Measuring emotional response towards aroma attributes in beer; a comparison of self-report, physiological and facial expression measures

By Camilla Beyts

Thesis submitted to The University of Nottingham
for the degree of Master of Philosophy

Sensory Science

Division of Food Science

School of Biosciences

The University of Nottingham

Acknowledgements

First and foremost I would like to thank my supervisor, Professor Joanne Hort, whose patience, expertise and belief helped me countless times along this journey. Your trusted support has guided me through the challenging decisions that I have had to make and you have always been there to offer valuable advice when it was most needed.

Thank you as well, Dr Carolina Chaya, for all the time you dedicated to both me and my project statistics. You equipped me with the necessary skills to analyse my own data as well as think about my project in new and interesting ways. Your visits to Sutton Bonington have been most enjoyable and gave a new lease of life to the BABS building!

I would also like to thank Dr Amparo Tarrega, Dr Qian Yang, Dr Rebecca Ford and Dr Louise Hewson for their continued support, advice and encouragement throughout this project. I am particularly grateful to both Amparo and Qian for always being on hand to offer a solution when things didn't go to plan.

This research would not have been possible without the generous support of SABMiller. I extend a warm thank you to both Dr Sue James and Dr Frieda Dehrmann who gave me valuable guidance on the industrial perspective of my research.

To all my friends at Sutton Bonington campus, thank you for always being there to calm my worries and making my time here so enjoyable. Finally to my boyfriend, Alex Cook, thank you for always being there and never doubting me.

Abstract

Emotion research within Sensory Science is at a cross roads. Some investigations have solely focused on explicit measures of emotional response, asking consumers to self-report their emotions. Others have focused on implicit measures such as changes in physiological and facial expression to capture the consumer's unconscious responses. However the discrimination ability of implicit and explicit measures has seldom been compared. The aim of this project was to compare physiological/facial expression, self-reported emotional response and traditional hedonic liking scores to determine which measure was more discriminating towards a range of beer aromas.

Two preliminary investigations assisted in the development of an experimental protocol and helped to define the number of replicates required for the main study. Implicit measures included changes in heart rate, skin temperature and electromyography recordings from two facial muscles; the corrugator supercilli and zygomatic major. Preliminary investigations also highlighted the need to include a range of pleasant and unpleasant aromas and promoted the use of an emotional lexicon specific to beer which would allow greater discrimination between aromas than more simple measures of valence and activation. Learnings from the preliminary stages were subsequently applied to the larger main investigation.

The main investigation compared changes in physiological/facial expression, self-reported emotional response and hedonic liking towards a series of

pleasant, neutral and unpleasant aromas within beer. The results revealed that corrugator and zygomatic activity could discriminate between unpleasant and pleasant or unpleasant and neutral samples respectively. However physiological measures were non-discriminating. Liking scores were found to be more discriminating than facial expression measures, allowing the distinction between pleasant and neutral samples. However self-reported emotional response was found to be the more discriminating than both liking and facial expression measures, allowing discrimination between pleasant and neutral samples as well as between the pleasant samples themselves.

This project found that self-reported emotional response provided the greatest discrimination between beer aromas and was found to be most discriminating compared with liking and physiological/facial expression measures of emotion. Consequently self-reported emotional response is recommended for studies which require a high degree of product discrimination. The ability for self-reported emotional response to distinguish between pleasant aromas is of particular interest to industry where commercial products may be poorly discriminated on the basis of liking alone.

Publications, presentations and awards

Oral presentations

C Beyts, F Dehrmann, S James, S Katherine, C Chaya, and J Hort. 2015. "Physiological response to selected aroma attributes in a lager beer." IFST Nursten Flavour Symposium 2015, Newcastle, UK

Poster presentations

C Beyts and J Hort. 2015. "Facial expression and autonomic nervous system responses to odours." IFST Sensory Science Group 2015: A Slice of Sensory, Nottingham, UK

C Beyts, F Dehrmann, S James, S Katherine, C Chaya, and J Hort. 2015. "Physiological response to selected aroma attributes in a lager beer." 11th Pangborn Sensory Science International Symposium 2015, Gothenburg, Sweden

Publications

C Beyts, C Chaya, F Dehrmann, S James, S Katherine and J Hort. 2016. "Self-reported emotional response towards beer aroma is more discriminating than implicit measures of emotion." *Not complete*

Awards

2014: Giract Research Bursary (Giract, Geneva, Switzerland)

2015: Kesteven WVS Travelling Scholarship (The University of Nottingham, UK)

2015: Pangborn Young Scientist Award (Pangborn, Elsevier)

Preface

Sensory Science can be broadly defined as a discipline which evokes, measures, analyses and interprets reactions perceived by the sight, smell, taste, touch and hearing senses (Stone et al., 2004). It is a scientific discipline which has derived from a variety of different fields including psychology, physiology, statistics and marketing (Stone et al., 2004). Traditionally this field has been primarily interested in understanding the link between sensory attributes and consumer liking. However liking scores are a relatively poor predictor of product success, demonstrated by the fact that 72-88% of all new food and beverage products fail within their first year in the market place (Rudolph, 1995; Stewart-Knox and Mitchell, 2003). Consequently, researchers have begun to investigate consumer emotions in order to provide discrimination between products which go beyond consumer likes and dislikes (Chaya et al., 2015a; Eaton, 2015; King et al., 2013; Ng et al., 2013; Porcherot et al., 2010). Continuing with this theme, this thesis focuses on consumer emotional response towards aroma attributes in beer.

Emotion research has gained momentum within the last 10 years and investigators have utilised a number of different methods in order to measure emotional response to sensory attributes. Most common are explicit methods, which require subjects to self-report their own conscious emotional response on a pre-defined emotion lexicon (For example: Chrea et al., 2009; King and Meiselman, 2010; Porcherot et al., 2010). Indeed it has been demonstrated that the emotions generated towards food and beverage

products are positively biased, highlighting a hedonic asymmetry (Schifferstein and Desmet, 2010). Others have used implicit methods to measure the unconscious responses of subjects. Using this approach, researchers have measured changes in the autonomic nervous system (such as heart rate and skin temperature) (Alaoui-Ismaïli et al., 1997a, 1997b; Bensafi et al., 2002a; Rousmans and Robin, 2000; Vernet-Maury and Alaoui-Ismaïli, 1999) and/or changes in facial expression (Danner et al., 2014a; de Wijk et al., 2014; He et al., 2014; Wendin et al., 2011; Zeinstra et al., 2009) to record these unconscious responses. Both measures have been shown to provide discrimination between samples but the joint application of physiological, facial expression, self-reported emotional response and hedonic liking has never been compared. The purpose of the research presented within this thesis was to compare changes in physiological/facial expression activity with self-reported emotional response and liking in order to determine which measure was more discriminating towards a selection of aromas within beer.

Structure of this thesis

This thesis compares the discrimination ability of physiological/facial expression measures with self-reported emotional response and liking scores towards a selection of aroma attributes in beer and is organised into four chapters. Chapter 1 comprises of a literature review on emotional response measures in Sensory Science. A definition of what is an emotion is given as

well as an explanation of the different theoretical approaches that have been used to conceptualise an emotion. This is followed by an overview of self-report, physiological and facial expression measurements used to measure emotional response and their applications within Sensory Science. Chapter two is comprised of two preliminary investigations: the pilot and validation studies, which were used to develop the methodological approaches which would subsequently be applied within the main investigation. The pilot study investigates the comparison of implicit measures with relatively simple self-report measures to an initial selection of beer aromas. The validation study further examines implicit responses towards a revised selection of aromas and an emotional lexicon developed specifically for beer. Chapter three concerns the approach, results and conclusions of the main investigation where physiological/facial expression, self-reported emotional response and liking responses to a selection of pleasant and unpleasant beer aromas are compared. Chapter four gives an overview of the overall findings found within this study and provides suggestions for future work, as well as the overall conclusions which can be taken from this study.

List of Abbreviations

%	Percent
˚C	Degrees Celsius
µg	Microgram
µS	Microsemens
Ag/AgCl electrodes	Silver chloride electrodes
ANOVA	Analysis of variance
ANS	Autonomic nervous system
AV bundle	Atrioventricular bundle
AV node	Atrioventricular node
bpm	Beats per minute
CD-CATA	Consumer defined check-all-that-apply
cm	Centre meter
CNS	Central nervous system
d.f.	Degrees of freedom
ECG	Electrocardiogram
EDA	Electrodermal activity
EEG	Electroencephalography
ERS	Event related responses
F	F statistic
FAC units	Facial action coding units
fEMG	Facial electromyography
FACS	Facial Action Coding System
fMRI	Functional magnetic resonance imaging
g	Grams
g/ml	Grams per millilitre
GEOS	Geneva Emotion Odour Scale
HSD	Honest significant difference
Hz	Hertz
I	Current
m	Mass
MAACL	Multiple Affective Check List
MEG	Magnetoencephalography
mg	Milligram
MGD	Miller Genuine Draft
ml	Millilitre
ms	Milliseconds
mV	Millivolts

NA	Negative affect
ng	Nanogram
NRS	Non-specific responses
P	P wave in ECG
p	Density
p	p value/calculated probability
PA	Positive affect
PANAS	Positive and Negative affect schedule
PC	Principal component
PC1	Principal component 1
PC2	Principal component 2
PCA	Principal component analysis
PNS	Parasympathetic nervous system
POMS	Profile of Mood States
P-R interval	Distance between P and R waves in an ECG
PrNS	Peripheral nervous system
ProEmo	Product Emotion Measurement Instrument
Q	Q wave in ECG
QRS interval	Distance between Q and S waves in an ECG
QT interval	Distance between Q and T waves in an ECG
R	R wave in ECG
R	Resistance
r	Pearson correlation coefficient
Rep1	Replicate 1
Rep2	Replicate 2
RMS	Root mean square
R-R interval	Distance between two consecutive R waves in an ECG
RSA	Respiratory sinus arrhymia
S	S wave in ECG
S.D.	Standard deviation
S.E.M.	Standard error of the mean
SA node	Sinoatrial node
SAM	Self Assessment Manikin
SCL	Skin conductance level
SCR	Skin conductance response
sec	Seconds
SNS	Sympathetic nervous system
T	T wave in ECG

V	Volts
V	Voltage
v	Volume
X^2	Chi-squared statistic

Contents List

Acknowledgements……i

Abstract……ii

Publications, presentations and awards……iv

Preface……v

List of abbreviations……vii

Chapter 1: General introduction and literature review……1

1.1. What is an emotion?……1

1.2. How to conceptualise an emotion?……2

1.2.1. "Basic" theories of emotion……2

1.2.2. "Dimensional" theories of emotion……3

1.3. Why study emotions within Sensory Science?……6

1.4. How to measure an emotion?……8

1.5. Self-reported measures of emotion……9

1.5.1. Using self-report verbal questionnaires in Sensory Science……11

1.6. Measuring changes in central nervous system activity……13

1.7. Measuring changes in autonomic nervous system activity……15

1.7.1. Overview of the autonomic nervous system activity……15

1.7.2. Changes in heart rate……18

1.7.2.1. Physiology of the heart……18

1.7.2.2. Recording heart rate……20

1.7.2.3. Changes in heart rate in response to emotional stimuli……21

1.7.3. Electrodermal activity……22

1.7.3.1. Changes in EDA to emotional stimuli……24

1.7.4. Skin temperature……24

1.7.5. Respiration……25

1.7.6. The application of physiological measures within Sensory Science……26

1.8. Measuring changes in behaviour……28

1.8.1. Facial action coding units and face reading technology……28
1.8.2. Facial electromyography……30
1.8.3. The application of facial expression measures in Sensory Science……31
1.9. Conclusions on emotional response measures……32
1.10. Approach of this investigation……33
1.11. Research objectives……34
2. Chapter two: Development of experimental protocol and selection of aroma attributes……37
Chapter two, part one: Pilot study……37
2.1. Introduction……37
2.2. Aims and objectives……41
2.3. Methods……42
2.3.1. Subjects……42
2.3.2. Samples……43
2.3.3. Physiological and facial expression measurements……46
2.3.3.1. Respiration activity……47
2.3.3.2. Heart rate……48
2.3.3.3. Skin temperature……48
2.3.3.4. Facial electromyography……49
2.3.4. Self-report measures……50
2.3.5. Experimental approach……51
2.3.6. Data processing of physiological and facial expression variables……54
2.3.6.1. Respiratory parameters……55
2.3.6.2. Heart rate……55
2.3.6.3. Skin temperature……56
2.3.6.4. Changes in facial muscle activity……56
2.4. Statistical analysis……56
2.5. Results……58
2.5.1. Physiological and facial expression variables……61

2.5.2. Self-report variables……61
2.5.3. Effects of session……65
2.5.4. Correlation analysis……65
2.5.5. Principal component analysis……68
2.6. Discussion of pilot investigation findings……70
2.6.1. Aroma evoked emotional response……70
2.6.2. Comparison between implicit and explicit measures of emotion……72
2.6.3. Correlations between physiological, behavioural and self-report measures……75
2.6.4. Correlations between self-report measures……76
2.6.5. Experimental protocol……79
2.7. Pilot study conclusions……80

Chapter two, part two: Validation study……82

2.8. Introduction……82
2.8.1. Selecting an emotional lexicon……82
2.9. Aims and objectives……87
2.10. Methods……88
2.10.1. Subjects……88
2.10.2. Samples……88
2.10.3. Physiological and facial expression measures……89
2.10.4. Self-report measures……90
2.10.5. Experimental approach……91
2.10.6. Data processing of physiological and facial expression variables……92
2.10.7. Statistical analysis……92
2.11. Results……92
2.11.1. Liking scores……93
2.11.2. Self-reported emotional response……93
2.11.3. Physiological and facial expression measures……95

2.11.4. Comparison of liking, emotional and physiological and facial expression measures……..96
2.11.5. Variability between replicate and day measurements……..99
2.12. Validation study discussion……101
2.13. Validation study conclusions……104

Chapter two, part three: Further methodological considerations……..105

2.14. Heart rate……105
2.15. Facial expression measures……..106
2.16. Pilot and validation study conclusions……109

3. Chapter three: Comparison of the discrimination ability of self-reported emotional response, liking and physiological/facial expression measures towards aroma attributes in beer……111
3.1. Introduction……111
3.2. Aims and objectives……114
3.3. Methods……116
3.3.1. Subjects……116
3.3.2. Samples……116
3.3.3. Physiological and facial expression variables……117
3.3.3.1. Heart rate……117
3.3.3.2. Skin temperature……117
3.3.3.3. Changes in facial muscle activity……118
3.3.4. Self-reported emotional response, liking and familiarity……118
3.3.5. Experimental approach……118
3.4. Data processing of physiological and facial expression variables……123
3.4.1. Exploratory analysis……124
3.4.1.1. Respiratory parameters……125
3.4.1.2. Heart rate……126

3.4.1.3. Corrugator and zygomatic activity……126
3.4.1.4. Exploratory statistical analysis……127
3.4.1.5. Exploratory analysis results……127
3.4.1.6. Exploratory analysis conclusions……131
3.4.2. Full analysis……132
3.4.2.1. Data processing of physiological and facial expression measures……132
3.4.3. Statistical analysis……134
3.5. Results……135
3.5.1. Physiological responses……136
3.5.2. Facial expression responses……138
3.5.3. Self-reported emotional response……141
3.5.4. Liking and familiarity scores……144
3.5.5. Correlation analysis……145
3.5.6. Principal component analysis……148
3.5.7. Comparison between implicit and explicit measures……150
3.5.8. Effects of gender……153
3.6. Discussion……154
3.6.1. Physiological and facial expression responses……155
3.6.2. Self-reported emotional response……159
3.6.3. Comparison between implicit and explicit measures……162
3.6.4. Effects of gender on emotional response……166
3.7. Conclusions……167

4. General discussion, conclusions and future work……169
4.1. Main findings……169
4.2. Suggestions for future work……175
4.2.1. Physiological and facial expression recordings……175
4.2.1.1. Skin temperature……176
4.2.1.2. Skin conductance response……177
4.2.1.3. Facial electromyography ……178
4.2.2. Self-reported emotional response……179

4.2.2.1. Emotional beyond aroma stimuli……..179
4.2.2.2. Emotions in context……180
4.2.2.3. Application of emotions within industry…….182
4.3. Conclusions……183
References……185

1.0 Chapter 1: Introduction and literature review

1.1. What is an emotion?

Defining what an emotion is has been one of the most vexing topics within emotion research. Repeated attempts have been made by psychologists, neuroscientists and philosophers as to how it is we can define an emotion yet no clear consensus exists, leading some researchers to argue that we should remove the term "emotion" from our vocabulary (LeDoux, 2012). Despite disagreements within the field, a general framework for emotion can be provided by a componential model of emotion (Scherer, 2005; Smith and Ellsworth, 1985). Within the approach outlined by Scherer (2005) stimulus provoking events are first judged as being relevant to an individual and evaluated on their significance before initiating an emotional response. Once initiated, an emotional response manifests itself in system wide changes in the central nervous system, physiology, behaviour and subjective emotional experience that allow an organism to respond appropriately to the stimulus (Figure 1.1). Consequently, emotions are considered rapid, high intensity events of short duration and these features allow them to be defined from preferences, mood states, attitudes or affective dispositions. Notably, preferences are of low intensity and refer to the inherent liking or disliking of a stimulus, forming part of the initial evaluation checks of an event. Mood states and attitudes are typically longer lasting, of a lower intensity and associated with predefined enduring beliefs in the case of attitudes. Affective dispositions are associated with the predisposition for certain individuals to

experience certain mood states more often than others, such as anxious or hostile tendencies.

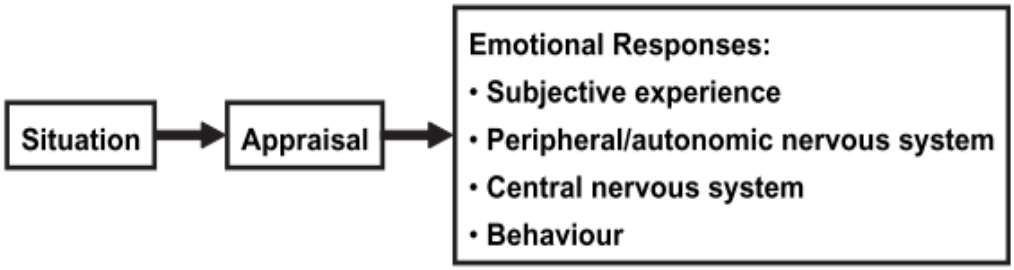


Figure 1.1. The framework outlining a componential model of emotion (Mauss and Robinson, 2009).

1.2. How to conceptualise an emotion

There are two broad ways in which an emotion can be conceptualised, these include treating emotions as discrete states (e.g. anger is a discrete and independent state from fear) or describing emotions based on how they are defined by two or more "core dimensions" that are shared by all emotional states.

1.2.1. "Basic" theories of emotion

Emotions have commonly been thought of as discrete states within psychology, with each emotion (e.g. fear, anger and sadness) having its own neurological, physiological and behavioural outputs (Izard, 2007). The main focus of discrete emotional states is the existence of so-called basic emotions which are present in humans from birth, being both innately expressed and recognised in all humans. Ekman (1971) identified six basic emotions (anger, disgust, fear, happiness, sadness and surprise) which humans can recognise from facial expressions within photographs and is consistent even across

different cultures (Ekman, 1992; Ekman and Frisen, 1986) and has been the most influential researcher to utilise a basic perspective. However different researchers have argued the existence of greater or fewer emotions which can range from four up to 22 that can still be considered basic (Ortony and Turner, 1990). Despite which emotions can fall into the basic category, each of these models hold the assumption that basic emotions trigger internal states that can be measured by characteristic changes in behaviour and physiology (Stemmler, 2004). Consequently emotions such as fear and sadness are said to have been distinguished on the basis of physiological patterns or facial movements (Ekman et al., 1983; Kreibig, 2010a). However the notion of distinct physiological patterns and even the existence of basic emotions has been highly debated by researchers (Barrett, 2006; Cacioppo et al., 2000).

1.2.2. "Dimensional" theories of emotion

An alternative theory of emotion proposes that the principal components of human emotion can be captured along two principal bipolar dimensions known as valence and arousal (Russell, 1980) (Figure 1.2). Where valence is the degree of pleasantness/unpleasantness and arousal is described by states of alertness to sleep. In other models the arousal dimension has been relabelled as the activation dimension (Larsen and Diener, 1992) referring to a comparative state of low and high energy or the entire affective space has been reconsidered as different extremes of activation whilst still communicating valence (Thayer, 1989). In some models the relative effects of

both valence and activation dimensions are considered most important and have been combined at 45˚ angles and re-labelled as positive affect (PA) (a highly activating state with positive valence) and negative affect (NA)(a highly activating state with negative valence) (Watson and Tellegen, 1985). These differing PA and NA states have often been thought to drive approach and avoidance subsystems in both humans as well as other animals, (Russell and Barrett, 1999) with approach subsystems facilitating the attraction to a stimuli, whilst avoidance would facilitate the repulsion from a stimuli. However it is now being recognised that all three of these models are effectively explaining the same emotional space, known as core affect, with subjective feelings being described by their relative valence and activation (Feldman Barrett and Russell, 1999).

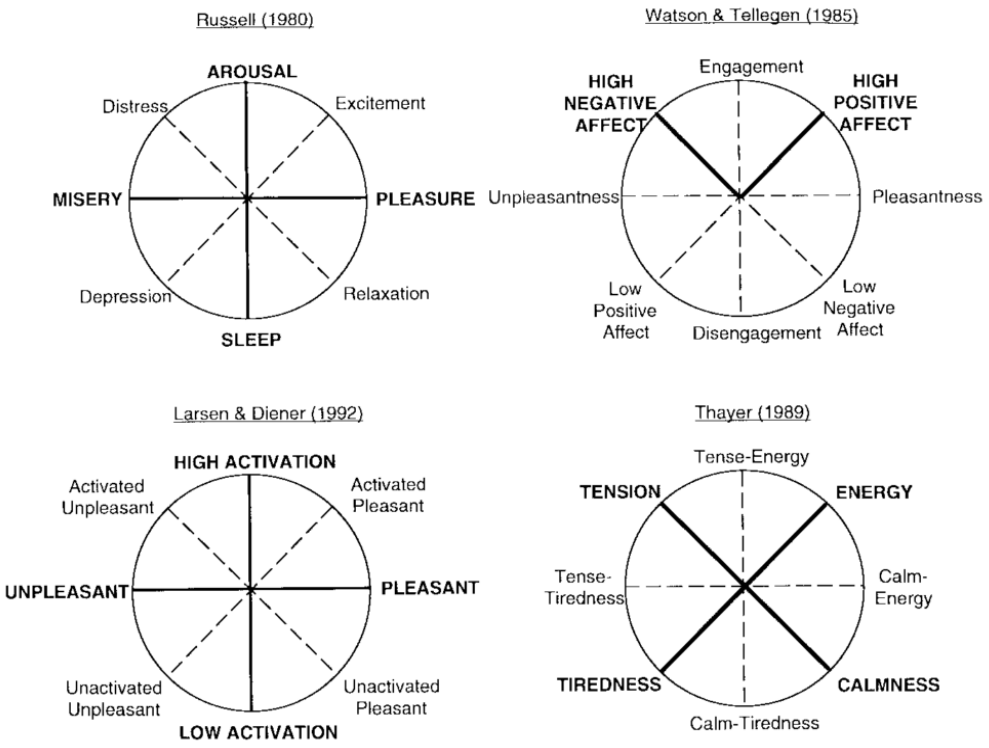


Figure 1.2. Examples of various dimensional models describing the structure of emotion (affect) (Feldman Barrett and Russell, 1999).

Whether to conceptualise emotions as discrete states or independent dimensions has been highly debated, (Ekman, 1992; Izard, 2007; Ortony and Turner, 1990; Panksepp, 2007) with researchers arguing that meta-analyses have failed to find coherent patterning of physiological or neurological activity between discrete emotions (Barrett, 2006; Cacioppo et al., 2000; Murphy et al., 2003; Phan et al., 2002). However researchers have proposed that both discrete and dimensional perspectives can be reconciled to some degree by placing discrete emotions within affective space and defining them based on their relative levels of valence and activation (for an example see Figure 1.3) (Christie and Friedman, 2004; Levenson, 1988). For example, excitement can be characterised by its high valence and arousal, whilst sadness could be better described by its low valence and moderate arousal (Barrett, 2006;

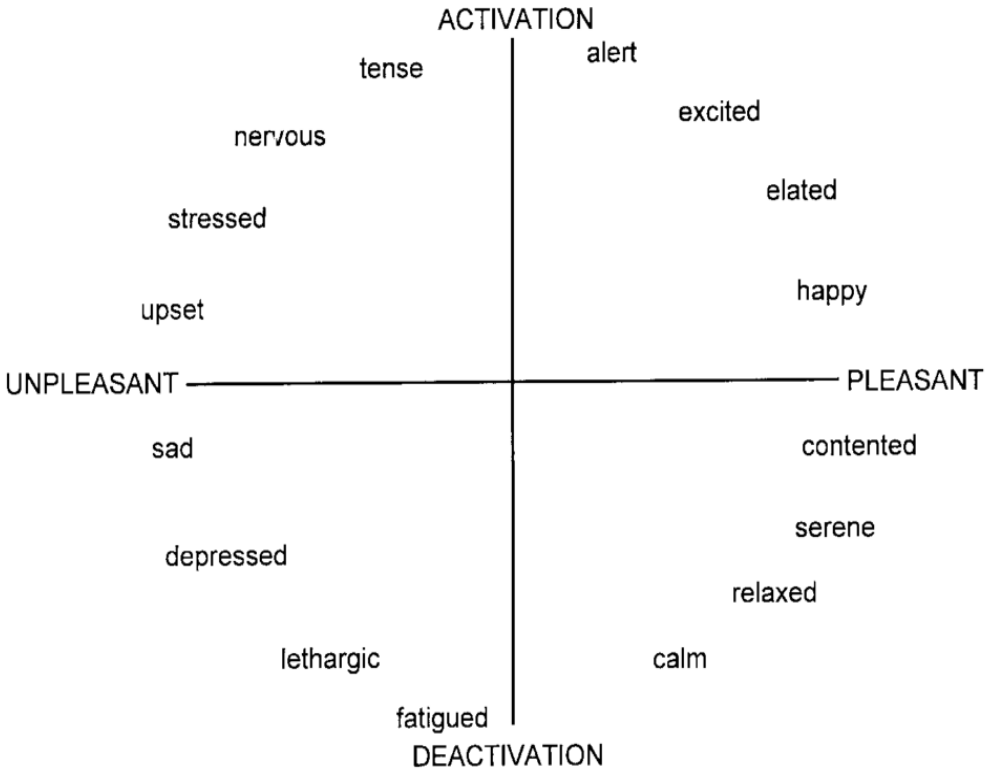


Figure 1.3. Two dimensional affective space with discrete emotions superimposed based on their relative valance and activation (Feldman Barrett and Russell, 1999).

1.3. Why study emotions within Sensory Science?

Research on food and beverage preferences within Sensory Science has traditionally focused on hedonic tests in order to determine consumer product liking. However research has recently shifted focus within the last 10 years to include the impact sensory attributes exert on consumer emotions (King and Meiselman, 2010; Meiselman, 2013). This is in part due to the realisation that although many products receive similar high liking scores, between 72-88% of all new food and beverage products fail within their first year in the market place (Rudolph, 1995; Stewart-Knox and Mitchell, 2003). Evidently consumers are not just basing their purchasing decisions on how much they like a product but are relying on a greater multitude of affective factors such as unconscious associations and emotions in order to make their judgements (Fernqvist and Ekelund, 2014; Letarte et al., 1997; Tuorila et al., 1994).

This is in recognition of the fact that emotions are synonymous with the eating and drinking experience. For example emotions themselves may result in changes to food intake or a particularly delicious food may elicit positive emotions in individuals (Evers et al., 2013; Macht, 2008). Furthermore other researchers have commented on the functional (e.g. viewing a product on how satisfying it is likely to be) and abstract (e.g. viewing a product as sophisticated or feminine) gains that products may additionally impart, influencing the overall product experience (Thomson et al., 2010).

Emotion research within Sensory Science can be classified into one of two different types. Firstly researches can focus on the impact an individual's affective state has on their eating behaviour. Secondly an emphasis can be placed on the impact consumption products have on an individual's subsequent emotional response (Köster and Mojet, 2015). The impact emotion has on eating choices has focused on people's eating preferences and behaviours. For example subjects have reported a greater tendency to consume junk food when experiencing negative emotions but will consume more healthy food when experiencing positive emotions (Lyman, 1982). Indeed this approach also has a clinical orientation, highlighting the association between negative emotions and weight gain leading to obesity (Striegel-Moore et al., 1999) and the association between stress and the suppression of food intake (Greeno and Wing, 1994). Consequently an individual's affective state and the emotions they experience day to day can have an impact on their food choices both in terms of quantity and quality (Desmet and Schifferstein, 2008).

This thesis focuses on the second application of emotions within Sensory Science, where the impact of the consumption of products on subsequent emotional response is investigated. Using this approach, some researchers have investigated how different tastes can evoke different basic emotions (Robin et al., 2003) or have asked consumers to rate the emotions they feel after they have consumed a product (Ng et al., 2013; Spinelli et al., 2014). One of the main goals of emotion research within Sensory Science is to find a method which can discriminate between products more effectively than liking

scores alone and additionally provide reasons as to why one product was more or less preferable than another (Meiselman, 2015). This is particularly important within research on commercial products where evaluations are made by regular consumers of a product, making the ability to find differences between products which are similar in desirability, quality and price all the more important. Consequently, emotion research in Sensory Science seeks to use emotions to provide greater discrimination between products which are similar in quality and price (Meiselman, 2015; Schifferstein et al., 2013).

