were not statistically different from null.

During the swirling phase, corrugator and levator muscle activity both reliably predicted LMS rating with their coefficients being 4.594 and 6.212 respectively, which indicated that when their muscle activity doubled, their corresponding LMS rating would be expected to increase by 4.594 and 6.212. Interestingly, the masseter muscle was found to influence the estimation positively, presenting the opposite pattern during the emptying phase, although this small coefficient was not a reliable predictor of intensity ratings. Negative influences on LMS rating was found in the zygomaticus muscle, indicating that increased zygomaticus cheek muscle activity resulted in lower intensity ratings.

When participants were thinking about the taste for 10 seconds after spitting out the liquid, only levator and masseter muscle activity influenced the estimation of LMS rating. Furthermore, compared with the emptying and the swirling phases, their coefficients increased dramatically to 13.281 for the levator muscle and 11.437 for the masseter muscle, which indicated that when more EMG activity in the levator and masseter muscles was present, higher intensity ratings were given by participants. What is of interest is that the corrugator muscle had a minimal influence on predicting the intensity rating during the thinking phase. Again, the zygomaticus muscle produced a small and unreliable positive effect on the estimation.

It should be noted that there was a decreasing effect on the estimation for the corrugator and zygomaticus muscles from the emptying, swirling and thinking phases. However, for the levator and masseter muscles, their predictive effect increased across these phases.

Variance Components

Level-1 variance showed the variance within participants. More within-participant variance could be explained during the emptying phase than the swirling and the thinking phases. All three within participant variance components predicted significant variance in the model compared to a null effect.

Taking VPC into consideration, 13.46%, 17.87% and 12.84% of the variance in the LMS rating was attributed to differences between participants for the emptying, swirling and thinking phases, respectively. Similar to the LAM models, these effects suggest that there were considerable individual differences in participants' judgments of intensity.

Goodness-of-fit

According to its ***-2LL***, the best fit of ***Model D*** to predict intensity ratings during the tasting block was ranked as the thinking (***-2LL***=1366.214), swirling (***-2LL***=1375.737) and finally the emptying phase (***-2LL***=1398.128). Furthermore, ***AIC*** and ***BIC*** values also presented the same trend as ***-2LL***.

Table 5-9 *Model D*: Facial muscle activity predicting LMS rating of the tasting block

Model D-LMS-Tasting Block					
		Parameter	**Tasting-Emptying**	**Tasting-Swirling**	**Tasting-Thinking**
			Fixed Effects		
	Intercept	Γ^{00}	17.625***	13.288**	15.711***
Muscle	Corrugator		20.408***	4.594**	-0.161
	Zygomaticus		-4.994	-3.677	-2.915
	Levator		3.675	6.212***	13.281***
	Masseter		-2.383	3.926	11.437**
			Variance Components		
Level 1	Within-Participants	σ^{2e}	555.579***	467.143***	451.423***
Level 2	Between-Participants	$\sigma^{2\mu}$	86.411	101.663	66.485
			Goodness-of-fit		
	-2LL		1398.128	1375.737	1366.214
	AIC		1412.128	1389.737	1380.214
	BIC		1433.249	1410.858	1401.335

Note: *p<.05; **p<.01; ***p<.001

5.4.1.2 Model D to predict LMS rating for the rating block

The predictive relationship between facial muscle activity and the LMS rating using ***Model D*** for the rating block is presented in Table 5-10.

Fixed effects

According to Equation 5-8, the overall average rating would be expected to be 20.201, 12.875, and 16.555 during the emptying, swirling and thinking phases of the rating block respectively if their muscle activity remained unchanged.

During the emptying phase, corrugator muscle activity had a strong positive influence on the estimation of the LMS rating, which indicated that if corrugator muscle activity doubled, its corresponding intensity rating would be expected to increase by 10.336. However, a negative effect was found for the zygomaticus muscle which reduced intensity ratings. When zygomaticus muscle activity doubled, the intensity rating would decrease by 8.528. There was a small and reliable increase in intensity ratings associated with levator activity, but no reliable influence of masseter activity.

Concerning the swirling phase, corrugator and levator muscle activity had a similar and positive influence on the LMS rating. When their muscle activity doubled, their corresponding rating would be expected to increase by 5.884 for the levator muscle, and 4.129 for the corrugator muscle and these coefficients were significantly different from zero suggesting that they were reliable effects. The zygomaticus muscle also influenced the estimation by reducing intensity ratings, whereas the masseter muscle increased intensity ratings. However, their influence was not as strong as the negative affect muscles.

In contrast, during the thinking phase only the levator muscle was found to influence the estimation by reliably increasing the intensity ratings, which indicated that when its activity doubled, the intensity rating would increase by 11.056. However, the magnitude of the coefficient for the corrugator muscle dropped dramatically from the emptying to the thinking phase. Therefore, for the rating block, levator activity increased the LMS rating, whereas corrugator activity reduced intensity. The zygomaticus and masseter muscles still presented the same pattern as for the swirling phase on the estimation of intensity rating.

In summary, a slightly different predictive effect was found between the tasting and the rating blocks during the emptying and thinking phases. Interestingly, the corrugator muscle had a significant decreasing influence on the intensity estimation whereas the levator muscle predicted an increase in intensity rating for the rating block.

Variance Components

A decreasing and significant pattern of variance within participants was found. The consistency to stimuli from each participant during the emptying phase varied a lot. Interestingly, only 0.91% of the variance in the LMS rating could be attributed to the differences between participants for the emptying phase. However, for swirling and thinking phases, their VPC was almost the same, which was 13.50% and 13.42%, respectively. This indicated that more variance could be explained by the Level-2 variance during the swirling and thinking phases than the emptying phase. Similar to previous models, this suggested that for intensity ratings there were greater differences between participants during the swirling and thinking phases than in the emptying phase.

Goodness-of-fit

According to its ***-2LL*** value, the thinking phase (***-2LL***=1380.395) still presented the best fit for ***Model D*** when the data from the rating block was entered to predict LMS ratings compared to the emptying (-***2LL***=1414.272) and the swirling phases (***-2LL***=1386.270). Furthermore, ***AIC*** and ***BIC*** values also presented the same trend as ***-2LL***. All models converged, and each resulted in reliable parameter estimates.

Table 5-10 ***Model D*****: Facial muscle activity predicting LMS rating of the rating block**

		Parameter	Rating-Emptying	Rating-Swirling	Rating-Thinking
Model D-LMS-Rating Block					
Fixed Effects					
	Intercept	Γ^{00}	20.201***	12.875**	16.555***
Muscle	Corrugator		10.336***	4.129**	1.101
	Zygomaticus		-8.528**	-2.824	-3.158
	Levator		3.918**	5.844***	11.056***
	Masseter		-3.131	1.225	5.502
Variance Components					
Level 1	Within-Participants	σ^{2e}	637.573***	483.484***	465.392***
Level 2	Between-Participants	$\sigma^{2\mu}$	5.864	75.476	72.112
Goodness-of-fit					
	-2LL		1414.272	1386.270	1380.395
	AIC		1428.272	1400.270	1394.395
	BIC		1449.439	1421.437	1415.562

Note: *p<.05; **p<.01; ***p<.001

5.4.5 Study 2: Example for the interpretation of *Model C* and *Model E* during the emptying phase of the tasting block for the sweet session

In this Study 3, multi-level modelling (MLM) was used to predict the hedonic liking rating and intensity rating for Study 1 and Study 2. Different models were established to interpret the predictive results from facial muscle activity, and different concentrations of sweet and bitter stimuli. ***Model D*** is the most important and useful model in this study for predicting ratings because only continuous variables (facial muscle activity) were used in the model. The results of ***Model D*** indicate that increased corrugator and levator muscle activity correlate with reduced liking for the stimuli, whereas increased zygomaticus activity correlates with increased liking for the stimuli, regardless of whether it was viewed or tasted. The remaining models ***Model C***, ***Model E*** and ***Model F*** include categorical variables (different concentration levels of sweet and bitter stimuli), which are not the main emphasis of this chapter. Therefore, the results of these models are placed in Appendix IV. Moreover, the example of how to interpret the result is listed in the following for readers to understand the modelling better. The explanation of these models including categorical variables is different from ***Model D***.

Table 5-11 presents the predictive relationship between the LAM ratings and the different kinds of variables, including categorical (concentration) and continuous (muscle) variables using ***Model C*** and ***E*** during the emptying phase of the tasting block of the sweet session. The psychophysiological and rating data were from Study 2.

Model C interpretation:

Model C was used to investigate the relationship between different concentration levels and rating predictions. Furthermore, concentration level was the only categorical variable taken into consideration for this ***Model C***.

Equation 5-9 $\textbf{LAM Rating} = B_0 + B_1 \textbf{* Concentration} + E$

Water control was the reference category and was held at 0, which was used to compare with the other concentration levels. SPSS automatically calculates a dummy coding scheme when a categorical predictor is entered into a multilevel model. This dummy coding scheme uses one degree of freedom per comparison (not including the reference category). This means that the B values for each concentration level reflect change versus the reference category (water) and can be interpreted as the slope between the reference category and the comparable level of the categorical predictor.

The intercept B_0 for ***Model C*** was -0.468, which indicated that without these categorical variables, the LAM rating would be expected to be close to 0. When comparing the different concentration levels, their contributions to predicting the LAM rating was ranked as the sweet-medium (B_2=6.740), the sweet-low (B_1=5.370) and then the sweet-high solutions (B_3=3.927). Here, B_1 are coefficients of categorical variables, which indicates the average difference in LAM rating between the category for water control and the category for different concentration levels. So, compared to water control for the sweet session, the LAM rating is approximately 6.740 higher with sweet-medium solutions, on average. Similarly, LAM ratings predicted by the sweet-low and sweet-high solutions would be estimated to 5.370 and 3.927 higher compared to water control.

The variance of within- and between- participants was 174.015 and 33.725, respectively. 16.23% was the proportion of unexplained variance that was due to the difference between participants. This high value of VPC reflects individual differences in sweet preference.

Model E interpretation:

For ***Model E***, the continuous variables, (corrugator, zygomaticus, levator and masseter muscles) are included as predictors to estimate the LAM rating together along with categorical variables.

Fixed Effects

Developing **Equation 5-3**, the linear regression model with two predictor variables is expressed as **Equation 5-10**

LAM = Overall model Intercept (B_0) + Participant Intercepts (U_{0j}) + B_1*Concentration + B_2* Corr + B_3*Lev + B_4*Zygo + B_5 * Mass + Error

The variables in the model are LAM rating, the response variable; Concentration, the categorical variable; Corr, Lev, Zygo and Mass, the continuous variables; and E, the residual error, which is an unmeasured variable.

The parameters in the model are B_0, the LAM rating-intercept; B_1, the concentration variable regression coefficient; and $B_{2\sim5}$, the muscle variable regression coefficient.

<u>Interpreting the Intercept B0</u>

Model E (see Table 5-11) presented that B_0 reflects the LAM rating that the participant would give that sample liquid if their face muscles remained unchanged. So, if they tasted a water sample (reference category for concentration) and their facial muscle activity remained at the baseline level (zero), then they would rate the liquid as -0.257 on the LAM scale.

<u>Interpreting Coefficients of Continuous Predictor Variables</u>

Since continuous variables were included (corrugator, zygomaticus, levator and masseter), $B_{2\sim5}$ represents the difference in the predicted value of LAM rating whenever activity doubled for each of the muscles after partialling out the categorical variables.

It was found from Table 5-11 that after partialling out the variance associated with concentration levels, masseter muscle activity influenced the estimation of the LAM rating negatively with strong significance, which indicated that there was a reliable effect where if the masseter muscle activity doubled, its corresponding LAM rating would be expected, on average, to be 7.316 lower. Although not reliably different from zero, the zygomaticus muscle influenced the estimation positively with its coefficient being 6.058. What's more, the regression coefficient for the corrugator muscle decreased slightly compared to the zygomaticus muscle, whose value was 4.557. The least but still negative influence on predicting the hedonic liking was found by the levator muscle, which indicated that when more levator muscle activity was generated, a lower liking rating was made by participants. Again, it is important to note that the only reliable effect was for the masseter muscle, and the activity of the other three muscles was more variable, which meant that they were not reliable predictors of the LAM rating.

Interpreting Coefficients of Categorical Predictor Variables

Similarly, within the model regression formula discussed earlier, SPSS calculates a set of dummy codes for the categorical variable. So the B_1 value is actually: B_1*Low+B_2*Medium+B_3*High. It means the increase in 1 versus reference means the switching from the reference category (water control) to the comparison category (low or medium or high), indicates the comparison of each concentration with water while holding the variance explained by the other concentration levels was constant.

From Table 5-11 , it can be seen that for the same type of muscle, compared to water control, the LAM rating of the sweet-medium solution would be expected to increase by 8.10, on average. For the sweet-low solution compared to water control, the LAM rating would be 7.240 higher. However, the highest concentration level had the least influence on predicting hedonic liking. Moreever, it should be noted that none of the effects were significantly different from 0 owing to our limited sample size and complex model.

Variance Components

The level-1 variance within-participants increased slightly from ***Model C*** to ***Model E*** after the continuous variable muscle factor was added. However, a huge decreasing trend occurred for the Level-2 variance when the continuous predictor was added from 33.725 (***Model C***) to 2.969

(***Model E***). The significant reduction in the between-participant variance suggests that the distribution of the LAM rating by muscle differs from participant to participant. The proportion of unexplained variance due to differences between participants increased slightly to 2.969/ (2.969+177.217) =16.48%. The similar VPC value of ***Model C*** indicates that muscle factors explain tiny variations in the LAM rating between the participants.

Goodness-of-fit

The first issue needed to be checked is allowing the intercepts to vary. According to Equation 5-5, comparing ***Model C*** and ***Model E***,

χ^2_{Change} = 618.678 – 610.931= 7.747

df_{Change} = 10 – 6 = 4

The critical values for the chi-square statistics with 4 degrees of freedom are 9.49 (p<.05) and 13.28 (p< .01); therefore, ***Model E*** made slight improvements compared to ***Model C***. However, it did not exceed the critical value, therefore there was not a statistically significant improvement between models. This result was also supported by the slight decrease in ***AIC*** from ***Model C*** to ***Model E.*** However, ***BIC*** increased here because it is penalised by the sample size and the number of parameters (BIC penalises complex models with low power).

Table 5-11 *Model C* and *Model E*: Sweet concentration level and facial muscle activity to predict LAM rating during the emptying phase of the tasting block

LAM-Tasting Block-Emptying Phase				
		Parameter	**Sweet *Model C***	**Sweet *Model E***
		Fixed Effects		
	Intercept	Γ^{00}	-0.468	-0.257
Concentration	High		3.927	4.357
	Medium		6.740	8.107
	Low		5.370	7.240
	Water		0.000	0.000
Muscle	Corrugator		-	4.557
	Zygomaticus		-	6.058
	Levator		-	-1.799
	Masseter		-	-7.316**
		Variance Components		
Level 1	Within-Participants	σ^{2e}	174.015***	177.217***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	2.969
		Goodness-of-fit		
	-2LL		618.678	610.391
	AIC		630.678	630.391
	BIC		644.662	653.699

Note: *p<.05; **p<.01; ***p<.001

5.5 Discussion

The results of Study 1 and Study 2 illustrated that increased EMG activity in the corrugator and levator muscles was found for lower liking ratings for visual and taste stimuli. On the other hand, for greater liking ratings of visual and taste stimuli, zygomaticus muscle activity was increased. No distinct pattern was found in the masseter muscle. Multi-level modelling was used to analyse the data to understand the predictive relationship between facial muscle activity and rating data using LAM/LMS/9-point scales. Both psychophysiological and rating data were collected in Study 1 and Study 2. Predicting hedonic liking rating using facial muscular activities was a priority of this study. Additionally, for Study 2, intensity ratings were also predicted by facial muscular activity. For Study 2, owing to EMG activity being recorded dynamically, different phases and blocks were separated to analyse the data to better understand the predictive relationship at a series of critical time points relating to the oral processing of liquids.

Several models including ***Model C***, ***Model D*** and ***Model E*** were established to investigate the factors that predict hedonic liking and intensity ratings under different conditions. ***Model D*** is the most theoretically important model for predicting the rating data, which will be discussed in detail. The other models were listed in Appendix IV.

Model D was designed to investigate the predictive relationship between facial muscle activity and liking and intensity ratings. In this model, only continuous variables (facial muscle activity) were used to predict the ratings. The expectation of the predicted results from this model indicates that increased EMG activity in corrugator and levator muscles would represent reduced liking for the stimuli. On the other hand, the increased zygomaticus muscle activity would reflect increased liking for the stimuli, which is not related to what kind of stimuli is being tasted or viewed.

From the result of Study 1, the corrugator and levator muscles influenced the prediction of hedonic liking negatively and significantly, which demonstrates that the corrugator and levator muscles can be relied upon to predict the hedonic liking rating. More corrugator and levator muscle contractions reflect negative affective responses to the stimuli. Although these results demonstrate the feasibility of using multi-level modelling to predict the hedonic liking rating, the dynamic predictive patterns are not able to be revealed. Therefore, Study 2 was focused on revealing the dynamic predictive relationship between rating and EMG activity during the emptying, swirling and thinking phases for the tasting and the rating blocks.

For Study 2, hedonic liking rating and intensity rating were both predicted by facial muscular activity. The relationship between hedonic liking rating and facial muscle activity will be discussed first. Generally, the same predictive result was found in the tasting and rating blocks during the emptying and thinking phases. For both the tasting and rating blocks, ***Model D*** suggested that during the swirling phase, facial muscle activity was less able to predict the hedonic liking rating compared with the emptying and thinking phases. It is because, during the swirling phase, functional muscle activity related to swirling dominated facial affective responses. During the emptying phase, corrugator, levator and zygomaticus muscles all influenced hedonic liking strongly as shown by their high coefficients, which demonstrates that the liking or disliking of solutions can be detected at the beginning of the tasting. In other words, the affect was evoked when liquids first touched participants' tongues. Additionally, corrugator and levator muscles influenced the estimation of hedonic liking negatively, indicating that stronger facial muscle contractions at these locations resulted in lower hedonic liking ratings. This is what we expected because the corrugator and levator muscles are involved in displays of negative affect. There was a similar situation for the zygomaticus muscle, but as the positive affect muscle, it predicted higher hedonic liking. During the thinking phase, only the levator muscle influenced the prediction negatively. This is because after spitting out the solution, only a small amount of solution residue was left in the mouth, which influenced the perception and the muscle activity. This demonstrates that the thinking phase is also an important point to measure affect and determine liking or disliking. Here, the predictive effect of the corrugator muscle decreased significantly with time, however, there was an increasing pattern of the levator muscle in predicting the hedonic liking rating. This interesting trend illustrated that corrugator muscle activity is an ideal candidate for predicting negative affect at the beginning, but its influence did not last long. Additionally, after spitting out the solution, the residue of the sample liquid was still in the mouth, at the moment when participants were attempting to think about the taste, which resulted in a reduced display of negative affect using the corrugator muscle. The increasing predictive pattern of the levator muscle from emptying to thinking phases indicated that the levator muscle is a more reliable muscle during oral processing because the location of levator muscle is close to the mouth and therefore it should be expected to be more involved in tasting and oral processing. Clearly, it is not sufficient to measure activity from single muscle sites, and a multivariate approach is important when assessing affective responses during tasting. Importantly, for future studies using facial muscles to predict liking of solid foods, attention should be given to the muscles that are assessed because the masseter muscle did not influence the prediction of the hedonic liking rating.