1.4. How to measure an emotion

According to a componential model, emotions prepare the organism for reaction by eliciting changes in: a) subjective experience, b) behaviour, c) the central nervous system and d) the autonomic nervous system (Figure 1.1). Self-report is an explicit measure of emotion which allows individuals to comment on their own subjective experience (Lottridge et al., 2011) but makes consumers aware of their own feelings and so is subject to various types of cognitive biases commonly associated with self-report methods (Podsakoff et al., 2003). Implicit measures of emotion are considered to reflect the unconscious and unarticulated effects of an emotion which are less subject to influences from cognitive bias (Mojet et al., 2015) and include measures such as changes in the central and autonomic nervous system as well behavioural responses, such as those associated with changes in facial expression. Over the following sections, details of how these measurements

are recorded are discussed, what they can infer about emotional response and what insights each of these measures can bring to Sensory Science.

1.5. Self-reported measures of emotion

Self-report measures of emotion can consist of both verbal and non-verbal questionnaires. Verbal questionnaires were not developed for product testing but have traditionally been applied within a clinical context using questionnaires such as the Profile of Mood States (POMS) (McNair et al., 1971) and the Multiple Affect Adjective Checklist (MAACL) (Zukerman and Lubin, 1965). As these questionnaires were developed to assess traits associated with depression and anxiety, these early questionnaires have a disproportionate number of negative compared to positive emotions. For example the POMS (McNair et al., 1971) consists of 65 terms divided amongst six dimensions, only one of which is associated with positive emotions, whilst the MAACL has 132 terms with only two out of five dimensions measuring positive emotions (Lubin et al., 1986). Furthermore due to their clinical nature these questionnaires contained a large number of individual emotional terms which are lengthy for subjects to answer.

In contrast the emotions associated with food and beverage products are largely associated with positive emotions. Desmet and Schiffestein (2008) collected a list of 22 basic emotions from the literature and asked consumers to rate which of these emotions they felt towards food in the preceding 24 hours. The results highlighted a hedonic asymmetry with mainly pleasant

emotions being elicited and only a few negative emotions being relevant when assessing foods. Indeed this has explained why some clinical questionnaires such as the Positive and Negative Affect schedule (PANAS) (Watson et al., 1988) have been found suitable for assessing emotional response towards consumption products (Kuesten et al., 2014) owing to its equal balance of terms denoting positive and negative affect.

From a more fundamental and non-clinical perspective in psychology, subjects can be asked to score their feelings of valence and activation on independent, bipolar scales (Mehrabian and Russell, 1974) in response to an emotional stimulus such as pictures (Lang et al., 1993) or music (Droit-Volet et al., 2013). It is now largely acknowledged that variance in response to emotional stimuli can be largely captured by valence and arousal, owing largely to the easy manipulation of the pleasantness and arousal of a stimulus (Mauss and Robinson, 2009; Poels and Dewitte, 2006). Such an approach offers the advantage of assessing stimulus effects on a subject's affective state relative to these dimensions without having to present lengthy questionnaires which can be time consuming and cognitively demanding for consumers, (Russell et al., 1989) yet are at a disadvantage as less information can be gained about a stimulus (Chrea et al., 2009).

Alternatively non-verbal questionnaires can also be used to assess emotional response. Both the Self-Assessment Manikin (SAM) and the Product Emotion Measurement Instrument (PrEmo) are examples of non-verbal questionnaires that ask subjects to rate their emotions using a set of pictures. Like when core

affect is measured using line scales, the SAM can be used to assess feelings of valence and arousal but each dimension is depicted by five pictorial images instead of a line scale (Bradley and Lang, 1994). In contrast the PrEmo questionnaire consists of 12 characters, six of which depict positive emotions and the remaining six show negative emotions (Desmet et al., 2000). Although both questionnaires were developed for assessing non-consumption products such as cars, telephones and advertising stimuli, (Desmet et al., 2000, 2007; Morris and Geason, 2002) more recent investigations have incorporated non-verbal measures into their assessments of food and aroma stimuli (Gutjar et al., 2014; He et al., 2016; Liao et al., 2015). Although researchers highlight that using non-verbal questionnaires are not as demanding as verbal questionnaires they still require consumers to use cognitive processes and consequently should not be considered an unconscious measure of emotion (Poels and Dewitte, 2006).

1.5.1. Using self-report verbal questionnaires in Sensory Science

Emotional lexicons generated in response to food stimuli can be largely divided into two categories. These include pre-defined and consumer-led emotion lexicons. The EsSense profile, created by King and Meiseleman (2010) is an example of a pre-determined lexicon. It contains 39 terms which were narrowed down from 81 terms originally collected from the literature and consumer internet surveys. Criteria for inclusion of an emotion was high frequency of use (20% or higher) and a clear positive or negative connotation.

Subsequent testing of the questionnaire revealed that the vast majority of emotions towards food were positive, which is reflected by the greater number of positive (25) compared to negative emotions (three) included in the EsSence Profile. Importantly, pre-defined emotional lexicons are designed to assess any product category and provide differentiation between products from consumers who like the product (King et al., 2010). Consequently, the EsSense profile (King and Meiselman, 2010) is one of the most popular pre-determined lexicons used to assess consumer emotional response and has been applied to a number of product categories such as chocolate, (Dorado et al., 2016b) breakfast drinks, (Gutjar et al., 2015) and beer (Chaya et al., 2015b).

In contrast to pre-defined lexicons, consumer- led emotion lexicons have been developed by incorporating terms generated by the consumers themselves. Examples of product categories where specific emotional lexicons have been developed include chocolate, (Thomson et al., 2010) chocolate and hazelnut spreads, (Spinelli et al., 2014) beer, (Chaya et al., 2015a) coffee (Bhumiratana et al., 2014) and wine (Ferrarini et al., 2010). Indeed product specific lexicons may help to reduce the number of irrelevant or confusing terms within questionnaires that may appear in pre-defined lexicons when assessing specific product categories (Jaeger et al., 2013).

Although emotional lexicons are efficient and easy to apply within a traditional sensory test environment they are prone to a number of limitations. In particular, rating multiple emotions on a scale can increase

consumer boredom and fatigue. Indeed due to the large number of items on the EsSense profile (39) it has been suggested that no more than two products should be assessed within a single session (King et al., 2013). In addition, due to factors such as social desirability bias, consumers may feel social pressure to over or under express certain emotions towards particular product categories (e.g. organic foods) in order to conform to social norms or society expectations (Zander and Hamm, 2010). Furthermore, rating items on a scale involves a significant amount of cognitive processing, making subjects aware of their own feelings and prevents a true unconscious measure of emotion (Podsakoff et al., 2003; Poels and Dewitte, 2006).

1.6. Measuring changes in central nervous system activity

The central nervous system (CNS) consists of the brain, brainstem and spinal cord and its activity is most appropriately measured by using brain imaging technology. Electroencephalography (EEG) is a non-invasive method which is used to measure brainwaves of subjects by measuring very small electrical changes in the brain by placing a series of electrodes on the scalp of a subject (Casson et al., 2010). The brain wave patterns recorded can be largely divided into a series of waves called alpha, beta, gamma and delta waves characterised by their frequencies and amplitudes. Many of these waves are important in studies of emotion and cognition, for example alpha waves are believed to predominate in relaxed and low arousal states, whereas gamma rays are thought to respond to sensory stimuli (Andreassi, 2007a). However studies investigating the emotional response to stimuli such as odours have

found mixed results with unpleasant odours such as valeric acid resulting in an increase in alpha wave power, whilst others have found odours such as saaz hops, which have a relaxing effect, to also increase alpha wave power (Brauchli et al., 1995; Kaneda et al., 2011; Kaneda and Kojima, 2011). Furthermore whilst EEG has a high temporal resolution, it is not able to provide a high spatial resolution of brain activity. Magnetoencephalography (MEG) on the other hand measures the magnetic fields associated with the electrical activity within the brain and can offer high spatial and reasonable temporal resolution. However there is a limited reference to the use of MEG within emotion research, possibly due to the advancements in newer imaging technologies.

Functional magnetic resonance imaging (fMRI) reflects changes in brain neural activity indirectly by measuring changes in blood flow to different regions within the brain. It is one of the most widely used imaging techniques used within psychology owing to its ability to provide high spatial resolution in brain regions which would be undetectable using EEG or MEG methods (Wagner et al., 2007). For example using fMRI, researchers have able to demonstrate how odour valence and intensity activate different regions of the brain, with odour valence associated with increased activity in the orbitofrontal cortex and odour intensity associated with increased activity in the amygdala (Anderson et al., 2003). However the equipment used to conduct fMRI scans is expensive and requires expert knowledge to operate. Indeed, although grounds have been made for the neural representation of olfactory stimuli, studies on emotion have been criticised owing to the large

degree of conflict between studies (Barrett, 2006; Cacioppo et al., 2000). Consequently brain imaging technology may not currently be suitable for studies on emotional response in Sensory Science.

1.7. Measuring changes in autonomic nervous system activity

Changes in organ activity such as heart rate and the vasodilation/vasoconstriction of blood vessels is under the control of the autonomic nervous system (ANS) and are frequently referred to as physiological measures. Owing to the complex nature of how organ activity is mediated, an overview of the ANS will be discussed first, followed by common measures of ANS activity in relation to emotional response, followed by how these measured are used as a whole in Sensory Science investigations.

1.7.1. Overview of the autonomic nervous system

The mammalian nervous system comprises of central nervous system (CNS) and the peripheral nervous system (PrNS). The ANS is part of the PrNS and consists of a series of spinal and cranial nerves that emerge from outside the spinal cord that relay information to organs and tissues within the body (Figure 1.4). The ANS is generally considered an automatic system, not operating under conscious control. Its main function is to maintain a constant internal environment within the body, known as homeostasis in response to external physical stimuli, internal fluctuations in physiology and changes to an individual's affective state (Gibbins, 2013). This is coordinated through two separate subdivisions of the ANS, known as the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS). Both the PNS and

SNS enervate organs, smooth muscle and secretary glands giving some neuronal input to all tissues in order to inhibit or enhance the organ's function, otherwise all homeostatic processes would occur without an inhibitory action and would be in a continuous state of activation (McCorry, 2007). The parasympathetic and sympathetic neurones can be largely divided based on where they exit the spinal cord, the neurotransmitters they use and the anatomy of their pre and post ganglionic neurones (Gibbins, 2013). However, whilst it is commonly stated that the sympathetic branch is involved with energy expenditure and fight and flight responses whereas the parasympathetic branch is increased in restful states, this is an oversimplification and misconception. For example, whilst heart rate is innervated by both parasympathetic and sympathetic branches, the sweat glands and blood vessels are only under the control of sympathetic activity (Andreassi, 2007a). Indeed these two branches should be seen as complementary and not reciprocal.

Higher control of the ANS is thought to occur within the brain. Although the evidence is mixed, a general consensus is that ANS is controlled within the hypothalamus which also receives information from the limbic system sensory motor cortex (Shields Jr, 1993). A recent meta-analysis conducted on brain imaging studies revealed that higher autonomic control may also reside in areas such as the anterior and midcingulate cortices, insula, ventromedial prefrontal cortex, mediodorsal thalamus, amygdala and hypothalamus (Beissner et al., 2013). Furthermore whilst some brain areas have been shown to be principally involved with parasympathetic or sympathetic

activity, the amygdala has been shown to be involved with both (Beissner et al., 2013). As the amygdala and associated brain areas of the limbic system are important structures involved in emotional processing, (Catani et al., 2013; LeDoux, 1992) this is principally why many autonomic nervous functions are believed to respond to emotional induction.

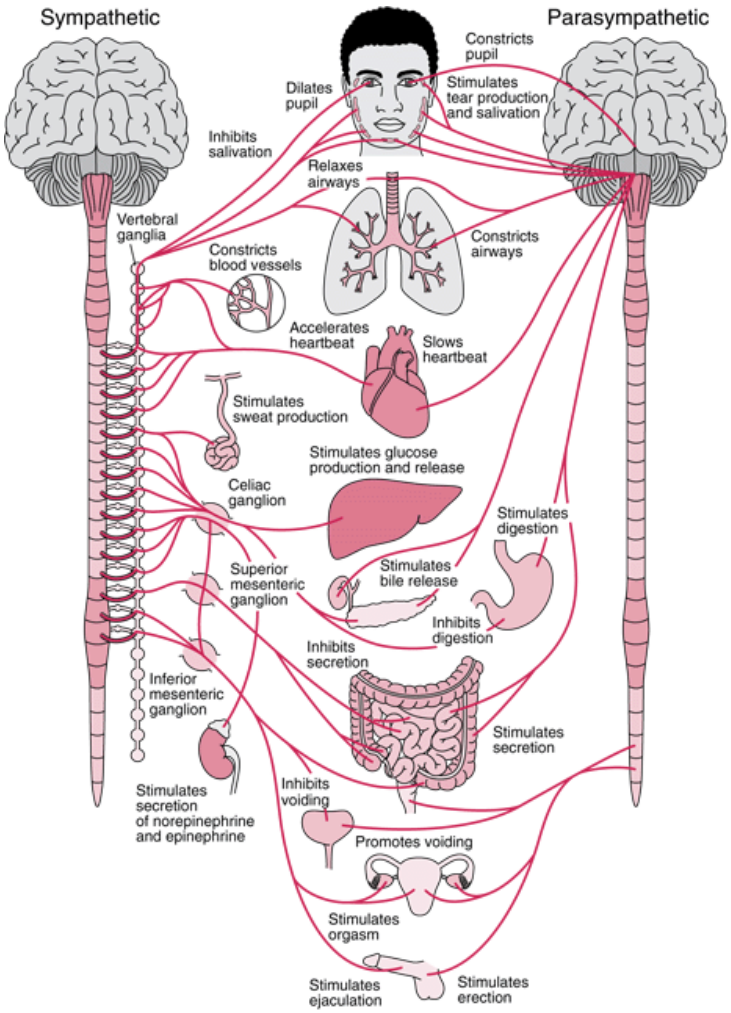


Figure 1.4. Overview of the different innervations and effects the sympathetic and parasympathetic nervous system has on various organs and tissues in the body (http://www.emedmd.com/content/diseases-autonomic-nervous-system).

1.7.2. Changes in heart rate

Measuring changes in heart activity is one of the most common physiological measures within emotion research (Kreibig, 2010a). This is because the heart is not only known to respond to fearful or stressful provoking situations (Dobkin and Pihl, 1992) but also responds to more subtle affective responses such as those when viewing pictures (Lang et al., 1993) or listening to music (Koelsch and Jäncke, 2015). Furthermore heart rate can be measured non-invasively by using an electrocardiogram (ECG) and as the heart is dually innervated by both parasympathetic and sympathetic branches of the ANS, this allows the heart to be sensitive to a wide range of changes in emotional activity (Berntson et al., 1995). An overview of basic cardio-physiology and measurement will be presented, followed by examples of how heart rate has been previously found to respond to emotionally relevant stimuli.

1.7.2.1. Physiology of the heart

The role of the heart is to supply blood, nutrients and oxygen to other organs and tissues within the body. It is comprised of a four chambered muscular system comprising of left and right atria and ventricles. Deoxygenated blood from tissues and organs in the body is transported to the right atrium where it is pumped through to the right ventral and subsequently pumped out of the heart and into the lungs to remove carbon dioxide and receive oxygen. Oxygenated blood is returned to the left atrium where it is pumped down to the larger left ventricle and propelled through the aorta to organs and tissues throughout the body, except for the lungs (Andreassi, 2007b).

Beat to beat activity of the heart is controlled by both internal and external mechanisms. Internally, the heart has a series of specialised myocardium (heart muscle) cells in specific locations which both generate and conduct electrical impulses, leading to contraction of heart muscle via electrical depolarisation of myocardium cells within separate chambers of the heart. The sinoatrial node (SA node) is a series of self-exciting cells positioned at the top of the right atrium wall which lead to the depolarisation of the left and right atria. This electrical conduction reaches the atrioventricular node (AV node) which in turn conducts the electrical impulses to the AV bundle (Oosthoek et al., 1993). The AV bundle distributes the electrical conduction down two branches corresponding to the two bottom chambers of the heart and impulses are distributed to all parts of the ventricular muscles via Purkinje fibres leading to the contraction of the ventricular myocardium (Katz, 2011a).

External control of heart rate is moderated from stretch receptors within the cardiac vasculature as well as autonomic control. Without external influence, the self-excitation of the SA node would lead to a resting heart rate of 100 beats per minute (Jose and Collison, 1970). However parasympathetic nerves innervate the heart and act on the SA and AV nodes to slow heart rate to its characteristic 70 beats per minute in a healthy resting individual. Sympathetic branches of the nervous system also innervate the SA and AV to increase heart rate but take longer to act owing to slower acting neurotransmitters (Pappano, 2010). Sympathetic and parasympathetic branches of the ANS predominate in certain areas of the heart, despite innervating similar regions. For example in the nodal areas of the heart, parasympathetic activity

predominates over sympathetic activity (leading to the characteristic resting heart rate averaging at 70 beats per minute). Whereas in the ventricular myocardium, sympathetic activity predominates over parasympathetic activity (Levy and Martin, 1981) possibly because parasympathetic innervation in the myocardium ventricles is very low (Takahashi et al., 2003). However it is important to note that an increase or decrease in heart rate does not automatically reflect respective changes in sympathetic or parasympathetic activity as an increase in heart rate in response to emotional stimuli may reflect reduced PNS activity or increased SNS firing (Levenson, 2014).

1.7.2.2. Recording heart rate

The electrical impulses that are generated by the conduction of the heart pass to the skin surface where they can be recorded by a series of electrodes placed on an individual's skin. The resultant potentials can be recorded via an electrocardiogram (ECG) where the electrical deflections are displayed (Andreassi, 2007b) (Figure 1.5). This can be recorded by a series of three bipolar leads which measure the potential difference across the heart. This is usually obtained by a "Lead II" placement where electrodes are attached to the left wrist and right ankle, allowing the electrical potential across the heart to be recorded, with the third electrode acting as a ground (Katz, 2011b). The P wave represents the depolarisation of the atria which is followed by a return to baseline before the larger spike denoting the QRS complex. The QRS complex is generated as a result of the depolarisation of ventricular myocardium muscles and the R spike is the largest deflection seen within the

ECG. Following QRS complex, the trace returns to baseline before the final T wave which represents the repolarisation of the ventricles (atria repolarisation is usually obscured within the QRS complex) (Katz, 2011b). Heart rate can be calculated from the ECG by measuring the time interval between consecutive R waves (known as the R-R interval) and calculating the number of R waves that may occur over a given time frame, leading to the characteristic measure, beats per minute (bpm) (Dawson et al., 2001).

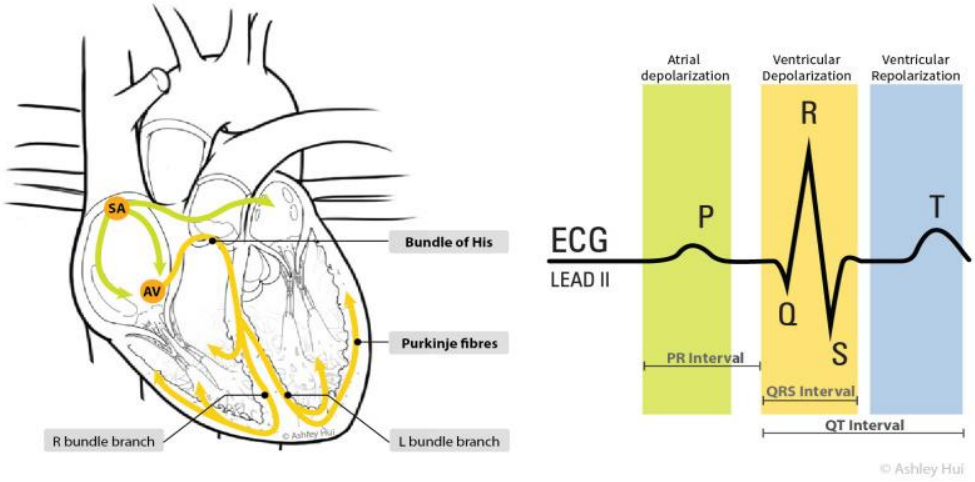


Figure 1.5. Overview of electrical conductivity of the heart and wave components within electrocardiogram recording (ECG) (http://ptexphys.utorontoeit.com/cardiovascular-physiology/heart-function-and-physiology/).

1.7.2.3. Changes in heart rate in response to emotional stimuli

Numerous studies have investigated the impact of emotions on heart rate, with some studies identifying that heart rate increases more under specific discrete states such as anger compared to others such as happiness or surprise (Rainville et al., 2006; Vernet-Maury and Alaoui-Ismaïli, 1999).

However the majority of studies have found that heart rate is correlated with the valence of a stimulus, resulting in an increase in heart rate in response to unpleasant picture, memory recall or music stimuli (Anttonen and Surakka, 2005; Codispoti et al., 2008; Lang et al., 1993; Libby et al., 1973; Sokhadze, 2007). Despite this there is still some inconsistency within the literature with some results showing that heart rate is more sensitive towards the arousal dimension of emotion (Cuthbert et al., 2003; van oyen Witvliet and Vrana, 1995). Indeed studies on animal welfare utilise heart rate as a direct measure of arousal (Boissy et al., 2007).

1.7.3. Electrodermal activity

Electrodermal activity (EDA) is an all-inclusive term used to refer to the measurement of changes in the electrical properties of the skin. Skin conductance is one type of EDA measurement and is related to the activity of the eccrine sweat glands which are only innervated by sympathetic nerves so increases in eccrine sweating reflect greater sympathetic nervous system activation (Braithwaite et al., 2013). Eccrine sweating is not only induced by elevation in the body's core temperature to facilitate heat transfer (Kimura and Low, 2007) but can also be induced by changes in an individual's emotional state, known as emotional or palmar sweating (Homma et al., 2001). Indeed several brain imaging studies have identified areas of the limbic system and related structures such as the amygdala, hippocampus, basal ganglia and pre-frontal cortex with skin conductance activity, supporting the notion that palmar sweating is related to emotional activity (Mangina and

Beuzeron-Mangina, 1996; Sequeira et al., 2009). Skin conductance is measured by determining how well the skin conducts electricity by applying a small voltage (0.5V) through two silver/silver chloride (Ag/AgCl) electrodes placed on the distal end (third phalanges) of the index and middle fingers. The principle behind the measurement can be described by Ohm's law which states that resistance (*R*) is equal to the voltage (*V*) applied between two electrodes divided by the current (*I*) and is expressed as $R = V/I$. As a known voltage is applied (0.5V) to the skin, the current passing through the epidermal surface will vary with skin resistance and is referred to as skin conductance recorded in microSiemens (µS) (Boucsein et al., 2012; Dawson et al., 2007). Consequently, the more sweat that accumulates in the sweat glands, the higher the skin conductance will be.

There are two types of signals that can be recorded in skin conductance measurements; these include tonic and phasic measures. Tonic recordings refer to the overall rise and fall of skin conductance activity, known as skin conductance level (SCL) (Macefield and Wallin, 1996). Phasic activity refers to characteristic peaks identified within the overall EDA signal referred to as skin conductance responses (SCR) which are the result of a momentary increase in sympathetic activity (Lidberg and Wallin, 1981). Studies which investigate the activity of emotional stimuli on skin conductance activity typically focus on phasic SCR in response to specific stimuli as it is more representative of stimulus specific activity and measured over shorter time intervals (Finger and Murphy, 2010). However owing to the fact that non-stimulus related SCR

(non-specific SCR) are frequent, only SCR measured within 1-8 seconds after stimulus presentation are considered stimulus specific (Boucsein et al., 2012).

1.7.3.1. Changes in EDA to emotional stimuli

Changes in SCR is one of the most widely exploited measures within psychology as changes in its activity is used to investigate subjects response to habituation (Zimmer, 2006), Pavlovian conditioning (Esteves et al., 1994), cognition (Nikula, 1991) as well as response to emotional stimuli (Dawson et al., 2007). With regards to emotional stimuli, skin conductance responses have been reliably shown to increase with the arousal of the stimuli (Sequeira et al., 2009). For example when subjects are presented with pictures which have similar valence levels but differ in their levels of activation, skin conductance magnitudes increase linearly with activation ratings (D'Hondt et al., 2010; Lang et al., 1993) and similar effects with regards to activation and valence have been found with other emotional stimuli such as music (Gomez and Danuser, 2007; van der Zwaag et al., 2011).

1.7.4. Skin temperature

The thermoregulation of body temperature is mediated not only by sweating but also by changes in the skin blood flow regulation. Skin is made up of glabrous (hairless skin on finger, palms and soles of feet) and non-glabrous skin, (hairy skin such as that on forearm) (Machado-Moreira and Taylor, 2011) both of which receive their blood supply from blood vessels that can either undergo vasoconstriction or vasodilation in response to environmental and internal cues. Vasodilation causes an increase in blood flow to the skin's

surface resulting in greater transfer of heat to the environment from the body, leading to an increase in skin temperature. In contrast, vasoconstriction leads to a decrease in blood flow to the skin, resulting in less heat escaping from the body and resulting in a decrease in skin temperature (Charkoudian, 2003). Both vasoconstriction and vasodilation are controlled by different sympathetic nerves but it is the vasoconstriction responses which are most readily observed within emotion research as these are tonically active under normal thermal conditions (Johnson, 1986). Thus changes in blood vessel dilation can be measured by recording changes in skin blood flow by using infra-red light to record red cell density or can be measured by recording small fluctuations in skin temperature (Petrofsky and Ph, 2012). Consequently changes in skin temperature or skin blood flow can give an indication to changes in sympathetic response towards emotional stimuli. Previous research has found mixed results with regards to skin temperature, with some studies reporting that skin temperature decreases in response to unpleasant emotions (such as fear) whilst others report skin temperature increases in response to negative emotions (Baumgartner et al., 2006; Kreibig, 2010a; Vos et al., 2012).

1.7.5. Respiration

The primary role of respiration is to provide gas exchange i.e. through the delivery of oxygen and removal of carbon dioxide from the body through inspiratory and expiratory cycles (Lorig, 2007). Although emotions are known to have an effect on respiratory parameters, (Boiten, 1998) respiration is not

usually included as a physiological measure as inspiration and expiration are heavily influenced by voluntary and non-voluntary mechanisms (Cornelis and Grossman, 1988). However respiration is often recorded alongside other physiological measures such as heart rate owning to the coupled relationship observed between the beat to beat control of the heart and respiration, known as respiratory sinus arrhythmia (RSA) (Berntson et al., 1993). This synchronised relationship between heart rate and respiration leads to a shortening the heart R-R intervals during inspiration (leading to an increase in heart rate) and a lengthening of heart R-R intervals during expiration (leading to a decrease in heart rate) (Yasuma and Hayano, 2004). Applications of RSA measurements are most useful in measurement periods occurring over a period of minutes and hours, (Task Force, 1996) as opposed to a period of seconds for heart rate (Berntson et al., 2007). Nevertheless, respiration is often recorded alongside heart rate measurements to ensure the respiration rate is consistent amongst subjects (Delplanque et al., 2009). Furthermore studies which use olfactory stimuli frequently record respiration in order to provide an accurate measure of when a subject has inhaled an aroma (Glass et al., 2014).

1.7.6. The application of physiological measures within Sensory Science

Physiological measures have been used within Sensory Science since the early 2000's in order to fully understand the response towards basic taste solutions. For example, Horio (2000) found that heart rate increased in response to

tasting all basic taste solutions (bitter, salty, sweet and sour) and in general observed a negative correlation between heart rate and hedonic liking, with heart rate increasing for more unpleasant tastes such as quinine sulphate (bitter) and sodium chloride (salty). Rousmans and Robin (2000) measured skin resistance, (a reciprocal measure for SCR) skin temperature, skin blood flow and heart rate and found that samples with a high liking score such as sucrose (sweet) were associated with autonomic responses that were weaker in amplitude and shorter in duration. However bitter, salty and sour samples that received low liking scores were associated with autonomic responses that were higher in amplitude and were longer lasting (Rousmans and Robin, 2000). The same group also analysed similar autonomic responses towards taste stimuli and their propensity to evoke basic emotions using classification criteria stipulated by Ekman et al (1983). Based in the pattern of ANS responses, they found that sucrose solutions were associated with the basic emotions happiness and surprise, whilst quinine sulphate and sodium chloride solutions were associated with disgust, anger and surprise (Robin et al., 2003). Similar results have also been obtained from the olfactory modality, with pleasant odours such as lavender and ethyl aceto acetate eliciting emotions such as happiness, whilst unpleasant aromas such as butyric acid and acetic acid eliciting mainly disgust and anger (Vernet-Maury and Alaoui-Ismaïli, 1999). When odours have been assessed using a dimensional approach, heart rate and skin conductance responses have been found to increase with unpleasant odours, whilst heart rate has been also found to decrease with pleasant odours (Bensafi et al., 2002a; Brauchli et al., 1995).

More contemporary studies within Sensory Science are now seeking to use autonomic measures to provide greater discrimination between commercial consumption products than liking scores can provide alone. For example although liking scores did not change significantly between a selection of yoghurt drinks, heart rate and skin temperature differed significantly between samples although skin conductance responses were not significant (de Wijk et al., 2014).

1.8. Measuring changes in behaviour

Facial movements associated with facial expression, mastication and speech are achieved through the coordinated movement of individual facial muscles within the face (Figure 1.6) (Huang et al., 2004). However unlike physiological measures under the control of the ANS, facial muscles can be controlled by both voluntary and non-voluntary mechanisms (Lapatki et al., 2003) and consequently is often thought of as a behavioural measure, rather than an unconscious measure of emotional response. Within implicit measures of emotion, it is these involuntary responses that researchers are interested in and there is a growing body of evidence to suggest that both voluntary and involuntary responses are controlled by separate but integrated neural networks (Morecraft et al., 2001).

1.8.1. Facial action coding units and face reading technology

Along with developing the theory on basic emotions, Ekman and Friesen (1978) developed the Facial Action Coding System (FACS) which provides an objective coding system to a series of 44 facial movements produced as a

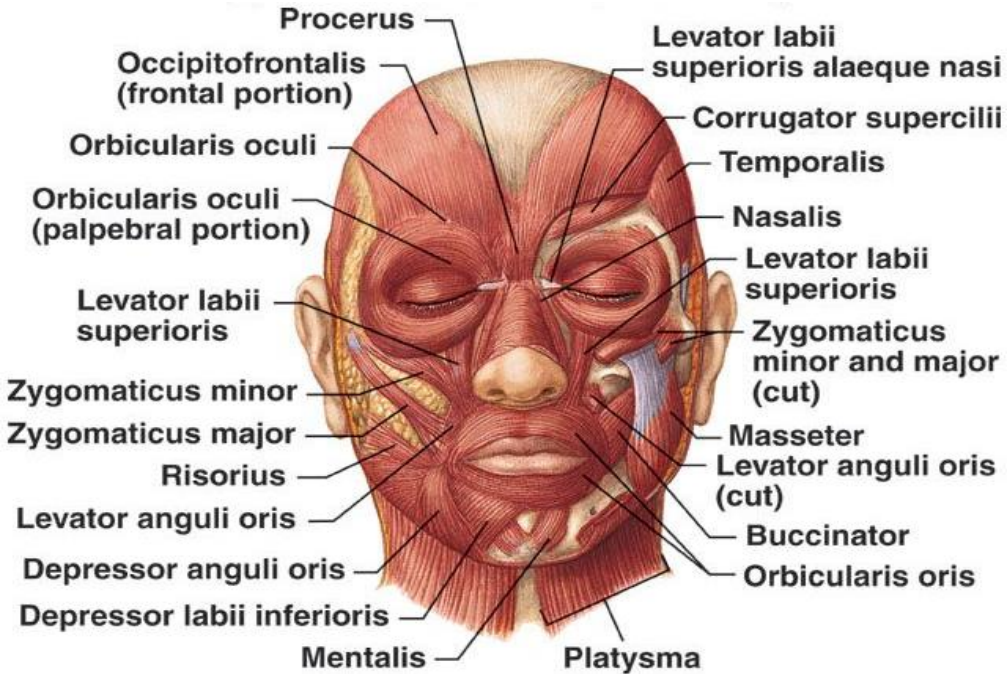


Figure 1.6. Facial muscle atlas showing names and positions of muscles within the human face (http://doctorlib.info/medical/anatomy/32.html)

result of emotional expression in a variety of different contexts (Ekman and Oster, 1979). However recording facial expressions via the FACS is a slow process: subjects must be video reordered and their facial expressions scored by two independent coders which can take 1-2 hours per six seconds of film (Zeinstra et al., 2009) making the process expensive. In more recent years, face reading technology has been developed to automatically read and code the facial expression of subjects from video recordings. FaceReader (Noldus Information Technology, Netherlands) was the first to be developed and is currently the most widely used face reader technology. The FaceReader technology is able to code both FACS and Ekman's basic emotions using a series of model points and algorithms which have been shown to have comparable accuracy with human coders (Lewinski et al., 2014). However studies which have utilised FaceReader technology with consumption products have commented that the higher number of negative emotions

(contempt, fear, anger and disgust) to positive emotions (happiness) makes comparison of well-liked food products difficult (Danner et al., 2014a).

1.8.2. Facial electromyography

One of the problems associated with visual detection methods are that they are insensitive to weak muscle movements which may not manifest themselves visually on the skin's surface. However these visually undetectable movements may make up a significant proportion of an involuntary response to a stimulus (Tassinary and Cacioppo, 1992). Facial electromyography (EMG) is sensitive enough to detect these weak and rapid facial movements, making it ideal to use in studies of investigating facial response to affective stimuli (Boxtel, 2010). EMG is recorded using two bipolar (Ag/Cl) electrodes placed over the muscle of interest. EMG measures the sum of the action potentials generated by muscle motor units between the two recording electrodes and consequently gives a measure of muscle contraction in terms of an electrical signal in millivolts (mV) (Criswell, 2011). Facial EMG has been most widely employed in the study of affective states in humans, examining the facial activity of two distinct muscles within the human face, the corrugator supercilii which draws the brow downward to form a frown and the zygomatic major muscles which elevates the cheek during smiling (Dimberg and Karlsson, 1997). For example, studies investigating the effect of picture valence have found that unpleasant pictures elicit high activity over the corrugator supercilii and low activity over the zygomatic major, whilst pleasant pictures cause high activity over the

zygomatic major and low activity over the corrugator supercilii (Larsen and Norris, 2009; Ritz et al., 1999; Tan et al., 2011). Furthermore, a series of experiments by Dimberg has demonstrated that facial muscle activity respond rapidly (under 500ms) to pictures of humans expressing emotions (Dimberg and Thunberg, 1989) and that the same muscles can be activated when participants are unconsciously exposed to happy and angry facial expressions (Dimberg et al., 2000). Taken in combination, studies on the impact of affective stimuli have shown that facial reactions are automatic and beyond unconscious control (Dimberg et al., 2002).

1.8.3. The application of facial expression measures in Sensory Science

The relationship between facial expressions and basic tastes was well described by the 1980's. Steiner (1974) commented on the gustiofacial response of neonatal infants towards bitter, sweet and sour solutions. The differentiated and coordinated facial expressions described towards bitter (complex face scrunching, gaping and frowning) and sweet solutions (lip smacking and smiling) described an innate response towards gustatory stimuli which was present from birth. Studies within adults have found similar responses by using the FACS, finding nose wrinkling towards bitter solutions as well as lip sucking and smiling in response to sweet tastes (Bredie et al., 2014; Greimel et al., 2006; Wendin et al., 2011). Bredie et al (2014) was able to further sort these FAC units into basic emotions but found that only anger and disgust (as well as surprise at high taste concentrations) could reliably

elicit a discernible expression characteristic of a basic emotion. Using facial EMG it has been additionally found that unpalatable drinks such as pickle juice have evoked greater activity over the levator labii muscle, the muscle used to wrinkle the nose in disgust reactions (Hu et al., 1999). Within the olfactory modality, similar EMG results have been observed towards unpleasant stimuli, with greater corrugator activity observed in response to unpleasant odours, indicating subjects were frowning in response to unpleasant stimuli (Bensafi et al., 2002b).

More recent studies have additionally sought to combine physiological measures of the autonomic nervous system with changes in facial expression using FaceReader technology (Danner et al., 2014a, 2014c, de Wijk et al., 2014, 2012). However such studies have been limited to recording only the changes in facial expression that correspond to the primary six basic emotions (anger, surprise, disgust, sadness, fear and happiness). Consequently, physiological response towards sensory stimuli has been mainly explored with regards to liking and basic emotions. However investigation into the relationship between physiological and self-reported emotional response is required to fully understand whether physiological and facial expression measures are beneficial within sensory science.

1.9. Conclusions regarding emotional response measures

Self-reported measures offer the most comprehensive measure of emotional response towards sensory stimuli and have been shown to be effective at discriminating between similar products within the same product category

(Chaya et al., 2015a; Dorado et al., 2016b; Ferrarini et al., 2010; Gutjar et al., 2015; Ng et al., 2013; Spinelli et al., 2014). Physiological measures appear to show some discrimination between different taste and olfactory stimuli and products which are well liked (Alaoui-Ismaïli et al., 1997b; Bensafi et al., 2002a; Brauchli et al., 1995; Danner et al., 2014b; de Wijk et al., 2014; He et al., 2014), however, it is unclear how these currently relate to emotional response within sensory products. Facial expressions have principally been measured using FACS and FaceReader technology but facial EMG appears to offer greater sensitivity owing to its ability to detect quick facial expressions which are undetectable with the naked eye and should be considered further for future studies. Finally brain imaging technologies such as fMRI require investment in expensive technologies which require expert knowledge to run and consequently are not as adaptable as self-report, physiological and facial expressions when carrying out Sensory Science investigations.

1.10. Approach of this investigation

This thesis aims to build upon previous studies and focus on the relationship between emotional, physiological and facial expression response towards sensory stimuli. In particular this study seeks to understand the emotional response towards aroma attributes within beer. Beer was chosen as the product of study because it has previously been shown to evoke a wide range of emotional responses, both with respect towards packaging (Chaya et al., 2015b) and the sensory properties within beer itself (Chaya et al., 2015a). Furthermore beer is associated with a wide range of flavour and aroma

properties (Meilgaard et al., 1979; Thomas, 2006) which are easily manipulated owing to the wide range of flavour standards available to assist in the training of sensory quality panels, examples of specialist flavour companies include: FlavorActiv™ (Quay Pharma, UK) and Aroxa™ (Cara Technology, UK). Finally aroma was chosen as the sensory modality of interest for two reasons. Firstly the study sponsors stated that they wished the project to be focused on olfactory stimuli only; secondly there is a close relation between olfaction and emotion (Chrea et al., 2009). In particular it is known that olfactory information travels from the nasal epithelium to the olfactory bulb and then to the olfactory cortex, bypassing the thalamus unlike other sense modalities (Stockhorst and Pietrowsky, 2004). Furthermore the olfactory cortex shares many close connections with structures in the limbic system, such as the amygdala which are heavily involved in emotional processing (Yeshurun and Sobel, 2010).

1.11. Research objectives

The purpose of this study was to investigate the effectiveness of physiological and facial expression measures to discriminate between different aromas in beer and whether physiological/facial expression measures were able to provide greater discrimination between aromas compared to self-reported emotional response and liking. This was achieved through a series of smaller preliminary investigations followed by a larger main investigation, the objectives of which are detailed below:

1. Chapter two reports the results from two preliminary investigations, referred to as the pilot and validation study.
    - The pilot study had two main objectives: the first aimed to validate whether a chosen set of beer aromas was sufficient to evoke an emotional responses in nine subjects. In particular it aimed to identify if emotional response was detectable via: a) physiological and facial expression measures, b) self-reported valence, activation, intensity and familiarity as well as; c) identify if there was relationship between the two types of measurements. The second objective was to develop an experimental protocol that was: a) suitable for assessing beer samples whilst physiological and facial expression measures were recorded and; b) establish a suitable protocol for data processing to allow raw physiological and facial expression measures to be analysed.
    - The Validation study built upon some of the findings made in the Pilot investigation and also had two main objectives. The first was to determine the suitability of: a) a revised set of beer aromas and; b) an emotional lexicon specific to beer to record self-reported emotional response. The second objective aimed to validate how self-reported and physiological/facial expression measures of emotion respond to repeated sample presentations both a) within a single session and b) between separate sessions, to help determine how many sessions and replicates should be included within the main investigation.

2. Chapter three reports the results from the main investigation. The objectives of the main study were to:
    - Explore the discrimination ability of physiological/facial expression measures towards beer aroma. This objective first aimed to: a) increase the sensitivity of implicit measurements by developing a revised data processing protocol. Before determining whether implicit measures could: b) discriminate between aromas within beer and a water sample with no aroma and; c) discriminate between aromas within beer.
    - Determine whether self-reported emotional response using a consumer-led emotional lexicon specific to beer could discriminate between aromas in beer.
    - Determine whether liking scores could discriminate between aromas in beer.
    - Compare the discrimination ability of physiological/facial expression responses, self-reported emotional response and liking scores in order to determine which measurement type is more discriminating towards a range of aromas within beer.
    - Determine if there is a difference in emotional response between genders and whether these are more easily detectable through implicit or explicit measures.

2. Chapter two: Development of experimental protocol and selection of aroma attributes

This chapter focuses on two preliminary investigations, referred to as the pilot and validation studies respectively, which aimed to explore the appropriateness of the experimental protocols and aromas which would be used within the larger main study detailed in Chapter three. The pilot is detailed within the first half of this chapter (part one) and is followed in the second half by details on the validation study (part 2). The chapter finishes by specifying some additionally methodological considerations as well as a summary of the key protocols which were subsequently applied within the main investigation (part 3).

Chapter 2, part one: Pilot Study

2.1. Introduction

A primary objective of the pilot investigation was to determine whether a predetermined set of beer aromas were sufficient to evoke changes in emotional response which were detectable via implicit measures such as changes in physiological/facial expression activity as well as by explicit self-reported measures of emotional response. Previous studies which have investigated the emotional response towards aroma stimuli have largely compared changes in implicit measures with self-reported emotional response in order to determine how physiological and facial expression activity is related to the cognitive component of emotion. Furthermore the majority of research has taken a fundamental approach, with studies focusing on a basic (see section 1.2.1) or dimensional (see section 1.2.2) perspective.

From a basic perspective, researchers have sought to find autonomic specificity of physiological responses where the coordinated pattern of the autonomic nervous system (ANS) can be reconciled into one of Ekman's basic emotions using a so called "decision tree" (Ekman et al., 1983). For example unpleasant odorants such as butyric acid have been found to be associated with disgust and anger whilst pleasant odours such as lavender have been found to elicit happiness (Vernet-Maury and Alaoui-Ismaïli, 1999). However other studies have found that there is a mismatch between the basic emotion determined via self-report and the emotion deducted from ANS responses (Alaoui-Ismaïli et al., 1997a) or have failed to find specific physiological patterns within the ANS to distinguish emotions between odours (Glass et al., 2014). This has resulted in many researchers adopting a dimensional approach when assessing emotional response towards olfactory stimuli.

From a dimensional perspective, researchers initially focused on how changes in ANS activity responded to odour valence. For example Alaoui-Ismalili et al (1997b) found that heart rate increased and skin conductance responses were longer for unpleasant compared to pleasant aromas. Other researchers also included self-reported measures of activation as a second dimension of emotion. For example Brauchli et al (1995) record valence, activation and intensity ratings in response to two aromas, whilst measuring heart rate and skin conductance responses. They found no difference in activation ratings but revealed heart rate and skin conductance increased in response to the unpleasant aroma valeric acid as well as finding that heart rate also decreased in response to the pleasant aroma, phenylethyl alcohol. Bensafi et al (2002a)

looked at the associations between valence, activation, intensity and familiarity ratings with heart rate and skin conductance scores in response to three pleasant and three unpleasant aromas. They found that heart rate had a negative association with aroma pleasantness, whilst skin conductance had a positive association with both activation and intensity ratings. Delplanque et al (2009) further looked at changes in ANS responses and facial expression in response to sample pleasantness, intensity and familiarity. They found that heart rate and skin conductance both increased in response to unpleasant aromas and additionally found that heart rate also increased with aroma familiarity. Furthermore greater frowning responses were also found to distinguish between both pleasant and unpleasant aromas. More recently He et al (2014) looked at heart rate, skin temperature and skin conductance responses to three concentrations of an unpleasant fish aroma and pleasant orange aroma and found heart rate increased in response to both unpleasant aroma and with increasing concentrations of both aroma types. Furthermore facial expressions indicative of displeasure were found to be more prevalent in response to the fish compared to the orange aroma.

The findings from previous studies on aroma reveal that physiological/facial expression responses primarily respond to aroma valence, with some influence from aroma activation. Consequently it was deemed appropriate to measure emotional response along the same dimensions within the pilot investigation in order to make relevant comparisons with other research within the literature. Intensity ratings were also included in order to allow for an additional comparison of aroma concentration. Finally a measurement of

aroma familiarity was thought important as beer is associated with a number of aromas, some of which may be more familiar to consumers than others, as demonstrated in previous studies (Chaya et al., 2015a; Eaton, 2015).

The second objective of the pilot investigation was to develop a suitable experimental protocol. Unlike studies that only assess self-reported hedonic or emotional response, research involving the measurement of physiological and/or facial expression variables requires additional methodological considerations. Most notably, physiological and facial expression measures are recorded continuously, making them subject to both movement artefacts as well as recording responses which are not stimulus related, also known as non-specific responses (NSR) (Braithwaite et al., 2013). If not correctly controlled for, the separation of artefacts and non-specific responses from event related responses (ERS) can be difficult to control, leading to inaccuracies in data recordings. In order to prepare subjects to receive the next stimulus and reduce the risk of movement artefacts or NSR, previous studies have incorporated the use of tones (de Wijk et al., 2014) or light signals (Rousmans and Robin, 2000) to indicate when subjects should expect to receive the next sample. Alternatively researchers have presented a series of visual instructions to subjects (de Wijk et al., 2014; Delplanque et al., 2009) which allows tighter control over subject behaviour and movement prior to the assessment of the stimulus. Furthermore in its raw form, physiological and facial expression raw values do not convey much information with regards to the physiological responses of subjects. In order to extract the necessary information from each measure, the data must be processed which

requires a) the location of stimulus presentations within the recordings to be identified, b) the application of necessary post recording filters to remove erroneous noise (such as electrical interference) from the data and c) extraction of key physiological parameters specific to each measure over a pre-determined time frame. Not surprisingly due to the number of considerations which need to be made when recording physiological/facial expression measures it is recommended that pilot investigations should be conducted prior to starting any full investigation (Gratton, 2007).

2.2. Aims and objectives

This pilot study had two overarching objectives, these were to:

1) Validate whether a chosen set of beer aromas were sufficient to evoke emotional responses in consumers. This were verified by:
    a. Determining if emotional responses were detectable via physiological and facial expression methods.
    b. Determining if emotional response were detectable via self-reported activation and valence as well as by aroma intensity and familiarity.
    c. Determine whether implicit and/or explicit measures were different between sessions, implying a session effect.
    d. Determining whether emotional response was dependent of the concentration of aroma used to help in the selection of appropriate aroma strengths.

e. Determining whether there were any correlations between self-report and physiological/facial expression responses which could imply a relationship between the two measurement types.

2) Development of an experimental protocol. This objective further aimed to:

   a. Ensure that a sample delivery protocol was suitable and practical for the assessment of beer aromas by subjects whilst recording their physiological/facial expression measures.

   b. Provide an opportunity to further understand physiological and facial expression recording characteristics and develop a suitable protocol to process raw data into meaningful measurements.

2.3. Methods

Ethical approval from The University of Nottingham's Bioscience Committee was received prior to starting this study (approval code: SBREC140115A). Ten samples of beer were presented to nine consumers whilst their physiological, facial expressions and self-reported emotional response were recorded. Samples included a base beer manipulated with two concentrations, low and high, of aroma compounds specific to beer.

2.3.1. Subjects

10 subjects (one male and nine females) aged between 20 and 26 were recruited prior to the start of the study from students at The University of Nottingham. They self-declared that they had no olfactory deficits or no

health problems and were not on any long term medication apart from contraceptives. All subjects gave their informed consent.

2.3.2. Samples

There were ten samples used within this study. These included two non-manipulated and non-spiked base beer samples and four manipulated base beer samples that were "spiked" with aroma compounds at ether a high or low concentration. This corresponded to two control samples and eight manipulated samples. Two control samples were included to gain an understanding of how repeatable responses were towards a control sample.

Miller Genuine Draft (MGD) (SABMiller, UK) was chosen as the base beer for this study because it is a lager style beer which is not dominated by any particular aroma attribute, making it easy to elevate specific aromas.

Food grade Aroxa^{TM} beer flavour standards (Cara Technology, Leatherhead, UK) were used as the source of manipulated aromas to "spike" the base beer. A pre-determined, precise quantity of each flavour standard is nano-encapsulated in cyclo dextrin and contained within plastic capsules. As aroma and not flavour or mouthfeel was the focus of this study, the compounds chosen are referred to as aromas throughout this thesis.

Isoamyl acetate, Lightstruck, Hoppy A and Hoppy B were the four aroma compounds used to spike the base beer and were decided by the project sponsors. However the concentration of specific compounds was decided upon by the lead investigator. Details of the aromas used and their respective concentrations can be found in Table 2.1. The high concentrations of

Lightstruck and Isoamyl acetate were principally determined by those used within a previous investigation which also utilised Aroxa™ beer flavour standards in MGD (Chaya et al., 2015a). Hoppy A and Hoppy B had a hop like character and were not known to have been used specifically within a previous investigation so their concentrations were determined informally by comparing their relative intensities with Lightstruck and Isoamyl acetate. This confirmed that the same number of flavour capsules would be required for the high concentration of Hoppy samples as was for the other two samples.

The entire contents of Aroxa™ flavour standard capsules are designed to be dissolved within one litre of beer. However as funding limits placed restrictions on the quantity of Aroxa™ flavour capsules and amount of beer that was available for the entire project, capsules were added to smaller volumes of beer (500ml and 750ml for low and high contractions respectively) to achieve the desired aroma concentrations.

Table 2.1. List and concentrations of compounds added to the MGD base beer and the respective threshold level of each compound for the general population.

Base beer	Compound	Low concentration per litre of MGD	High concentration per litre of MGD	Threshold level per litre of beer*
MGD	Isoamyl acetate	7mg	10.5mg	1.1mg
	Lightstruck (3-methyl-2-butene-1-thiol)	200ng	300ng	4-30ng
	Hoppy A	9mg	13.5mg	N/A
	Hoppy B	17mg	25.5mg	N/A

***Threshold levels obtained from Aroxa™ website (Aroxa, 2014).**

MGD is a carbonated beverage and consequently has a propensity to foam when poured. Therefore accurate volume measurements of fully carbonated MGD would have required lengthy measurements periods in order to allow foam build up to dissipate within thin necked volumetric flasks. This was circumvented by calculating the density (equation 1) of MGD in order to determine its mass. Six replicate 500ml volume measures were taken using a volumetric flask and were used to calculate MGD density (Table 2.2).

Equation 1: $p = m/v$

Where:

p = density

m = mass

v = volume

The average density calculation obtained from Table 2.2, 1.0075 g/ml was used to calculate the mass of MGD required for 500ml and 750ml of beer for low and high aroma conditions respectively (Table 2.3).

Table 2.2. Volume, density and mass values for MGD lager.

Replicate	Volume of MGD (ml)	Mass of MGD (g)	Density of MGD (g/ml)
1	500	503.65	1.0073
2	500	503.77	1.0075
3	500	503.51	1.007
4	500	503.87	1.0077
5	500	503.78	1.0076
6	500	503.84	1.0077
Average ± standard deviation.	500	503.74 ± 0.13	1.0075 ± 0.0003

Table 2.3. Respective mass measurements for 500ml and 750ml volumes of MGD.

Volume of MGD and aroma condition	Mass of MGD (g)	Number of Aroxa capsules added
500ml of MGD for low aroma condition	503.74	1
750ml of MGD for high aroma condition	755.61	2

2.3.3. Physiological and Facial Expression Measurements

Physiological and facial expression expressions were recorded using a MP150WSW system from Biopac (Biopac, Goleta, CA, USA) with separate settings and amplifiers for respiration, (RESP100C) skin temperature, (SKT100C) electrocardiogram (EGC100C) and two facial electromyography (EMG100C) recordings. Signals were recorded from the subject in the experimental room and processed by the MP150 system located in the adjacent recording room via amplifier specific electrode leads (an example of how recording equipment were secured to subjects can be seen in Figure 2.1). Physiological and facial expression signals were recorded in real time on a Windows laptop screen connected to the MP150 system and recordings were stored on an external hard drive. All signals were filtered online by means of the hardware based filters built into the amplifiers. Details of data processing and filters applied post recording can be found in section 2.3.6.

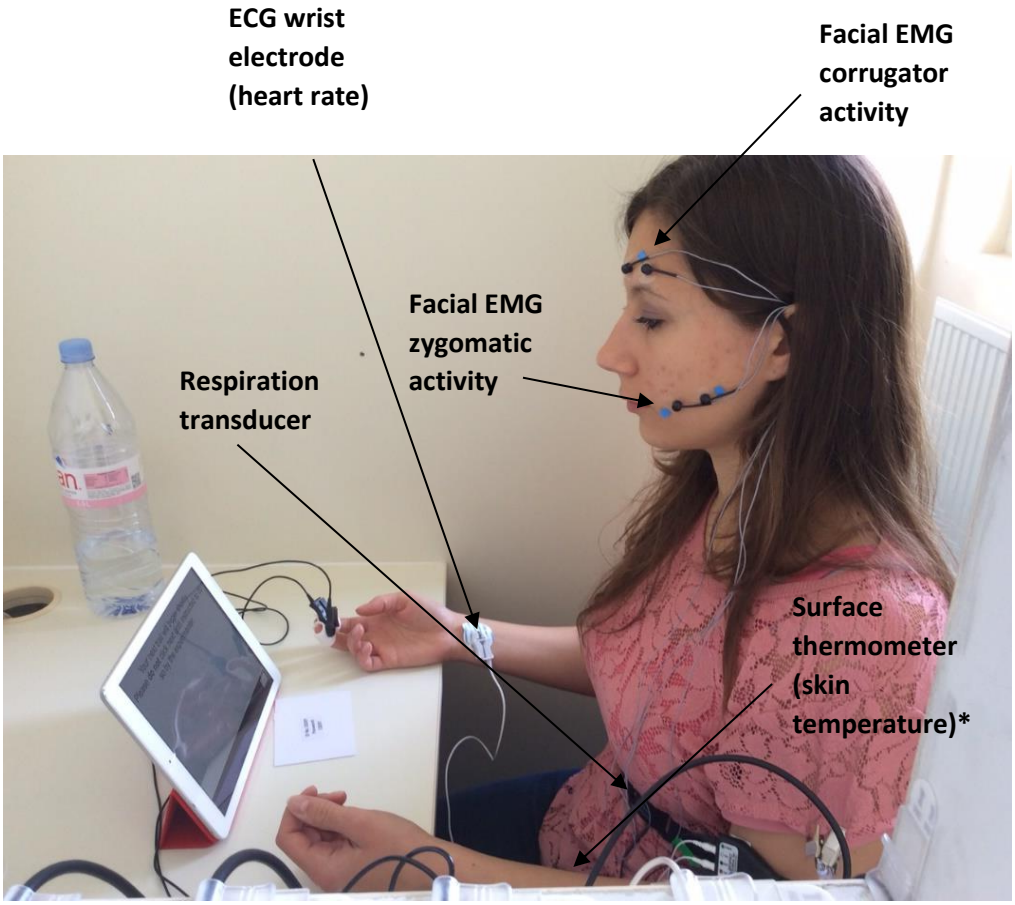


Figure 2.1. Schematic of subject physiological and facial recording set up for pilot investigation. (*surface thermometer out of frame).

2.3.3.1. Respiration activity

Respiration activity was recorded by placing a respiration transducer belt (TDS201) around the chest of a subject in order to measure thoracic expansion and contraction. Respiration was measured in volts (V) and displayed on screen as a series of cycles corresponding to inspiration and expiration. Respiration was not used as a direct measure of ANS activity but was used to identify exactly when a subject had started to inhale an aroma. The sampling rate was 31.250 Hz and the signal was low pass filtered at 1 Hz to remove any high frequency movement artefacts from the data.

2.3.3.2. Heart Rate

Cardiac activity was recorded because heart rate has been previously shown to be a good indicator of aroma valence (Alaoui-Ismaïli et al., 1997b; Bensafi et al., 2002a, 2002c; Brauchli et al., 1995; Delplanque et al., 2009; He et al., 2014; Pichon et al., 2015). Heart rate was recorded using two disposable, pre-gelled general purpose electrodes (EL503). One electrode was attached to the right wrist, the other to the inside left ankle of the subject to form a typical type II electrocardiogram configuration (section 1.7.2.2). The signal was sampled at 500Hz and high pass filtered at 1Hz. As the laboratory was not electrically shielded, an additional 60Hz notch filter was used to remove an interfering electrical noise from the signal. Heart rate was recorded in beats per minute, (bpm) details of which can be found in section 1.7.2.2 of this chapter.

2.3.3.3. Skin Temperature

Although skin temperature is not always used in physiological recordings as a measure of ANS activity, it is increasingly being used in more recent studies (Danner et al., 2014a; de Wijk et al., 2014, 2012; Glass et al., 2014; He et al., 2014). Therefore in order to provide a comparison to recent investigations, skin temperature was recorded as part of this study. Skin temperature was measured in °C by a banjo style surface thermistor (TDS202B) secured to the inside of the forearm, approximately 5cm below the elbow, using micro-porous tape. The signal was sampled at 31.205Hz and low pass filtered at 1Hz.

2.3.3.4. Facial Electromyography

In comparison to studies using FaceReader technology, (Danner et al., 2014a, 2014c, de Wijk et al., 2014, 2012; He et al., 2014) fEMG was chosen as a measure of facial expression owing to its high sensitivity to small muscle movements in comparison to less sensitive facial recognition tools (Boxtel, 2010) (see section 1.8.2). Following the results from previous research, muscle movements were recorded from the zygomatic major muscle (the muscle used to elevate the cheek when smiling) and the corrugator supercilli muscle (the muscle used to pull the brow down when frowning) (Boxtel, 2010; Larsen et al., 2003; Tan et al., 2011). Both muscles have been shown to be relevant in positive and negative emotion displays respectively (Dimberg et al., 2002).

Four reusable shielded electrodes, (EL245S, two placed adjacent above each site) filled with electrode gel (GEL100) were fixed to the skin above the two facial muscles of interest, the corrugator supercilli and the zygomatic major muscles. Prior to attaching the electrodes, the subject's skin was exfoliated using abrasive pads (ELPAD) to remove excess oil and dead skin from the site, providing a better connection between the electrode and skin. Both corrugator and zygomatic activity was recorded in millivolts (mV). Signals from both sites were sampled at 2,000Hz and high pass filtered at 500Hz and low pass filtered at 10Hz.