In Study 2, the sample stimuli were composed of RO water and sucrose/quinine regents. Furthermore, accordingly the concentrations were selected using an independent group so that there were affective differences between concentrations of sweet and bitter stimuli. It is the reason why affective relevant muscles can be used to predict the intensity rating. The predictive effect of the corrugator muscle was found during the emptying and swirling phases for both the tasting and the rating blocks. Importantly, its effect decreased significantly with time. These results indicated that:

1) Increased EMG activity in the corrugator muscle represented higher perceived intensity of stimuli;

2) Negative affect expressed using the corrugator muscle always emerged quickly, but was transient and returned to baseline quickly, which was likely the reason why the corrugator

muscle always influenced the rating significantly at the beginning of each tasting trial but it didn't last until the end of the thinking phase;

3) The corrugator muscle is a reliable muscle used at the beginning of the tasting.

As the negative affect muscle, the levator presented an opposite pattern of influence on the estimation. Interestingly, its predictive effect increased significantly from the emptying to the thinking phases for both tasting and rating blocks, which indicates that the levator muscle reliably predicts the intensity rating at the end of tasting or during oral processing. This is because the levator muscle was involved in swirling the liquids during this stage, which indicates that whole mouth swirling is useful in releasing the flavour of liquids (de Wijk et al., 2011). More emphasis on swirling the liquid is likely to interrupt the affective processes. The zygomaticus muscle, as a positive affect muscle, was only able to predict the intensity rating negatively, at the beginning of the tasting for the rating block. Additionally, its predictive effect decreased slightly with time, which indicates that the beginning of the tasting is the best time point to predict the intensity rating using zygomaticus muscle activity. Interestingly, the masseter muscle is a functional muscle and there was no distinct pattern affecting the prediction for both the tasting and rating blocks. However, by contrast to the emptying and swirling phases, the strongest contribution to predicting the intensity rating was found during the thinking phase but this was an unreliable effect. These results indicate that the masseter muscle as a functional muscle is not able to predict the hedonic liking rating or intensity rating. If EMG is to be used in the future, the inclusion or not of the masseter muscle deserves consideration especially for chewing solid food. In this study, the masseter muscle was not able to reflect any relationship between food preference and its muscle activity varied because swirling behaviour is related to minimum oral processing. If solid food stimuli is to be used in the future, the relationship between EMG activity in the masseter muscle and its hedonic liking deserves being studied further.

Model C, Model E, and ***Model F*** as more complicated models, were specifically selected to interpret the predictive results of Study 2. Different variables, included categorical variables (Concentration: water, low, medium, high), continuous variables (Muscle: corrugator, levator, zygomaticus, masseter) and the interaction between Concentration and Muscle. These models are not the emphasis of our study and the results are in Appendix IV.

5.6 Summary of key findings from Multi-level modelling analysis

In Study 1 and Study 2, strong EMG activity in the corrugator and levator muscles correlated with decreased liking of stimuli. Moreover, liked stimuli did not evoke strong positive affect or minimal increases in the activity of the zygomaticus muscle. No distinct pattern was found for the masseter muscle. The ANOVA results reveal the basic significant relationship between facial muscle activity and the hedonic liking rating of stimuli. These conventional statistical analyses results included factors for the analysis such as whether the images were believed to be positive or negative by the experimenters, which led to no statistical significant differences being found for EMG activity of the zygomaticus muscle and the hedonic liking rating of positive imagery stimuli. To overcome these statistical limitations, multi-level modelling was introduced as a method that can predict hedonic liking ratings using the activity of all of the facial muscles simultaneously. Multi-level modelling has not previously been used in food research with facial muscle activity so different models were first established to predict the hedonic liking rating using different selections of variables. ***Model D*** is the most important model in this study and this was discussed in depth. The results of other models have been placed in Appendix IV. The importance of ***Model D*** is that only continuous variables (Muscle: corrugator, levator, masseter, and zygomaticus) are used to predict the hedonic liking rating without considering any category grouping of stimuli.

The results of ***Model D*** were as follows:

1. For Study 1, increased corrugator and levator muscle activity reliably predicted a decrease in hedonic liking rating measured using a 9-point scale;

2. In Study 2, the beginning and the end of the tasting were the best stages to predict the hedonic liking and intensity ratings compared to periods of liquid oral processing (swirling). Qualitatively similar results were found for both the tasting only and the tasting and rating blocks;

3. For Study 2, at the beginning of the tasting the corrugator and levator muscles were the only reliable muscles that predicted negative change in hedonic liking ratings (disliking), whereas positive change in hedonic liking was only possible with the zygomaticus muscle. At the end of the tasting (after spitting the liquid), only the levator muscle predicted the hedonic liking rating;

4. For Study 2, corrugator muscle activity was a reliable predictor for increased intensity ratings of liquids during the emptying and swirling phases for both the tasting only and the tasting and rating blocks. The levator muscle was predictive of increased intensity ratings during swirling of the liquid and during the aftertaste period after spitting the liquid out.

These results indicate that it is useful to measuring activity of facial muscles because they can predict hedonic responses during food viewing and liquid tasting.

6 General Discussion

This thesis systematically investigated whether facial EMG can be used to assess food acceptability. This work builds on two established findings: first, that oral processing is dynamic (Foster et al., 2011); and second, that facial EMG can be used as a hedonic measure of responses to taste stimuli (Armstrong et al., 2007b; Horio, 2003). As oral processing is dynamic when consuming food, then it is logical to assume the hedonic responses to food during oral processing is also dynamic. Currently, hedonic scales are still the most commonly used measurements to assess hedonic liking to food, but there are a number of limitations to these such as objectivity of judgements, individual differences, and that it is a single overall hedonic liking rating of a dynamic process and these are not easily avoided. With the development of new techniques such as the temporal drivers of liking (TDL) and the temporal dominance of emotion (TDE) there have be substantial positive steps towards assessing dynamic hedonic liking ratings, but these temporal techniques are still interruptive of normal food behaviours and this influences participant judgement. Therefore, to overcome these limitations, facial EMG, a psychophysiological measurement, is a potential method to more accurately assess dynamic acceptability.

Facial EMG has previously been used to investigate the relationship between hedonic responses and sensory attributes. Vrana (1993b) studied the psychophysiology of disgust using sensory stimulation. Later, Jancke and Kaufmann (1994) recorded facial muscle activity over corrugator, precerus, nasalis, levator, orbicular and zygomaticus muscles to investigate the responses to odours. More recently, there have been studies detecting responses to taste stimuli and odours by children and adults using facial EMG (Armstrong et al., 2007b; Horio, 2003). These studies all illustrated that there was a correlation between facial muscle activity and acceptability of stimuli. However, although this research builds upon these previous results, it has focused on the dynamic hedonic response and predictions of ratings.

6.1 Review of experimental chapters and eliciting of findings

Chapter 3 presented the first study. The purpose of this study was to 1) assess dynamic emotion changes when participants viewed different kinds of food imagery stimuli by detecting their facial muscle activity, and 2) investigate the correlation between facial muscle activity and the hedonic liking rating. This study was composed of two experiments: a food appearance survey to select the food image stimuli for the planned EMG study. Thirty participants participated in the appearance survey and rated the food images using a modified 9-point scale. The 20 food images from the food appearance survey were divided into five negative, five positive and ten high variability images, which were used as the stimuli in the next experiment. During the second experiment, facial EMG was recorded from 16 new participants. Three blocks of images were presented, including Block I practice, Block II viewing images and Block III viewing and rating images. Five high variability images were provided for participants to view to familiarise themselves with the instructions and procedure. 15 food imagery stimuli were presented three times during Block II for participants to view, and facial EMG recorded their facial muscle activity at the same time. For the last block, participants viewed the same food imagery stimulus as Block II, but this time, after viewing each imagery stimuli, participants were asked to give a hedonic liking rating to the stimuli. All the imagery stimuli were presented only once in this final block.

The results of the food appearance survey agreed with previous findings that food appearance is another important influencing factor on acceptability (MacDougall, 2003). Some food images such as newborn mice on bread, cockroach soup, cooked dog's head and bird's egg with a young bird were rejected by participants because these foods are locally considered disgusting (although other cultures find them acceptable). This kind of disgust response is congruent with findings of other objects related to animals or animal products that are considered disgusting (Rozin & Fallon, 1980). However, liking ratings to food images varied from person to person in this study. This is because factors such as culture, past eating experience, and physiological status influence acceptability judgements (Clark, 1998). In other words, participants universally rejected disgusting images, but varied in their acceptance of non-disgusting foods. This is the reason why these disgusting images were always rated negatively by participants, and even resulted in a floor effect. Furthermore, disgust patterns enhanced and aroused the floor effect (Rozin & Fallon, 1980). Fewer ceiling effects were able to be found for the positive images because participants' preferences for positive images varied. There were no ceiling effects because of the individual differences in the evaluation of positive images (e.g. most people liked roast chicken a lot, although vegetarians did not like it at all; some people disliked sweet foods, but the majority rated desserts highly positive).

The levator, zygomaticus, and corrugator muscles are commonly used facial muscles to detect hedonic responses using facial EMG (Tassinary et al., 1989a; Vrana, 1993a). The results illustrated that EMG activity over the corrugator and levator muscles were the main sites for assessing negative affect evoked by these negative images which were also rated negatively by participants (Dimberg, 1997; Rymarczyk et al., 2011). Frowning, disgust faces, and grimaces are typical facial expressions when human beings are confronted with disgusting images. Interestingly, zygomaticus muscle activity is commonly reported to be a symbol of positive affect (Armstrong et al., 2007a; Jancke, 1996b; Sato et al., 2008a) but positive affect was not evoked by the highly rated positive images used in this study (see Figure 3-4). In this experiment, for example, if the participant did not like chocolates or was losing weight at the time, he/she tended to present his/her dislike of the positive image 'chocolates' and 'chocolate cake'. It is possible that the positive images didn't detect liking for a variety of reasons. It was not sensitive to the mild positive affect evoked by positive food images, participants were not consistently experiencing the positive food images as positive (e.g. vegetarians not considering roast chicken as positive), or those positive facial expressions are not consistently displayed when an individual is not in a social situation (smiling is a form of communication).

In contrast, from this experiment, the corrugator muscle was able to discriminate negative from positive images and negative from high variability images, respectively. Comparisons of the different categories of image across the time course of image viewing revealed some interesting results. Negative and positive images were only able to be discriminated by the corrugator muscle at the beginning of viewing images (from 0~500ms), but the corrugator muscle reliably discriminated the negative and high variability images for most of the viewing time. Similarly, the levator muscle reliably discriminated positive from negative images from 500~5000ms. However, no distinct pattern was found for zygomaticus and masseter muscles. Attention should be paid to the corrugator and levator muscles because they always demonstrated a fast response to images that discriminated each category, but their activity returned to baseline fairly quickly. It is assumed that hedonic responses are best determined at the beginning of exposure when participants saw/tasted the sample; furthermore, acceptability is likely to be determined by the first sight or taste.

The second study was conducted to understand the relationship between the acceptability of taste stimuli and facial muscle activity. From this study, we wanted to know:

1) Will dynamic emotion patterns be different when emptying, swirling and thinking about the taste stimuli?

2) Will bitter stimuli still evoke a negative affect so that the strong EMG activity in the corrugator and levator muscle will be found?

3) Will positive affect be elicited by sweet stimuli and will zygomaticus muscle activity increase when tasting sweet stimuli?

4) Will there be any relationship between EMG activity and hedonic liking/intensity rating of stimuli?

5) Will the pure EMG activity be the same as interruptive EMG activity (tasting with rating the scale)?

This study was composed of three main experiments, including a PROP supertaster test, acceptability testing to select the optimum taste stimuli for EMG measurement, and facial EMG measurement with the tasting of liquid stimuli. The purpose of the supertaster testing session was to screen out non-tasters and supertasters and retain medium-tasters. This was to ensure that the participants' physiological ability to taste bitter solutions was similar. The acceptability testing session was designed to select the optimum concentration level of sucrose and quinine solutions for the sweet and bitter tastant stimuli for facial EMG measurement. During acceptability testing, five different concentrations of sucrose and quinine solutions were provided for ten medium-taster participants to give their hedonic liking and intensity ratings. The results illustrated that there was no link between taster status and liking for sucrose solutions as supported by other researchers (Drewnowski, Henderson, & Shore, 1997). Furthermore, concentration was an important factor in influencing the acceptability of the liquids (Reed et al., 2006). The primary outcome for the acceptability testing session was to identify three discriminable concentrations of sucrose and quinine solutions for medium-tasters. These solutions plus a water control were selected as the taste stimuli for the following facial EMG measurement.

Facial EMG measurement on tasting liquid stimuli was composed of three blocks: practice, tasting and rating. During each block, instructions were presented on the computer screen and participants were required to follow the instructions to complete the experiment. The instructions are listed in Figure 4-8. Each block of the experiment was separated into three important phases: emptying, swirling and thinking phases. These three phases represented activities of interest when tasting liquids. The emptying phase recorded facial muscle activity when participants emptied the solutions in their mouths. The swirling phase detected the EMG activity when participants swirled the liquids. The thinking phase happened after participants had spat out the solutions, but before rinsing their mouths with water. The practice block was to let participants become familiar with the instructions presented on the computer. For the tasting block, four solutions (three selected from the acceptability rating experiment and a water control) were tasted three times in a random order. The procedure was the same for the rating block, but the difference compared to the tasting block was that participants were required to give their liking and intensity ratings to the sample after the thinking phase. Pure EMG activity was recorded for tasting liquid stimuli during the tasting block, whereas interruptive EMG activity was recorded for the rating block, because during this block, rating scales were provided for participants to rate and this might have influenced facial behaviour when tasting.

EMG activity for corrugator and levator muscles was evoked by bitter-medium and bitter-high concentration solutions (Jancke & Kaufmann, 1994; Larsen et al., 2003). Similar to the food image experiment results, no strong positive affect was found when participants tasted sweet solutions. Additionally, when tasting sweet-high concentration solutions, some participants also expressed negative affect with increasing EMG activity in the corrugator muscle. This is because sweet stimuli are normally a pleasant taste, but high concentrations (beyond an individual's bliss point) can arouse negative affects such as unpleasantness, disgust, and disliking (Reed et al., 2006). Apart from that, participants' usual eating behaviour is another important influencing factor on liking. Some participants are sweet-likers, and they were more likely to have their highest preference to the highest concentrations of sweet solutions, whereas sweet-dislikers reject high concentrations of sucrose solutions. In this study, there was no assessment to screen for sweet-liker or sweet-disliker and it is not possible to confidently discriminate sweet likers and dislikers according to their taster status (Chang et al., 2006; Looy & Weingarten, 1992); but the liking ratings and facial muscle activity provide a method to discriminate sweet-liking in future research. Dynamic EMG activity was recorded during the emptying, swirling and thinking phases. The results of the emptying phase illustrated that affective responses to sucrose and bitter solutions were able to be detected when participants emptied the liquids into their mouths. This is very important because acceptability of food is likely to be determined by consumers at the first bite of foods. No distinct pattern was found in the bitter session during the swirling phase. On the contrary, when encountering the sweet stimuli, participants were more likely to swirl the liquid samples. High and medium concentrations of sweet and bitter stimuli still evoked strong EMG activity in corrugator, levator, zygomaticus and masseter muscles during the thinking phase, which illustrated that the concentration of solutions is an important factor when determining acceptability (Kocher & Fisher, 1969; Reed et al., 2006). What interests us is that participants presented similar EMG activity in all facial muscles for water control and low concentration level of solutions. This is most likely because the participants in the study were all medium PROP tasters and medium tasters and were not sensitive to all concentrations, and they could not discriminate the low concentration solutions and water control. Considering the emptying, swirling and thinking phases, negative and positive affect presented different patterns. Negative affect grew quickly and sharply from the liquid stimuli being emptied into the mouth to the beginning of swirling the liquid, but after that period, negative affect kept a gradually decreasing trend until the end of the thinking phase. However, positive affect was found to present a long, stable and developing pattern.

Some common findings from Study 1 and Study 2 were able to be found. More EMG activity in the corrugator and levator muscles was found for less liked visual or taste stimuli, whereas for more liked visual or taste stimuli, only zygomaticus muscle activity and minimal EMG activity in the corrugator muscle were found. These results indicate that it is more difficult to screen out the more liked stimuli for all participants. This is the reason why no correlation was found between EMG activity in the zygomaticus muscle and the hedonic liking rating.

In the last chapter, multilevel modelling analyses were used to predict the hedonic liking and intensity rating by facial muscular activity for Study 1 and Study 2. All psychophysiological and rating data was collected by Study 1 and Study 2. The advantage of MLM is that several levels of variables can be included in the model. In this analysis, two levels of variables are introduced and different models are built to analyse the effect of muscles on ratings. The most important model is ***Model D*** to predict the hedonic liking and intensity rating using only facial muscular activity without considering any categorical variables such as positive, negative, and high variability imagery stimuli and any concentration level of sample solutions (***Models A*** and ***B*** were the Null model, and Null model with the participant as a random intercept variable). This is probably the most important of all these models because usually in product testing there is no knowledge of which product the panel will prefer. For Study 1, corrugator and levator muscles were found to influence the hedonic liking rating negatively using ***Model D***. Study 1 was a simpler experimental design so that no dynamic pattern could be detected. The results of ***Model D*** from Study 2 illustrated that muscles have differential predictive effects over the phases of the experiment, but the tasting and rating blocks presented a similar result. Corrugator, zygomaticus and levator muscles were able to explain substantial variance in ratings and were reliable predictors of the acceptability rating during the emptying phase; furthermore, corrugator and levator muscles had a negative effect on the ratings, whereas the zygomaticus muscle influenced the estimation positively. Specifically, increased activity in corrugator and levator muscles was evoked by less liked solutions, but for the zygomaticus muscle, more activity was evoked by more liked solutions. These findings are what we expected because corrugator and levator muscles are used to display negative facial affect whereas a positive affect relating to smiling is a common use of the zygomaticus muscle (Schwartz, Fair, Salt, Mandel, & Klerman, 1976; Tassinary et al., 1989b). During the swirling of the liquid, no distinct predictive pattern was able to be found. However, after spitting out the solutions, the levator muscle was the dominant predictor of liking ratings, and increased levator muscle activity resulted in decreased liking. Regarding the predicting of intensity ratings, the same result was found in the tasting and rating blocks. During the emptying phase, corrugator and zygomaticus muscles influenced the prediction of intensity rating positively and negatively, respectively, which indicated that more EMG activity in the corrugator muscle was evoked by high concentration taste solutions whereas the zygomaticus muscle was found to be less active with more concentrated solutions. For the swirling phase, some facial muscles were used functionally to swirl the liquids, so there was no distinct predictive pattern. The levator muscle was the dominant muscle for predicting intensity ratings during the thinking phase; furthermore, it always had a positive influence. This indicated that after spitting out the solution, the muscles around the mouth are better predictors than the corrugator muscle.