2.3.4. Self-reported Measures

Subjects self-reported their emotional response (valence and activation) and how intense and familiar the aroma smelt on four continuous line scales. Line scales were programmed in Compusense Cloud (Compusense, Ontario, Canada) and displayed on a 9.7 inch iPad tablet (Apple Inc, California, USA). Following the methodology of previous investigations, the four line scales were always presented in the same order: valence, activation, intensity and familiarity for each subject as well as after each aroma presentation (Bensafi et al., 2002a; Delplanque et al., 2009; Distel et al., 1999; He et al., 2014). Left and right scale extremes were set between 0 and 100 and anchors were placed at the two extremes of the scale, with an additional central anchor in the middle.

For both valence and activation subjects were asked to, "Please indicate on the scale below how unpleasant/deactivated or pleasant/activated this aroma made you feel." Line scales were anchored from very "unpleasant/very deactivated" to "very pleasant/activated" from the left to right respectively with a neutral anchor in the centre. Prior to answering the questions, subjects were instructed to answer based on how the aroma made them feel as opposed to how they were feeling in general.

Samples were presented at both high and low concentrations. Therefore to detect whether a difference in intensity could be perceived, subjects were asked to rate the intensity of the aroma; "Please indicate on the scale below how intense you perceive this aroma to be." Like previous investigations on

aroma which have utilised an intensity score, subjects were asked to score intensity from “not perceived” on the left to “very Intense” on the right with a “medium intensity” option in the centre of the scale (Delplanque et al., 2009). Furthermore in order to understand how familiarity may have impacted on the emotional scores, subjects were asked to rate how familiar the aroma smelt to them; “Please indicate on the scale below how unfamiliar or familiar this aroma smelt to you.” The scale was anchored from left to right with, “not at all familiar” to “very familiar” with “somewhat familiar” within the middle on the scale.

2.3.5. Experimental approach

Subjects attended two experimental sessions, held one week apart, each lasting approximately 1 hour and 15 minutes. Sessions took place in two adjacent rooms within the Sensory Science Centre at The University of Nottingham. Upon arrival, the lead experimenter explained the nature of the study and subjects were given the opportunity to ask any questions before giving their informed consent. After physiological and facial expression recording equipment had been secured to participants, they were seated in an upright position in front of a desk displaying an iPad screen in the experimental room. Once the subject was comfortable, the lead experimenter returned to the adjacent recording room where sample presentation and subject communication could occur via a head/shoulder level wall partition (Figure 2.2). All physiological and facial expression recordings were displayed on a laptop within the recording room which were only visible to the experimenter.

During the course of each session, subjects smelt the 10 beer samples, presented according to a balanced design. A trial consisted of presenting a single beer sample 1cm under the nose of the subject by the experimenter for 2 seconds. 200g of each sample was presented in clear crystal glass tumblers (height: 10cm) (John Lewis, London, UK). Subjects were instructed when to inhale and for how long via instructions displayed on their iPad tablet situated in front of them. On screen protocols are frequently used by researchers to deliver emotive stimuli and the protocol used in this study was developed from the experimental procedures reported on related studies using both aroma and consumption stimuli (Delplanque et al., 2009; Wijk et al., 2014). However the protocol was adapted for beer aroma samples by trialling and refining the procedure informally with colleagues prior to starting the pilot.

On-screen instructions told subjects to: a) "wait" and breath normally for 30 seconds, b) exhale gently for 2 seconds through their nose, c) inhale gently for 2 seconds through their nose and d) "wait" and breath normally for 30 seconds. Before the instruction "c" to inhale for 2 seconds, the beer sample was placed under the subject's nose so that the sample would be smelt for the duration of the entire 2 second inhale. The experimenter logged the respiration cycle associated with smelling each sample by pressing a hot key function on the laptop recording. After waiting for 30 seconds during instruction "d" subjects were permitted to e) smell the aroma again before f) being asked to answer sample valence, activation, familiarity and intensity questions on their iPad. There was an inter-trial interval of 120 seconds to prevent the sensory adaptation of subjects. Figure 2.3 provides a schematic

diagram of the evaluation process. All trial instructions and wait times were programed using Compusense Cloud. Four water samples were used as practice trials at the start of the study to allow subjects to become familiar with the protocol but this data was not included within the analysis.

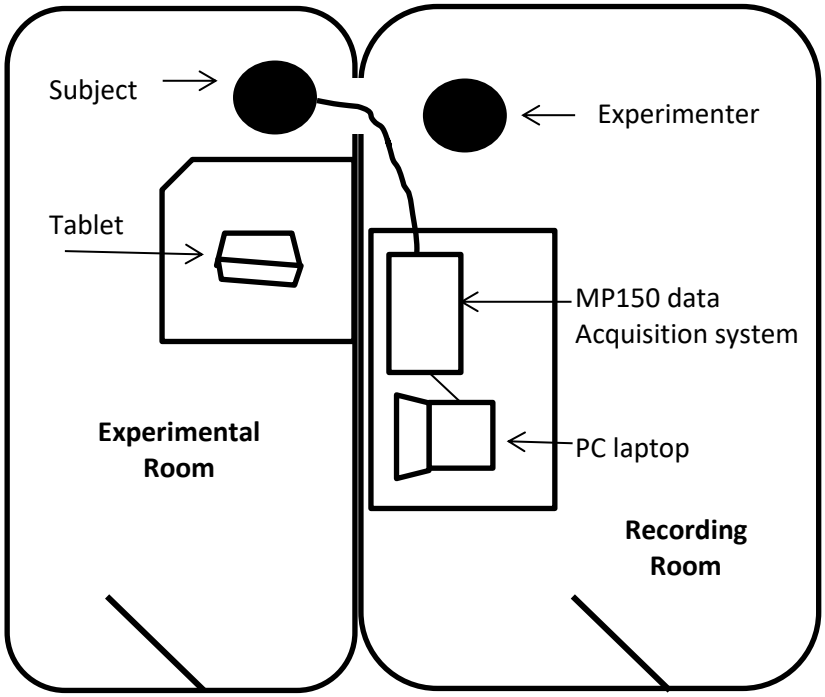


Figure 2.2. Schematic diagram of the experimental set up of both the experimental and recording rooms. This diagram is not to scale.

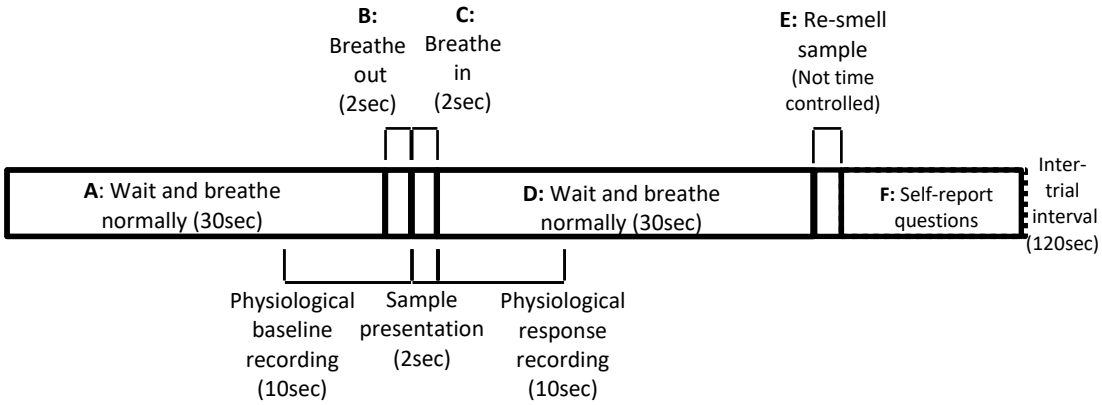


Figure 2.3. Schematic representation of instruction and physiological recording time frame used in pilot study. Instructions were presented in Compusense Cloud.

2.3.6. Data processing of physiological and facial expression variables

One of the objectives of the pilot study was to develop a suitable method in order to process the raw physiological and facial expression data. Figure 2.4 shows a screenshot of the physiological and facial expression measures prior to data processing. Details of the data processing techniques used is described in the following section below. The raw data from physiological and facial expression variables has to be processed in order to extract the necessary information from each measure. Data processing was conducted in three stages: a) the location of stimulus presentations within the recording identified, b) application of necessary post recording filters to remove erroneous noise from the data and c) extraction of key physiological parameters specific to each measure over a pre-determined time frame.

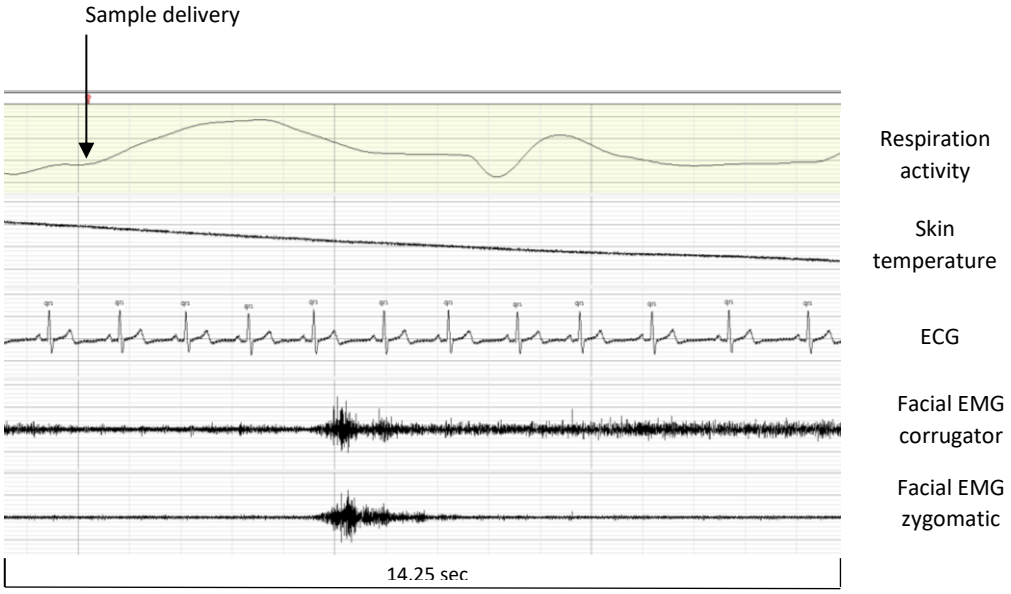


Figure 2.4. Annotated screen shot of physiological measures and facial expression measures prior to data processing.

These three processes were achieved using the analysis tools available in the Biopac data processing software 'Acqknowledge' (Biopac, Goleta, CA, USA). Due to the large variation in fEMG, skin temperature and heart rate values between subjects, mean response values were subtracted from each individual's baseline values to standardise the large differences between subjects (Gratton, 2007).

2.3.6.1. Respiratory parameters

Respiration recordings served as a useful marker for identifying when a subject smelt an aroma. The hot key markers placed when subjects smelt a sample were used to identify the respiration cycle associated with each sample. After data collection, these were inspected and the start of the target respiration cycles were identified. The deepest point of expiration prior to when the subject began to inhale was used as the corrected time of sample delivery. The corrected time of sample delivery was subsequently applied to other physiological and facial recording parameters to accurately represent the time of sample delivery.

2.3.6.2. Heart Rate

R waves (see section 1.7.2.2) in-between consecutive cardiac cycles were detected offline using an automatic analysis tool available in Acqknowledge ((Biopac, Goleta, CA, USA). Intervals between heartbeats were converted into heart rate, expressed as beats per minute (bpm). The mean heart rate during the 10 seconds before sample delivery served as a baseline. In order to identify the change in physiological activity in response to each sample, the

mean heart rate during the 10 seconds after sample delivery was subtracted from the baseline.

2.3.6.3. Skin Temperature

The average skin temperature 10 seconds before sample delivery served as the baseline. The average change in skin temperature 10 seconds after sample delivery was subtracted from the baseline in order to identify changes in mean skin temperature.

2.3.6.4. Changes in facial muscle activity

As the laboratory was not electrically shielded, an additional comb band 50hz filter was used to remove electrical noise from the recording. The waveform was smoothed and rectified using a root mean square transformation with a 500ms time constant. The mean amplitude of transformed EMG values during the 10 seconds before stimulus presentation served as a baseline. The mean EMG baseline values during the 10 seconds before sample delivery was then subtracted from response values.

2.4. Statistical analysis

To investigate the effect of aroma, aroma concentration and session had on implicit and explicit measures, separate analyses were carried out for each physiological, facial expression measures and self-reported measures using mixed model analysis of variance (ANOVA). All statistical analyses were performed in XLSTAT (v2015.6, Addinsoft, USA).

Aroma, session and aroma x session interaction were included as fixed factors whilst subject was included as a random factor. For each aroma (Isoamyl

acetate, Lighstruck, Hoppy A and Hoppy B), three different levels (control, low and high) were tested in the mixed model ANOVAs. Where a significant main effect was found for sample, session or interaction effects, Tukey HSD tests were conducted in order to identify significant comparisons ($p < 0.05$). Significant effects of subject are common when assessing self-report and physiological data which is due to the differences in scale use and large differences in how individual's respond physically to stimuli (Næs and Langsrud, 1998). Consequently large main effects from assessors were expected and will not be reported beyond the main effects throughout this thesis.

Individual scores collected from self-report and physiological/facial expression variables were subjected to a Persons Correlation Analysis in order to understand the relation between physiological/facial expressions and self-report measures as well as the relation between the implicit and explicit measures themselves.

Mean scores for each aroma were used to conduct a Principal Component Analysis (PCA) in order to investigate similarities/differences amongst aromas in terms of the response pattern across physiological/facial expression and self-report variables. Only self-report and physiological/ facial expression variables found to be significant within the univariate analysis were used as active variables with the PCA. Non-significant terms were included as supplementary variables.

2.5. Results

The following section presents the results concerning:

- The capability of physiological and facial expression measures to distinguish between Control and spiked beer samples and whether these variables could distinguish between high and low aroma concentrations.
- The capability of self-report measures to distinguish between Control and spiked beer samples and whether these variables could distinguish between high and low aroma concentrations.
- Effects of session on physiological/facial expression and self-report measures.
- Comparison of physiological/facial expression measures with self-report measures.

The mean scores obtained from heart rate, skin temperature, corrugator and zygomatic scores as well as self-reported responses in response to control and high/low concentrations of each aroma are displayed in Table 2.4. The p-values of main effects and interactions from the mixed model ANOVA can be found in Table 2.5.

Table 2.4. Mean values for physiological, facial expression and self-report measures for aroma type and concentration. Corrected for baseline. HR = heart rate, ST = skin temperature, bpm = beats per minute.

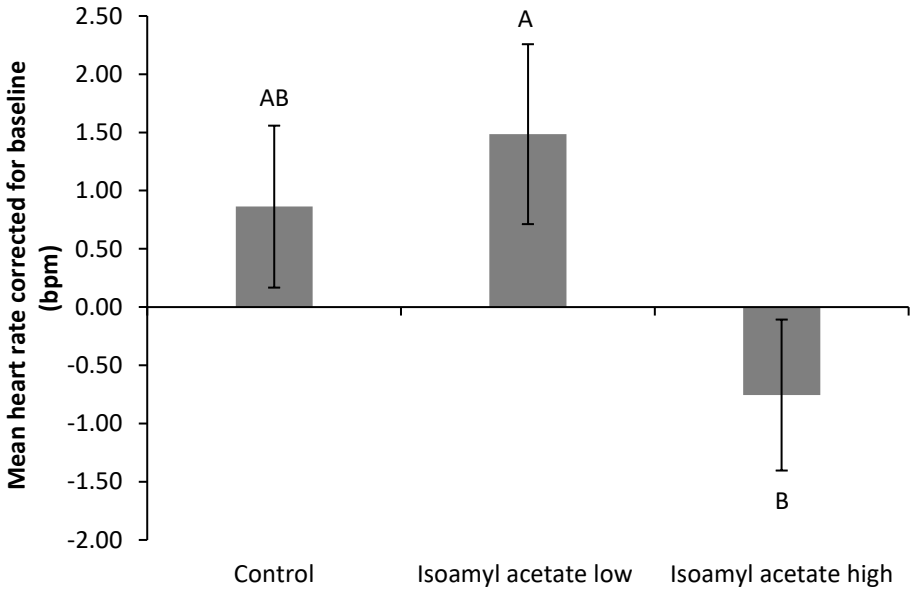
Aroma	Aroma level	Physiological measures		Facial expression measures		Self-report recordings			
		HR (bpm)	ST (˚C) (x1000)	Corrugator supercilli (mV) (x10000)	Zygomatic major (mV) (x10000)	Valence	Activation	Intensity	Familiarity
Isoamyl acetate	Control	0.86	-5.11	4.04	7.52	55.84	51.38	48.49	56.35
	Low	1.49	-8.01	5.08	4.69	64.32	64.47	52.61	55.07
	High	-0.76	-1.83	3.58	-1.22	68.77	65.07	58.99	56.82
Lightstruck	Control	0.86	-5.11	4.04	7.52	55.84	51.38	48.49	56.35
	Low	1.60	-3.14	1.47	15.64	60.81	57.73	57.93	76.11
	High	1.66	-5.43	4.91	22.62	64.89	59.19	52.86	75.82
Hoppy A	Control	0.86	-5.11	4.04	7.52	55.84	51.38	48.49	56.35
	Low	0.06	-4.06	7.03	7.25	58.03	61.78	58.39	52.90
	High	0.74	-5.64	6.95	6.45	59.91	67.98	65.33	51.39
Hoppy B	Control	0.86	-5.11	4.04	7.52	55.84	51.38	48.49	56.35
	Low	1.01	-2.18	4.28	8.57	64.22	56.04	61.20	55.06
	High	1.73	-3.58	3.46	14.57	60.39	56.67	60.49	52.98

Table 2.5. Statistical output and P-values from mixed model ANOVA carried out on physiological, facial expression and self-report measures. Subject was included as a random factor and Session, Aroma and Session x Aroma interaction were included as fixed factors. (p-values in bold indicate significant effect at 0.05 level of significance). DF = degrees of freedom, F = F statistic, P = p-value.

			Physiological measures				Facial expression measures				Self-report measures							
			Heart rate		Skin temperature		Corrugator supercilli activity		Zygomatic major		Valence		Activation		Intensity		Familiarity	
Aroma	Factor	D.F.	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Isoamyl acetate	Subject	8	7.493	**< 0.0001**	2.355	**0.029**	4.722	**0.0001**	1.233	0.297	1.849	0.086	2.157	**0.044**	6.413	**< 0.0001**	4.964	**0.0001**
	Session	1	0.580	0.449	0.309	0.580	0.380	0.540	6.675	**0.012**	3.157	0.081	0.152	0.698	0.297	0.588	0.654	0.422
	Aroma	2	3.235	**0.047**	1.298	0.281	0.139	0.871	0.630	0.536	3.413	**0.040**	7.185	**0.002**	2.677	0.077	0.039	0.961
	Session x aroma	2	0.875	0.422	0.262	0.770	1.729	0.187	1.535	0.224	0.208	0.813	0.325	0.724	0.727	0.488	0.018	0.982
Lightstruck	Subject	8	5.268	**< 0.0001**	2.932	**0.008**	3.777	**0.001**	1.996	0.063	2.150	**0.045**	2.307	**0.032**	4.227	**0.0001**	5.435	**< 0.0001**
	Session	1	0.152	0.698	0.204	0.654	2.064	0.156	1.166	0.285	0.076	0.784	0.607	0.439	0.643	0.426	0.404	0.528
	Aroma	2	0.442	0.645	0.391	0.678	0.710	0.496	1.464	0.240	1.504	0.231	1.978	0.148	2.157	0.125	12.470	**< 0.0001**
	Session x aroma	2	0.106	0.900	0.054	0.948	0.046	0.955	0.773	0.466	0.869	0.425	0.022	0.978	0.015	0.985	0.097	0.908
Hoppy A	Subject	8	7.427	**< 0.0001**	2.217	**0.039**	8.277	**< 0.0001**	2.667	**0.014**	4.673	**0.0001**	3.302	**0.004**	5.420	**< 0.0001**	2.502	**0.021**
	Session	1	0.005	0.943	0.904	0.346	0.098	0.755	1.053	0.309	0.027	0.870	0.897	0.348	3.783	0.057	0.243	0.624
	Aroma	2	0.433	0.651	0.140	0.870	0.680	0.511	0.024	0.976	2.786	0.070	8.270	**0.001**	6.185	**0.004**	0.393	0.677
	Session x aroma	2	0.048	0.953	0.673	0.514	0.307	0.737	0.251	0.778	0.767	0.469	0.002	0.998	0.859	0.429	0.833	0.440
Hoppy B	Subject	8	6.857	**< 0.0001**	0.668	0.717	4.227	**0.0001**	2.945	**0.008**	4.910	**0.0001**	1.071	0.396	3.641	**0.002**	1.940	0.071
	Session	1	0.303	0.584	0.044	0.834	0.287	0.594	0.134	0.715	4.992	**0.029**	1.026	0.315	0.750	0.390	0.743	0.392
	Aroma	2	0.425	0.656	0.312	0.734	0.040	0.961	0.383	0.683	1.706	0.191	0.786	0.461	4.403	**0.017**	0.166	0.847
	Session x aroma	2	0.209	0.812	1.077	0.347	1.092	0.342	0.063	0.939	0.127	0.881	0.173	0.841	0.016	0.984	0.209	0.812

2.5.1. Physiological and facial expression variables

Analysis of physiological and facial expression variables revealed that there was only a significant change in heart rate in response to Isoamyl acetate samples. Post hoc analysis of heart rate scores for Isoamyl acetate revealed that heart rate decreased in response to smelling the higher compared to the lower concentration of Isoamyl acetate but there was no significant difference in heart rate between Control and Isoamyl acetate samples (Figure 2.5). No other significant effects were found in response to any of the other physiological or facial expression variables.



2.5.2. Self-reported variables

The mixed model ANOVA revealed significant main effects of valence and activation for Isoamyl acetate, familiarity for Lightstruck, activation and intensity for Hoppy A samples and intensity ratings for Hoppy B samples. Post

hoc analysis for Isoamyl acetate samples found that subjects rated the Isoamyl acetate high sample significantly more pleasant than the Control sample but additionally found both Isoamyl acetate samples more activating than the Control (Figure 2.6).

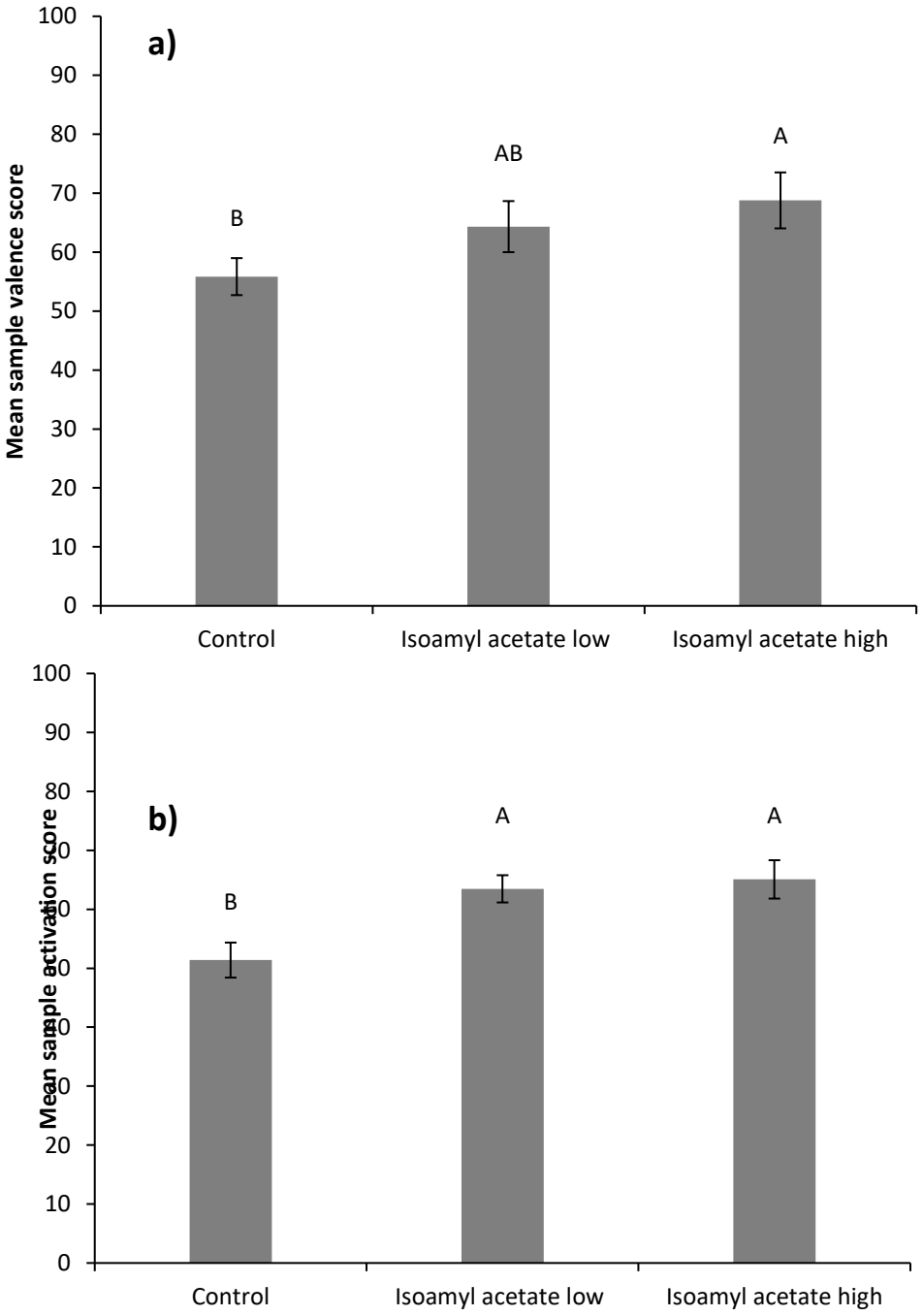


Figure 2.6. a) Effect of aroma on mean valence scores given to Control, Isoamyl acetate low and high samples. b) Effect of aroma on mean. Activation scores given to Control, Isoamyl acetate low and high samples. Different letters indicate significant differences ($p < 0.05$) between samples. Error bars represent standard error of the mean.

Post hoc analysis of Lightstruck samples additionally revealed that both high and low concentrations of Lightstruck samples were found to be significantly more familiar than the control sample (Figure 2.7).

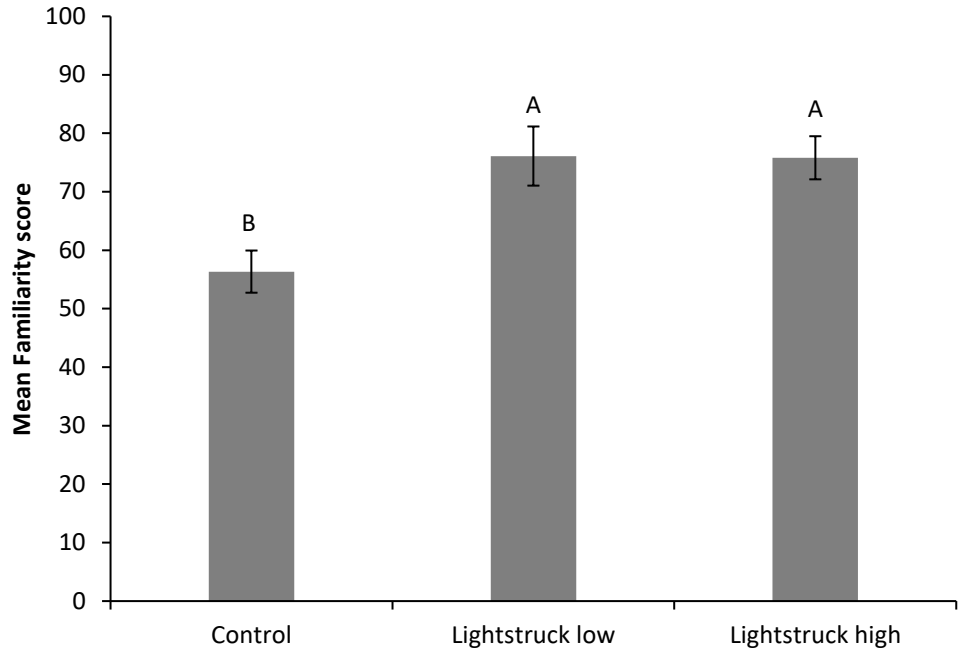


Figure 2.7. Effect of aroma on Familiarity scores for Control and Lightstruck low and high samples. Different letters indicate significant differences ($p < 0.05$) between samples. Error bars represent standard error of the mean.

Turning to the post hoc analysis of the hop based samples, both concentrations of Hoppy A were found to be more activating than the Control sample. In contrast, only the highest concentration of Hoppy A was significantly more intense than the Control aroma (Figure 2.8). Interestingly the lower concertation of Hoppy B was found to be significantly more intense than the Control sample, despite no differences between the two Hoppy samples or the higher concentration of Hoppy B being found (Figure 2.9).

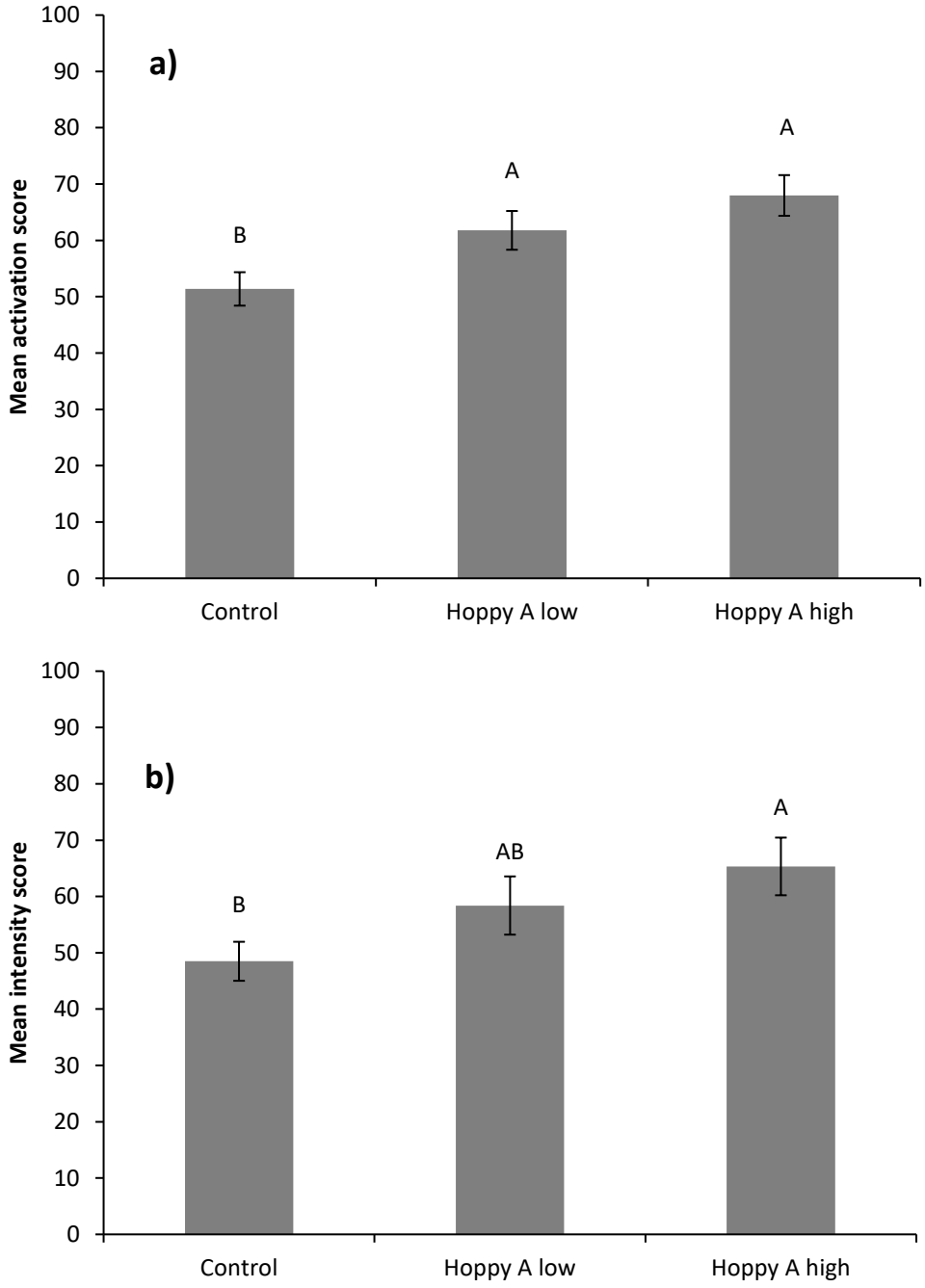


Figure 2.8. a) Effect of aroma on mean activation scores in response to smelling Control, Hoppy A acetate low and high samples. b) Effect of aroma on Intensity scores towards Control, Hoppy A low and high samples. Different letters indicate significant differences ($p < 0.05$) between samples. Error bars represent standard error of the mean.

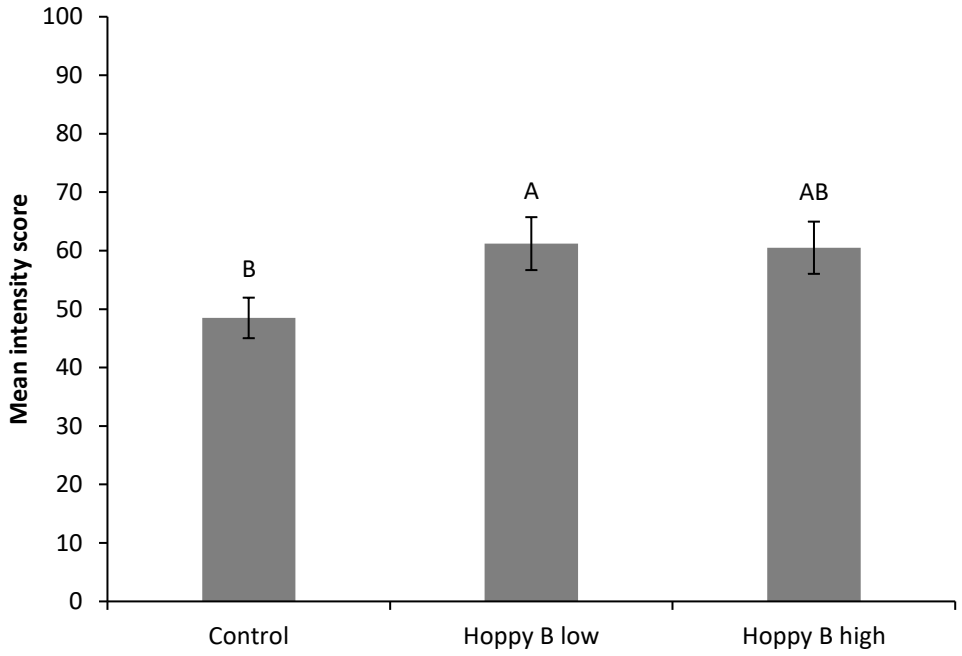


Figure 2.9. a) Effect of aroma on mean intensity scores given to Control, Hoppy B low and high samples. Different letters indicate significant differences ($p < 0.05$) between samples. Error bars represent standard error of the mean.

2.5.3. Effects of session

There was no significant effect of session in general (Table 2.5) apart from some minor exceptions. Significantly lower zygomatic activity was observed towards Isoamyl acetate within the first compared to the second session (Figure 2.10a). Furthermore higher valence scores were observed in session 1 compared to session 2 for Hoppy B samples (Figure 2.10b).

2.5.4. Correlation analysis

In order to assess the relationship between physiological, facial expression and self-report measures, Pearson's Product Moment Correlations were computed and significance tests were performed (Table 2.6). High positive correlations (> 0.5) with a strong significance ($p < 0.01$) were observed between activation and valence ratings. Significant moderate positive

correlations were observed between heart rate and zygomatic activity, corrugator activity and zygomatic activity, activation and intensity ratings, as well as a significant moderate negative correlation between valence and corrugator activity. All other significant correlations between variables were between $0.1 < |r| < 0.3$ and deemed to be small linear relationships.

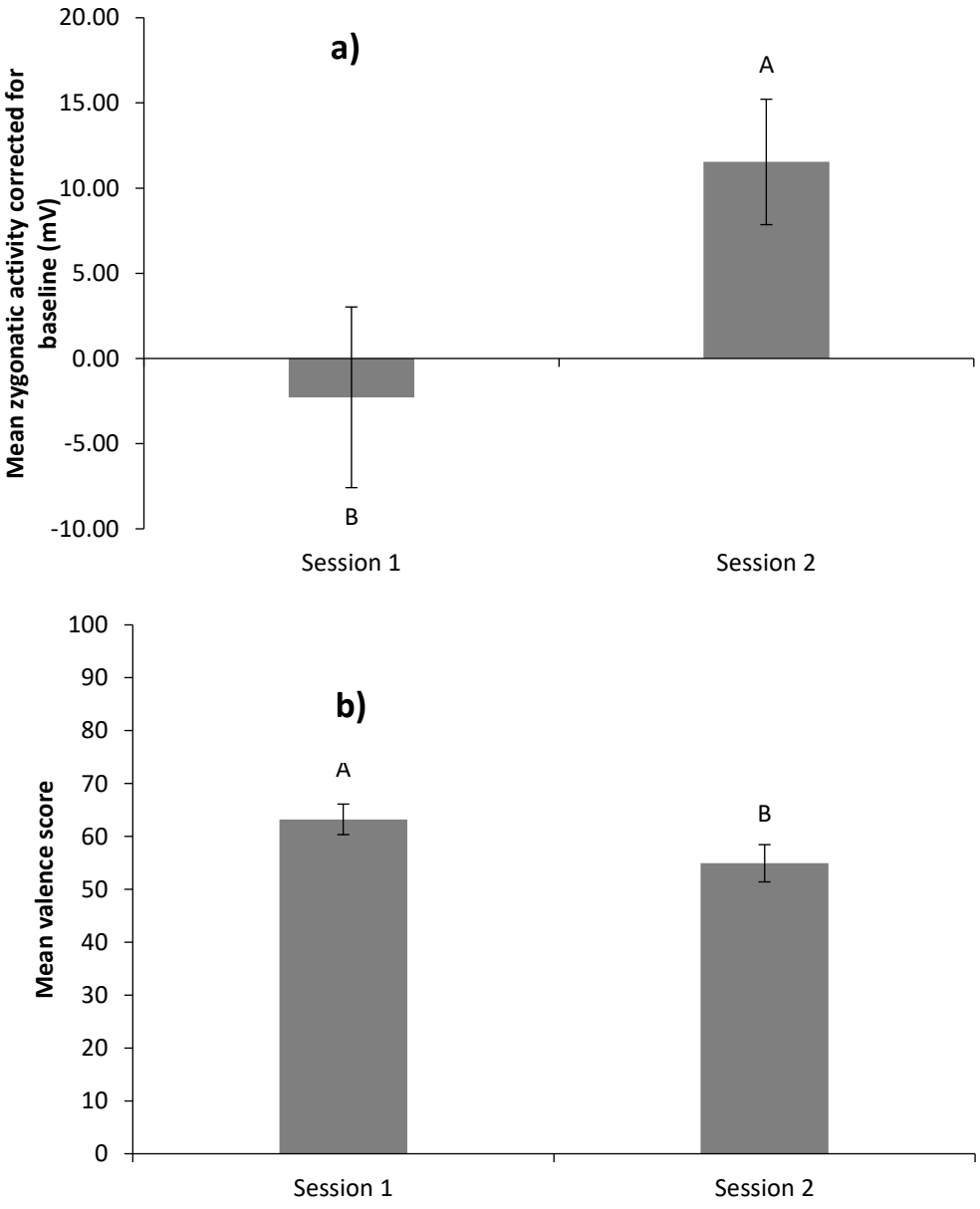


Figure 2.10. Effect of session on a) Isoamyl acetate zygomatic major activity and b) Hoppy B valence ratings. Different letters indicate significant differences ($p < 0.05$) between sessions. Error bars represent standard error of the mean.

Figure 2.6. Pearson Product Moment correlation coefficients between physiological, facial expression and self-report measures. (Statistically significant correlations are highlighted in bold. * denotes significance at p < 0.05, and ** p < 0.01 levels).

Variable	Heart rate	Corrugator activity	Zygomatic activity	Skin temperature	Valence	Activation	Intensity	Familiarity
Heart rate	1	**0.176***	**0.436****	0.027	-0.049	0.083	**0.242****	**0.229****
Corrugator activity	**0.176***	1	**0.376****	0.144	**-0.300****	-0.006	-0.101	-0.025
Zygomatic activity	**0.436****	**0.376****	1	0.081	-0.028	0.094	0.066	0.057
Skin temperature	0.027	0.144	0.081	1	**0.154***	**0.251****	0.063	**0.252****
Valence	-0.049	**-0.300****	-0.028	**0.154***	1	**0.507****	**0.182***	**0.147***
Activation	0.083	-0.006	0.094	**0.251****	**0.507****	1	**0.311****	**0.256****
Intensity	**0.242****	-0.101	0.066	0.063	**0.182***	**0.311****	1	**0.150***
Familiarity	**0.229****	-0.025	0.057	**0.252****	**0.147***	**0.256****	**0.150***	1

2.5.5. Principal Component Analysis

A Principal Component Analysis (PCA) was run on the self-reported measures of valence, activation, intensity and familiarity. Heart rate was also included as an additional variable as aroma was found to have a significant effect on heart rate within the univariate analysis. Skin temperature, corrugator activity and zygomatic activity was only included as supplementary variables within the PCA because these variables had no significant effect on aroma within the univariate analysis. As supplementary variables, they did not contribute to the PCA solution but were projected onto the results.

The first two principal components (PC) explained 67.86% of the total variance with 42.54% explained by PC1 and 25.32% explained by PC2. Inspection of the PCA correlation circle (Figure 2.11) revealed that Activation and intensity ratings were highly correlated (0.82 and 0.70 respectively) with PC1 whilst heart rate had a negative correlation with PC1 (- 0.70). In comparison, valence (0.80) and familiarity (0.72) ratings were positively correlated with PC2. Therefore PC1 could be best described by the activation dimension of emotion, whilst PC2 was better described by how pleasant and familiar a sample was. Examination of the observations (Figure 2.12) and their projection onto PC1 and PC2 showed that Lightstruck samples, Isoamyl acetate High and Control samples loaded well onto both PC1 and PC2. The Control sample was therefore described by its lower values of activation, valence and intensity ratings whilst Isoamly acetate high was better described by its high valence and activation. The Lightstruck samples had the highest familiarity ratings and mean/low intensity however were principally best

described by high pleasantness and familiarity ratings. The Isoamyl acetate low, Hoppy A low as well as Hoppy B low and high did not load particularly well onto PC1 or PC2 but this is not surprising considering their they did not score highly in any of the self-report categories.

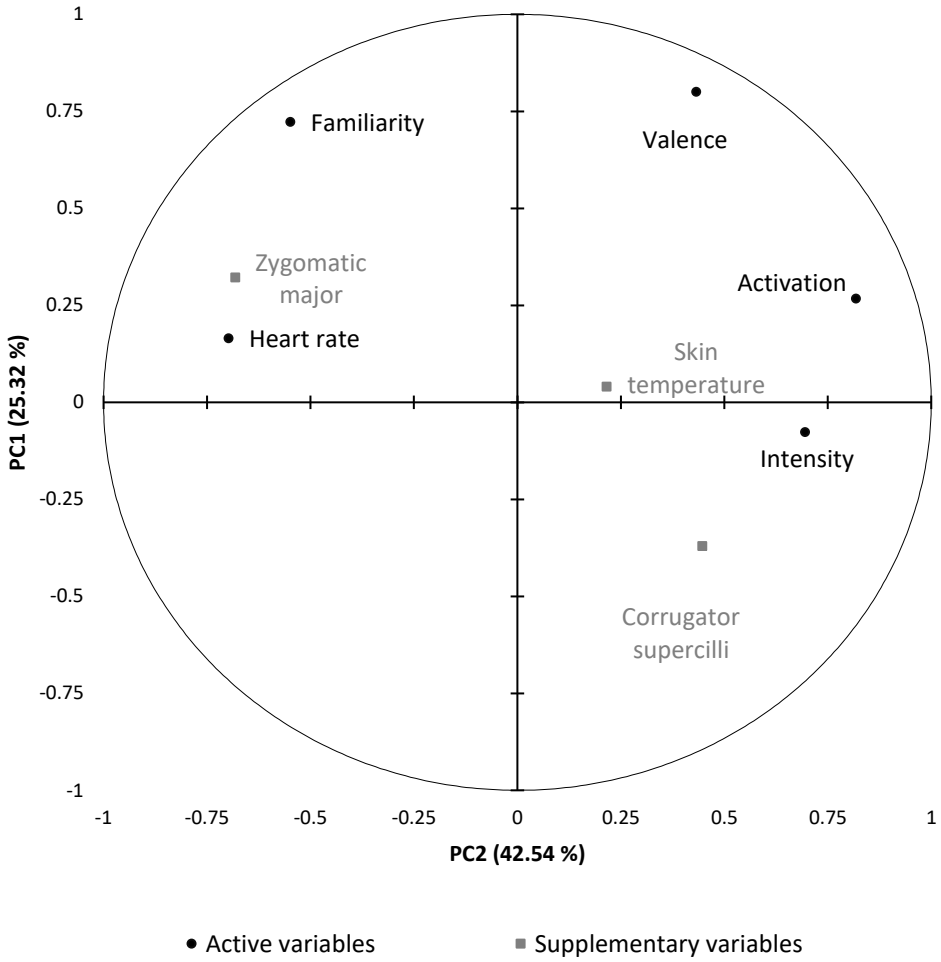


Figure 2.11. Correlation circle for PC1 and PC2. Active variables only included variables found to be significantly different in the univariate analysis. Non-significant variables from univariate analysis were included as supplementary variables.

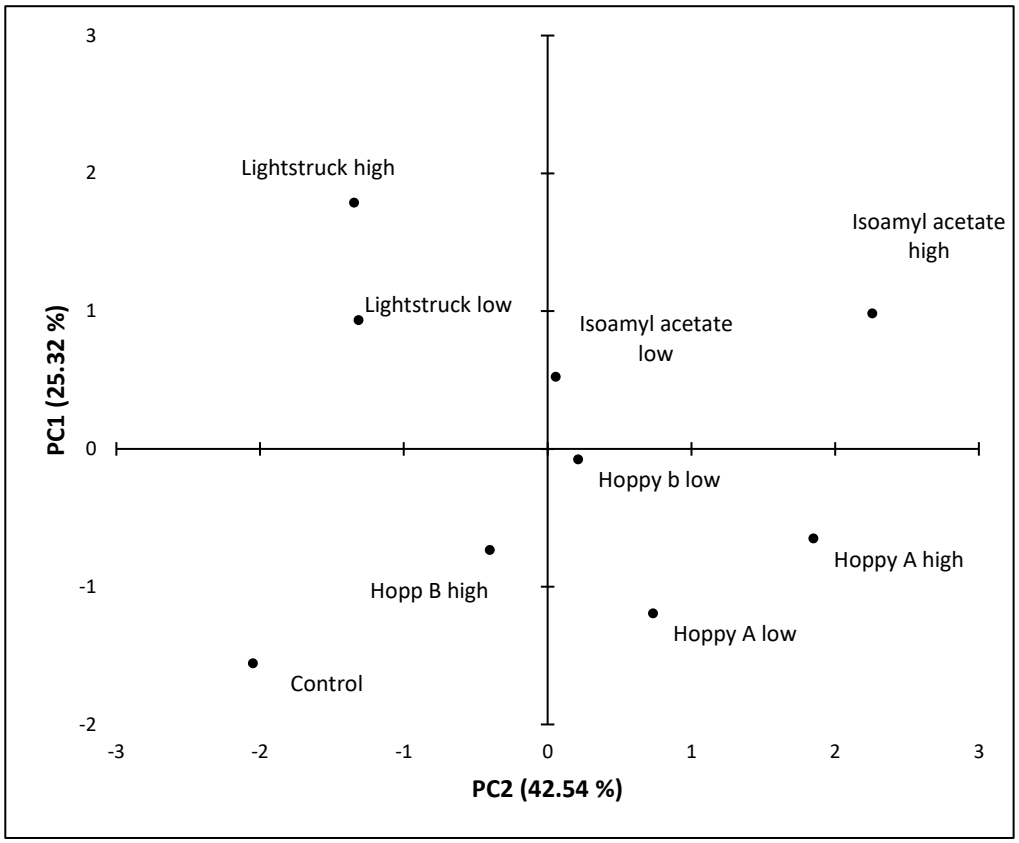


Figure 2.12. Observation plot showing beer samples in relation to PC1 and PC2.

2.6. Discussion of pilot investigation findings

2.6.1. Aroma evoked emotional response

The first objective of this pilot investigation was to validate whether a chosen set of beer aromas were sufficient to evoke an emotional response in subjects. With regards to physiological and facial expression measurements, the results of the mixed model ANOVA revealed that heart rate could successfully distinguish between Isoamyl acetate samples. However heart rate, skin temperature and facial expression responses did not change significantly in response to any other aroma. Evidently aside from heart rate, physiological and facial expression measures poorly discriminated between samples.

With regards to emotional response ratings, Isoamyl acetate and Hoppy A could be discriminated from the Control on the basis of activation and/or valence and consequently distinguished from the Control on the basis of emotional response. Furthermore despite not finding a significant effect of valence or activation on Hoppy B or Lightstruck samples, these samples could be distinguished from the Control on the basis of aroma intensity and familiarity respectively. Consequently self-report was successful in discriminating between spiked and non-spiked samples.

Alongside determining whether the chosen set of aromas could evoke an emotional response, this pilot study also aimed to determine whether the high or low concentrations of respective aromas should be used for the main study. With regards to Isoamyl acetate, both low and high samples were significantly more activating than the Control aroma. However a significant decrease in heart rate was recorded between low to high Isoamyl acetate samples and valence scores increased significantly between the Control and high sample. Consequently it was deemed sensible to include only the high concentration of Isoamyl acetate within the main study. Concerning Hoppy A samples, although both high and low concentrations received activation ratings higher than the Control sample it was decided to include the higher concentration of Hoppy A to ensure that the main sample set included a highly activating aroma. It was decided to only include the lower concentration of Lightstruck as both samples were equally highly familiar, which can most likely be attributed to the fact that Lightstruck has a low threshold level within the population (Cardoso and Olsen, 2006). Although

Lightstruck did not elicit changes in ratings of activation and valence, familiarity has been considered as an important aspect of emotional response towards aroma (Chrea et al., 2009; Porcherot et al., 2010) as well as beer (Chaya et al., 2015a; Sester et al., 2013a) and for this reason it was considered important to include Lightstruck within the final sample set. As only a number of samples could be included within the main investigation due to sample expenses, it was decided to not include Hoppy B within the final sample set because it only influenced ratings of aroma intensity.

Concerning an effect of session, it was noted that zygomatic activity and valence ratings showed a significant difference between test days, indicating a significant session effect. It was decided that both implicit and explicit responses should be explored further with regards to effects between sessions as well as effects within session replicates. This would further help to confirm whether replicate measurements should be made within the same or separate sessions.

2.6.2. Comparison between implicit and explicit measures of emotion

Inspection of the PCA analysis revealed that the samples were principally classified according to their relative intensity and activation along PC1 as well as their familiarity and pleasantness along PC2. These results were broadly in alignment with circumplex models of emotion (Section 1.2.2) (Larsen and Diener, 1992; Russell, 2003; Watson and Tellegen, 1985) which state that emotional response can be principally defined by their relative valence and

activation. Indeed within the present study, familiarity had a comparable influence to valence ratings which was primarily influenced by the high familiarity ratings given to the Lightstruck sample. Finding that Lightstruck evokes high feelings of familiarity is not unique to this investigation and has been previously been reported when assessing emotional response towards beer (Chaya et al., 2015a). However the strong influence of familiarity with the PCA highlights that feelings beyond valence and activation may need to be considered when assessing emotional response towards consumption products.

Studies which have only assessed explicit as opposed to a combination of explicit and implicit responses towards food and beverage products have included a wide range of emotional terms. For example, the non-product specific EsSense profile contains 39 emotion terms (King and Meiselman, 2010) whilst product specific lexicons such as EmoSemio for chocolate spreads (Spinelli et al., 2014) and a consumer defined check-all-that-apply lexicon for blackcurrant squash (Ng et al., 2013) have found the inclusion of 23 and 36 respective terms necessary and relevant for the discrimination of samples within a product category. More recently, a consumer-led emotion lexicon developed specific to beer has been developed which employs the use of nine emotion categories (Eaton, 2015). This investigation not only has a high relevance to the present study but also used similar flavour compounds, allowing clear comparisons with the present study to be made. As previous investigations have shown emotions show an increased capability to discriminate between samples (Ng et al., 2013; Spinelli et al., 2014), it was

recommended that an emotion lexicon should be employed in the larger main investigation. However such a lexicon needed to be validated as to its appropriateness to assess beer aroma as well as being assessed alongside implicit measures.

Turning to the results from the mixed model ANOVA, comparisons of post hoc groupings for Isoamyl acetate revealed the high concentration sample was rated as significantly more pleasant and activating compared to the Control sample and resulted in a decrease in heart rate in comparison to low concentrations. This suggests that heart rate was responding to the valence and/or activation dimension of emotion. This corroborates similar findings on olfactory stimuli, where heart rate has been found to decrease with relative pleasantness of an aroma (Bensafi et al., 2002a; Brauchli et al., 1995). Furthermore, given that no change in heart rate was found for Hoppy A, which also received high ratings within the activation dimension, it is likely that heart rate was responding to the valence dimension of emotion.

Failure to find a significant difference in any of the other physiological and facial expression variables may reside in the fact that samples were too similar in their rated valence. Inspection of the mean valence values for each aroma reveals that the Hoppy A high sample had the highest mean valence whilst the Control sample had the lowest mean valence score (however large standard deviations in Hoppy A mean valence scores resulted in a non-significant comparison when compared with the Control). Evidently the Control, as the most unpleasant sample, did not receive an average rating below 50 on a 100

point scale. Previous studies that have reported significant differences in physiological activity between odours have mainly done so between pleasant and unpleasant samples (Bensafi et al., 2002a, 2002c; Brauchli et al., 1995; He et al., 2014; Pichon et al., 2015). In contrast studies that have used products which have been rated similar in pleasantness or liking have failed to find significant differences in heart rate, skin temperature or facial muscle activity (Danner et al., 2014a; de Wijk et al., 2012; Pichon et al., 2015) suggesting that samples must have opposing valence scores in order to elicit detectible changes in physiology. Indeed whilst high levels of Isoamyl acetate and Lightstruck are considered undesirable by brewers, (Stephenson and Bamforth, 2002; Thomas, 2006) it is clear that within the present sample set the subjects did not associate them with unpleasant experiences. Therefore as physiological measures appear to be more sensitive to unpleasant compared to pleasant stimuli, it is recommended that additional fermentation derived unpleasant odours such as mercaptan (methanethiol) and hydrogen sulphide (Hawthorne et al., 1991) should be included in the main investigation in order to provide better discrimination between samples.

2.6.3. Correlations between physiological, facial expression and self-report measures

Owing to the fact that samples were generally perceived as pleasant within this study, it is not surprising that there was no correlation between heart rate and valence scores. In comparison there was a moderate negative correlation between valence scores and corrugator activity, with greater corrugator activity observed in response to decreasing unpleasantness of a sample.

Previous research has found corrugator activity is associated with emotional displays of displeasure (Dimberg, 1990; Dimberg et al., 2002; Dimberg and Thunberg, 1989). Therefore despite the finding that no overall difference in corrugator activity between samples, a significant negative correlation suggests that facial activity is sensitive enough to the valence of an aroma that an association can even be found between relatively pleasant samples. In contrast there was no association between zygomatic activity and valence, despite evidence that zygomatic activity is a good indicator of positive displays of emotion (Larsen and Norris, 2009). However Delplanque et al (2009) also failed to find a relationship between valence and zygomatic activity within a larger study involving a combination of pleasant and unpleasant stimuli. Indeed research from facial coding studies have also revealed that the number of facial expressions to unpleasant odours are twice as many to those recorded for pleasant odours (Gilbert et al., 1987) and have also reported that expressions towards pleasant odours are less intense than those recorded in response to unpleasant odours (Steiner, 1979). Indeed there was a small positive correlation between corrugator and zygomatic scores and it is possible that smelling beer samples caused an increase in general muscle tension (due to subject concentration) or that subjects were performing facial movements unrelated to emotional response (such as swallowing) (Dimberg, 1990).

2.6.4. Correlations between self-report measures

One interesting association observed within the present study was the strong positive correlation between valence and activation ratings which resulted in

aromas becoming more activating the more pleasant they were perceived to be. The simultaneous recording of valence and activation ratings is rarely performed when assessing emotional response towards aroma. In the few studies that have recorded affective response on both dimensions, Bensafi et al (2002a) found that there was no correlation between valence and activation scores to a set of pleasant and unpleasant aromas. Nevertheless, studies utilising picture stimuli have observed that activation is a V shaped function of valence, with activation increasing in response to both pleasant and unpleasant pictures (Lang et al., 1993). More recently a critical review which included empirical and statistical testing of the relation between both dimensions concluded that activation does have a moderate V shaped relationship to valence (Kuppens et al., 2013). Indeed the lack of a correlation previously observed within aroma stimuli may reside in the fact that a V shaped relation exists but requires separate correlations to be computed for both pleasant and unpleasant aromas (Bensafi et al., 2002a). Visual observation of the scatter plot between individual's respective valence and activation scores within the present study showed only a positive monotonic relationship between valence and activation (data not shown). However as mean scores for samples suggested that all samples were generally well liked, it is likely that the full V shaped relationship would not be observable within this study.

Results within the Bensafi et al, (2002a) study highlighted a very strong positive correlation ($r = 0.986$) between odour activation and intensity ratings, despite not manipulating the concentration of each aroma used. Indeed

within olfactory research there is a preference to use intensity as an alternative to the arousal dimension (Winston et al., 2005) however there is a lack of consistency between studies as to whether aroma intensity is manipulated via a concentration dependant manner (Anderson et al., 2003; He et al., 2014; Winston et al., 2005; Zatorre et al., 2000) or is treated as just the inherent property of a stimulus (Bensafi et al., 2002a, 2002c; Delplanque et al., 2009; Distel et al., 1999). Within the present study, there was a moderate positive correlation between activation and intensity ($r = 0.311$), therefore whilst intensity scores increased with activation, the relationship was not strong enough (i.e. $r = >0.5$) to declare that intensity should be used as an alternative to activation with the present sample set. Indeed this conclusion concurs with empirical work conducted by emotion theorists who argue that mean correlation scores of $r = 0.21$ is not large enough to conclude that the activation and intensity represent the same dimension (Feldman Barrett and Russell, 1999). Previous research has also demonstrated intensity ratings can be influenced by the familiarity and pleasantness of an odour, with intensity scores increasing with sample familiarity or pleasantness (Distel et al., 1999). Concurrently, both intensity and activation scores were found to have a positive association with both pleasantness and familiarity but the strength of association was stronger for activation compared to intensity scores, further suggesting a disassociation between these scores within the present sample set.