In summary, some common findings from Study 1 and Study 2 were able to be found. More EMG activity in the corrugator and levator muscles was found on less liked visual or taste stimuli, whereas for more liked visual or taste stimuli, only certain zygomaticus muscle activity and minimum EMG activity in the corrugator muscle were both found. These results indicate that it is more difficult to screen out the more liked stimuli for all participants. In any future study of food preference, more attention should be paid to the selection of pleasant stimuli. This is a possible reason why no correlation was found between EMG activity of the zygomaticus muscle and the hedonic liking rating. A defining category group of stimuli is difficult, so using facial EMG and multi-level modelling provides a potential application for assessing dynamic hedonic liking. A different EMG activity pattern was found for more liked and less liked stimuli, which should be studied further. For example, some disliked stimuli were also able to evoke zygomaticus muscle activity, which increases the difficulty in discriminating positive and negative affect by the zygomaticus muscle. Single facial muscle activity recording is not suggested in facial EMG study. Interestingly, the corrugator muscle is a reliable muscle to discriminate negative affect and positive affect at the beginning of the tasting, but with timing, it is not suitable to detect the emotion change on aftertaste mouth feel and during oral processing. On the other hand, although the levator muscle can differentiate affect at the beginning as well, its discriminating power increase with timing so that it is the best one to predict hedonic liking and intensity rating during oral processing and after swallowing. In our study, the masseter muscle is not able to discriminate any positive or negative affect. This is a very important finding, which provides basic evidence in assessing detected emotion changes on chewing solid food. For example, the masseter muscle will still be used when chewing solid food. Because it is not able to discriminate affect and is used as a functional muscle, chewing solid food will increase the noise and co-activation of facial muscles. Dynamic emotion changes on emptying, swirling and thinking phases also demonstrate hedonic liking during oral processing. The multi-level modelling results illustrate that hedonic liking is determined at the beginning of viewing and tasting, which can simplify the process of facial EMG. The same result between the tasting and the rating blocks implies that pure EMG recording data is able to predict the hedonic liking rating. In other words, it is not essential to include the rating scale if EMG is used in future studies. There is no doubt that not being able to discriminate bitter-low solution and some sweet stimuli reveals concern at the ability of facial EMG to assess preference for homogeneous products. This is also another challenge of this technique because, in our study, two extreme stimuli were always designed to evoke negative and positive affects.

6.2 Further Directions

This thesis is a starting point and represents only a preliminary investigation into the viability of facial EMG as a dynamic measure of subjective liking of food. The current study is only relevant to viewing images and swirling liquids. More potential directions should be taken into consideration. For example, using real foods rather than simple solutions will have relevance to the food industry. Some research directions are listed in the following:

1. using facial EMG to investigate any dynamic emotion change when chewing solid foods;
2. using facial EMG to assess hedonic liking of more complex bitter beverages such as beer and tonic water;
3. using facial EMG to investigate the influence that textural attributes such as particle size have on emotion when chewing solid food;
4. using facial EMG for some social research projects such as while shopping or viewing food packaging;
5. using facial EMG to assess dynamic emotion change while tasting other basic tastes such as sour or umami.

For future studies, the screening of stimuli is critical because positive affect is not easily evoked by all participants for all food stimuli. However, when facial EMG is used with multi-level modelling, this allows for individual differences between participants and overcomes this limitation. More facial muscles can be investigated for tasting other taste stimuli such as sour and umami. When chewing solid foods, the texture of solid food is hard, so flavour perception and hedonic liking during oral processing might present different patterns in contrast to the swirling of liquids. Including masseter and temporalis muscles might be important in these future studies.

As a psychophysiological technique, facial EMG has potential for use in food research and has commercial applications. It is hoped that this thesis provides a stable foundation for these future studies.

7 Conclusions

This thesis investigated whether facial EMG is useful as a measure of food acceptability. This method was utilised for images and liquids using rating scales, including the 9-point scale, LAM and LMS and a direct physiological technique to investigate the relationship between rating and facial muscle activity. The results revealed that more EMG activity in the corrugator and levator muscles led to less liking of images or taste stimuli; furthermore, minimal EMG activity in the corrugator muscle was present for liked stimuli. These findings are similar to previous studies that used EMG measurement, where frowning and facial expressions of disgust were typical expressions of anger and disgust (Armstrong et al., 2007b; Tassinary et al., 1989b; Vrana, 1993b). The timing data illustrates that facial muscle activity recorded using facial EMG can reflect hedonic responses to stimuli. A negative affect was evoked quickly and sharply at the beginning of the first sight or taste, followed by a long, slow development, but a stable trend was found for positive affect. No distinct and reliable patterns were able to be found for the zygomaticus and masseter muscles. Finally, facial EMG was used to predict the liking and intensity ratings in models that allowed participants to have individual differences in taste preference. The results found that at different time points, these four muscles had different predictive effects. Corrugator and levator muscles had the dominant influence on predicting the hedonic liking rating negatively at the beginning of the tasting whereas a positive effect was found in the zygomaticus muscle. The levator muscle reliably predicted the hedonic liking rating of aftertaste mouth feel. However, the beginning and end of the tasting are better stages to discriminate the affect than the oral processing period. Taste stimuli were special, so the intensity rating was also able to be predicted by facial muscle activity. The corrugator muscle reliably predicted the intensity rating at the beginning of tasting whereas, at the end of the tasting, the levator muscle influenced the prediction positively. Therefore, it can be concluded that negative and positive affect can be distinguished at the beginning of tasting food and at the end of tasting food. Additionally, the oral processing is not the ideal stage to predict hedonic liking or intensity ratings. Pure EMG activity in facial muscles can predict the hedonic liking rating, so it is not essential that rating scales are included in the future.

Based on these findings, we now know that facial EMG is able to assess food acceptability dynamically and predict hedonic liking and intensity ratings. Here, this psychophysiological technique has been demonstrated to measure dynamic acceptability and reveal its potential for commercial application in the food industry.

8 Appendix

I

Food Appearance Survey

Objective: The purpose of this survey is to find out how much individuals like a variety of different foods.

Instruction:

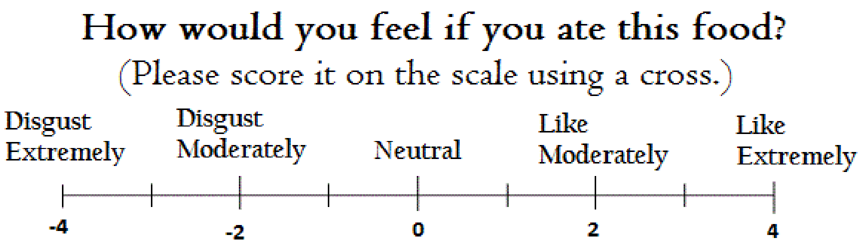
- There are 30 pictures of food for you to look at and then rate.
- Please take just the appearance of into the consideration, not other factors.
- Please complete the survey around 3 hours after eating a meal.

Questionnaire

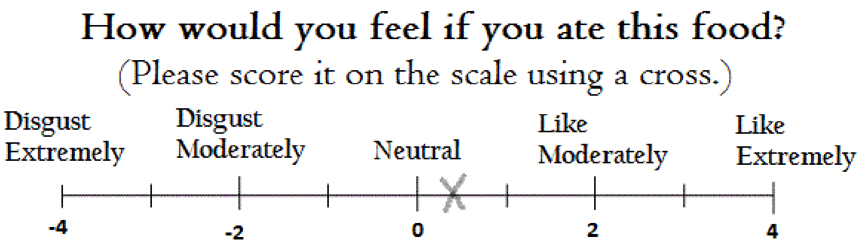
Gender:

Age:

An example is presented below which demonstrates how to complete the questionnaire and how to use the 9-point scale.



- **First, look at the picture and imagine yourself eating the food shown in the picture.**
- **Second, put a cross anywhere on the scale to rate the picture based on the feeling it induces.**



How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

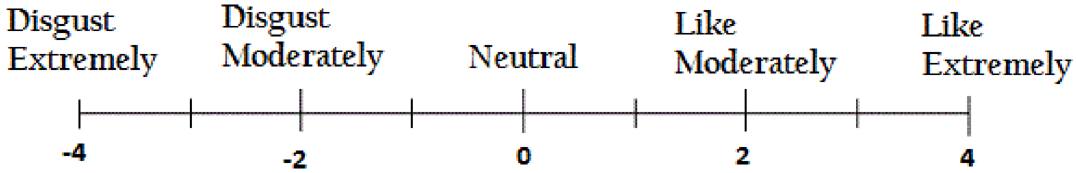
How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)



How would you feel if you ate this food?

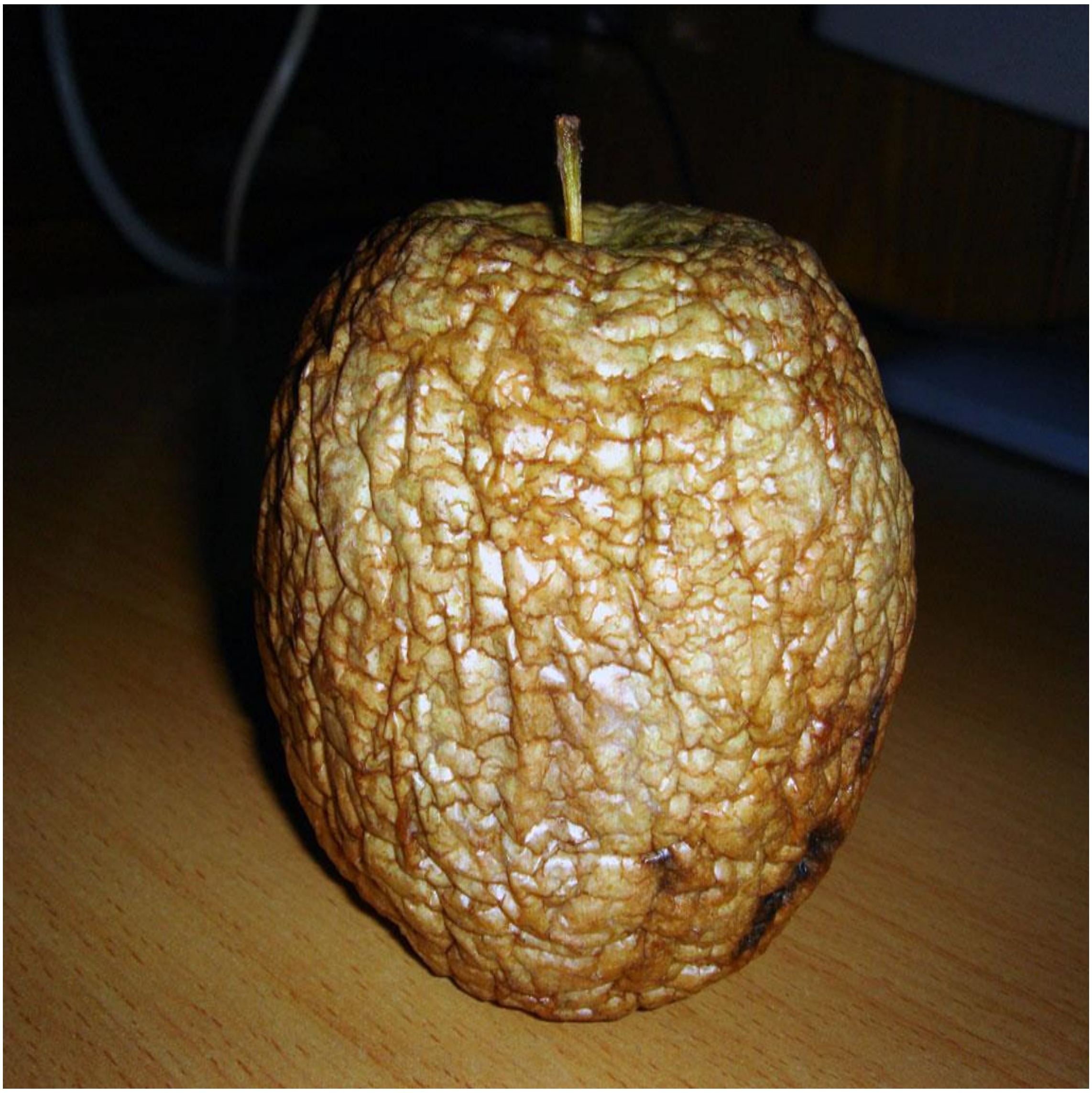
(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4



How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

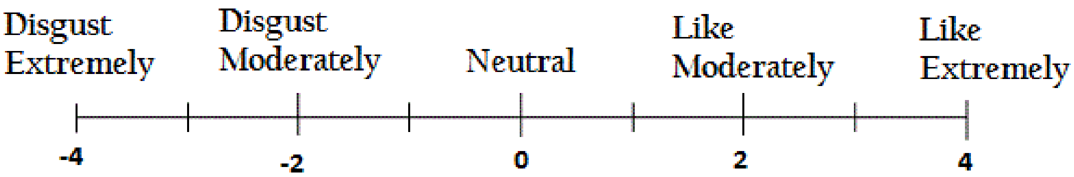
How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)



How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

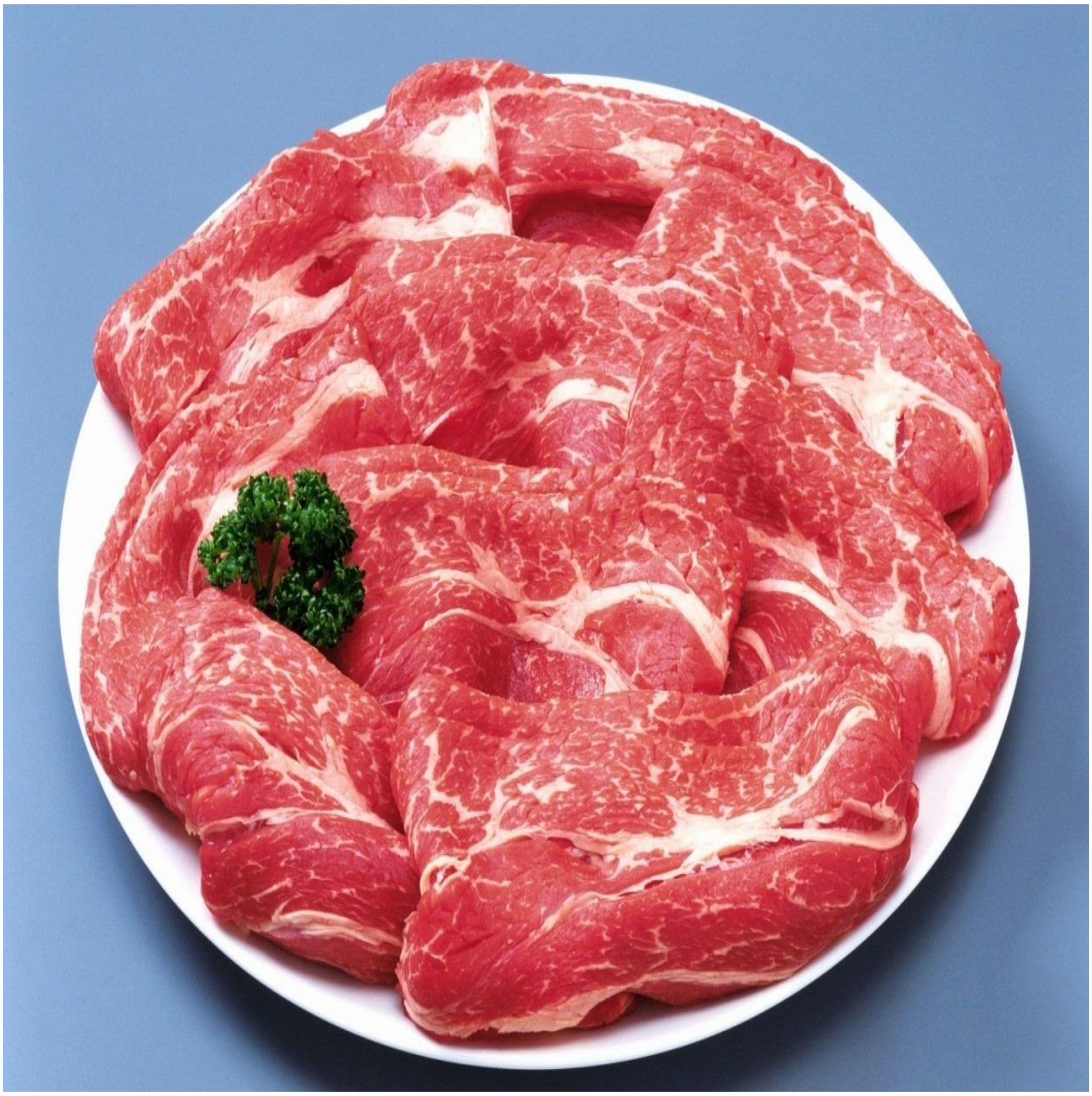
(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4



How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

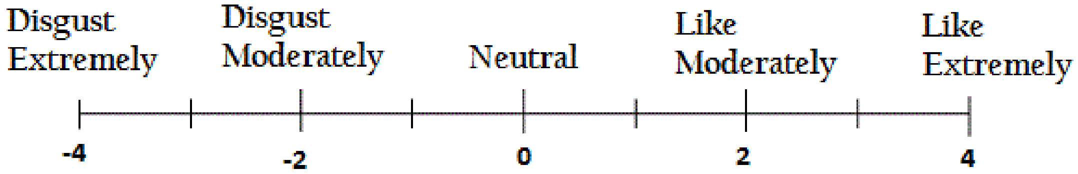
How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)



How would you feel if you ate this food?

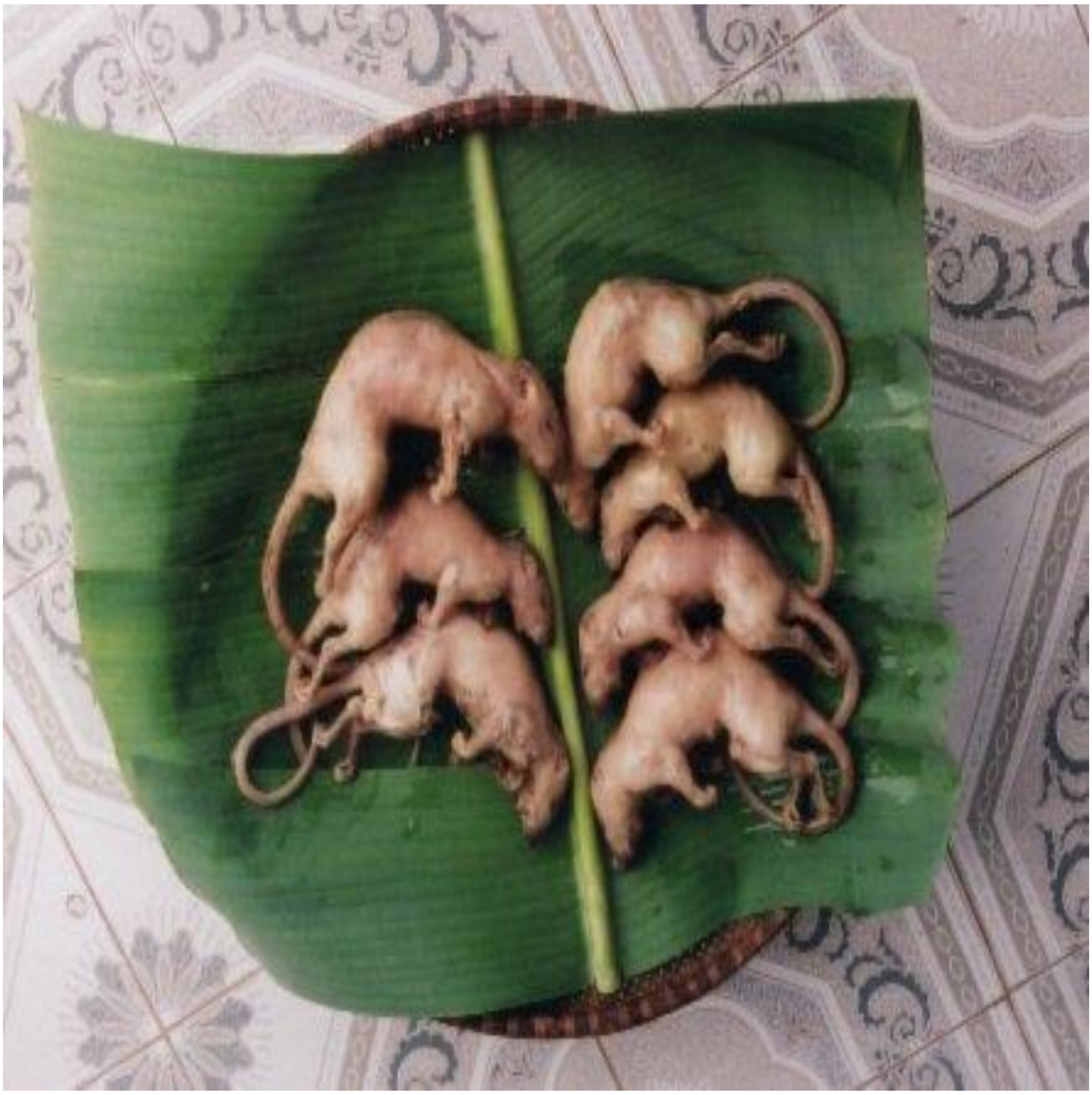
(Please score it on the scale using a cross.)

Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4



How would you feel if you ate this food?

(Please score it on the scale using a cross.)

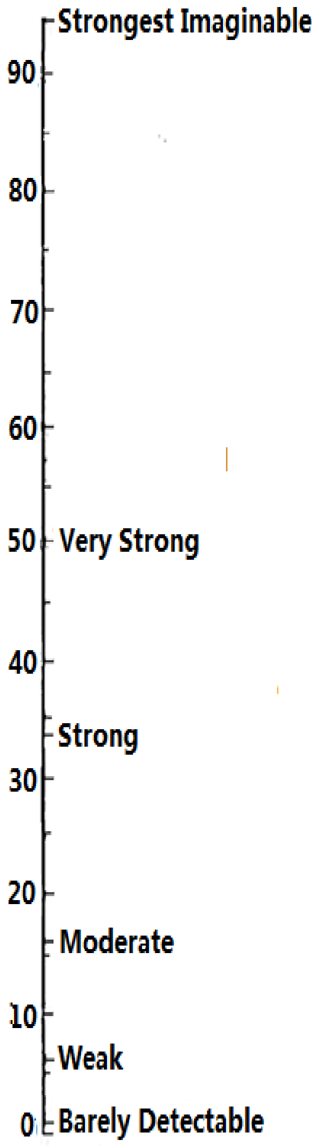
Disgust Extremely		Disgust Moderately		Neutral		Like Moderately		Like Extremely
-4		-2		0		2		4

How would you feel if you ate this food?

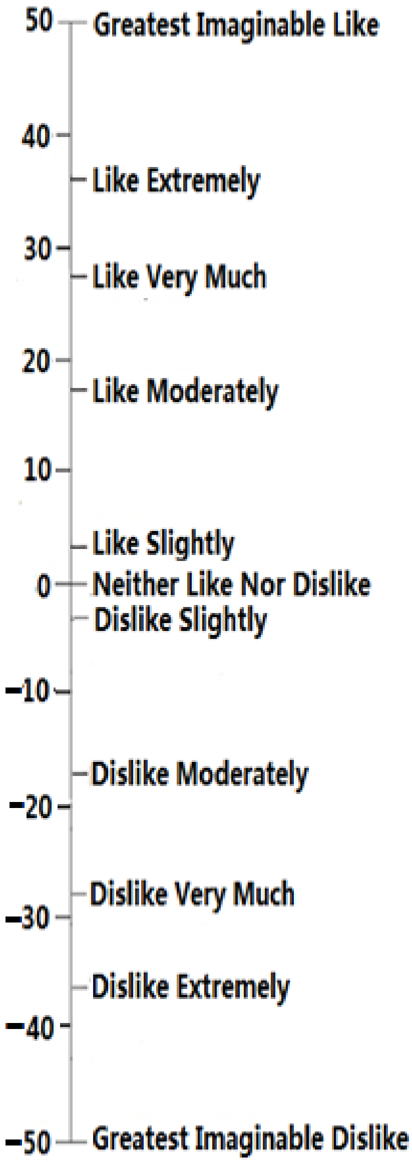
(Please score it on the scale using a cross.)

Disgust Extremely	Disgust Moderately	Neutral	Like Moderately	Like Extremely
-4	-2	0	2	4

II Labelled Magnitude Scale



III Labelled Affective Scale



IV Multi-Level Modelling – *Model C*, *Model E* and *Model F* to predict LAM/LMS rating during the different phases of the Tasting and the Rating Blocks for Sweet/Bitter sessions

Table 8-1 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the emptying phase for the tasting block for sweet session

LAM - Emptying Phase - Tasting Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-0.468	-0.257	0.945
Concentration	High		3.927	4.357	-3.237
	Medium		6.740	8.107	8.974
	Low		5.370	7.240	7.324
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	4.557	-6.906
	Zygomaticus		-	6.058	-1.664
	Levator		-	-1.799	0.152
	Masseter		-	-7.316**	1.781
Concentration*Muscle	High*Corrugator		-	-	18.815*
	Medium*Corrugator		-	-	12.242
	Low*Corrugator		-	-	-2.011
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	30.477***
	Medium*Zygomaticus		-	-	2.198
	Low*Zygomaticus		-	-	-3.548
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-5.752
	Medium*Levator		-	-	0.735
	Low*Levator		-	-	0.562
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-19.745
	Medium*Masseter		-	-	-16.579
	Low*Masseter		-	-	-2.978
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	174.015***	177.217***	114.185***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	2.969	13.251
Goodness-of-fit					
	-2LL		618.678	610.391	583.998
	AIC		630.678	630.391	656.998
	BIC		644.662	653.699	678.274

Note: *p<.05; **p<.01; ***p<.001

Table 8-2 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity to used predict LAM rating during the swirling phase for the tasting block for sweet session

LAM - Swirling Phase - Tasting Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-0.468	-0.110	-4.380
Concentration	High		3.972	3.341	8.504
	Medium		6.740	6.678	13.068
	Low		5.370	5.330	10.841
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	2.937	-7.506
	Zygomaticus		-	0.512	-6.061
	Levator		-	-1.549	4.461
	Masseter		-	1.490	12.326
Concentration*Muscle	High*Corrugator		-	-	12.004
	Medium*Corrugator		-	-	1.378
	Low*Corrugator		-	-	-2.912
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	17.625*
	Medium*Zygomaticus		-	-	0.989
	Low*Zygomaticus		-	-	-0.656
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-9.419
	Medium*Levator		-	-	-5.302
	Low*Levator		-	-	-0.178
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-24.756
	Medium*Masseter		-	-	1.746
	Low*Masseter		-	-	-8.777
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	174.015***	170.735***	127.212***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	32.401	47.682
Goodness-of-fit					
	-2LL		618.678	617.063	601.368
	AIC		630.678	637.063	645.368
	BIC		644.662	660.370	696.644

Note: *p<.05; **p<.01; ***p<.001

Table 8-3 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity to used predict LAM rating during the thinking phase for the tasting block for sweet session

LAM - Thinking Phase-Tasting Block-Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-0.468	-1.993	-0.684
Concentration	High		3.927	2.563	-0.370
	Medium		6.740	5.098	8.945
	Low		5.370	4.696	6.504
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-1.598	0.464
	Zygomaticus		-	12.732*	-9.601
	Levator		-	-5.847	0.243
	Masseter		-	2.784	12.397
Concentration*Muscle	High*Corrugator		-	-	0.272
	Medium*Corrugator		-	-	-15.306
	Low*Corrugator		-	-	-7.791
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	30.501
	Medium*Zygomaticus		-	-	24.383
	Low*Zygomaticus		-	-	-6.798
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-11.905
	Medium*Levator		-	-	-3.514
	Low*Levator		-	-	-0.244
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-8.442
	Medium*Masseter		-	-	-27.086
	Low*Masseter		-	-	15.640
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	174.015***	181.196***	144.726***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	5.249	18.292
Goodness-of-fit					
	-2LL		618.678	612.930	601.541
	AIC		630.678	632.930	645.541
	BIC		644.662	656.237	696.817

Note: *p<.05; **p<.01; ***p<.001

Table 8-4 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the emptying phase for the rating block for sweet session

LAM - Emptying Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-0.468	4.209	-0.523
Concentration	High		3.927	3.298	5.261
	Medium		6.740	6.022	17.091**
	Low		5.370	5.361	6.806
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	2.623	-2.241
	Zygomaticus		-	7.664***	-0.972
	Levator		-	-3.777**	1.309
	Masseter		-	-8.419	-6.971
Concentration*Muscle	High*Corrugator		-	-	2.841
	Medium*Corrugator		-	-	13.208
	Low*Corrugator		-	-	2.138
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	17.323**
	Medium*Zygomaticus		-	-	13.599*
	Low*Zygomaticus		-	-	-4.308
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-7.188**
	Medium*Levator		-	-	-9.990*
	Low*Levator		-	-	-0.777
	Water*Levator		-	-	0.000
	High*Masseter		-	-	3.405
	Medium*Masseter		-	-	-5.227
	Low*Masseter		-	-	11.224
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	174.015***	166.382***	108.126***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	10.904	27.205
Goodness-of-fit					
	-2LL		618.678	608.788	584.840
	AIC		630.678	628.788	628.840
	BIC		644.662	652.095	680.116

Note: *p<.05; **p<.01; ***p<.001

Table 8-5 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the swirling phase for the rating block for sweet session

LAM - Swirling Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	-0.468	-0.099	-1.113
Concentration	High		3.927	6.777	12.226
	Medium		6.740	8.347*	23.046***
	Low		5.370	6.769	10.132
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.882	-5.131
	Zygomaticus		-	8.075*	1.505
	Levator		-	-10.067***	1.991
	Masseter		-	3.706	-5.664
Concentration*Muscle	High*Corrugator		-	-	12.648**
	Medium*Corrugator		-	-	9.806
	Low*Corrugator		-	-	-0.248
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	15.506*
	Medium*Zygomaticus		-	-	0.001
	Low*Zygomaticus		-	-	-8.616
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-11.445**
	Medium*Levator		-	-	-12.622**
	Low*Levator		-	-	-3.566
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-12.331
	Medium*Masseter		-	-	7.769
	Low*Masseter		-	-	21.135
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	174.015***	149.137***	97.351***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	17.912	24.541
Goodness-of-fit					
	-2LL		648.678	603.503	586.880
	AIC		630.678	623.503	620.880
	BIC		644.662	646.810	672.156

Note: *p<.05; **p<.01; ***p<.001

Table 8-6 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the thinking phase for the rating block for sweet session

LAM - Thinking Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
	Fixed Effects				
	Intercept	r^{00}	-0.468	-0.099	-1.697
Concentration	High		3.927	6.777	6.043
	Medium		6.740	8.347*	16.450**
	Low		5.370	6.769	9.711
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.882	-4.275
	Zygomaticus		-	8.075*	-2.804
	Levator		-	-10.067***	3.486
	Masseter		-	3.706	8.004
Concentration*Muscle	High*Corrugator		-	-	4.741
	Medium*Corrugator		-	-	1.802
	Low*Corrugator		-	-	-2.967
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	19.536
	Medium*Zygomaticus		-	-	12.137
	Low*Zygomaticus		-	-	-0.428
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-15.787
	Medium*Levator		-	-	-18.463
	Low*Levator		-	-	-7.077
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-8.680
	Medium*Masseter		-	-	-15.499
	Low*Masseter		-	-	3.073
	Water*Masseter		-	-	0.000
	Variance Components				
Level 1	Within-Participants	σ^{2e}	174.015***	149.137***	112.685***
Level 2	Between-Participants	$\sigma^{2\mu}$	33.725	17.912	29.914
	Goodness-of-fit				
	-2LL		618.678	603.503	588.496
	AIC		630.678	623.506	632.496
	BIC		644.662	646.810	683.773

Note: *p<.05; **p<.01; ***p<.001

Table 8-7 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the emptying phase for the tasting block for bitter session

LAM - Emptying Phase - Tasting Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-3.778	-6.728**	-6.766**
Concentration	High		36.100***	32.499***	-32.434***
	Medium		15.736***	13.469***	-15.934***
	Low		0.382	1.307	3.312
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-5.501*	-12.182
	Zygomaticus		-	-0.702	0.460
	Levator		-	1.702	1.916
	Masseter		-	0.859	1.775
Concentration*Muscle	High*Corrugator		-	-	7.064
	Medium*Corrugator		-	-	12.833
	Low*Corrugator		-	-	12.142
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	4.271
	Medium*Zygomaticus		-	-	-0.673
	Low*Zygomaticus		-	-	0.496
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-1.722
	Medium*Levator		-	-	0.370
	Low*Levator		-	-	-1.316
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-1.32
	Medium*Masseter		-	-	-7.808
	Low*Masseter		-	-	-4.195
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	43.351***	36.649***	31.638***
Level 2	Between-Participants	$\sigma^{2\mu}$	32.314**	29.674**	27.016**
Goodness-of-fit					
	-2LL		528.400	510.173	499.921
	AIC		540.400	530.173	543.921
	BIC		554.385	553.348	594.906

Note: *p<.05; **p<.01; ***p<.001

Table 8-8 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the swirling phase for the tasting block for bitter session

LAM - Swirling Phase - Tasting Block - Bitter Session					
	Parameter		***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r_{00}	-3.778	-2.068	-6.955
Concentration	High		36.100***	35.312***	26.559***
	Medium		15.736***	15.716***	14.659***
	Low		0.382	0.080	0.579
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.255	-0.525
	Zygomaticus		-	-0.696	-0.497
	Levator		-	-0.286	3.285
	Masseter		-	-0.166	-3.837
Concentration*Muscle	High*Corrugator		-	-	1.391
	Medium*Corrugator		-	-	-1.668
	Low*Corrugator		-	-	5.640
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	2.556
	Medium*Zygomaticus		-	-	6.167
	Low*Zygomaticus		-	-	-0.515
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-5.501**
	Medium*Levator		-	-	-1.667
	Low*Levator		-	-	-0.237
	Water*Levator		-	-	0.000
	High*Masseter		-	-	2.941
	Medium*Masseter		-	-	-2.452
	Low*Masseter		-	-	-0.440
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	43.351***	43.010***	31.950***
Level 2	Between-Participants	$\sigma^{2\mu}$	32.314**	32.404**	34.415**
Goodness-of-fit					
	-2LL		528.400	521.144	504.144
	AIC		540.400	541.144	548.144
	BIC		554.385	564.319	599.129

Note: *p<.05; **p<.01; ***p<.001

Table 8-9 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the thinking phase for the tasting block for bitter session

LAM - Thinking Phase - Tasting Block - Bitter Session					
		Parameter	*Model C*	*Model E*	*Model F*
Fixed Effects					
	Intercept	Γ^{00}	-3.778	-0.954	1.433
Concentration	High		36.100***	34.193***	36.871***
	Medium		15.736***	14.749***	17.685***
	Low		0.382	-0.567	-0.378
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	1.222	-0.987
	Zygomaticus		-	-1.801	-2.360*
	Levator		-	-2.804	-4.454
	Masseter		-	-0.297	-6.305
Concentration*Muscle	High*Corrugator		-	-	2.978
	Medium*Corrugator		-	-	1.609
	Low*Corrugator		-	-	3.262
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	3.876
	Medium*Zygomaticus		-	-	8.207
	Low*Zygomaticus		-	-	0.244
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	0.414
	Medium*Levator		-	-	3.426
	Low*Levator		-	-	-5.045
	Water*Levator		-	-	0.000
	High*Masseter		-	-	7.240
	Medium*Masseter		-	-	-5.727
	Low*Masseter		-	-	5.926
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	43.351***	38.460***	29.874***
Level 2	Between-Participants	$\sigma^{2\mu}$	32.314**	36.079**	35.541**
Goodness-of-fit					
	-2LL		528.400	515.957	500.649
	AIC		540.400	5353.957	544.649
	BIC		554.385	559.132	595.633

Note: *p<.05; **p<.01; ***p<.001

Table 8-10 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the emptying phase for the rating block for bitter session

LAM - Emptying Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-3.348	-2.333	-2.290
Concentration	High		36.830***	35.497***	34.590***
	Medium		14.942***	14.345***	16.431***
	Low		0.495	0.450	-0.218
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-3.304***	-7.959
	Zygomaticus		-	1.032	0.282
	Levator		-	0.182	0.513
	Masseter		-	-0.228	6.147
Concentration*Muscle	High*Corrugator		-	-	4.648
	Medium*Corrugator		-	-	6.635
	Low*Corrugator		-	-	4.809
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	4.137
	Medium*Zygomaticus		-	-	0.520
	Low*Zygomaticus		-	-	-3.259
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-1.439
	Medium*Levator		-	-	0.511
	Low*Levator		-	-	0.702
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-5.237
	Medium*Masseter		-	-	-8.910
	Low*Masseter		-	-	-5.428
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	43.714***	37.628***	32.228***
Level 2	Between-Participants	$\sigma^{2\mu}$	30.682**	23.922**	25.524**
Goodness-of-fit					
	-2LL		528.184	515.423	506.735
	AIC		540.184	535.423	550.735
	BIC		554.168	558.730	602.012

Note: *p<.05; **p<.01; ***p<.001

Table 8-11 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the swirling phase for the rating block for bitter session

LAM - Swirling Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	-3.778	-3.629	-7.457
Concentration	High		36.100***	34.839***	-30.255***
	Medium		15.736***	15.115***	-17.378***
	Low		0.382	0.474	-1.866
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.261	2.010
	Zygomaticus		-	0.126	-0.161
	Levator		-	-0.069	1.998
	Masseter		-	-0.297	-1.172
Concentration*Muscle	High*Corrugator		-	-	-1.095
	Medium*Corrugator		-	-	-3.652
	Low*Corrugator		-	-	1.799
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	5.727
	Medium*Zygomaticus		-	-	4.882
	Low*Zygomaticus		-	-	0.117
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-4.353**
	Medium*Levator		-	-	-0.279
	Low*Levator		-	-	1.267
	Water*Levator		-	-	0.000
	High*Masseter		-	-	0.701
	Medium*Masseter		-	-	-0.930
	Low*Masseter		-	-	-3.575
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	43.651***	43.513***	30.746***
Level 2	Between-Participants	$\sigma^{2\mu}$	32.314**	30.329**	41.955**
Goodness-of-fit					
	-2LL		528.400	527.685	511.478
	AIC		540.400	547.685	555.478
	BIC		554.385	570.992	606.754

Note: *p<.05; **p<.01; ***p<.001

Table 8-12 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LAM rating during the thinking phase for the rating block for bitter session**

LAM - Thinking Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	-3.703	-0.849	-1.060
Concentration	High		33.493***	32.593***	33.118***
	Medium		15.013***	15.514***	14.120***
	Low		0.342	-1.007	-3.491
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.708	2.425
	Zygomaticus		-	-2.153	-2.324
	Levator		-	-0.797	-3.935
	Masseter		-	0.961	2.409
Concentration*Muscle	High*Corrugator		-	-	-2.123
	Medium*Corrugator		-	-	-7.472
	Low*Corrugator		-	-	1.201
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	11.084
	Medium*Zygomaticus		-	-	-15.835
	Low*Zygomaticus		-	-	0.260
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	0.401
	Medium*Levator		-	-	9.027*
	Low*Levator		-	-	5.625
	Water*Levator		-	-	0.000
	High*Masseter		-	-	0.669
	Medium*Masseter		-	-	1.565
	Low*Masseter		-	-	-2.101
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	86.108***	83.604***	67.919***
Level 2	Between-Participants	$\sigma^{2\mu}$	53.045**	48.184*	50.267*
Goodness-of-fit					
	-2LL		577.911	574.777	562.422
	AIC		589.911	594.777	606.422
	BIC		603.896	618.084	657.698