2.6.5. Experimental protocol

The second major objective of this study was to develop an experimental protocol which would allow subjects to smell beer aromas whilst recording artefact free physiological and facial expression data. Subjects were required to "breathe out" for two seconds before being asked to "breathe in" for two seconds in order to smell an aroma. The two second exhale phase permitted adequate time for the experimenter to position the sample under the nose of the participant and discussion with subjects after the study confirmed that two seconds was a comfortable length of time for both inspiration and expiration.

A 30 second "wait" period was included before and after aroma presentation to reduce movement artefacts in recordings. This was useful as it alerted subjects to remain still when whilst target data was collected. However this wait period was reduced to 20 seconds for the main study as only 10 seconds of baseline and response data was required during this time and would also increase subject comfort. Indeed, although subjects largely remained still during this time frame, small movements caused significant movement artefacts in ECG recordings. Consequently it was recommended to further explore alternative ECG electrode configurations to reduce movement artefacts in the main investigation.

The pilot also allowed an opportunity to gain a further understanding of the data processing required for both physiological and facial expression responses. A 10 second period was chosen for both baseline and response

measurements and was based on the parameters used in previous investigations (Glass et al., 2014). However it was decided that exploratory analysis should be conducted on a subset of subjects (e.g. 10 random subjects) in the main investigation to find the most appropriate time periods for each measurement. This was not explored within the pilot due to time constraints but confirming the most appropriate time frames for each measurement could increase the discrimination ability of physiological/facial expression measurements. Indeed it is likely that the sensitivity of the EMG activity was limited over a 10 second period, especially when this measure is most readily recorded during the first few seconds of a response (Delplanque et al., 2009; Larsen et al., 2003; Liao et al., 2015; Pichon et al., 2015). Furthermore facial EMG muscle specificity needed to be further examined to ensure that muscle recordings were made from the target muscle and not receiving too much cross talk from non-target muscles (Cram et al., 2011).

2.7. Pilot study conclusions

There was sufficient evidence to confirm that beer aroma could evoke significant changes in physiological, facial expression and self-reported emotion. In particular heart rate was found to decrease in response to Isoamyl acetate and valence and activation scores increased for both Hoppy A and Isoamyl acetate samples. Furthermore there was a negative correlation between corrugator and valence scores. However it was suggested that the inclusion of a self-reported emotional lexicon may improve discrimination ability of self-report ratings. Following on from the results obtained towards individual aromas, Isoamyl acetate and Hoppy A high as well as Lightstruck

low were chosen to be used within the main investigation. However as samples were all very pleasant in this pilot investigation, it was also decided to include a selection of both pleasant and unpleasant samples. Furthermore there was evidence that self-report and physiological/facial expression responses were significantly affected by sessions held on different days. It was therefore decided that day and within session replicate effects should be explored further before proceeding with a final design for the main investigation. Finally the experimental protocol and data processing techniques were deemed to be sufficient but a number of suggestions for improvements were made for the main study.

Chapter two, part two: Validation Study

2.8. Introduction

Self-reported valence scores from the pilot investigation demonstrated that a greater range of both pleasant and unpleasant aromas should be included, with the expectation that observable changes in physiological and facial expression responses would more likely to be observed between pleasant and unpleasant samples. Furthermore whilst valence and activation were an appropriate starting point for this thesis, they were insufficient to describe the potential range of emotional responses towards aromas in beer. Consequently the inclusion of an emotional lexicon was deemed sensible as the next appropriate step for assessing self-reported emotional response. Finally it was deemed necessary to validate the variability in self-reported emotional and physiological/facial expression responses both within session replications and between sessions when held on different days. This was to determine how many replications and thus sessions should be included for the main investigation.

2.8.1. Selecting an emotional lexicon

A major focus of studies investigating physiological response towards sensory stimuli has been on understanding how changes in heart rate, skin temperature or facial expression are related to the affective properties (such as valence) of a stimulus (Bensafi et al., 2002a; Delplanque et al., 2009; He et al., 2014; Horio, 2000; Robin et al., 2003; Rousmans and Robin, 2000). Furthermore studies have principally incorporated theoretical concepts into their designs, either taking a dimensional perspective by asking consumers to

rate their feelings of activation and/or valence (Bensafi et al., 2002a; Distel et al., 1999; He et al., 2014; Horio, 2000; Pichon et al., 2015; Rousmans and Robin, 2000) or comparing physiological responses to a number of so-called basic emotions elicited by taste or odour stimuli (Alaoui-Ismaïli et al., 1997a; Bensafi et al., 2002b; Glass et al., 2014; Vernet-Maury and Alaoui-Ismaïli, 1999). Consequently these investigations have been more concerned with the relationship between self-report and physiological response and less concerned with how sensory stimuli were discriminated.

Within Sensory Science the ultimate goal of measuring emotional response is to be able to show greater discrimination between samples than would otherwise be able to achieve with liking scores alone (Meiselman, 2015). Consequently the theoretical underpinnings of emotions have been largely set aside and the distinction between mood states, emotions and feelings is relaxed in order to allow a host of characterisations needed to describe a product to be used (Köster and Mojet, 2015). However the number of emotion questionnaires have increased over the past 10 years (Meiselman, 2015) and can now be largely divided into pre-determined lexicons and consumer-led lexicons (See section 1.5.1.). Therefore it is important for researchers to consider which type of lexicon, pre-defined or consumer-led, they should choose for a study.

The EsSense profile (King and Meiselman, 2010) and The Geneva Emotion and Odour Scale (GEOS) (Chrea et al., 2009) questionnaire are examples of a pre-determined lexicon which have been developed to assess consumer

emotional response towards a range of products. The GEOS was developed specifically to assess emotional response towards a host of broad spectrum of odours. The authors collected affective terms within the literature (including terms from both dimensional and basic models) but did not apply any theoretical concept of their own. The 480 affective terms collected were then narrowed down into 36 terms by presenting consumers with a range of 56 aromas to remove terms which were not relevant for consumers to describe their emotional response to an aroma. Using exploratory analysis and data reduction techniques such as factor analysis, the 36 terms were grouped into six dimensions which were termed sensuality, relaxation, pleasant-feeling, refreshment, sensory pleasure and unpleasant feeling (Chrea et al., 2009). Importantly the aromas tested included a range of everyday odours which included a mix of pleasant, unpleasant, familiar and unfamiliar odours which were derived from a range of fine fragrances, food, wood, floral and body aromas. Further refinement of the lexicon with an industrial application in mind allowed the full lexicon of six dimensions and 36 terms to be reduced into one called SCENT MOVE which retained all six dimensions but only included three terms within each dimension. Comparison of the full and reduced forms showed high agreement and correlation between both questionnaires, highlighting the appropriateness of applying a shorter questionnaire in order to save time and resources (Porcherot et al., 2010).

Recently a consumer-led product specific emotional lexicon has been developed specifically to assess the emotional responses towards the sensory attributes in beer and was developed at The University of Nottingham (Eaton,

2015). This method was outlined in Chaya et al (2015a) where a Spanish equivalent was developed. As part of the Eaton (2015) investigation, the author generated 100 emotion terms from 17 consumers divided into three groups, who developed their own emotional terms to a selection of 14 samples of beer presented in triplicates (a method known as triadic elicitation) (Fransella et al., 2004). The 100 resultant terms were further reduced to 45 by eliminating synonyms and then to 43 terms by presenting consumers with 14 beer samples and removing terms that consumers rated as irrelevant emotions when assessing beer. Further consumer assessment with 10 beer samples and subsequent multifactorial and hierarchical cluster analysis allowed the 43 terms to be clustered into nine emotion categories (containing a mix of both pleasant and unpleasant emotion categories) which could be assessed on nine independent line scales as a reduced lexicon form. These nine emotion categories were then found to be sufficient in finding significant differences towards 14 samples of beer when assessed by 109 naive consumers. Importantly when the full and reduced lexicons were compared they were highly correlated and had comparable discriminating power (Eaton, 2015). Due to the fewer number of emotional terms consumers had to rate (and hence lowered the risk of consumer fatigue) the reduced lexicon form was considered superior to the full lexicon form.

Although no direct comparison between GEOS/SCENT MOVE and the consumer-led emotional lexicon specific to beer has been quantitatively assessed, there is a growing acknowledgement of the superior ability of product specific lexicons to discriminate between category specific products,

despite the increased investment in time required in order to develop them. For example, comparison of product discrimination between a consumer-defined check-all-that-apply (CD-CATA) lexicon and the EsSense profile towards blackcurrant squashes found that the CD-CATA lexicon contained a better balance of positive and negative affective terms. This permitted better discrimination between products which was missed by the EsSense profile as it contained mainly positive terms (Ng et al., 2013). Furthermore comparison of the product specific EmoSemio and nonspecific EsSense profile towards chocolate and hazelnut spreads found that nine highly discriminating terms in EmoSemio were not present within the EsSense profile. Nevertheless, terms that were shared between lexicons were more discriminating within the product specific EmoSemio questionnaire compared to the EsSense profile (Spinelli et al., 2014). The superior discriminating ability of consumer-led lexicons is therefore a major advantage when applying a specific lexicon to the product category they have been developed for.

As part of this validation study it was decided to use the consumer-led emotion lexicon which had been developed specifically for beer. This was not only due to the increasing evidence that product specific lexicons outperform pre-defined lexicons (Ng et al., 2013; Spinelli et al., 2014) but also because many of the samples used within the development and assessment of the beer specific lexicon were similar to those used within the present investigation (Chaya et al., 2015a; Eaton, 2015). Consequently this would permit comparisons between these previous investigations and the current

study, allowing important conclusions to be made regarding the differences smelling and tasting beer has on the subsequent sample emotional profile.

2.9. Aims and objectives

1) The first objective of the validation study was to determine whether the beer aroma samples and emotional lexicon chosen were appropriate for the main investigation. With the specific goals to determine:
    - that the beer aroma samples chosen contained a mix of pleasant and unpleasant samples that could be discriminated by liking scores.
    - that the beer aroma samples chosen contained a mix of pleasant and unpleasant samples that could be discriminated by pleasant and unpleasant emotion categories using a consumer led-emotion lexicon, specific to beer.
    - if beer aroma samples showed some discrimination between physiological and facial expression measures.
2) To investigate how self-reported and physiological/facial expression measures of emotion respond to repeated sample presentation both:
    - within a single session (within session replicate).
    - between sessions held on separate days (day).

    in order to determine whether sample replicates should be presented over one or two sessions in the main study.

2.10. Methods

Seven samples of beer were presented in four replicates to subjects over the course of two separate sessions. Sessions were organised on two separate days and consumers smelt each sample twice during the course of each session. In order to conserve research costs of the main investigation, only four consumers were used for this second pilot study.

2.10.1. Subjects

Four subjects, (who had not taken part in the first pilot study) aged between 22 and 31 were recruited to take part in the validation study.

2.10.2. Samples

There were seven samples used within this study. These included one non-manipulated base beer MGD sample and six manipulated base beer samples that were "spiked" with an aroma compound.

As with the pilot investigation, Aroxa^{TM} beer flavour standards were used as the source of manipulated aromas within this study to "spike" the base beer (section 2.3.2). Details of the samples and concentrations used can be found in Table 2.7. The samples Isoamyl acetate, Lightstruck and Hoppy (formally known as Hoppy A) were used within the first pilot investigation. The concentrations used within this investigation were based on the results obtained within the first pilot investigation. The samples Diacetyl, Mercaptan and Hydrogen sulphide were not used in the pilot investigation. The inclusion of Mercaptan and Hydrogen sulphide was decided based on their propensity to smell unpleasant at high concentrations. Diacetyl was included because it

is not only considered a key characteristic of certain styles of lager, such as Czech Pilsners (Andrés-Iglesias et al., 2016) but is also considered an off-flavour in other lager styles, (Krogerus et al., 2015) making this an interesting aroma to look at emotional response to. The concentration of Mercaptan, Hydrogen sulphide and Diacetyl was decided informally in the Sensory laboratory by matching intensity levels with the other three experimental samples.

Table 2.7. Names and concentrations of odorants adder per litre of base beer and the respective threshold level of each compound in the general population.

Base beer	Compound	Concentration per litre of MGD	Threshold level (per litre of beer)*
MGD	Isoamyl acetate	10.5 mg	1.1 mg
	Lightstruck (3-methyl-2-butene-1-thiol	200 ng	4-30 ng
	Diacetyl (2,3-butanedione)	390 µg	10-40 µg
	Hoppy	13.5 mg	N/A
	Mercaptan (methanethiol)	10.5 µg	1.5 µg
	Hydrogen sulphide	36 µg	4 µg

***Threshold levels obtained from Aroxa™ website (http://www.aroxa.com/).**

2.10.3. Physiological and facial expression measures

Details of the physiological and facial expression measures used can be found in section 2.3.3. All measures were recorded in the same manner as described in the first pilot study.

2.10.4. Self-reported measures

Subjects self-reported their emotional response using a consumer-led emotional lexicon specifically designed for beer samples. Subjects also reported their hedonic liking and how intense and familiar each beer was.

A consumer-led emotion lexicon specifically developed for UK beer consumers (Eaton, 2015) was used to evaluate subject explicit emotional response to the beer. Following on from the approach used by Dorado et al (2016b), curious was moved from the excited category to form its own independent group, making a total of 10 emotion categories (Table 2.8). Subjects were presented with 10 continuous line scales, each associated with an emotion category. Subjects were instructed to read all of the emotional terms within each category and score from very low to very high their underlying feeling having smelt the most recent beer sample. Each emotion category order presentation was randomised between assessors but categories remained consistent for each consumer's sample set (Dorado et al., 2016b; King et al., 2013). Prior to giving their emotional response, consumers also rated sample liking, intensity and familiarity on identical line scales. Liking scores allowed liked and disliked samples to be distinguished as well as providing a useful comparison between traditional hedonic measures and self-report. Intensity scores were introduced to identify how aroma intensities compared between samples and familiarity was included to allow increased interpretation and comparison towards emotional response. The discrimination of intensity and familiarity scores were not discussed as part of this investigation but allowed their suitability for inclusion to be assessed for the main study. All scores

were recorded using tablets and data collected using Compusense Cloud. Left and right scale extremes were set between 0 and 10 with anchors set at 0.5 and 9.5 (very low and very high) at each extreme.

Table 2.8. Terms included in each category of consumer-led lexicon

Emotion category	Emotion terms
Shocked	Shocked, alarmed, cheated, confused, overwhelmed, strange, weird
Bored	Bored
Content	Content, calm, comfortable, comforted, enjoyment, good, happy, nice, pleasant, pleased, relaxed, satisfied
Excited	Excited, enthusiastic, fulfilled, fun, Impressed, interested, optimistic, pleasantly surprised, want, warm
Nostalgic	Nostalgic, delirious, relieved
Disconfirmed	Disappointed, dissatisfied, unpleasantly surprised
Disgusted	Disgusted, horrible, repulsed, repelled, unpleasant
Tame	Tame, safe
Underwhelmed	Underwhelmed
Curious	Curious

2.10.5. Experimental approach

A similar experimental procedure to the first pilot (section 2.3.5) was followed apart from the following key differences. Subjects attended two sessions (held one week apart) and were required to smell each of the seven samples twice in a single session. The seven samples were assessed according to a partially balanced design with a second replicate set being assessed directly after the first. As 14 samples were assessed in a single session, sessions were extended to 1 hour and 30 minutes.

2.10.6. Data processing of physiological and facial expression variables

Details of data processing can be found in section 2.3.6.

2.10.7. Statistical analysis

Univariate statistical analysis was not performed on the data as p-values would not have provided meaningful results owing to results being collected from only four subjects. Sample means and standard deviations (S.D.) were used to assess the effect of aroma on emotion categories and physiological/facial expression responses. Means and S.D. were also used to assess the effect of day and within session replicate on explicit and implicit scores. A principal component analysis (PCA) was performed on the sample set in order to visualise where the major sources of variation occurred between samples. All variables were included as active variables within the PCA. The PCA was generated using the statistical software, XLSTAT (v2015.6 Addinsoft, USA).

2.11. Results

The following section presents results concerning:

- The discrimination of beer aromas on the basis of liking scores.
- The discrimination of beer aromas on the basis of self-reported emotional response.
- The discrimination of beer aromas on the basis of physiological and facial expression measures.

- The variability of self-report and physiological measures between replicate and day.

2.11.1. Liking scores

Mean scores and ± S.D. for liking, intensity and familiarity scores are displayed in Table 2.9. Assessment of mean values revealed that (broadly speaking) the Isoamyl acetate, Hoppy and Lightstruck samples received higher liking scores than the Mercaptan and Hydrogen sulphide samples. Intensity and familiarity scores showed less variability between aromas than liking scores.

Table 2.9. Mean scores ± standard deviations for liking, intensity and familiarity scores for each aroma.

Aroma	Liking	Intensity	Familiarity
Control	5.31± 1.3	5.65± 1.9	3.95± 1.8
Isoamyl acetate	6.36± 1.4	6.64± 1.4	5.28± 2.1
Lightstruck	6.05± 1.0	7.38± 1.5	5.54± 2.0
Diacetyl	5.61± 1.5	6.04± 1.6	5.46± 1.8
Hoppy	7.41± 2.0	6.21± 2.5	6.81± 1.5
Mercaptan	3.39± 1.9	5.07± 1.5	5.28± 1.9
Hydrogen sulphide	2.54± 1.4	5.20± 1.9	6.28± 1.8

Exploratory results provided by the validation study with only four subjects

2.11.2. Self-reported emotional response

Mean scores ± S.D. for emotional response scores are displayed in Table 2.10. Broadly speaking, the samples which showed higher liking scores (Isoamyl acetate, Hoppy and Lightstruck) received higher mean scores within some pleasant emotion categories: content, excited and tame/safe compared to Mercaptan and Hydrogen sulphide samples. Similarly samples which received

Table 2.10. Mean scores ±standard deviations for emotion categories.

Aroma	Shocked	Bored	Content	Excited	Nostalgic	Dis-confirmed	Disgusted	Tame/Safe	Under-whelmed	Curious
Control	1.02± 0.4	3.55± 2.2	4.34± 1.8	3.47± 2.1	2.42± 1.8	1.93± 1.3	1.48± 1.0	4.84± 2.1	4.53± 2.5	2.79± 2.0
Isoamyl acetate	1.06± 0.6	2.79± 2.7	5.84± 2.2	5.17± 2.7	3.58± 2.5	1.81± 1.7	1.17± 0.9	5.57± 2.1	2.61± 2.6	3.68± 2.7
Light-struck	0.84± 0.3	2.83± 2.4	5.92± 1.4	5.26± 2.5	4.13± 2.3	1.60± 1.4	1.12± 0.6	5.81± 2.0	2.91± 2.5	2.66± 2.3
Diacetyl	1.65± 1.4	3.11± 2.4	4.52± 2.3	3.59± 2.2	3.54± 2.4	2.42± 1.9	1.88± 1.8	4.45± 1.6	2.92± 2.2	3.33± 2.3
Hoppy	1.13± 1.0	1.65± 1.7	7.18± 2.0	6.76± 2.2	4.23± 2.8	1.43± 1.8	0.88± 0.6	5.66± 2.2	2.10± 2.4	6.07± 2.2
Merc-aptan	2.61± 1.9	3.36± 2.3	2.73± 2.0	2.15± 1.9	1.91± 1.3	4.13± 2.2	4.46± 2.7	3.14± 2.1	3.10± 2.6	2.04± 1.7
Hydrogen sulphide	3.93± 1.9	2.59± 1.9	1.63± 1.4	1.57± 1.2	1.45± 1.4	5.37± 1.8	6.48± 1.8	2.36± 2.3	2.02± 1.6	1.73± 1.1

Exploratory results provided by the validation study with only four subjects

lower liking scores were rated higher in some unpleasant emotion categories: disgusted, disconfirmed and shocked.

2.11.3. Physiological and facial expression measures

Mean scores ± S.D. for physiological and facial expression measures are displayed in Table 2.11. Although some variation in physiological measures were observed, (e.g. smaller heart rate scores towards Hoppy samples and more corrugator in response to Mercaptan and Hydrogen sulphide samples) there were very large S.D. for each measurement. Consequently due to the large S.D. and as only the responses from four individuals were included, it is not possible to determine whether physiological and facial expression measures changed in response to aroma.

Table 2.11. Mean scores ± standard deviations for physiological and facial expression measures. bpm = beats per minute.

	Physiological Measures		Facial expression Measures	
Aroma	Heart rate (bpm)	Skin temperature (˚C) (x100)	Corrugator activity (mV) (x10000)	Zygomatic activity (mV) (x10000)
Control	1.86± 3.9	-6.40± 9.5	0.84± 26.3	18.64± 92.9
Isoamyl acetate	1.06± 3.3	-5.96± 13.0	-4.77± 19.3	-3.58± 24.4
Light-struck	2.44± 3.4	1.41± 13.9	1.72± 17.2	9.09± 27.3
Diacetyl	2.99± 3.7	-2.26± 13.4	4.37± 20.6	6.67± 23.1
Hoppy	0.16± 3.6	-1.22± 11.6	-0.06± 18.3	3.26± 37.6
Mer-captan	1.49± 2.5	-5.19± 9.9	7.33± 18.0	28.18± 48.0
Hydrogen sulphide	1.62± 3.5	-7.93± 14.6	7.32± 37.9	4.99± 55.2

Exploratory results provided by the validation study with only four subjects

2.11.4. Comparison of liking, emotional and physiological and facial expression measures

A PCA was run which included all of the self-report measures as well as the physiological and facial expression measures. It should be re-acknowledged that as the data was from only four individuals, the PCA can only give a general indication as to the associations between variables.

Heart rate and zygomatic activity were included within the PCA because it was necessary to visualise how all of the variables were represented and as the subject number was so small, no variables were included or excluded on the basis of statistical significance.

The first two principal components (PCs) together explained 83.1% of the total variance with 60.85% explained by PC1 and 22.24% explained by PC2. Inspection of the correlation circle (Figure 2.13) revealed that the emotion categories shocked, disconfirmed, and disgusted were highly negatively correlated with PC1 whilst the categories content, excited, nostalgic, tame/safe and curious were positively correlated with PC1. Hedonic liking and familiarity were also highly correlated with PC1. Intensity scores were highly positively correlated with PC2, whilst the underwhelmed and bored categories were negatively correlated with PC2. Together these two dimensions were consistent with the circumplex models of emotion (see section 1.2.2). PC1 accounted for the valence (pleasantness/unpleasantness) dimension of emotion with emotion categories, disgust and disconfirmed etc. associated with unpleasantness and content and excited etc. associated with

pleasantness. PC2 accounted for the activation (high activation/low activation) dimension of emotion with the emotion categories bored and underwhelmed best describing a state of low activation. Interestingly, self-reported intensity was located opposite to bored and underwhelmed emotion categories, a similar location on the activation dimension as in previous studies (Chaya et al., 2015a) . Corrugator activity was negatively correlated with PC1 and so was well described by sample unpleasantness. However zygomatic activity and heart rate were not correlated with either PC1 or PC2 so were not well described by either valence or activation.

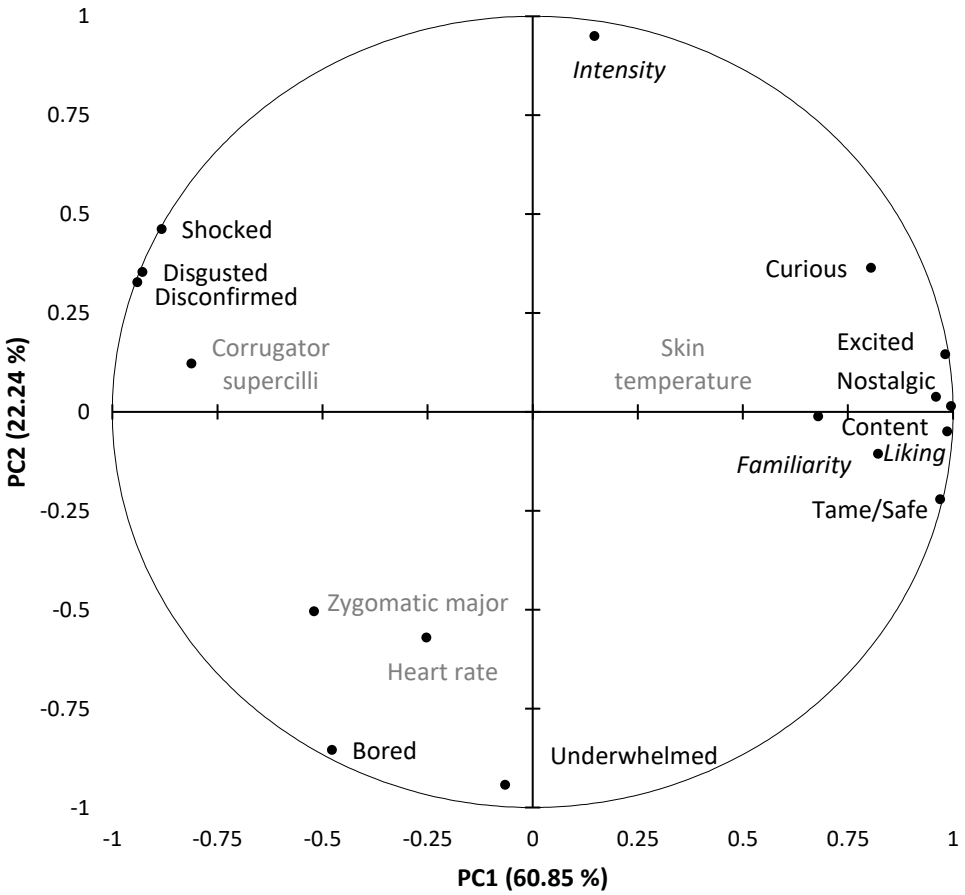


Figure 2.13. Correlation circle for PC1 and PC2. Active variables include 10 emotion categories from consumer-led lexicon (black, not italicised), self-reported intensity, liking and familiarity (black, italicised) as well as physiological and facial expression measures (grey).

Samples within the observation plot (Figure 2.14) demonstrated that the Lightstruck and Isoamyl acetate samples were correlated with the pleasantness dimension, whilst the Hoppy sample was best described by its high pleasantness and high activation. The Mercaptan sample was best described by its low pleasantness whilst the Hydrogen sulphide sample could be described by high activation and unpleasantness. Finally the Control sample was best described by low activation whilst the Diacetyl sample, not scoring highly for activation or valence, was associated with a more neutral emotion.

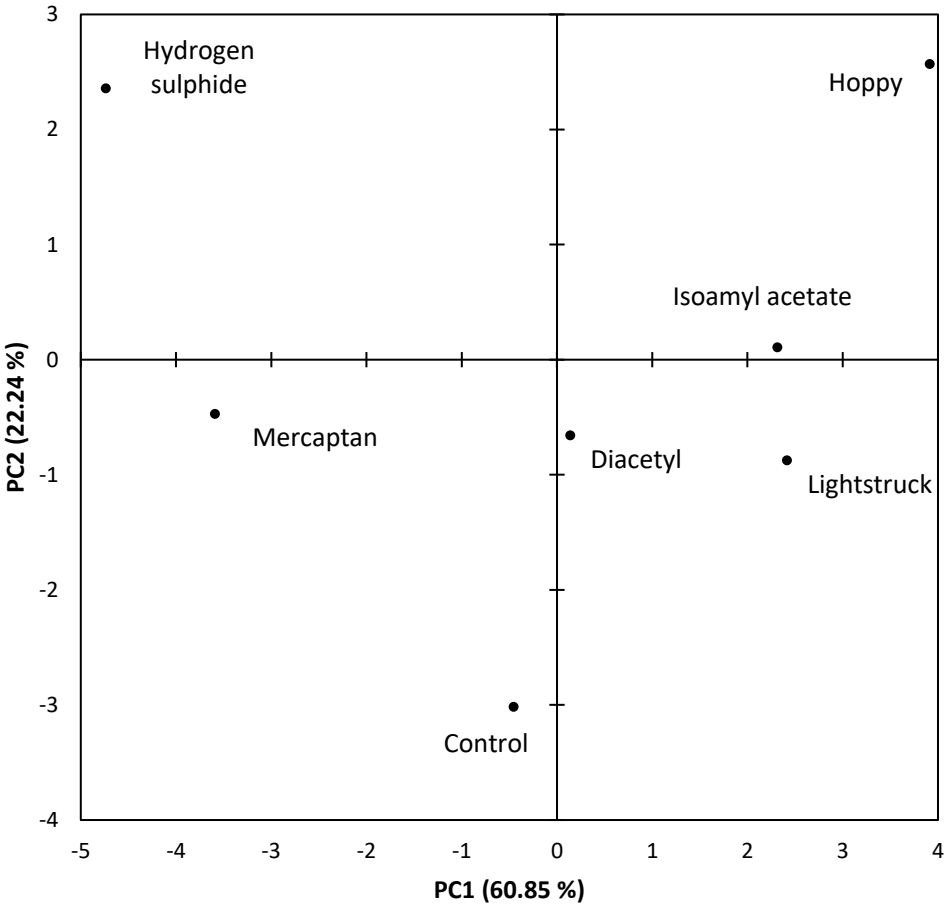


Figure 2.14. Observation plot displaying position of beer samples within PC1 and PC2.