Note: *p<.05; **p<.01; ***p<.001

Table 8-13 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the emptying phase for the tasting block for sweet session

LMS - Emptying Phase - Tasting Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	4.480	4.822	5.521
Concentration	High		43.731***	42.924***	39.240***
	Medium		24.252***	23.549***	23.011***
	Low		4.587	3.307	4.371
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	0.187	2.598
	Zygomaticus		-	-5.704	4.042
	Levator		-	1.302	-2.962
	Masseter		-	4.279	3.116
Concentration*Muscle	High*Corrugator		-	-	-4.246
	Medium*Corrugator		-	-	-5.080
	Low*Corrugator		-	-	-9.497
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-18.451**
	Medium*Zygomaticus		-	-	-17.082**
	Low*Zygomaticus		-	-	2.132
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	6.711
	Medium*Levator		-	-	5.505
	Low*Levator		-	-	1.091
	Water*Levator		-	-	0.000
	High*Masseter		-	-	13.181
	Medium*Masseter		-	-	7.809
	Low*Masseter		-	-	-3.306
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	119.337***	122.775***	80.781***
Level 2	Between-Participants	$\sigma^{2\mu}$	59.076*	36.324	47.325*
Goodness-of-fit					
	-2LL		599.855	596.102	572.383
	AIC		611.855	616.102	616.383
	BIC		625.839	693.410	667.660

Note: *p<.05; **p<.01; ***p<.001

Table 8-14 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the swirling phase for the tasting block for sweet session

LMS - Swirling Phase - Tasting Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	4.480	5.309	7.718
Concentration	High		43.731***	44.187***	41.352***
	Medium		24.252***	24.554***	22.073***
	Low		4.587	4.659	30.778
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.166	1.152
	Zygomaticus		-	-1.608	4.477
	Levator		-	-0.190	-3.348
	Masseter		-	2.199	-6.881
Concentration*Muscle	High*Corrugator		-	-	-1.345
	Medium*Corrugator		-	-	4.643
	Low*Corrugator		-	-	-4.987
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-7.329
	Medium*Zygomaticus		-	-	-5.586
	Low*Zygomaticus		-	-	-4.909
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	4.699
	Medium*Levator		-	-	2.363
	Low*Levator		-	-	-2.448
	Water*Levator		-	-	0.000
	High*Masseter		-	-	6.476
	Medium*Masseter		-	-	6.665
	Low*Masseter		-	-	27.017
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	119.337***	118.902***	102.250***
Level 2	Between-Participants	$\sigma^{2\mu}$	59.076*	58.364*	67.596*
Goodness-of-fit					
	-2LL		599.855	599.470	591.933
	AIC		611.855	619.470	635.933
	BIC		625.839	642.778	687.209

Note: *p<.05; **p<.01; ***p<.001

Table 8-15 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the thinking phase for the tasting block for sweet session**

LAM - Thinking Phase - Tasting Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	4.480	3.212	5.073
Concentration	High		43.731***	42.507***	40.521***
	Medium		24.252***	24.669***	21.208***
	Low		4.587	5.579	2.249
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	2.971	-3.311
	Zygomaticus		-	-13.470**	-1.140
	Levator		-	6.840*	0.134
	Masseter		-	9.616	2.508
Concentration*Muscle	High*Corrugator		-	-	4.214
	Medium*Corrugator		-	-	25.673**
	Low*Corrugator		-	-	0.298
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-21.106
	Medium*Zygomaticus		-	-	-22.524
	Low*Zygomaticus		-	-	11.101
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	15.547
	Medium*Levator		-	-	1.107
	Low*Levator		-	-	-3.335
	Water*Levator		-	-	0.000
	High*Masseter		-	-	3.200
	Medium*Masseter		-	-	27.834**
	Low*Masseter		-	-	-0.262
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	119.337***	122.044***	79.999***
Level 2	Between-Participants	$\sigma^{2\mu}$	59.076*	27.718	31.118
Goodness-of-fit					
	-2LL		599.855	592.914	566.542
	AIC		611.855	612.914	610.542
	BIC		625.839	636.221	661.818

Note: *p<.05; **p<.01; ***p<.001

Table 8-16 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the emptying phase for the rating block for sweet session

LMS - Emptying Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	4.480	3.788	6.111
Concentration	High		43.731***	41.061***	34.652***
	Medium		24.253***	23.405***	17.021***
	Low		4.587	2.847	4.454
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	5.960*	2.279
	Zygomaticus		-	-7.632**	1.469
	Levator		-	2.953*	-1.749
	Masseter		-	1.681	3.156
Concentration*Muscle	High*Corrugator		-	-	13.573**
	Medium*Corrugator		-	-	7.982
	Low*Corrugator		-	-	1.161
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-17.192***
	Medium*Zygomaticus		-	-	-13.533**
	Low*Zygomaticus		-	-	2.917
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	8.582***
	Medium*Levator		-	-	8.609***
	Low*Levator		-	-	-0.657
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-7.660
	Medium*Masseter		-	-	-5.789
	Low*Masseter		-	-	-1.678
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	119.337***	115.742***	63.799***
Level 2	Between-Participants	$\sigma^{2\mu}$	59.076*	31.173	42.745**
Goodness-of-fit					
	-2LL		599.855	590.673	556.27
	AIC		611.855	610.673	600.27
	BIC		625.839	633.981	651.546

Note: *p<.05; **p<.01; ***p<.001

Table 8-17 ***Model C*****,** ***Model E*** **and** ***Model F*****: Stimuli concentration and facial muscle activity used to predict LMS rating during the swirling phase for the rating block for sweet session**

LMS - Swirling Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	4.480	0.710	5.447
Concentration	High		43.731***	40.854***	34.300***
	Medium		24.253***	23.487***	14.358**
	Low		4.587	3.437	4.972
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	1.713	2.532
	Zygomaticus		-	-2.264	0.208
	Levator		-	4.547***	-0.355
	Masseter		-	-3.903	-2.079
Concentration*Muscle	High*Corrugator		-	-	0.593
	Medium*Corrugator		-	-	-3.875
	Low*Corrugator		-	-	-3.806
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-5.627
	Medium*Zygomaticus		-	-	-6.023
	Low*Zygomaticus		-	-	1.393
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	6.430
	Medium*Levator		-	-	9.761*
	Low*Levator		-	-	-2.733
	Water*Levator		-	-	0.000
	High*Masseter		-	-	0.249
	Medium*Masseter		-	-	-1.582
	Low*Masseter		-	-	8.787
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	119.337***	114.071***	90.026***
Level 2	Between-Participants	$\sigma^{2\mu}$	59.076*	44.662	51.649*
Goodness-of-fit					
	-2LL		599.855	594.094	580.341
	AIC		611.855	614.094	624.341
	BIC		625.839	637.402	675.617

Note: *p<.05; **p<.01; ***p<.001

Table 8-18 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the thinking phase for the rating block for sweet session

LMS - Thinking Phase - Rating Block - Sweet Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r_{00}	4.480	2.282	3.983
Concentration	High		43.731***	41.163***	39.647***
	Medium		24.253***	23.938***	19.305***
	Low		4.587	4.034	3.987
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	1.248	2.969
	Zygomaticus		-	-9.992	-6.290
	Levator		-	9.311**	-2.607
	Masseter		-	8.364	8.762
Concentration*Muscle	High*Corrugator		-	-	-1.255
	Medium*Corrugator		-	-	0.958
	Low*Corrugator		-	-	-2.564
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-9.037
	Medium*Zygomaticus		-	-	-9.085
	Low*Zygomaticus		-	-	10.373
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	12.982
	Medium*Levator		-	-	11.425
	Low*Levator		-	-	-1.581
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-0.068
	Medium*Masseter		-	-	13.905
	Low*Masseter		-	-	-2.146
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2}_{e}	119.337***	102.906***	77.985***
Level 2	Between-Participants	σ^{2}_{μ}	59.076*	37.742	41.492*
Goodness-of-fit					
	-2LL		599.855	585.006	568.443
	AIC		611.855	605.006	612.443
	BIC		625.839	628.314	663.719

Note: *p<.05; **p<.01; ***p<.001

Table 8-19 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the emptying phase for the tasting block for bitter session**

LMS - Emptying Phase - Tasting Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
	Fixed Effects				
	Intercept	Γ^{00}	12.205**	20.453***	16.885**
Concentration	High		63.995***	59.835***	67.729***
	Medium		22.682***	19.555***	22.794***
	Low		-1.246	-3.187	-1.788
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	7.705*	19.245
	Zygomaticus		-	5.399	1.072
	Levator		-	-5.219*	-3.682
	Masseter		-	-1.616	-2.112
Concentration*Muscle	High*Corrugator		-	-	-14.521
	Medium*Corrugator		-	-	-10.776
	Low*Corrugator		-	-	-10.466
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	3.533
	Medium*Zygomaticus		-	-	-4.261
	Low*Zygomaticus		-	-	0.085
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-2.378
	Medium*Levator		-	-	-0.615
	Low*Levator		-	-	0.328
	Water*Levator		-	-	0.000
	High*Masseter		-	-	2.207
	Medium*Masseter		-	-	7.713
	Low*Masseter		-	-	1.209
	Water*Masseter		-	-	0.000
	Variance Components				
Level 1	Within-Participants	σ^{2e}	138.473***	119.802***	109.939***
Level 2	Between-Participants	$\sigma^{2\mu}$	174.773**	168.067**	149.543**
	Goodness-of-fit				
	-2LL		624.607	607.428	600.489
	AIC		636.607	627.428	644.489
	BIC		650.591	650.603	694.473

Note: *p<.05; **p<.01; ***p<.001

Table 8-20 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the swirling phase for the tasting block for bitter session**

LMS - Swirling Phase - Tasting Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
	Fixed Effects				
	Intercept	Γ^{00}	12.205**	8.892	19.607***
Concentration	High		63.995***	58.962***	45.616***
	Medium		22.682***	20.344***	17.308***
	Low		-1.246	-2.003	-2.875
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	-0.130	0.616
	Zygomaticus		-	0.229	0.075
	Levator		-	1.598	-5.987
	Masseter		-	1.372	7.478
Concentration*Muscle	High*Corrugator		-	-	-3.558
	Medium*Corrugator		-	-	4.757
	Low*Corrugator		-	-	-10.317
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-10.137
	Medium*Zygomaticus		-	-	-3.120
	Low*Zygomaticus		-	-	0.550
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	11.503**
	Medium*Levator		-	-	2.229
	Low*Levator		-	-	2.877
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-2.218
	Medium*Masseter		-	-	-1.266
	Low*Masseter		-	-	-5.175
	Water*Masseter		-	-	0.000
	Variance Components				
Level 1	Within-Participants	σ^{2e}	138.473***	131.996***	104.136***
Level 2	Between-Participants	$\sigma^{2\mu}$	174.773**	187.181**	197.142**
	Goodness-of-fit				
	-2LL		624.607	614.871	601.841
	AIC		636.607	634.871	645.841
	BIC		650.591	658.046	696.826

Note: *p<.05; **p<.01; ***p<.001

Table 8-21 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the thinking phase for the tasting block for bitter session**

LMS - Thinking Phase - Tasting Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r^{00}	12.205**	9.662*	3.740
Concentration	High		63.995***	58.324***	68.630***
	Medium		22.682***	21.097***	24.051***
	Low		-1.246	-1.499	0.945
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	0.427	-1.517
	Zygomaticus		-	1.701	3.163
	Levator		-	0.993	9.195
	Masseter		-	5.557	14.268
Concentration*Muscle	High*Corrugator		-	-	1.665
	Medium*Corrugator		-	-	2.833
	Low*Corrugator		-	-	-3.073
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-11.170
	Medium*Zygomaticus		-	-	-8.119
	Low*Zygomaticus		-	-	-2.737
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-7.324
	Medium*Levator		-	-	-9.411
	Low*Levator		-	-	3.960
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-11.064
	Medium*Masseter		-	-	6.648
	Low*Masseter		-	-	-6.091
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	138.473***	129.742***	102.007***
Level 2	Between-Participants	$\sigma^{2\mu}$	174.773**	160.407**	156.846**
Goodness-of-fit					
	-2LL		624.607	611.394	596.853
	AIC		636.607	631.394	640.853
	BIC		650.591	654.568	691.838

Note: *p<.05; **p<.01; ***p<.001

Table 8-22 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the emptying phase for the rating block for bitter session**

LMS - Emptying Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	Γ^{00}	10.299**	9.298*	7.113
Concentration	High		65.265***	65.385***	69.373***
	Medium		21.458***	20.935***	25.982***
	Low		-1.475	-0.422	1.564
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	2.140	11.264
	Zygomaticus		-	0.128	-2.392
	Levator		-	-0.936	0.181
	Masseter		-	4.247	-6.650
Concentration*Muscle	High*Corrugator		-	-	-11.481
	Medium*Corrugator		-	-	-7.693
	Low*Corrugator		-	-	-10.199
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-6.222
	Medium*Zygomaticus		-	-	3.446
	Low*Zygomaticus		-	-	5.760
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	0.771
	Medium*Levator		-	-	-2.584
	Low*Levator		-	-	-1.343
	Water*Levator		-	-	0.000
	High*Masseter		-	-	12.758
	Medium*Masseter		-	-	9.897
	Low*Masseter		-	-	7.585
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^{2e}	133.844***	128.960***	115.967***
Level 2	Between-Participants	$\sigma^{2\mu}$	136.406**	100.148**	104.458**
Goodness-of-fit					
	-2LL		618.694	611.839	605.937
	AIC		630.694	631.839	649.937
	BIC		644.678	655.146	701.213

Note: *p<.05; **p<.01; ***p<.001

Table 8-23 ***Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the swirling phase for the rating block for bitter session**

LMS - Swirling Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
Fixed Effects					
	Intercept	r_{00}	12.205**	11.544*	17.608**
Concentration	High		63.995***	59.199***	55.107***
	Medium		22.682***	20.232***	23.046***
	Low		-1.246	-1.781	3.345
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	0.647	-1.097
	Zygomaticus		-	-0.703	0.855
	Levator		-	0.570	-2.668
	Masseter		-	1.153	-2.632
Concentration*Muscle	High*Corrugator		-	-	0.191
	Medium*Corrugator		-	-	5.044
	Low*Corrugator		-	-	-5.420
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-15.432**
	Medium*Zygomaticus		-	-	-6.279
	Low*Zygomaticus		-	-	0.664
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	7.128**
	Medium*Levator		-	-	-0.254
	Low*Levator		-	-	-1.711
	Water*Levator		-	-	0.000
	High*Masseter		-	-	4.522
	Medium*Masseter		-	-	5.016
	Low*Masseter		-	-	2.363
	Water*Masseter		-	-	0.000
Variance Components					
Level 1	Within-Participants	σ^2_e	138.473***	132.365***	95.716***
Level 2	Between-Participants	σ^2_μ	174.773**	171.171**	193.266**
Goodness-of-fit					
	-2LL		624.607	621.564	604.252
	AIC		636.607	641.564	648.252
	BIC		650.591	664.871	699.528

Note: *p<.05; **p<.01; ***p<.001

Table 8-24 *Model C*, *Model E* and *Model F*: Stimuli concentration and facial muscle activity used to predict LMS rating during the thinking phase for the rating block for bitter session

LMS - Thinking Phase - Rating Block - Bitter Session					
		Parameter	***Model C***	***Model E***	***Model F***
	Fixed Effects				
	Intercept	r^{00}	12.610**	8.557	6.985
Concentration	High		63.589***	62.104***	66.772***
	Medium		21.853***	22.798***	20.357**
	Low		-0.230	1.919	4.637
	Water		0.000	0.000	0.000
Muscle	Corrugator		-	2.008	-1.886
	Zygomaticus		-	2.641	1.718
	Levator		-	-0.934	8.236
	Masseter		-	2.416	3.845
Concentration*Muscle	High*Corrugator		-	-	3.693
	Medium*Corrugator		-	-	8.764
	Low*Corrugator		-	-	-6.066
	Water*Corrugator		-	-	0.000
	High*Zygomaticus		-	-	-8.148
	Medium*Zygomaticus		-	-	-14.999
	Low*Zygomaticus		-	-	-0.769
	Water*Zygomaticus		-	-	0.000
	High*Levator		-	-	-7.933
	Medium*Levator		-	-	-13.960
	Low*Levator		-	-	-4.830
	Water*Levator		-	-	0.000
	High*Masseter		-	-	-4.837
	Medium*Masseter		-	-	-1.499
	Low*Masseter		-	-	1.462
	Water*Masseter		-	-	0.000
	Variance Components				
Level 1	Within-Participants	σ^{2e}	166.806***	162.370***	134.084***
Level 2	Between-Participants	$\sigma^{2\mu}$	153.260**	131.813**	123.555**
	Goodness-of-fit				
	-2LL		633.861	629.989	617.309
	AIC		645.861	649.989	661.309
	BIC		659.845	673.296	712.585

Note: *p<.05; **p<.01; ***p<.001

9 References

Adolphs, R. (2002). Recognizing emotion from facial expressions: Psychological and neutrological mechanisms. *Behavioral and Cognitive Neuroscience Reviews, 1*(1), 2162.

Albert, A., Salvador, A., Schlich, P., & Fiszman, S. (2012). Comparison between temporal dominance of sensations (TDS) and key-attribute sensory profiling for evaluating solid food with contrasting textural layers: Fish sticks. *Food Quality and Preference, 24*(1), 111-118. doi:10.1016/j.foodqual.2011.10.003

Angyal, A. (1941). Disgust and related aversions *Journal of Abnormal and Social Psychology, 36*, 393-412.

Armstrong, J. E., Hutchinson, I., Laing, D. G., & Jinks, A. L. (2007a). Facial electromyography: Responses of children to odor and taste stimuli. *Chemical Senses, 32*(6), 611-621. doi:10.1093/chemse/bjm029

Armstrong, J. E., Hutchinson, I., Laing, D. G., & Jinks, A. L. (2007b). Facial electromyography: responses of children to odor and taste stimuli. *Chem Senses, 32*(6), 611-621. doi:10.1093/chemse/bjm029

Bartoshuk, L. M., Duffy, V. B., & Miller, I. J. (1994). PTC/PROP tasting: anatomy, psychophysics, and sex effects. *Physiology & Behavior, 56*(6), 1165-1171. doi:10.1016/0031-9384(94)90361-1

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Brain Res Cogn Brain Res, 17*(3), 613-620. doi:10.1016/s0926-6410(03)00174-5

Bemfeito, R. M., Rodrigues, J. F., e Silva, J. G., & Abreu, L. R. (2016). Temporal dominance of sensations sensory profile and drivers of liking of artisanal Minas cheese produced in the region of Serra da Canastra, Brazil. *J Dairy Sci, 99*(10), 7886-7897. doi:10.3168/jds.2016-11056

Benton, D., & Donohoe, R. T. (1999). The effects of nutrients on mood. *Public Health Nutr, 2*(3A), 403-409. doi:10.1017/s1368980099000555

Bielser, M. L., Creze, C., Murray, M. M., & Toepel, U. (2016). Does my brain want what my eyes like? - How food liking and choice influence spatio-temporal brain dynamics of food viewing. *Brain Cogn, 110*, 64-73. doi:10.1016/j.bandc.2015.10.005

Birch, G. G., Latymer, Z., & Hollaway, M. (1980). Intensity-Time Relationships in Sweetness - Evidence for a Queue Hypothesis in Taste Chemoreception. *Chemical Senses, 5*(1), 63-78. doi:DOI 10.1093/chemse/5.1.63

Birch, G. G., Odonnell, K., & Musgrave, R. (1982). Intensity Time Studies of Sweetness - Psychophysical Evidence for Localized Concentration of Stimulus. *Food Chemistry, 9*(3), 223-237. doi:Doi 10.1016/0308-8146(82)90100-5

Blair, E. H., Wing, R. R., & Wald, A. (1991). The effect of laboratory stressors on glycemic control and gastrointestinal transit time. *Psychosom Med, 53*(2), 133-143.

Borg, G. (1982). A category scale with ratio properties for intermodal and interindividual comparisons. In H. G. Geissler & P. Petzold (Eds.), Psychophysical judgment and the proceess of perception (pp. 25-34). *New York, NY: North -Holland Publishing Company*.

Bourne, M. C., & Szczesniak, A. S. (2003). Sensory Evaluation: Texture. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 5167-5174). USA: Academic Press.

Briner, R. B., & Kiefer, T. (2005). Psychological reserach into the experience of emotion at work: definitely older, but are we any wiser? . In N. M. Ashkanasy, W. J. Zerbe, & C. E. J. Hartel (Eds.), *Effect of Affect in Organizational Settings* (Vol. 1, pp. 281-307).

Buettner, A., Beer, A., Hannig, C., Settles, M., & Schieberle, P. (2002). Physiological and analytical studies on flavor perception dynamics as induced by the eating and swallowing process. *Food Quality and Preference, 13*(7-8), 497-504. doi:Pii S0950-3293(02)00052-6

Burton, K. W., Hargrave, K., Myers, S., Warren, A., Wolsfeld, S., Tompkins, D., . . . Reminger, S. (2008). Habitual emotion regulation and increased zygomaticus major activity evoked by negative images (or 'grimacing'). *Psychophysiology, 45*, S118-S118.

Cabanac, M. (2002). What is emotion? *Behavioural Processes, 60*(2), 69-83. doi:10.1016/s0376-6357(02)00078-5

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (2000). The psychophysiology of emotion. In R. Lewis & J. M. Haviland-Jones (Eds.), *The handbook of emotion* (2 ed., pp. 173-191). New York: Guilford.

Cacioppo, J. T., Martzke, J. S., Petty, R. E., & Tassinary, L. G. (1988). Specific forms of facial EMG response index emotions during an interview: from Darwin to the continuous flow hypothesis affect-laden information processing. *Journal of Personality and Social Psychology, 54*(4), 592-604. doi:10.1037/0022-3514.54.4.592

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic Activity over Facial Muscle Regions Can Differentiate the Valence and Intensity of Affective Reactions. *Journal of Personality and Social Psychology, 50*(2), 260-268. doi:Doi 10.1037//0022-3514.50.2.260

Canary, D. J., Cupach, W. R., & Messman, S. J. (1995). *Relationship conflict: conflict in parent-child, friendship, and romantic relationships*. USA: Sage Publication Inc.

Canetti, L., Bachar, E., & Berry, E. M. (2002). Food and emotion. *Behav Processes, 60*(2), 157-164. doi:10.1016/s0376-6357(02)00082-7

Cannon, P. R., Schnall, S., & White, M. (2011). Transgressions and Expressions: Affective Facial Muscle Activity Predicts Moral Judgments. *Social Psychological and Personality Science, 2*(3), 325-331. doi:10.1177/1948550610390525

Cardello, A., Lawless, H. T., & Schutz, H. G. (2008). Effects of extreme anchors and interior label spacing on labeled affective magnitude scales. *Food Quality and Preference, 19*(5), 473-480. doi:10.1016/j.foodqual.2008.02.003

Cardello, A. V., & Schutz, H. G. (1996). Food appropriateness measures as an adjunct to consumer preference/acceptability evaluation. *Food Quality and Preference, 7*(3-4), 239-249. doi:Doi 10.1016/S0950-3293(96)00012-2

Catanzaro, D., Chesbro, E. C., & Velkey, A. J. (2013). Relationship between food preferences and PROP taster status of college students. *Appetite, 68*, 124-131. doi:10.1016/j.appet.2013.04.025

Chang, W. I., Chung, J. W., Kim, Y. K., Chung, S. C., & Kho, H. S. (2006). The relationship between phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) taster status and taste thresholds for sucrose and quinine. *Archives of Oral Biology, 51*(5), 427-432. doi:10.1016/j.archoralbio.2005.10.002

Chapman, H. A., Kim, D. A., Susskind, J. M., & Anderson, A. K. (2009). In Bad Taste: Evidence for the Oral Origins of Moral Disgust. *Science, 323*(5918), 1222-1226. doi:10.1126/science.1165565

Chen, M. Y., & Chen, C. C. (2010). The contribution of the upper and lower face in happy and sad facial expression classification. *Vision Res, 50*(18), 1814-1823. doi:10.1016/j.visres.2010.06.002

Christensen, L. (1993). Effects of eating behavior on mood: a review of the literature. *Int J Eat Disord, 14*(2), 171-183. doi:10.1002/1098-108x(199309)14:2<171::aid-eat2260140207>3.0.co;2-u

Clark, C. C., & Lawless, H. T. (1994). Limiting response alternatives in time-intensity scaling: an examination of the halo-dumping effect. *Chem Senses, 19*(6), 583-594. doi:10.1093/chemse/19.6.583

Clark, J. E. (1998). Taste and flavour: their importance in food choice and acceptance. *Proceedings of the Nutrition Society, 57*(4), 639-643. doi:Doi 10.1079/Pns19980093

Cliff, M., & Heymann, H. (1992). Descriptive Analysis of Oral Pungency. *Journal of Sensory Studies, 7*(4), 279-290. doi:10.1111/j.1745-459X.1992.tb00195.x

Cliff, M., & Heymann, H. (1993). Development and Use of Time-Intensity Methodology for Sensory Evaluation - a Review. *Food Research International, 26*(5), 375-385. doi:Doi 10.1016/0963-9969(93)90081-S
Cohen, S., Doyle, W. J., Turner, R. B., Alper, C. M., & Skoner, D. P. (2003). Emotional style and susceptibility to the common cold. *Psychosom Med, 65*(4), 652-657. doi:10.1097/01.psy.0000077508.57784.da
Conner, M., Fitter, M., & Fletcher, W. (1999). Stress and snacking: A diary study of daily hassles and between-meal snacking. *Psychology & Health, 14*(1), 51-63. doi:Doi 10.1080/08870449908407313
Cordonnier, S. M., & Delwiche, J. F. (2008). An alternative method for assessing liking: Positional relative rating versus the 9-point hedonic scale. *Journal of Sensory Studies, 23*(2), 284-292. doi:DOI 10.1111/j.1745-459X.2008.00155.x
Costell, E., Tarrega, A., & Bayarri, S. (2010). Food Acceptance: The Role of Consumer Perception and Attitudes. *Chemosensory Perception, 3*(1), 42-50. doi:10.1007/s12078-009-9057-1
Darwin, C. R. (1872). *The Expression of the Emotions in Man and Animals* Chicage: University of Chicago Press.
Davis, C., Levitan, R. D., Kaplan, A. S., Carter, J., Reid, C., Curtis, C., . . . Kennedy, J. L. (2008). Reward sensitivity and the D2 dopamine receptor gene: A case-control study of binge eating disorder. *Prog Neuropsychopharmacol Biol Psychiatry, 32*(3), 620-628. doi:10.1016/j.pnpbp.2007.09.024
Davis, M. (1989). Neural systems involved in fear-potentiated startle. *Ann N Y Acad Sci, 563*, 165-183. doi:10.1111/j.1749-6632.1989.tb42197.x
de Jong, P. J., Koster, E. H., van Wees, R., & Martens, S. (2010). Angry facial expressions hamper subsequent target identification. *Emotion, 10*(5), 727-732. doi:10.1037/a0019353
de Wijk, R. A., Engelen, L., & Prinz, J. F. (2003). The role of intra-oral manipulation in the perception of sensory attributes. *Appetite, 40*(1), 1-7. doi:10.1016/s0195-6663(02)00172-1
de Wijk, R. A., Janssen, A. M., & Prinz, J. F. (2011). Oral movements and the perception of semi-solid foods. *Physiology & Behavior, 104*(3), 423-428. doi:10.1016/j.physbeh.2011.04.037
Delwiche, J. F., Buletic, Z., & Breslin, P. A. S. (2001). Relationship of papillae number to bitter intensity of quinine and PROP within and between individuals. *Physiology & Behavior, 74*(3), 329-337. doi:10.1016/s0031-9384(01)00568-6
Desmet, P. M., & Schifferstein, H. N. (2008). Sources of positive and negative emotions in food experience. *Appetite, 50*(2-3), 290-301. doi:10.1016/j.appet.2007.08.003
Di Monaco, R., Verneau, Professor Christopher J, F., Miele, N. A., Volpe, S., Masi, P., & Cavella, S. (2016). Temporal dominance of sensations and dynamic liking evaluation of polenta sticks. *British Food Journal, 118*(3), 749-760. doi:10.1108/bfj-07-2015-0236
Dijksterhuis, G. B., & Piggott, J. R. (2000). Dynamic methods of sensory analysis. *Trends in Food Science & Technology, 11*(8), 284-290. doi:Doi 10.1016/S0924-2244(01)00020-6
Dimberg, U. (1982). Facial reactions to facial expressions. *Psychophysiology, 19*(6), 643-647. doi:10.1111/j.1469-8986.1982.tb02516.x
Dimberg, U. (1997). Facial EMG: Indicator of rapid emotional reactions. *International Journal of Psychophysiology, 25*(1), 52-53. doi:Doi 10.1016/S0167-8760(97)85483-9
Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11*(1), 86-89. doi:10.1111/1467-9280.00221
Dinnella, C., Masi, C., Zoboli, G., & Monteleone, E. (2012). Sensory functionality of extra-virgin olive oil in vegetable foods assessed by Temporal Dominance of Sensations and Descriptive Analysis. *Food Quality and Preference, 26*(2), 141-150. doi:10.1016/j.foodqual.2012.04.013
Dixon, T. (2012). "Emotion": One Word, Many Concepts. *Emotion Review, 4*(4), 387-388. doi:10.1177/1754073912445826

Drewnowski, A. (1997). Taste preferences and food intake. *Annu Rev Nutr, 17*, 237-253. doi:10.1146/annurev.nutr.17.1.237
Drewnowski, A. (2001). The science and complexity of bitter taste. *Nutrition Reviews, 59*(6), 163-169.
Drewnowski, A., Brunzell, J. D., Sande, K., Iverius, P. H., & Greenwood, M. R. C. (1985). SWEET TOOTH RECONSIDERED - TASTE RESPONSIVENESS IN HUMAN OBESITY. *Physiology & Behavior, 35*(4), 617-622. doi:10.1016/0031-9384(85)90150-7
Drewnowski, A., Henderson, S. A., & Shore, A. B. (1997). Genetic sensitivity to 6-n-propylthiouracil (PROP) and hedonic responses to bitter and sweet tastes. *Chemical Senses, 22*(1), 27-37. doi:10.1093/chemse/22.1.27
Drewnowski, A., Henderson, S. A., Shore, A. B., & BarrattFornell, A. (1997). Nontasters, tasters, and supertasters of 6-n-propylthiouracil (PROP) and hedonic response to sweet. *Physiology & Behavior, 62*(3), 649-655. doi:10.1016/s0031-9384(97)00193-5
Duizer, L. M., Bloom, K., & Findlay, C. J. (1997). Dual-attribute time-intensity sensory evaluation: A new method for temporal measurement of sensory perceptions. *Food Quality and Preference, 8*(4), 261-269. doi:Doi 10.1016/S0950-3293(96)00052-3
Duizer, L. M., Gullett, E. A., & Findlay, C. J. (1996). The relationship between sensory time-intensity, physiological electromyography and instrumental texture profile analysis measurements of beef tenderness. *Meat Science, 42*(2), 215-224. doi:Doi 10.1016/0309-1740(95)00022-4
Edwards, J. S. A., Meiselman, H. L., Edwards, A., & Lesher, L. (2003). The influence of eating location on the acceptability of identically prepared foods. *Food Quality and Preference, 14*(8), 647-652. doi:10.1016/S0950-3293(02)00189-1
Ekman, P. (1992a). An Argument for Basic Emotions. *Cognition & Emotion, 6*(3-4), 169-200. doi:Doi 10.1080/02699939208411068
Ekman, P. (1992b). Facial Expressions of Emotion - New Findings, New Questions. *Psychological Science, 3*(1), 34-38. doi:DOI 10.1111/j.1467-9280.1992.tb00253.x
Ekman, P., Friesen, W. V., & Ancoli, S. (1980). Facial signs of emotional experience. *Journal of Personality and Social Psychology, 39*(6), 1125-1134.
Ekman, P., Friesen, W. V., O'Sullivan, M., Chan, A., Diacoyanni-Tarlatzis, I., Heider, K., . . . et al. (1987). Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology, 53*(4), 712-717. doi:10.1037/0022-3514.53.4.712
El Dine, A. N., & Olabi, A. (2009). Effect of reference foods in repeated acceptability tests: testing familiar and novel foods using 2 acceptability scales. *J Food Sci, 74*(2), S97-106. doi:10.1111/j.1750-3841.2008.01034.x
Engelen, L., van den Keybus, P. A., de Wijk, R. A., Veerman, E. C., Amerongen, A. V., Bosman, F., . . . van der Bilt, A. (2007). The effect of saliva composition on texture perception of semi-solids. *Arch Oral Biol, 52*(6), 518-525. doi:10.1016/j.archoralbio.2006.11.007
Engen, T., & McBurney, D. H. (1964). Magnitude and category scales of the pleasantness of odors. *Journal of Experimental Psychology, 68*, 435-440.
Epstein, L. H., & Paluch, R. A. (1997). Habituation of facial muscle responses to repeated food stimuli. *Appetite, 29*(2), 213-224. doi:10.1006/appe.1997.0102
Ferris, S. J., Kempton, R. A., & Muir, D. D. (2003). Carryover in sensory trials. *Food Quality and Preference, 14*(4), 299-304. doi:Pii S0950-3293(02)00090-3
Finch, J. F., Baranik, L. E., Liu, Y., & West, S. G. (2012). Physical health, positive and negative affect, and personality: A longitudinal analysis. *Journal of Research in Personality, 46*(5), 537-545. doi:10.1016/j.jrp.2012.05.013
Fisher, C. D. (2002). Antecedents and consequences of real-time affective reactions at work. *Motivation and Emotion, 26*(1), 3-30. doi:Unsp 0146-7239/02/0300-0003/0

Foster, K. D., Bronlund, J. E., & Paterson, A. H. J. (2006). Glass transition related cohesion of amorphous sugar powders. *Journal of Food Engineering, 77*(4), 997-1006. doi:10.1016/j.jfoodeng.2005.08.028

Foster, K. D., Grigor, J. M., Cheong, J. N., Yoo, M. J., Bronlund, J. E., & Morgenstern, M. P. (2011). The role of oral processing in dynamic sensory perception. *J Food Sci, 76*(2), R49-61. doi:10.1111/j.1750-3841.2010.02029.x

Fredrickson, B. L., Cohn, M. A., Coffey, K. A., Pek, J., & Finkel, S. M. (2008). Open hearts build lives: positive emotions, induced through loving-kindness meditation, build consequential personal resources. *Journal of Personality and Social Psychology, 95*(5), 1045-1062. doi:10.1037/a0013262

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23*(5), 567-589. doi:10.1111/j.1469-8986.1986.tb00676.x

Friedman, H. S., & Booth-Kewley, S. (1987). The "disease-prone personality". A meta-analytic view of the construct. *Am Psychol, 42*(6), 539-555. doi:10.1037/0003-066x.42.6.539

George, J. M., & Brief, A. P. (1992). Feeling Good Doing Good - a Conceptual Analysis of the Mood at Work Organizational Spontaneity Relationship. *Psychological Bulletin, 112*(2), 310-329. doi:Doi 10.1037/0033-2909.112.2.310

Gibson, E. L. (2006a). Emotional influences on food choice: Sensory, physiological and psychological pathways. *Physiology & Behavior, 89*(1), 53-61. doi:10.1016/j.physbeh.2006.01.024

Gibson, E. L. (2006b). Emotional influences on food choice: sensory, physiological and psychological pathways. *Physiol Behav, 89*(1), 53-61. doi:10.1016/j.physbeh.2006.01.024

Gohm, C. L., & Clore, G. L. (2002). Four latent traits of emotional experience and their involvement in well-being, coping, and attributional style. *Cognition & Emotion, 16*(4), 495-518. doi:10.1080/02699930143000374

Gonzalez, R., Montoya, I., & Carcel, J. (2001). Review: The use of electromyography on food texture assessment. *Food Science and Technology International, 7*(6), 461-471. doi:10.1106/Nrht-L39d-Hy1y-8rgb

Goodmurphy, C. W., & Ovalle, W. K. (1999). Morphological study of two human facial muscles: orbicularis oculi and corrugator supercilii. *Clin Anat, 12*(1), 1-11. doi:10.1002/(SICI)1098-2353(1999)12:1<1::AID-CA1>3.0.CO;2-J

Green, B. G., Shaffer, G. S., & Gilmore, M. M. (1993). Derivation and Evaluation of a Semantic Scale of Oral Sensation Magnitude with Apparent Ratio Properties. *Chemical Senses, 18*(6), 683-702. doi:DOI 10.1093/chemse/18.6.683

Greeno, C. G., & Wing, R. R. (1994). Stress-induced eating. *Psychological Bulletin, 115*(3), 444-464. doi:10.1037/0033-2909.115.3.444

Grigoriadis, A., Johansson, R. S., & Trulsson, M. (2014). Temporal profile and amplitude of human masseter muscle activity is adapted to food properties during individual chewing cycles. *J Oral Rehabil, 41*(5), 367-373. doi:10.1111/joor.12155

Guinard, J. X., Pangborn, R. M., & Lewis, M. J. (1986a). Effect of repeated ingestion on temporal perception of bitterness in beer. *Journal of the American Society of Brewing Chemists, 44*(1), 28-32.

Guinard, J. X., Pangborn, R. M., & Lewis, M. J. (1986b). The Time-Course of Astringency in Wine Upon Repeated Ingestion. *American Journal of Enology and Viticulture, 37*(3), 184-189.