2.11.5. Variability between replicate and day measurements

Inspection between scores for replicate and day suggested that liking scores changed very little between both days and replicates one and two (Figure 2.15). Inspection of replicate and day scores for emotional response suggested that three out of ten emotion categories showed limited change between replicates or day (excited, disconfirmed and disgusted) (e.g. disconfirmed in Figure 2.16). The remaining seven categories showed some change between replicates, the four categories varying more between replicates on day 1 than day 2. However the variation was generally quite limited (e.g. nostalgic in Figure 2.16).

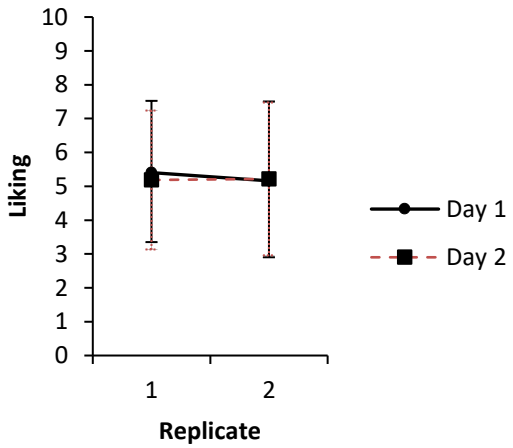


Figure 2.15. Mean scores (± standard deviations) for liking both within sessions (replicate) and sessions held on separate days (day).

With regards to the physiological and facial expression measurements, visual inspection of the interaction between replicate and day suggested that responses varied with both day and replicate. In particular, heart rate and zygomatic scores were more variable between replicates 1 and 2 on day 2. However for corrugator activity responses were more variable for day 1 and

there was a crossover interaction between replicate and day for skin temperature (Figure 2.17).

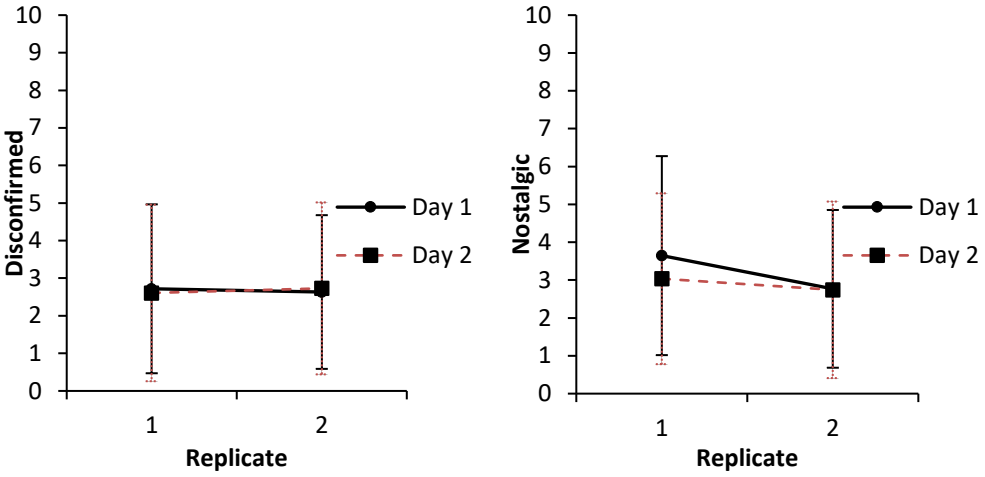


Figure 2.16. Mean scores (± standard deviations) for disconfirmed and nostalgic emotion categories both within sessions (replicate) and sessions held on separate separate days (day).

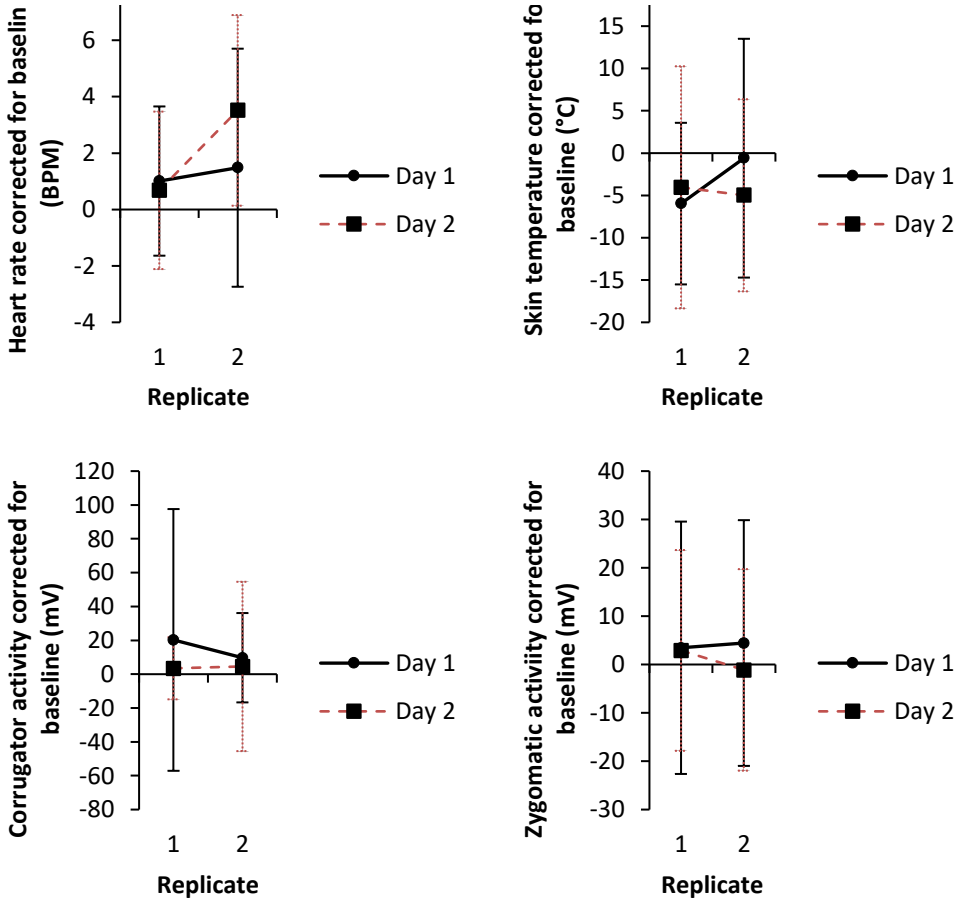


Figure 2.17. Mean scores (± standard deviations) for heart rate, skin temperature as well as corrugator and zygomatic activity both within sessions (replicate) and sessions held on separate days (day). bpm= beats per minute.

2.12. Validation study discussion

As the results from four subjects were only included within this investigation, a discussion as to the broader implication of the results would not be appropriate. Instead the results will be discussed with regards to methodological consideration for the larger main study that followed (Chapter 3) as well as the suitability of the samples and measurements used.

The first objective of this study was to validate a revised set of beer aromas to ensure that the samples included a mix of both liked and disliked samples which were also distinguishable on the basis of emotional response. Liking score showed that the Lightstruck, Hoppy and Isoamyl acetate samples were generally liked more than the Mercaptan and Hydrogen sulphide samples, indicating that there was some discrimination between samples on the basis of liking. Furthermore well liked samples were found to be better described by pleasant emotion categories such as content, excited and tame/safe, whilst disliked samples were better described by unpleasant emotion categories such as disgusted, disconfirmed and shocked. Consequently this sample set was deemed appropriate for the main investigation as it was shown to contain a mix of both liked/pleasant and disliked/unpleasant aromas.

In addition to assessing the appropriateness of the samples used, this validation study also aimed to determine whether a consumer-led emotion lexicon was appropriate for assessing the emotional response towards beer aroma. The PCA analysis demonstrated that samples could be well described by the two principal dimensions of emotion, valence and activation (Larsen

and Diener, 1992; Russell, 2003; Watson and Tellegen, 1985). The majority of the variation was described by the valence dimension, with samples and emotion categories such as Isoamyl acetate, Lightstruck, excited and content being described by the pleasantness dimension of emotion, whilst Mercaptan, Hydrogen sulphide, disgusted and disconfirmed were well described by the unpleasant dimension of emotion. Furthermore the bored and underwhelmed emotion categories as well as Control sample better describe the smaller activation dimension of emotion. The representation of the emotion space, with a greater weight towards the valence dimension, has been previously described in other research utilising successful and highly discriminating product specific lexicons (Chaya et al., 2015a; Ng et al., 2013). Consequently, the consumer-led emotion lexicon was considered appropriate to be used within the main investigation.

In comparison to liking and emotional response scores, physiological and facial expressions towards aromas showed some variability but there were large variations in standard deviation measurements, leading to high variability within these implicit measures. However as demonstrated in the pilot investigation, subjects show wide variation in their physiological response, it is not surprising that limited change was observed with a sample set of four individuals. This supports the need for a large number of subjects to take part in the main investigation.

The second objective of this investigation was to determine the appropriate number of sessions and sample replications that should be included within

the main investigation. Physiological and facial expression scores between replications suggested that there was large variability between days 1 and 2. With regards to facial expression measures of corrugator and zygomatic activity, changes between sessions held on different days may be related to small changes in the relative position of electrodes which can have a substantial effect on both the activity recorded between subjects and within subjects between sessions (Boxtel, 2010; Larsen et al., 2003). Furthermore as differences between heart rate and skin temperature scores were also observed between sessions it was deemed sensible that subjects should only attend one session to limit the amount of inter-session variability. However within session replicates should also be included in order to account for the variability observed within sessions and assist in determining how reliable different types of physiological and facial expression responses are.

Scores towards emotional categories suggested that self-report ratings were generally less variable within session 1 compared to session 2. Although there was some variability within session replicates, this was small in comparison to those observed for physiological and facial expression measures. Previous studies utilising a combination of self-report and physiological measures have reported that liking and intensity ratings do not vary significantly with sample replicate (de Wijk et al., 2014) and consequently it was decided to only include one replicate of emotional response within the main investigation.

2.13. Validation study conclusions

The validation was based on the results from four individuals so firm conclusions cannot be made on the basis of statistical significance. However the results provided an indication as to the suitability of the beer aromas and self-reported emotional lexicon for the main study as well as assisting how replicate measurements should be taken. The sample set, containing a non-spiked beer and six spiked samples were shown to have some variability in liking and emotional response scores and so were deemed suitable for the main investigation. The emotional lexicon was also found to be discriminating towards pleasant and unpleasant samples and responses could be structured according to a circumplex model of emotion, making it also suitable to be used in the main investigation. Finally it was decided to assess consumer response towards two replicate sample presentations within a single session. Physiological and facial expression would be assessed towards both replicates but self-report would only be assessed towards the first replicate as minimal variation was found towards responses. Finally owing to the variability of facial expression responses held on different days, it was advised that facial electrode placement should be further explored to ensure electrode positioning was consistent.

Chapter two, part three: Further methodological considerations

Methodological recommendations were made on heart rate and facial expression recordings in both the pilot and validation studies. The methodological considerations which went into improving these are described within this section.

2.14. Heart rate

Owing to the type II placement of heart rate electrodes on both the wrist and ankles of subjects (see section 1.7.2.2) used in both the pilot and validation investigations, the resulting ECG output was vulnerable to movement artefacts (see Figure 2.18 for an example). Any movement artefacts within the recording made deciphering R waves from the noise within the recording difficult and would increase data processing times. In order to find an electrode configuration that was not as sensitive to movement artefacts, numerous electrode configurations were trialled with a subject prior to starting the main investigation.

Other recommended electrode placements include sternal (vertical placement on rib cage) and axillary placements (underarm, horizontal placement on rib cage) (Andreassi, 2007b). However the respiration band interfered with both sternal and axillary placement of electrodes, putting the subject in discomfort. Through multiple configurations, an appropriate electrode configuration was found that was suitable for the needs of this investigation. This included the placement of the negative lead placement below the right collar bone and the positive lead above the left hip. This created the necessary polarity across the

heart (see section 1.7.2.2) to generate well defined R waves that were free from artefact movements when the subject shifted their weight or moved their arms in a typical fashion as those by subjects in the pilot investigation.

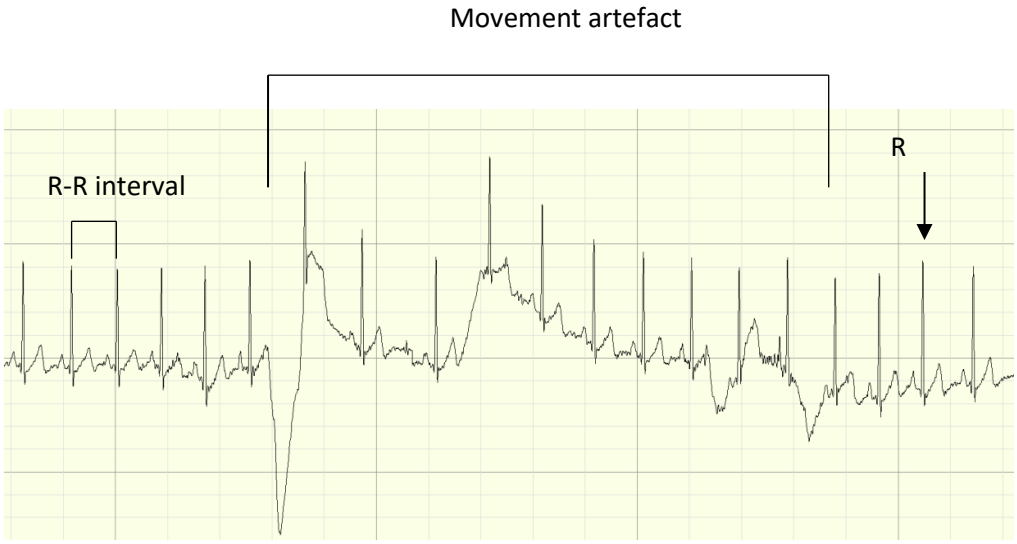


Figure 2.18. Example of electrocardiogram recording containing a section with some small movement artefacts. The characteristic large R wave spikes are highlighted in this diagram.

2.15. Facial expression measures

In both the pilot and validation investigations it was unclear whether the effects of session were caused by the subjects' perception of an aroma or due to the irregular placement of facial electrodes. Furthermore it was unclear whether the non-significant values obtained with regards to corrugator and zygomatic activity within the pilot investigation were the result of a lack of effect aroma had on facial movements or whether results may have been affected by cross talk between muscles close to the target muscles. In order to observe the potential impacts of electrode position and muscle crosstalk and find methods to reduce these effects in further investigations, muscle movements were measured informally in five subjects in order to refine and characterise good electrode positioning.

As the corrugator major muscle is a small muscle, it is at risk of receiving cross talk from the larger frontalis muscle (elevation of the brow) during recordings (Cram et al., 2011) (see section 1.8). Consequently it is necessary to ensure that corrugator positioning is accurately positioned above the midline of the muscle belly. In order to assess the impact that cross talk from the frontalis muscle may have on the corrugator muscle; the activity of both sites was recorded simultaneously during informal trials (see Figure 2.19 for an example). Subjects were asked to either furrow their brow to evaluate corrugator activity or raise their brow to evaluate frontalis activity. The placement of electrodes was "tweaked" to ensure that maximal activity was observed at the corrugator site when subjects formed a frown as well as minimal activity was observed at the corrugator site when subjects raised their eyebrows. Consequently asking subjects to furrow or raise their eyebrows whilst recording from the corrugator site was deemed an appropriate means to assess correct corrugator electrode positioning for the main investigation.

The zygomatic major muscle is closely positioned to the buccinator (retraction of cheek during chewing) and masseter muscles (closing and grinding of the jaw) (section 1.8). Whilst it is common for the buccinator muscle to show some cross reactivity when smiling, the masseter muscle is activated when a subject clenches their jaw and is consequently unrelated to smiling or zygomatic activity (Cram et al., 2011). During informal trials, muscle activities were simultaneously recorded from the zygomatic and masseter sites whilst asking subjects to either smile or clench their jaw in a pre-determined manner

(see Figure 2.20 for an example). The observation of activity of smiling and jaw clenching on the target zygomatic activity helped to refine electrode placement in subjects and was adopted as an appropriate means assess correct electrode positioning for the main study.

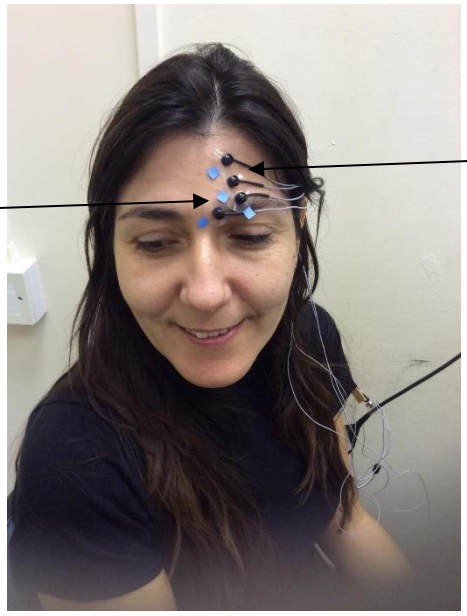


Figure 2.19. Example of electrode positioning to measure target muscle activity over corrugator supercili muscle and cross talk activity from the frontalis muscle.

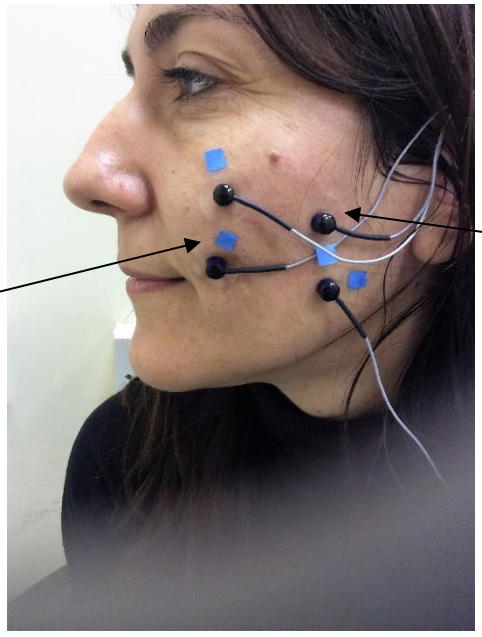


Figure 2.20. Example of electrode positioning to measure target muscle activity over zygomatic major muscle and cross talk activity from the masseter muscle.

2.16. Pilot and validation study Conclusions

The pilot and validation investigations allowed several decisions to be made with regards selection of aromas and the measurement of both implicit and explicit responses within the main investigation. These included:

1. Beer aromas
    a. Seven beer samples (Control, Isoamyl acetate, Lightstruck, Diacetyl, Hoppy, Mercaptan and Hydrogen sulphide) will be assessed. These were the aromas used in the validation study and were confirmed to include a selection of both pleasant and unpleasant beer aromas.
    b. Beer samples will be assessed twice within a single session to include a replicate measurement.
2. Physiological and facial expression measurements
    a. Physiological and facial expression variables will be explored from a subset of subjects after data collection to determine to most appropriate data processing methods.
    b. Muscle specificity for EMG measurements will be confirmed within each subject at the start of a session by ensuring the greatest activity is recorded from the target muscle.
    c. Physiological and facial expression will be recorded in response to both aroma presentations.
3. Self-report

a. An emotional lexicon specific to beer (as well as liking and familiarity) will be used to record emotional response towards beer aroma samples.
b. Self-report will only be assessed in response to the first aroma presentation only.

3. Chapter three. Main Investigation: Comparison of the discrimination ability of self-reported emotional response, liking and physiological/facial expression measures towards aroma attributes in beer

3.1. Introduction

Emotion research within sensory science has generally proceeded in one of two directions. Researchers have either implemented emotional lexicons for consumers to self-report their own emotions using verbal questionnaires (King and Meiselman, 2010; Porcherot et al., 2010), non-verbal questionnaires (Desmet et al., 2000; Gutjar et al., 2014) or have used lexicons which are specific (Chaya et al., 2015a; Ng et al., 2013; Spinelli et al., 2014) or non-specific (King and Meiselman, 2010) to particular product categories. Alternatively researchers have measured physiological changes in the autonomic nervous system, (Alaoui-Ismaïli et al., 1997b; Bensafi et al., 2002a; Glass et al., 2014; Horio, 2000; Rousmans and Robin, 2000; Vernet-Maury and Alaoui-Ismaïli, 1999) behavioural measures such as changes in facial expression (Soussignan and Schall, 1996; Zeinstra et al., 2009) or a combination of physiological and behavioural measures (Delplanque et al., 2009; Liao et al., 2015; Pichon et al., 2015). Both types of measures aim to record different types of responses, where self-reported emotional response is believed to primarily reflect the conscious component of emotion, (explicit measures) (Lottridge et al., 2011). Whereas, physiological and facial expression measures are believed to reflect the automatic and unconscious component of emotional response (implicit measures) (Mojet et al., 2015) (see section 1.4). However explicit and implicit measures have rarely been

combined within a single investigation (aside from pleasantness, intensity and familiarity ratings) in order to determine which measure can provide better discrimination between samples.

High discrimination between whole food and beverage products is becoming increasingly important in Sensory Science owning to the fact that many commercial products are similar in both quality and price (Schifferstein et al., 2013) and generate more positive compared with negative emotions in consumers (Schifferstein and Desmet, 2010). Currently physiological and facial expression methods have been restricted to comparisons with liking scores, in order to determine whether implicit responses can provide greater discrimination than liking scores alone. For example De Wijk et al (2014) found that although liking scores did not vary between five breakfast drinks, heart rate and skin temperature could discriminate between samples, with both responses showing a trend to increase with liking scores. Although facial expressions measured using FaceReader technology did not vary with breakfast drink, there was a negative association between liking scores and anger, surprise and disgust reactions (de Wijk et al., 2014). In a separate study, the same group also found that whilst heart rate did not vary with liking scores, skin temperature and skin conductance responses decreased or increased respectively between personalised liked and disliked foods in adults and children. Furthermore the group found that facial expressions towards the sight of disliked foods induced more disgusted, sad and angry facial expressions (de Wijk et al., 2012). Danner et al (2014a) found that five fruit juice samples, well discriminated on the basis of liking could be further

discriminated by skin conductance responses, with less well liked samples inducing larger responses. Furthermore liking scores were also found to be negatively correlated with negative facial expressions such as sad, disgusted and angry (Danner et al., 2014a). Evidently, physiological and facial expression measures have been able to provide additional discrimination between samples, some of which show associations with liking scores. However no comparison between physiological/facial expression measures and self-reported emotional response were made.

In a recent series of studies by He et al (2016, 2014) a direct comparison between physiological, facial expression and self-reported emotional response was made towards unpleasant fish and pleasant orange odours, presented at low, medium and high concentrations. In the first of the two studies, the group related heart rate, skin conductance and skin temperature recordings with facial expressions using FaceReader and self-reported pleasantness, familiarity and intensity scores (He et al., 2014). In the second study, the group compared self-reported responses made on a ProEmo questionnaire and changes in facial expression measured using FaceReader technology (He et al., 2016). As part of this later study, the researchers found that both facial expression and self-reported emotional responses could successfully distinguish between both the pleasant and unpleasant aromas. For example with regards to self-reported emotions, the orange odour evoked more pleasant emotions such as joy, satisfaction and hope, whilst the fish odour evoked more unpleasant emotions such as dissatisfaction, fear and disgust. Facial expression responses were also found to vary with the function

of valence with neutral and surprise expressions in response to orange odours and disgust, anger and sad expressions associated with fish odours. By further looking at the temporal dynamics of facial expressions, the researchers maintained that facial measures could provide greater depth of emotion compared to self-reported emotional response (He et al., 2016). However the researchers never directly compared physiological, facial expression and self-reported emotional response within the same investigation. Furthermore this study only investigated emotional response towards two aromas and did not look at commercial products. Within the present chapter, a comparison between physiological, facial expression, self-reported emotional response and liking was made towards different aromas within the commercial beverage, beer.

3.2. Aims and objectives

The overall aim of the investigation presented in this chapter was to compare both implicit (physiological and facial expression) and explicit (self-report) measures of emotional response in order to identify whether implicit or explicit measures could provide better discrimination between different aromas within beer. This investigation also aimed to compare implicit and explicit measures with liking scores to determine whether one or both of these measures could provide better discrimination than liking scores alone. These aims were achieved through the following objectives:

1) To explore the discrimination ability of physiological/facial expression measures. This objective further aimed to:

a. Explore the response profiles of heart rate, corrugator and zygomatic activity from 10 individuals to identify where the largest response activity occurred after stimulus delivery to increase the discrimination power of these measures.
b. Determine whether physiological and facial expression measures can discriminate between aromas within beer and a water sample to further understand how physiological measures discriminate between samples with an aroma (beer samples) and a sample with no aroma (water).
c. Determine whether physiological measures can discriminate between aromas in beer.

2) Determine whether self-reported emotional response using a consumer-led emotional lexicon specific to beer can discriminate between aromas in beer.
3) Determine whether liking scores can discriminate between aromas in beer.
4) To compare the discrimination ability of physiological/facial expression responses, self-reported emotional response and liking scores between a range of aromas within beer.
5) To determine if differences in emotional response between genders occur and if so whether these are more easily detectable through implicit or explicit measures.

3.3. Methods

Ethical approval was received from The University of Nottingham's Biosciences Ethical Committee prior to starting this study (approval code: SBREC140115A). Seven samples of beer and two water samples were presented in duplicate to 60 subjects during a single session, whilst they had their physiological and facial expression responses recorded to both replicates as well as self-reported emotional response recorded to the first replicate. The beer samples included a base beer sample spiked with six different aroma compounds commonly found in beer as well as a 7th non-manipulated base beer sample.

3.3.1. Subjects

67 subjects were recruited from staff and students at the University of Nottingham. However owing to technical and sample presentation errors, the data set was reduced to 60 subjects. The average age of participants was 25.65 standard deviation ± 6.05 years, 32 of which were male and 28 were female. All participants gave their informed consent. Please see section 2.3.1 for details on how subjects were recruited.

3.3.2. Samples

Seven beer samples were used within this study. These included one non-manipulated base beer MGD sample and six manipulated base beer samples that were "spiked" with an aroma compound. This corresponded to one control sample and six manipulated samples. These were the same samples which were used within the validation study; please see section 2.10.2 for

further details on the beer and aromas used within the main investigation. For the reader's convenience, a summary table of the aromas used has been replicated in this chapter from section 2.10.2.

Table 3.1. Names and concentrations of odorants adder per litre of base beer and the respective threshold level of each compound in the general population. (Table replicated from Table 2.7 in section 2.10.2)

Base beer	Compound	Concentration per litre of MGD	Threshold level (per litre of beer)*
MGD	Isoamyl acetate	10.5 mg	1.1 mg
	Lightstruck (3-methyl-2-butene-1-thiol	200 ng	4-30 ng
	Diacetyl (2,3-butanedione)	390 µg	10-40 µg
	Hoppy	13.5 mg	N/A
	Mercaptan (methanethiol)	10.5 µg	1.5 µg
	Hydrogen sulphide	36 µg	4 µg

***Threshold levels obtained from Aroxa™ website (http://www.aroxa.com/).**

3.3.3. Physiological and facial expression variables

3.3.3.1. Heart rate

Heart rate was recorded using electrodes attached below a subject's right collar bone and above their left hip in the manner described in section 2.14.

3.3.3.2. Skin temperature

Skin temperature recordings were made following the method outlined in Section 2.3.3.3.

3.3.3.3. Changes in facial muscle activity

Details of subject skin preparation, electrodes and electrode gel used to record corrugator and zygomatic activity can be found in Section 2.3.3.4. After attaching the electrodes, muscle specificity was tested by asking subjects to perform maximal movements of target and non-target muscles, details of which can be found within this chapter, section 3.3.5.

3.3.4. Self-reported emotional response & liking and familiarity

A consumer-led emotion lexicon specifically developed for UK beer consumers (Eaton, 2015) was used to evaluate subject explicit emotional response to the beer. Details of the questionnaire can be found in section 2.10.4. As with the validation study, liking and familiarity questions were asked before subjects proceeded to the emotion questionnaire. Aroma familiarity was asked in order to help interpret emotional response. However unlike in the validation study, aroma intensity was not recorded as it was deemed unnecessary considering only one concentration of each aroma was included within the study design. All self-report scores were recorded on an iPad tablet using Compusense Cloud.

3.3.5. Experimental approach

A similar experimental approach was used to that described within the pilot investigation (section 2.3.5). However a number of key modifications were made with regards to facial electrode placement and modifications to trial protocols which were based on the learnings gained from both the pilot and validation investigations. Most importantly, based on the conclusions from

the validation study, (section 2.13) consumers were only required to attend a single session which lasted approximately 1 hour and 30 minutes. Over the course of the session, consumers smelt each of the seven beer samples twice in two blocks, presented according to a balanced design. Further based upon the results from the validation study, physiological and facial expression measures were assessed after each replicate whilst self-reported emotional response and liking and familiarity were taken only in response to the first sample presentation. Two, as opposed to one, iPad tablets were used (Figure 3.2) in order to display experimental instructions as well as liking/familiarity and the emotional questionnaire on separate screens. This was to allow a more efficient display of instructions. A schematic of the subject experimental set is provided in Figure 3.3.