Harburg, E., Julius, M., Kaciroti, N., Gleiberman, L., & Schork, M. A. (2003). Expressive/suppressive anger-coping responses, gender, and types of mortality: a 17-year follow-up (Tecumseh, Michigan, 1971-1988). *Psychosom Med, 65*(4), 588-597. doi:10.1097/01.psy.0000075974.19706.3b

Hauber, R. P., Rice, M. H., Howell, C. C., & Carmon, M. (1998). Anger and blood pressure readings in children. *Appl Nurs Res, 11*(1), 2-11. doi:10.1016/s0897-1897(98)80021-9

Heath, M. R., & Prinz, J. F. (1999). Oral processing of foods and the sensory evaluation of texture. In A. J. Rosenthal (Ed.), *Food Texture: Measurement and Perception* (pp. 18-26). Aspen Publishers Inc: Gaithersburg.
Heldman, D. R. (2004). Identifying food science & technology research needs. *Food Technology, 58*(12), 32-34.
Hepworth, R., Mogg, K., Brignell, C., & Bradley, B. P. (2010). Negative mood increases selective attention to food cues and subjective appetite. *Appetite, 54*(1), 134-142. doi:10.1016/j.appet.2009.09.019
Hersleth, M., Ueland, O., Allain, H., & Naes, T. (2005). Consumer acceptance of cheese, influence of different testing conditions. *Food Quality and Preference, 16*(2), 103-110. doi:10.1016/j.foodqual.2004.02.009
Hiiemae, K., Heath, M. R., Heath, G., Kazazoglu, E., Murray, J., Sapper, D., & Hamblett, K. (1996). Natural bites, food consistency and feeding behaviour in man. *Arch Oral Biol, 41*(2), 175-189. doi:10.1016/0003-9969(95)00112-3
Horio, T. (2003). EMG activities of facial and chewing muscles of human adults in response to taste stimuli. *Perceptual and Motor Skills, 97*(1), 289-298. doi:10.2466/pms.97.4.289-298
Hu, S. Q., Player, K. A., Mcchesney, K. A., Dalistan, M. D., Tyner, C. A., & Scozzafava, J. E. (1999). Facial EMG as an indicator of palatability in humans. *Physiology & Behavior, 68*(1-2), 31-35. doi:Doi 10.1016/S0031-9384(99)00143-2
Hutchings, J. B., & Lillford, P. J. (1988). The Perception of Food Texture - the Philosophy of the Breakdown Path. *Journal of Texture Studies, 19*(2), 103-115. doi:DOI 10.1111/j.1745-4603.1988.tb00928.x
Izard, C. E. (2010). The Many Meanings/Aspects of Emotion: Definitions, Functions, Activation, and Regulation. *Emotion Review, 2*(4), 363-370. doi:10.1177/1754073910374661
Jager, G., Schlich, P., Tijssen, I., Yao, J. L., Visalli, M., de Graaf, C., & Stieger, M. (2014). Temporal dominance of emotions: Measuring dynamics of food-related emotions during consumption. *Food Quality and Preference, 37*, 87-99. doi:10.1016/j.foodqual.2014.04.010
Jancke, L. (1996a). Facial EMG in an anger-provoking situation: individual differences in directing anger outwards or inwards. *International Journal of Psychophysiology, 23*(3), 207-214. doi:10.1016/s0167-8760(96)00062-1
Jancke, L. (1996b). Facial EMG in an anger-provoking situation: Individual differences in directing anger outwards or inwards. *International Journal of Psychophysiology, 23*(3), 207-214. doi:10.1016/s0167-8760(96)00062-1
Jancke, L., & Kaufmann, N. (1994). Facial EMG responses to odors in solitude and with an audience. *Chem Senses, 19*(2), 99-111. doi:10.1093/chemse/19.2.99
Jellinek, G. (1964). Introduction to and critical review of modern methods of sensory analysis (odour, taste and flavour evaluation) with special emphasis on descriptive sensory analysis (flavour profile method). *Indian Journal of Nutrition and Dietetics, 1*, 219-260.
Kamenetzky, J. (1959). Contrast and Convergence Effects in Ratings of Foods. *Journal of Applied Psychology, 43*(1), 47-52. doi:DOI 10.1037/h0041264
Kaminski, L. C., Henderson, S. A., & Drewnowski, A. (2000). Young women's food preferences and taste responsiveness to 6-n-propylthiouracil (PROP). *Physiology & Behavior, 68*(5), 691-697. doi:10.1016/s0031-9384(99)00240-1
Kassinove, H., & Sukhodolsky, D. G. (1995). Anger disorder: Basic science and practice issues. In H. Kassinove (Ed.), *Anger disorders: Definition, diagnosis, and treatment* (pp. 1-27). Washington, DC: Taylor & Francis.
Keeley, J. W., English, T., Irons, J., & Henslee, A. M. (2013). Investigating Halo and Ceiling Effects in Student Evaluations of Instruction. *Educational and Psychological Measurement, 73*(3), 440-457. doi:10.1177/0013164412475300

Keltner, D., & Buswell, B. N. (1997). Embarrassment: its distinct form and appeasement functions. *Psychological Bulletin, 122*(3), 250-270. doi:10.1037//0033-2909.122.3.250

Kemp, S. E., Hollywood, T., & Hort, J. (2009). *Sensory evaluation: A practical handbook.* New York, USA: John Wiley & Sons Inc.

Kerr, M. A., & Schneider, B. H. (2008). Anger expression in children and adolescents: a review of the empirical literature. *Clin Psychol Rev, 28*(4), 559-577. doi:10.1016/j.cpr.2007.08.001

King, S. C., Meiselman, H. L., Hottenstein, A. W., Work, T. M., & Cronk, V. (2007). The effects of contextual variables on food acceptability: A confirmatory study. *Food Quality and Preference, 18*(1), 58-65. doi:10.1016/j.foodqual.2005.07.014

Kocher, E. C., & Fisher, G. L. (1969). Subjective intensity and taste preference. *Percept Mot Skills, 28*(3), 735-740. doi:10.2466/pms.1969.28.3.735

Korsmeyer, C. (2002). Delightful, delicious, disgusting (Aesthetics, food). *Journal of Aesthetics and Art Criticism, 60*(3), 217-225. doi:Doi 10.1111/1540-6245.00069

Krebs, H., Macht, M., Weyers, P., Weijers, H. G., & Janke, W. (1996). Effects of stressful noise on eating and non-eating behavior in rats. *Appetite, 26*(2), 193-202. doi:10.1006/appe.1996.0015

Kreibig, S. D., Wilhelm, F. H., Roth, W. T., & Gross, J. J. (2007). Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films. *Psychophysiology, 44*(5), 787-806. doi:10.1111/j.1469-8986.2007.00550.x

Labbe, D., Schlich, P., Pineau, N., Gilbert, F., & Martin, N. (2009). Temporal dominance of sensations and sensory profiling: A comparative study. *Food Quality and Preference, 20*(3), 216-221. doi:10.1016/j.foodqual.2008.10.001

Lang, P. J. (1995). The emotion probe. Studies of motivation and attention. *Am Psychol, 50*(5), 372-385. doi:10.1037//0003-066x.50.5.372

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). *Motivated attention: Affect, activation, and action*.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology, 40*(5), 776-785. doi:10.1111/1469-8986.00078

Larson-Powers, N., & Pangborn, R. M. (1978). Paired Comparison and Time-Intensity Measurements of the Sensory Properties of Beverages and Gelatins Containing Sucrose or Synthetic Sweeteners. *Journal of Food Science, 43*(1), 41-46. doi:10.1111/j.1365-2621.1978.tb09732.x

Lartey, A. (2013). Introduction of Solids and Semi-Solid Foods: Critical Nutrient and Energy Density. *Annals of Nutrition and Metabolism, 63*, 34-34.

Lawless, H. (1980). A Comparison of Different Methods Used to Assess Sensitivity to the Taste of Phenylthiocarbamide (Ptc). *Chemical Senses, 5*(3), 247-256. doi:DOI 10.1093/chemse/5.3.247

Lawless, H. T., & Malone, G. J. (1986a). The discriminative efficiency of common scaling methods *Journal of Sensory Studies, 1*(1), 85-89.

Lawless, H. T., & Malone, G. J. (1986b). A comparison of rating scales: sensitivity, replicates and relative measurements. *Journal of Sensory Studies, 1*(2), 155-174.

Lawless, H. T., Popper, R., & Kroll, B. J. (2010). A comparison of the labeled magnitude (LAM) scale, an 11-point category scale and the traditional 9-point hedonic scale. *Food Quality and Preference, 21*(1), 4-12. doi:10.1016/j.foodqual.2009.06.009

Le Révérend, F. M., Hidrio, C., Fernandes, A., & Aubry, V. (2008). Comparison between temporal dominance of sensations and time intensity results. *Food Quality and Preference, 19*(2), 174-178. doi:10.1016/j.foodqual.2007.06.012

Leach, E. J., & Noble, A. C. (1986). Comparison of Bitterness of Caffeine and Quinine by a Time Intensity Procedure. *Chemical Senses, 11*(3), 339-345. doi:DOI 10.1093/chemse/11.3.339

Lee, Chung, S. J., Lee, O. H., Lee, H. S., Kim, Y. K., & Kim, K. O. (2008). Development of sample preparation, presentation procedure and sensory descriptive analysis of green tea. *Journal of Sensory Studies, 23*(4), 450-467. doi:DOI 10.1111/j.1745-459X.2008.00165.x
Lee, S. M., Lee, H. S., Kim, K. H., & Kim, K. O. (2009). Sensory Characteristics and Consumer Acceptability of Decaffeinated Green Teas. *Journal of Food Science, 74*(3), S135-S141. doi:10.1111/j.1750-3841.2009.01100.x
Lee, W. E. (1986). A Suggested Instrumental Technique for Studying Dynamic Flavor Release from Food-Products. *Journal of Food Science, 51*(1), 249-250. doi:DOI 10.1111/j.1365-2621.1986.tb10888.x
Lemon, C. H. (2015). Perceptual and Neural Responses to Sweet Taste in Humans and Rodents. *Chemosensory Perception, 8*(2), 46-52. doi:10.1007/s12078-015-9177-8
Lenfant, F., Loret, C., Pineau, N., Hartmann, C., & Martin, N. (2009). Perception of oral food breakdown. The concept of sensory trajectory. *Appetite, 52*(3), 659-667. doi:10.1016/j.appet.2009.03.003
Levenson, R. W., Ekman, P., & Friesen, W. V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology, 27*(4), 363-384. doi:10.1111/j.1469-8986.1990.tb02330.x
Lewis-Beck, M. S., Bryman, A., & Liao, T. F. (2004). *The SAGE Encyclopedia of Social Science Reserach Methods*: SAGE Publications, Inc. .
Lewis, M., Sullivan, M. W., Ramsay, D. S., & Alessandri, S. M. (1992). Individual-Differences in Anger and Sad Expressions during Extinction - Antecedents and Consequences. *Infant Behavior & Development, 15*(4), 443-452. doi:Doi 10.1016/0163-6383(92)80012-J
Li, W. J. (2012). The effect of fasting on the interaction between taste perception and metabolic regulation
Lim, J., & Fujimaru, T. (2010). Evaluation of the Labeled Hedonic Scale under different experimental conditions. *Food Quality and Preference, 21*(5), 521-530. doi:10.1016/j.foodqual.2010.02.001
Lim, J., Wood, A., & Green, B. G. (2009). Derivation and evaluation of a labeled hedonic scale. *Chem Senses, 34*(9), 739-751. doi:10.1093/chemse/bjp054
Lim, J. Y. (2011). Hedonic scaling: A review of methods and theory. *Food Quality and Preference, 22*(8), 733-747. doi:10.1016/j.foodqual.2011.05.008
Liu, Y., Gao, J. H., Liu, H. L., & Fox, P. T. (2000). The temporal response of the brain after eating revealed by functional MRI. *Nature, 405*(6790), 1058-1062. doi:10.1038/35016590
Looy, H., & Weingarten, H. P. (1992). Facial Expressions and Genetic Sensitivity to 6-Normal-Propylthiouracil Predict Hedonic Response to Sweet. *Physiology & Behavior, 52*(1), 75-82. doi:Doi 10.1016/0031-9384(92)90435-5
Lyman, B. (1982). The Nutritional Values and Food Group Characteristics of Foods Preferred during Various Emotions. *Journal of Psychology, 112*(1), 121-127.
MacDougall, D. B. (2003). Sensory Evaluation: Appearance. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 5161-5166). USA: Academic Press.
Macht, M. (1999). Characteristics of eating in anger, fear, sadness and joy. *Appetite, 33*(1), 129-139. doi:10.1006/appe.1999.0236
Macht, M., Gerer, J., & Ellgring, H. (2003). Emotions in overweight and normal-weight women immediately after eating foods differing in energy. *Physiology & Behavior, 80*(2-3), 367-374. doi:10.1016/j.physbeh.2003.08.012
Macht, M., & Simons, G. (2000). Emotions and eating in everyday life. *Appetite, 35*(1), 65-71. doi:10.1006/appe.2000.0325
Matsumoto, D., Yoo, S. H., & Chung, J. (2000). The Expression of Anger Across Cultures. In M. Potegal, G. Stemmler, & C. Spielberger (Eds.), *International Handbook of Anger* (pp. 125-139). New York: Springer.

Matysiak, N. L., & Noble, A. C. (1991). Comparison of Temporal Perception of Fruitiness in Model Systems Sweetened with Aspartame, an Aspartame + Acesulfame K Blend, or Sucrose. *Journal of Food Science, 56*(3), 823-826. doi:DOI 10.1111/j.1365-2621.1991.tb05391.x
Mauss, & Robinson, M. D. (2009). Measures of emotion: A review. *Cogn Emot, 23*(2), 209-237. doi:10.1080/02699930802204677
Mauss, I., & Robinson, M. (2009). Measures of emotion: A review. *Cognition & Emotion, 23*(2), 209-237. doi:10.1080/02699930802204677
McEwan, J. A. T., D. M. H. (1988). A behavioural interpretation of food acceptability. *Food Quality and Preference, 1*(1), 3-9.
Mcnair, D. M. (1984). Citation Classic - Manual for the Profile of Mood States. *Current Contents/Social & Behavioral Sciences*(27), 20-20.
Meillon, S., Urbano, C., & Schlich, P. (2009). Contribution of the Temporal Dominance of Sensations (TDS) method to the sensory description of subtle differences in partially dealcoholized red wines. *Food Quality and Preference, 20*(7), 490-499. doi:10.1016/j.foodqual.2009.04.006
Meiselman, H. L., & Cardello, A. V. (2003). Food Acceptability: Affective methods In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 2569-2575). USA: Academic Press.
Melo, L. L. M. M. d., Bolini, H. M. A., & Efraim, P. (2009). Sensory profile, acceptability, and their relationship for diabetic/reduced calorie chocolates. *Food Quality and Preference, 20*(2), 138-143. doi:10.1016/j.foodqual.2008.09.001
Meyners, M. (2011). Panel and panelist agreement for product comparisons in studies of Temporal Dominance of Sensations. *Food Quality and Preference, 22*(4), 365-370. doi:10.1016/j.foodqual.2011.01.006
Meyners, M. (2016). Temporal liking and CATA analysis of TDS data on flavored fresh cheese. *Food Quality and Preference, 47*, 101-108. doi:10.1016/j.foodqual.2015.02.005
Meyners, M., & Pineau, N. (2010). Statistical inference for temporal dominance of sensations data using randomization tests. *Food Quality and Preference, 21*(7), 805-814. doi:10.1016/j.foodqual.2010.04.004
Miyaoka, Y., Ashida, I., Yamazaki, T., Ito, N., Tamaki, Y., Kawakami, S. Y., & Iwamori, H. (2014). Masseter activity patterns during chewing of gummy candies and their taste components. *Chemical Senses, 39*(7), 646-647.
Moore, L. J., & Shoemaker, C. F. (1981). Sensory Textural Properties of Stabilized Ice-Cream. *Journal of Food Science, 46*(2), 399-&. doi:DOI 10.1111/j.1365-2621.1981.tb04870.x
Moskowit, H. R., & Sidel, J. L. (1971). Magnitude and Hedonic Scales of Food Acceptability. *Journal of Food Science, 36*(4), 677-&. doi:DOI 10.1111/j.1365-2621.1971.tb15160.x
Moskowit.Hr, & Sidel, J. L. (1971). Magnitude and Hedonic Scales of Food Acceptability. *Journal of Food Science, 36*(4), 677-&. doi:DOI 10.1111/j.1365-2621.1971.tb15160.x
Moskowitz, J. T. (2003). Positive affect predicts lower risk of AIDS mortality. *Psychosom Med, 65*(4), 620-626. doi:10.1097/01.psy.0000073873.74829.23
Mottram, D. S., & Elmore, J. S. (2003). Sensory Evaluation: Aroma. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 5174-5179). USA: Academic Press.
Murphy, C., & Withee, J. (1986). Age-related differences in the pleasantness of chemosensory stimuli. *Psychol Aging, 1*(4), 312-318.
Nasrawi, C. W., & Pangborn, R. M. (1990). Temporal Gustatory and Salivary Responses to Capsaicin Upon Repeated Stimulation. *Physiology & Behavior, 47*(4), 611-615. doi:Doi 10.1016/0031-9384(90)90066-D
Neumann, S. A., & Waldstein, S. R. (2001). Similar patterns of cardiovascular response during emotional activation as a function of affective valence and arousal and gender. *Journal of Psychosomatic Research, 50*(5), 245-253. doi:Doi 10.1016/S0022-3999(01)00198-2

Neyraud, E., Peyron, M. A., Vieira, C., & Dransfield, E. (2005). Influence of bitter taste on mastication pattern. *J Dent Res, 84*(3), 250-254.

Ng, M., Lawlor, J. B., Chandra, S., Chaya, C., Hewson, L., & Hort, J. (2012). Using quantitative descriptive analysis and temporal dominance of sensations analysis as complementary methods for profiling commercial blackcurrant squashes. *Food Quality and Preference, 25*(2), 121-134. doi:10.1016/j.foodqual.2012.02.004

Nguyen-Michel, S. T., Unger, J. B., & Spruijt-Metz, D. (2007). Dietary correlates of emotional eating in adolescence. *Appetite, 49*(2), 494-499. doi:10.1016/j.appet.2007.03.005

Nicolas, L., Marquilly, C., & O'Mahony, M. (2010). The 9-point hedonic scale: Are words and numbers compatible? *Food Quality and Preference, 21*(8), 1008-1015. doi:10.1016/j.foodqual.2010.05.017

Ohman, A., & Soares, J. J. (1994). "Unconscious anxiety": phobic responses to masked stimuli. *J Abnorm Psychol, 103*(2), 231-240. doi:10.1037/0021-843x.103.2.231

Oliver, G., & Wardle, J. (1999). Perceived effects of stress on food choice. *Physiology & Behavior, 66*(3), 511-515. doi:10.1016/s0031-9384(98)00322-9

Pangborn, R. M., & Koyasako, A. (1981). Time-Course of Viscosity, Sweetness and Flavor in Chocolate Desserts. *Journal of Texture Studies, 12*(2), 141-150. doi:DOI 10.1111/j.1745-4603.1981.tb01228.x

Patel, K. A., & Schlundt, D. G. (2001). Impact of moods and social context on eating behavior. *Appetite, 36*(2), 111-118. doi:10.1006/appe.2000.0385

Paulhus, D. L., & Reid, D. B. (1991). Enhancement and Denial in Socially Desirable Responding. *Journal of Personality and Social Psychology, 60*(2), 307-317. doi:Doi 10.1037/0022-3514.60.2.307

Pearce, J. H., Korth, B., & Warren, C. B. (1986). Evaluation of three scaling methods for hedonics. *Journal of Sensory Studies, 1*, 27-46.

Peryam, D. R., & Pilgrim, F. J. (1957). The Hedonic Scale Method of Measuring Food Preference. *Food Technology, 11*(4), 32-32.

Pineau, N., de Bouillé, A. G., Lepage, M., Lenfant, F., Schlich, P., Martin, N., & Rytz, A. (2012). Temporal Dominance of Sensations: What is a good attribute list? *Food Quality and Preference, 26*(2), 159-165. doi:10.1016/j.foodqual.2012.04.004

Pineau, N., Schlich, P., Cordelle, S., Mathonniere, C., Issanchou, S., Imbert, A., . . . Kosterf, E. (2009). Temporal Dominance of Sensations: Construction of the TDS curves and comparison with time-intensity. *Food Quality and Preference, 20*(6), 450-455. doi:10.1016/j.foodqual.2009.04.005

Pionnier, E., Nicklaus, S., Chabanet, C., Mioche, L., Taylor, A. J., Le Quere, J. L., & Salles, C. (2004). Flavor perception of a model cheese: relationships with oral and physico-chemical parameters. *Food Quality and Preference, 15*(7-8), 843-852. doi:10.1016/j.foodqual.2004.04.011

Pliquett, R. U., Fuhrer, D., Falk, S., Zysset, S., von Cramon, D. Y., & Stumvoll, M. (2006). The effects of insulin on the central nervous system--focus on appetite regulation. *Horm Metab Res, 38*(7), 442-446. doi:10.1055/s-2006-947840

Pochedly, J. T., Widen, S. C., & Russell, J. A. (2012). What emotion does the "facial expression of disgust" express? *Emotion, 12*(6), 1315-1319. doi:10.1037/a0027998

Prescott, J., & Bell, G. (1995). Cross-Cultural Determinants of Food Acceptability - Recent Research on Sensory Perceptions and Preferences. *Trends in Food Science & Technology, 6*(6), 201-205. doi:Doi 10.1016/S0924-2244(00)89055-X

Prescott, J., & Swain-Campbell, N. (2000). Responses to repeated oral irritation by capsaicin, cinnamaldehyde and ethanol in PROP tasters and non-tasters. *Chemical Senses, 25*(3), 239-246. doi:10.1093/chemse/25.3.239

Pressman, S. D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin, 131*(6), 925-971. doi:10.1037/0033-2909.131.6.925

Prutkin, J., Duffy, V. B., Etter, L., Fast, K., Gardner, E., Lucchina, L. A., . . . Bartoshuk, L. M. (2000). Genetic variation and inferences about perceived taste intensity in mice and men. *Physiology & Behavior, 69*(1-2), 161-173. doi:10.1016/s0031-9384(00)00199-2
R., M. H. (1977). Magnitude estimaiton: Notes on what, how, when and why to use it. *Journal of Food Quality, 3*, 195-227.
Reed, D. R., Tanaka, T., & McDaniel, A. H. (2006). Diverse tastes: Genetics of sweet and bitter perception. *Physiology & Behavior, 88*(3), 215-226. doi:10.1016/j.physbeh.2006.05.033
Rinn, W. E. (1984). The neuropsychology of facial expression: a review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin, 95*(1), 52-77. doi:10.1037/0033-2909.95.1.52
Risvik, E. (1994). Sensory properties and preferences. *Meat Sci, 36*(1-2), 67-77. doi:10.1016/0309-1740(94)90034-5
Robinson, M. D., & Clore, G. L. (2002). Episodic and semantic knowledge in emotional self-report: evidence for two judgment processes. *Journal of Personality and Social Psychology, 83*(1), 198-215. doi:10.1037//0022-3514.83.1.198
Root, A. A., & Stephens, J. A. (2003). Organization of the central control of muscles of facial expression in man. *J Physiol, 549*(Pt 1), 289-298. doi:10.1113/jphysiol.2002.035691
Rousset, S., Deiss, V., Juillard, E., Schlich, P., & Droit-Volet, S. (2005). Emotions generated by meat and other food products in women. *Br J Nutr, 94*(4), 609-619. doi:10.1079/bjn20051538
Rozin, P., & Fallon, A. (1980). The Psychological Categorization of Foods and Non-Foods - a Preliminary Taxonomy of Food Rejections. *Appetite, 1*(3), 193-201.
Rozin, P., Lowery, L., & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of Personality and Social Psychology, 66*(5), 870-881. doi:10.1037//0022-3514.66.5.870
Rozin, P., & Vollmecke, T. A. (1986). FOOD LIKES AND DISLIKES. *Annual Review of Nutrition, 6*, 433-456. doi:10.1146/annurev.nu.06.070186.002245
Rymarczyk, K., Biele, C., Grabowska, A., & Majczynski, H. (2011). EMG activity in response to static and dynamic facial expressions. *International Journal of Psychophysiology, 79*(2), 330-333. doi:10.1016/j.ijpsycho.2010.11.001
Sanna, L. J., Turley, K. J., & Mark, M. M. (1996). Expected evaluation, goals, and performance: Mood as input. *Personality and Social Psychology Bulletin, 22*(4), 323-335. doi:Doi 10.1177/0146167296224001
Sato, W., Fujimura, T., & Suzuki, N. (2008a). Enhanced facial EMG activity in response to dynamic facial expressions. *International Journal of Psychophysiology, 70*(1), 70-74. doi:10.1016/j.ijpsycho.2008.06.001
Sato, W., Fujimura, T., & Suzuki, N. (2008b). Enhanced facial EMG activity in response to dynamic facial expressions. *International Journal of Psychophysiology, 70*(1), 70-74. doi:10.1016/j.ijpsycho.2008.06.001
Scherer, K. R., & Ellgring, H. (2007). Multimodal expression of emotion: affect programs or componential appraisal patterns? *Emotion, 7*(1), 158-171. doi:10.1037/1528-3542.7.1.158
Scherer, K. R., & Wallbott, H. G. (1994). Evidence for universality and cultural variation of differential emotion response patterning. *Journal of Personality and Social Psychology, 66*(2), 310-328. doi:10.1037/0022-3514.66.2.310
Schwartz, G. E., Fair, P. L., Salt, P., Mandel, M. R., & Klerman, G. L. (1976). Facial muscle patterning to affective imagery in depressed and nondepressed subjects. *Science, 192*(4238), 489-491. doi:10.1126/science.1257786
Schwarz, N. (1998). Warmer and more social: Recent developments in cognitive social psychology. *Annual Review of Sociology, 24*, 239-264. doi:DOI 10.1146/annurev.soc.24.1.239

Sinesio, F., Moneta, E., & Esti, M. (2005). The dynamic sensory evaluation of bitterness and pungency in virgin olive oil. *Food Quality and Preference, 16*(6), 557-564. doi:10.1016/j.foodqual.2004.12.002
Sokolowsky, M., & Fischer, U. (2012). Evaluation of bitterness in white wine applying descriptive analysis, time-intensity analysis, and temporal dominance of sensations analysis. *Anal Chim Acta, 732*, 46-52. doi:10.1016/j.aca.2011.12.024
Spielberger, C. D., Johnson, E. H., Russell, S. F., Crane, R. J., Jacobs, G. A., & Worden, T. J. (1985). The experience and expression of anger: Construction and validation of an anger expression scale. In M. A. Chesney & R. H. Rosenman (Eds.), *Anger and hostility in cardiovascular and behavioral disorders* (pp. 5-30). New York: Hemisphere/McGraw-Hill.
Stepper, S., & Strack, F. (1993). Proprioceptive Determinants of Emotional and Nonemotional Feelings. *Journal of Personality and Social Psychology, 64*(2), 211-220. doi:Doi 10.1037//0022-3514.64.2.211
Stevens, S. S. (1956). The direct estimation of sensory magnitudes-loudness. *Am J Psychol, 69*(1), 1-25. doi:10.2307/1418112
Stevens, S. S. (1957). On the psychophysical law. *Psychol Rev, 64*(3), 153-181. doi:10.1037/h0046162
Stevenson, R. J., Prescott, J., & Boakes, R. A. (1999). Confusing tastes and smells: How odours can influence the perception of sweet and sour tastes. *Chemical Senses, 24*(6), 627-635. doi:DOI 10.1093/chemse/24.6.627
Susskind, J. M., Lee, D. H., Cusi, A., Feiman, R., Grabski, W., & Anderson, A. K. (2008). Expressing fear enhances sensory acquisition. *Nat Neurosci, 11*(7), 843-850. doi:10.1038/nn.2138
Szczesniak, A. S. (1972). Consumer awareness of and attitudes to food texture. II. Children and teenagers. *Journal of Texture Studies, 3*(2), 206-217. doi:10.1111/j.1745-4603.1972.tb00624.x
Szczesniak, A. S., & Kahn, E. L. (1971). Consumer Awareness of and Attitudes to Food Texture. *Journal of Texture Studies, 2*(3), 280-295. doi:10.1111/j.1745-4603.1971.tb01005.x
Tassinary, L. G., Cacioppo, J. T., & Geen, T. R. (1989a). A psychometric study of surface study of surface electrode placemnets for facial electromyographic recording.1. The brow and cheek muscle regions. *Psychophysiology, 26*(1), 1-16. doi:10.1111/j.1469-8986.1989.tb03125.x
Tassinary, L. G., Cacioppo, J. T., & Geen, T. R. (1989b). A psychometric study of surface electrode placements for facial electromyographic recording: I. The brow and cheek muscle regions. *Psychophysiology, 26*(1), 1-16. doi:10.1111/j.1469-8986.1989.tb03125.x
Tepper, B. J., Christensen, C. M., & Cao, J. (2001). Development of brief methods to classify individuals by PROP taster status. *Physiology & Behavior, 73*(4), 571-577. doi:10.1016/s0031-9384(01)00500-5
Tepper, B. J., & Nurse, R. J. (1997). Fat perception is related to PROP taster status. *Physiology & Behavior, 61*(6), 949-954. doi:10.1016/s0031-9384(96)00608-7
Tepper, B. J., White, E. A., Koelliker, Y., Lanzara, C., d'Adamo, P., & Gasparini, P. (2009). Genetic Variation in Taste Sensitivity to 6-n-Propylthiouracil and Its Relationship to Taste Perception and Food Selection. In T. E. Finger (Ed.), *International Symposium on Olfaction and Taste* (Vol. 1170, pp. 126-139).
Thomas, S. P., Groer, M., Davis, M., Droppleman, P., Mozingo, J., & Pierce, M. (2000). Anger and cancer: an analysis of the linkages. *Cancer Nurs, 23*(5), 344-349. doi:10.1097/00002820-200010000-00003
Tracy, J. L., & Robins, R. W. (2004). Show your pride - Evidence for a discrete emotion expression. *Psychological Science, 15*(3), 194-197. doi:DOI 10.1111/j.0956-7976.2004.01503008.x
Twisk, J. W. R. (2006). Applied multilevel analysis: A practical guide. *Cambridge: Cambridge University Press*.

Valentova, H., & Panovska, Z. (2003). Sensory Evaluation: Taste. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 5180-5187). USA: Academic Press.

Vanman, E. J., Paul, B. Y., Ito, T. A., & Miller, N. (1997). The modern face of prejudice and structural features that moderate the effect of cooperation on affect. *Journal of Personality and Social Psychology, 73*(5), 941-959. doi:Doi 10.1037/0022-3514.73.5.941

Veldhuizen, M. G., Wuister, M. J. P., & Kroeze, J. H. A. (2006). Temporal aspects of hedonic and intensity responses. *Food Quality and Preference, 17*(6), 489-496. doi:10.1016/j.foodqual.2005.07.004

Vrana, S. R. (1993a). THE PSYCHOPHYSIOLOGY OF DISGUST - DIFFERENTIATING NEGATIVE EMOTIONAL CONTEXTS WITH FACIAL EMG. *Psychophysiology, 30*(3), 279-286. doi:10.1111/j.1469-8986.1993.tb03354.x

Vrana, S. R. (1993b). The psychophysiology of disgust: differentiating negative emotional contexts with facial EMG. *Psychophysiology, 30*(3), 279-286. doi:10.1111/j.1469-8986.1993.tb03354.x

Wallis, D. J., & Hetherington, M. M. (2004). Stress and eating: the effects of ego-threat and cognitive demand on food intake in restrained and emotional eaters. *Appetite, 43*(1), 39-46. doi:10.1016/j.appet.2004.02.001

Wallis, D. J., & Hetherington, M. M. (2009). Emotions and eating. Self-reported and experimentally induced changes in food intake under stress. *Appetite, 52*(2), 355-362. doi:10.1016/j.appet.2008.11.007

Walsh, A. M., Duncan, S. E., Bell, M. A., O'Keefe, S. F., & Gallagher, D. L. (2017). Breakfast meals and emotions: Implicit and explicit assessment of the visual experience. *Journal of Sensory Studies, 32*(3). doi:ARTN e1226510.1111/joss.12265

Waters, A. J., Sayette, M. A., Franken, I. H., & Schwartz, J. E. (2005). Generalizability of carry-over effects in the emotional Stroop task. *Behav Res Ther, 43*(6), 715-732. doi:10.1016/j.brat.2004.06.003

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070. doi:10.1037/0022-3514.54.6.1063

Wolf, K., Mass, R., Ingenbleek, T., Kiefer, F., Naber, D., & Wiedemann, K. (2005). The facial pattern of disgust, appetence, excited joy and relaxed joy: an improved facial EMG study. *Scand J Psychol, 46*(5), 403-409. doi:10.1111/j.1467-9450.2005.00471.x

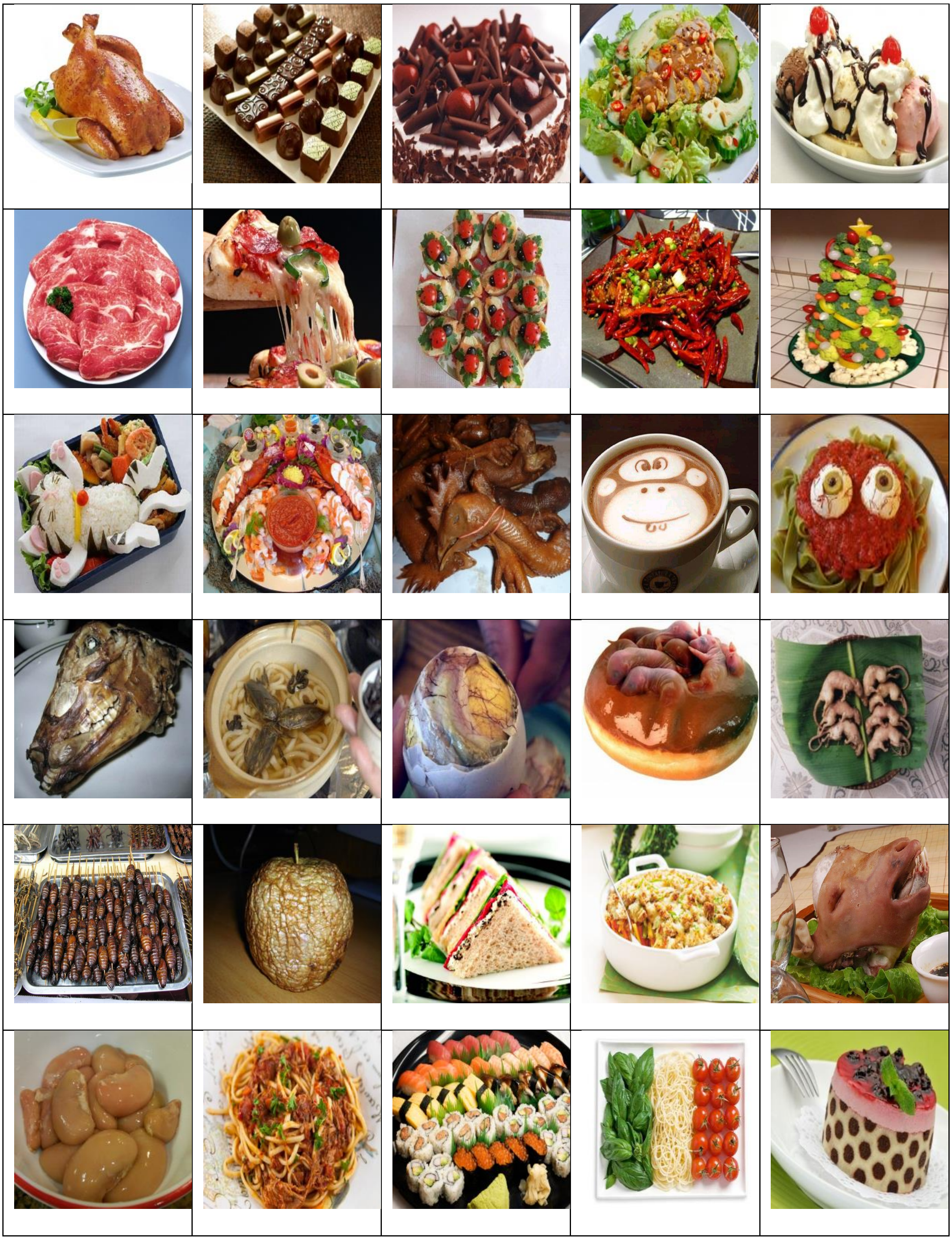
York, R., & Vaisey-Genser, M. (2003). Sensory Evaluation: Sensory characteristics of human foods. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2 ed., pp. 5125-5127). USA: Academic Press.

Zellner, D. A., Loaiza, S., Gonzalez, Z., Pita, J., Morales, J., Pecora, D., & Wolf, A. (2006). Food selection changes under stress. *Physiology & Behavior, 87*(4), 789-793. doi:10.1016/j.physbeh.2006.01.014

Zevon, M. A., & Tellegen, A. (1982). The Structure of Mood Change - an Idiographic Nomothetic Analysis. *Journal of Personality and Social Psychology, 43*(1), 111-122. doi:Doi 10.1037//0022-3514.43.1.111

Zhao, L. Q., Kirkmeyer, S. V., & Tepper, B. J. (2003). A paper screening test to assess genetic taste sensitivity to 6-n-propylthiouracil. *Physiology & Behavior, 78*(4-5), 625-633. doi:10.1016/s0031-9384(03)00057-x

Documentation -Identified food images of which copy rights belongs to thirds parties (See Chapter 3.2 and Appendix I)



Possible links to the electronic sources of the food images in this study

http://www.lthforum.com/bb/viewtopic.php?p=23270

http://imagevat.com/g.php?t=Creepy_Crawly_Japanese_Delicacies

http://chefsblade.monster.com/benefits/articles/606-sweet-success-how-to-sell-desserts

https://icecreamjournal.turkeyhill.com/index.php/2009/05/13/recipe-sauteed-banana-split/

http://www.momrising.org/researchers-develop-low-fat-chocolate/

http://www.hdwallpaperspics.com/chocolate-cake-pictures.html

http://nutritionally-fit.com/healthy-families/5-steps-to-making-a-delicious-healthy-sandwich/

http://all4food.weebly.com/cute-food.html

http://openwalls.com/image?id=8014

https://sproutinghealth.wordpress.com/2011/07/14/italia-come-butta/

http://wolijazz.com/popular-foods-in-italy-free-3d-moving-wallpapers-for-windows-7/

http://tuttoitalianos.blogspot.co.nz/2012/12/italians-have-their-own-meal-structure.html#!/2012/12/italians-have-their-own-meal-structure.html

http://thedesigninspiration.com/articles/50-fancy-and-pretty-arts-of-coffee-foam/

http://www.arabia.msn.com/lifestyle/cooking/365256/grilled-seafood-platter/

http://gunpla-inochi.com/2009/12/17/spicy-chinese-food/

https://angelamooreblog.wordpress.com/2013/03/11/your-church-is-like-chicken/

http://fenryss.blogspot.co.nz/2013/02/disgusting-food.html

http://www.cosmoscaffe.com/menu/seafood_platters.html