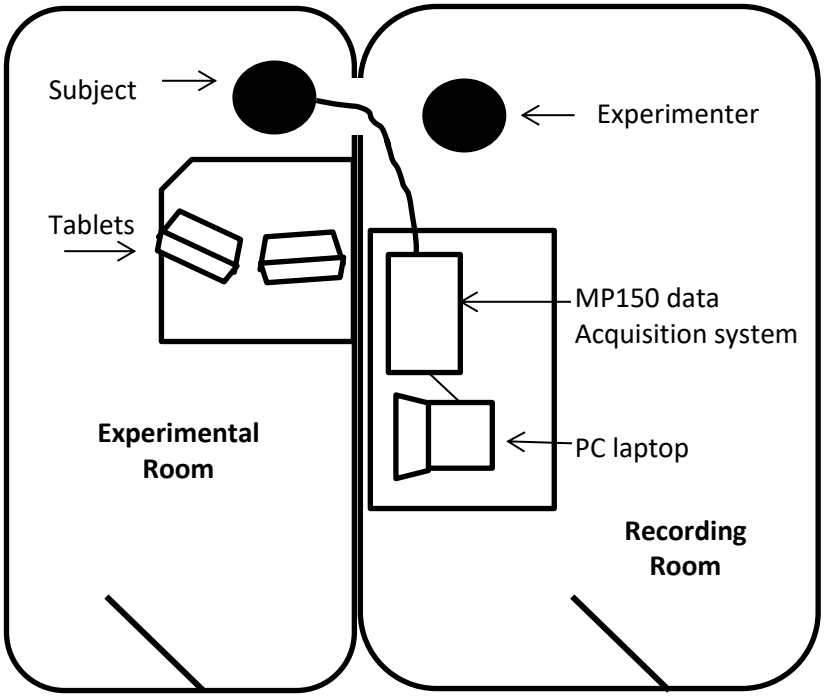


Figure 3.2. Schematic diagram of the experimental set up of both the experimental and recording rooms. This diagram is not to scale.

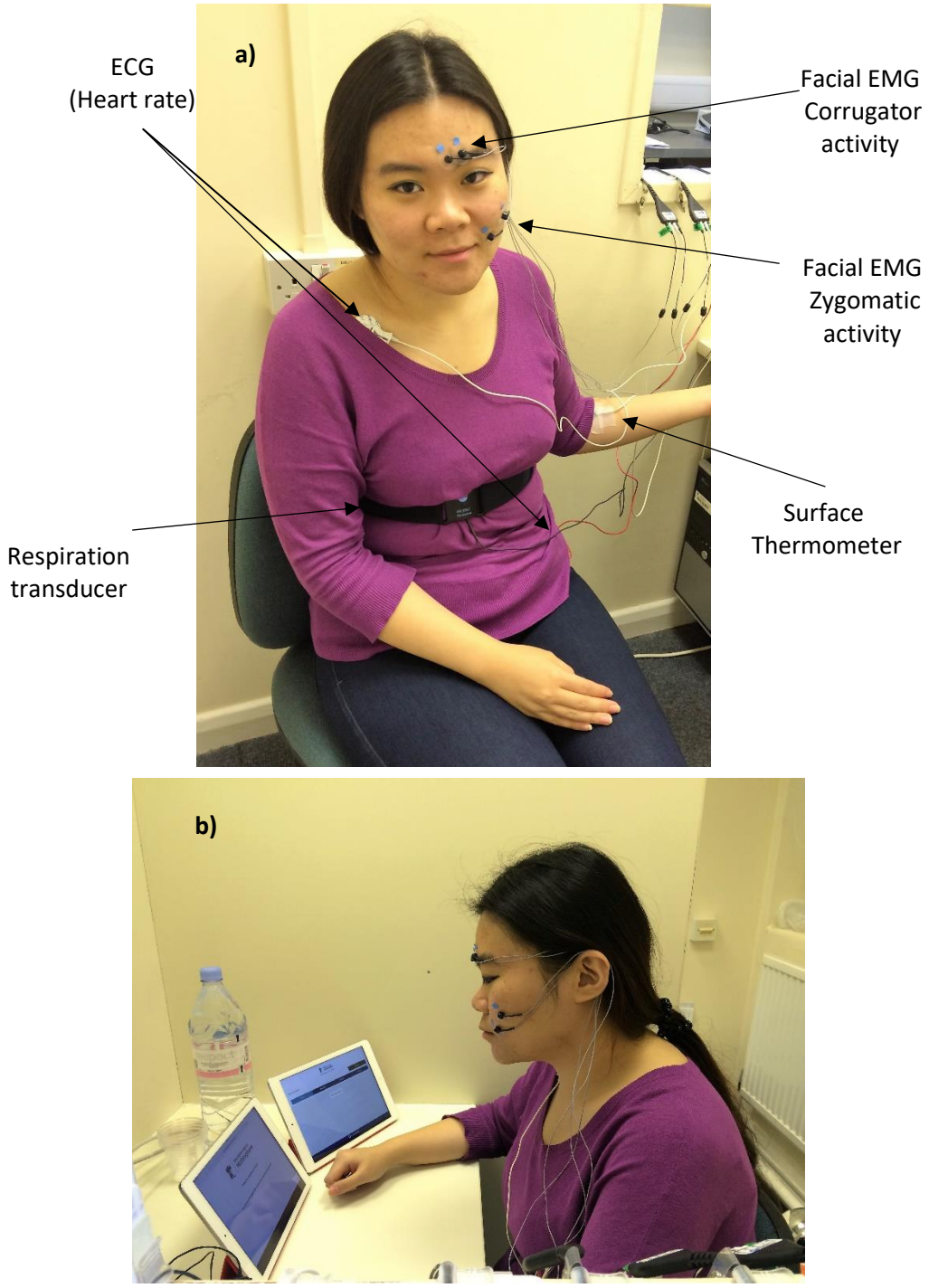


Figure 3.3. a) Example of physiological and facial measure recordings taken a subjects. b) Example of iPad set up.

After subjects were seated in the experimental room, the accuracy of facial electrode positioning was assessed by asking subjects to perform certain facial muscle movements which were recorded and displayed on the laptop computer within the recording room (in real time). This methodology was developed from informal trials conducted before the main study trails (see section 2.15). In order to confirm the accuracy of corrugator supercilli electrode positioning, subjects were asked to furrow their brow maximally for three seconds before relaxing for one second in order to record target corrugator activity. Subjects then raised their eyebrows as high as possible for three seconds to measure cross talk activity from the non-target frontalis muscle. This process was repeated three times. Sufficient specificity of the corrugator muscle was deemed acceptable when greater activity (measured in mV) was recorded from the corrugator activity when subjects furrowed their brow, compared to when subjects raised their eyebrows. The same procedure was followed to determine electrode positioning of zygomatic activity however subjects were asked to raise the corner of their lips to assess target muscle activity and to clench their jaw to measure non-target/cross talk activity. Instructions using words such as frown and smile were avoided to ensure subjects were not aware of the specific facial expressions which were under investigation in the study.

Prior to starting the experiment, subjects were asked to watch a short neutral emotion video clip on one of the tablets. The video clip, “Alaska’s Wild Denali” (Hardestry, 1997) has been previously shown to evoke neutral, calm

affective states in studies using video-clips as emotive stimuli (Rottenburg et al., 2007). Consequently this film clip aided the establishment of an emotional baseline in subjects before starting the study.

Finally modifications were made to the experimental protocol described as stages a-f within the pilot study (section 2.3.5). Specifically, as part of stages "a" and "d", subjects were only required to wait for 20 seconds (as opposed to 30 seconds) as this was deemed an appropriate length of time to record sufficient physiological and facial expression activity. Samples were prepared in triplicate to ensure that each replicate had enough time to develop headspace. The first sample in a triplicate was presented between stage b and c when subjects first smelt an aroma. The second sample in the triplicate was presented after stage e when subjects re-smelt a samples and the third sample in the triplicate was once again presented in stage b and c when subjects smelt an aroma during the second replicate (where self-report was not assessed). An updated schematic diagram of the trial procedure can be seen in Figure 3.4. Two water samples with no-aroma were presented to subjects first before presenting subjects with beer samples.

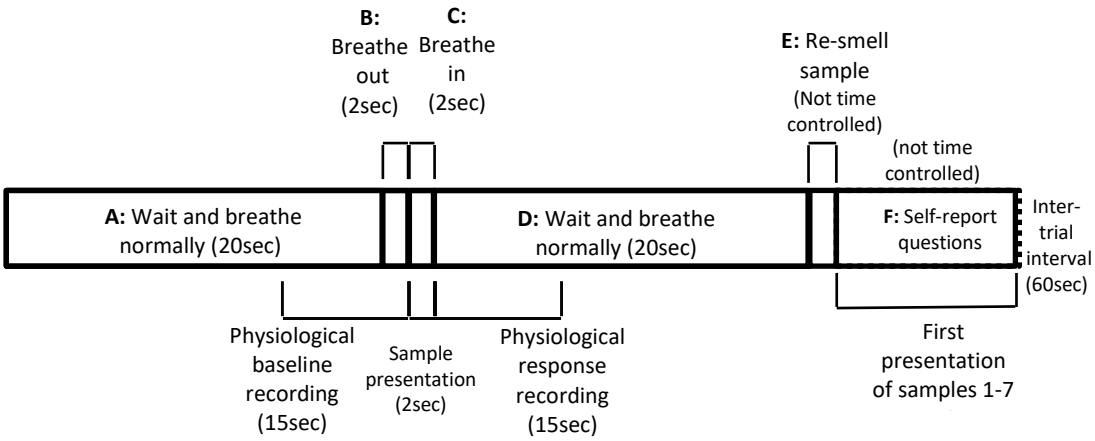


Figure 3.4. Schematic representation of instruction and physiological recording time frame used in main study. Instructions were presented in Compusense Cloud.

3.4. Data processing of physiological and facial expression measures

The processing of physiological and facial expression variables was conducted in two stages: a) exploratory analysis - precisely determining the location of stimulus presentations from respiration recordings as well as the extraction, processing and analysis of heart rate and facial expression activity from 10 individuals to determine optimum time frames for data extraction and analysis; b) full analysis - data extraction and analysis of full sample set from all subjects using protocols and time frames developed from exploratory analysis. It should be noted that the extracted time frames previously reported in the literature have varied between 7 to 30 seconds for heart rate (Bensafi et al., 2002b; Brauchli et al., 1995; Croy et al., 2013; de Wijk et al., 2014, 2012; Delplanque et al., 2009) and between 1 – 6 seconds for facial EMG activity (Delplanque et al., 2009; Liao et al., 2015; Pichon et al., 2015). Consequently there is no set recommendation for how heart rate and EMG

activity should be analysed and is down to the judgement of the experimenter.

3.4.1. Exploratory analysis

The ECG, skin temperature and EMG responses were recorded continuously throughout the session. One of the aims of the main investigation was to refine the physiological/facial expression data processing techniques in order to extract the most meaningful and stimulus dependant response for each measure. This was an important step within the data handling process as physiological and facial expression responses were recorded continuously throughout a session. Consequently measuring responses within a time frame which is too short increases the risk of excluding responses related to the stimulus and conversely, time frames which are too long increase the risk of including responses unrelated to the stimulus (such as movement artefacts) or diluting the response within physiological background "noise" (Gratton, 2007). The physiological and facial expression results from a random subset of 10 consumers were extracted from recordings and their temporal profile was inspected and analysed in order to determine the key time points (epochs) that should be extracted from the full data set.

The physiological and facial expression recordings from 10 subjects were selected randomly from the 67 total recordings obtained from the main study. Data from heart rate, corrugator and zygomatic activity was inspected for each individual for the first presentation of the Control, Lightstruck and Mercaptan samples, as the Lightstruck and Mercaptan samples were expected

to represent a pleasant and unpleasant sample (consequently evoking the largest physiological/facial expression responses) based on the results of the validation study (see section 2.11). A water sample was also included in order to compare beer samples with a non-aroma control. A decision was made to use only data from the second and not the first presentation of water as some subjects assessed the first water sample incorrectly due to inexperience. The extraction, analysis and results of heart rate and corrugator/zygomatic activity is explained in the following sections. This is proceeded by details on the modifications made to the time of sample delivery assessment in respiration parameters. Skin temperature recordings were not explored as there was minimal variation in their responses.

3.4.1.1. Respiratory parameters

As with the pilot and validation studies, respiration recordings served as a method for identifying when subjects smelt an aroma and were not directly used as a measure of emotional response. To aid identification of when subjects began to inhale, the start of a sample related inhalation cycle was identified off-line by applying a double differential to a duplicate respiration waveform. This assisted in identifying the steep rate of change associated with the start of a sniff to be located, allowing the start of respiration to be identified and was used as the new time of sample delivery. This method was developed following the assistance from the UK supplier of Biopac equipment (Linton Instrumentation, personal communication). This was an improvement to the method used within the pilot and validation investigations where the start of respiration was judged by eye only.

3.4.1.2. Heart rate

Raw ECG scores were converted into heart rate and expressed as beats per minute (see section 2.3.6.2). Heart rate scores were extracted as a series of 1 second epochs over 15 seconds, leading to six 1 second epochs at 3, 5, 8, 10, 13 and 15 seconds after sample delivery. Owing to the large absolute differences in responses between individuals, response values at each epoch were divided by a baseline value (the mean heart rate in the 10 seconds proceeding sample delivery). A 10 second baseline period was used for all epochs to ensure data extractions at different time points could be easily compared.

3.4.1.3. Corrugator and zygomatic activity

Raw EMG scores were filtered and rectified using a root mean squared transformation (RMS) as described in section 2.3.6.4. Time windows for RMS were decreased from 500ms to 50ms which allowed faster changes in facial responses to be tracked (Boxtel, 2010). EMG scores were extracted as a series of 1 second epochs over 10 seconds, leading to 10 x 1 second epochs which started at the point of sample delivery. The mean corrugator and zygomatic activity 1 second before sample delivery served as the baseline for each epoch due to large absolute values between individuals. A 1 second baseline was used for all epochs to ensure data extractions at different time points could be easily compared.

3.4.1.4. Exploratory statistical analysis

Separate mixed model ANOVAs were conducted with heart rate, corrugator and zygomatic data as a single dependant variable in order to analyse the effect of sample, epoch and interactions between samples and epochs. Subject was included as random factor whilst sample and epoch were included as fixed factors. Where a significant effect was found for a fixed factor, a Tukey post hoc test was conducted on the results to identify which samples and or epochs were significantly different from one another. Statistical analysis was performed in XLSTAT (v2015.6, Addinsoft, USA).

3.4.1.5. Exploratory analysis results

The results of the mixed model ANOVA on heart rate (Table 3.2) showed that there was a significant effect of epoch on heart rate and post hoc analysis of epoch revealed that heart rate decreased significantly from 3 – 5seconds after sample delivery (Figure 3.5). However there was no significant effect of aroma or an interaction between aroma and samples (Table 3.2).

Table 3.2. P-values from mixed model ANOVAs on heart rate, corrugator and zygomatic activity. Aroma and epoch were fixed factors and subject was a random factor. Heart rate epoch = 3,5,8,10 and 15 seconds. Corrugator and zygomatic epoch = 1-10 seconds.

Variable	Subject	Aroma	Epoch	Aroma x epoch
Heart rate	<0.0001	0.946	**<0.0001**	0.991
Corrugator activity	<0.0001	**0.001**	0.304	0.990
Zygomatic activity	0.002	0.069	0.067	0.991

For the facial expression variables, there was a significant effect on aroma on corrugator activity and a significant effect of aroma and epoch on zygomatic activity at the 10% (p = 0.1) significance level (Table 3.2).

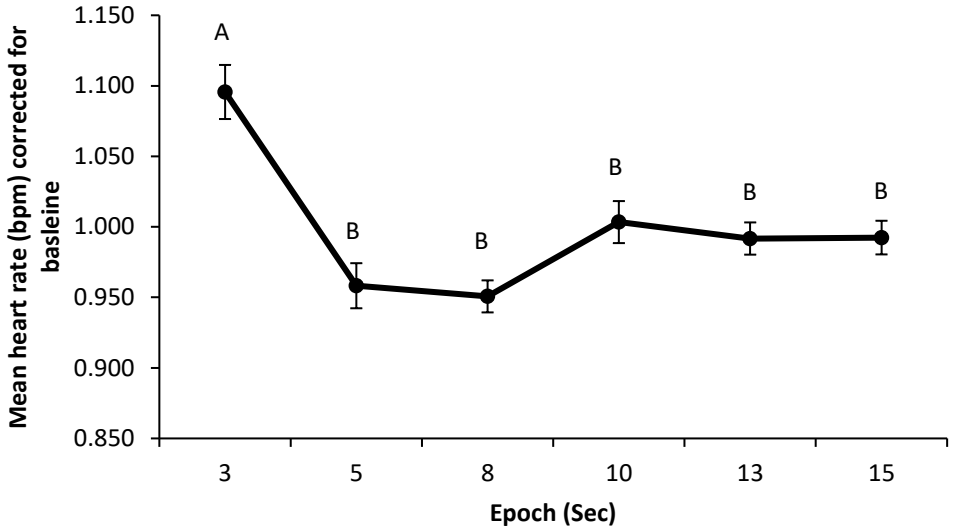


Figure 3.5. Mean (plus standard error of the mean) heart rate over a series of seconds after smelling aroma. Different letters indicate significant differences (Tukey post hoc test, p > 0.05. bpm = beats per minute.

Visual inspection of the mean epoch values obtained for corrugator and zygomatic activity suggested that the majority of the variance in EMG activity occurred within epochs 1-3 (Figure 3.6). In order to inspect this statistically, the data from both EMG recordings was re-analysed with aroma, epoch and an aroma x epoch interaction but only epochs 1-3 were included within the analysis.

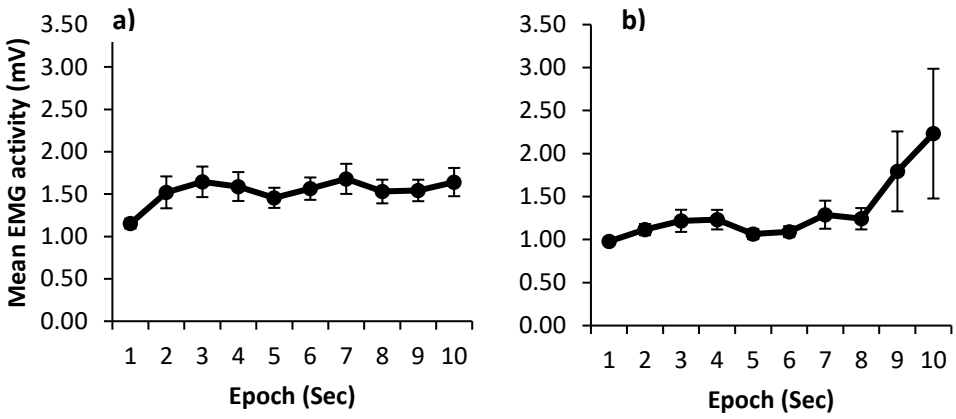


Figure 3.6. a) Mean (plus standard error of the mean) corrugator and b) zygomatic activity corrected for baseline at epochs 1-10.

The results now revealed that there was an overall significant effect of epoch on corrugator activity but no significant effect of aroma or interaction between aroma and epoch on corrugator or zygomatic activity (Table 3.3). Post hoc analysis of corrugator epoch revealed that significantly greater activity was observed in the epoch at 3rd second compared to the epoch taken at the 1st second (Figure 3.7a). Although there was no significant interaction between aroma and epoch, the mean corrugator activity at epochs 1, 2 and 3 were visually inspected per aroma to ensure that the overall effect of epoch was not caused by one aroma. The subsequent visual inspection of epoch per aroma confirmed that corrugator activity for both Mercaptan and Lightstruck samples increased from epochs 1 to 2 and epoch 2 to 3 (Figure 3.7b). It is likely that this interaction was not significant due to the low number of samples and high variability (variability not shown).

Table 3.3. P-values from mixed model ANOVAs on corrugator and zygomatic activity. Aroma and epoch were fixed factors and subject was a random factor. Corrugator and zygomatic epoch = 1-3 seconds.

Variable	Subject	Aroma	Epoch	Aroma x epoch
Corrugator activity	0.001	0.466	**0.039**	0.911
Zygomatic activity	0.030	0.171	0.117	0.765

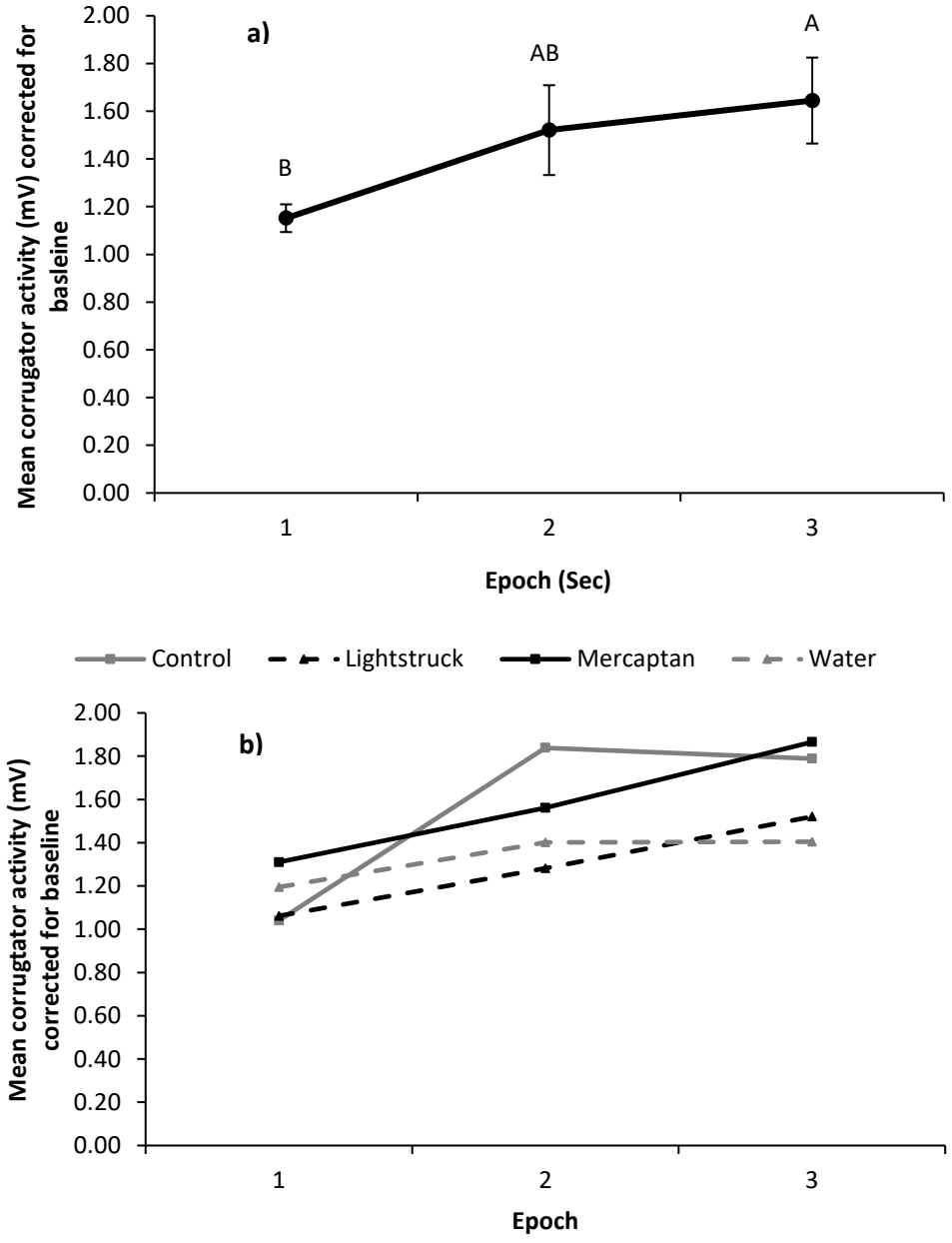


Figure 3.7. a) Overall mean (plus standard error of the mean) corrugator scores over 1-3 seconds after sample delivery. Different letters indicate significant differences between samples. (Tukey test $p < 0.05$). b) Mean corrugator scores per sample over 1-3 seconds after sample delivery.

3.4.1.6. Exploratory analysis conclusions

Performing analysis on physiological data from 10 individuals enabled an insight into where the greatest sources of variation existed within the data set. Heart rate showed significantly higher values at 3 seconds compared to values obtained from later epochs but it is likely that heart rate was increasing in response to respiration owing to the coupled relationship between respiration and R-R intervals (see section 1.7.5) (Yasuma and Hayano, 2004). However as heart rate did not appear to differ significantly between epochs 5 and 15 it was decided to extract mean heart rate from 0-5 seconds, 0-10 seconds and 0-15 seconds after sample presentation for the full analyses in order to compare results within these response times. Corrugator activity showed the largest variation in response between epochs 1 and 3. Although no significant effect of zygomatic activity was found between epochs 1-3, visual inspection of the mean values obtained in between epochs 1 to 10 suggested that the majority of variation was restricted to these time points. Consequently, for the full data set it was decided to only extract data within the first three seconds after sample presentation (mean EMG activity at 0-1 seconds, 0-2 seconds and 0-3 seconds). Although variations could be seen at epochs 7 and 15, these were considered to occur too late after inhalation to be sample related.

3.4.2. Full analysis

3.4.2.1. Data processing of physiological and facial expression measures

Based on the conclusions for the exploratory analysis, data was extracted to investigate mean heart rate at: 0-5 seconds, 0-10 seconds and 0-15 seconds after sample delivery. With regards to EMG activity, corrugator and zygomatic data was extracted to investigate mean muscle response at; 0-1 seconds, 0-2 seconds and 0-3 seconds after sample delivery. Data extractions at these time points allowed the examination and statistical analysis of key sections within the data where stimulus specific responses were expected to be more discriminating based on the results from the exploratory analysis. Skin temperature was extracted at 0-10 seconds only. All responses were divided by baseline values and facial expression responses underwent a log10 transformation as they were right skewed. A summary of the data processing methods for each measurement variable can be found in Table 3.4. The results of one subject's physiological/facial expression measures had to be removed owing to a recording error leading to a total of 59 subjects for physiological/facial expression measures and 60 subjects for self-report responses. The results from the first replicate of Mercaptan and Lightstruck observations were also removed from two subjects in both implicit and explicit recordings owing to data recording errors restricted to these samples. Finally heart rate recordings were removed from additional Mercaptan, Control and Water sample replicates owing to ECG recording errors.

Table 3.4. Summary of the physiological and facial expression data processing used in full study analysis.

Measurement type	Measurement name	Measurement units	Mean response measurement	Mean baseline measurement (before stimulus presentation	Data trans-formation	Offline filter
Physiological measures	Heart rate	Beats per minute (bpm)	0-5sec, 0-10sec*, 0-15sec	10sec	None	None
	Skin temperature	Degrees Celsius (°C)	0-10sec*	10sec	None	None
Facial expression measures	Corrugator activity	Millivolts (mV)	0-1sec, 0-2sec, 0-3sec*	1sec	Log10	FIR bandpass filter (20Hz to 500Hz), Comb band filter (50Hz)(Boxtel, 2010)
	Zygomatic activity	Millivolts (mV)	0-1sec, 0-2sec, 0-3sec*	1sec	Log10	FIR bandpass filter (20Hz to 500Hz), Comb band filter (50Hz)(Boxtel, 2010)

*** Indicates results reported in thesis**

3.4.3. Statistical analysis

Physiological and facial expression measures were analysed using mixed model ANOVAs with both sample, replicate and a sample x replicate interaction. Sample and replicate were included as fixed factors and subject as a random factor. Where significant effects were found Tukey post hoc tests were conducted in order to determine which samples, replicates or interactions were significantly different from one another. Zygomatic activity was also analysed non-parametrically using a Friedman analysis (with Nemenyi's post hoc test) in order to determine whether the significance of this variable could be determined by its rank order instead of its magnitude.

Gender effects were analysed separately for each physiological and facial expression measure using ANOVA where gender, sample and replicate were included as fixed factors. Replicate was included within physiological/facial expression gender analysis, to take into account the effect of replicate had on responses of males and females. In addition it helped to pull apart any aroma specific effects of replicate which were not evident in the mixed model ANOVA.

Self-reported emotional response, liking and familiarity were analysed using mixed model ANOVAs where sample was a fixed factor and subject was included as a random factor. Where significant main effects were found, Tukey post hoc tests were conducted in order to determine which aromas could be significantly distinguished from one another.

In order to investigate the effect of gender, male and female scores were analysed for each aroma within each of the 10 emotion categories and liking and familiarity using independent samples T-tests.

In order to compare physiological/facial expression, self-reported emotional response and liking scores, mean scores from each emotion category (as well as liking and familiarity) and physiological/facial expression responses were used for a Pearson's Correlation analyses and multivariate principle component analysis (PCA) analyses. P-values < 0.05 were considered significant. All statistics were performed in XLSTAT (Version 2015.6, Addinsoft, NY, USA).

3.5. Results

The following results section presents results concerning:

- The discrimination ability of physiological and facial expression responses between a) water and beer samples and b) within beer samples.
- The discrimination ability of self-reported emotional response, liking and familiarity scores.
- Comparison of the discrimination ability of physiological/facial expression responses with self-reported emotional response and liking.
- Differences in emotional response in males and females measured through implicit and explicit measures.

3.5.1. Physiological responses

Mean values and standard error of the mean (S.E.M) for both heart rate and skin temperature in response to water and beer aromas are displayed in Table 3.5. With respect to the comparison between the water sample and beer aromas, the mixed model ANOVA did not reveal a significant effect of sample, replicate or interaction between sample x replicate for either heart rate or skin temperature when $p < 0.05$ (Table 3.6). However, heart rate analysis yielded a p-value of the sample effect which was close to significance ($p = 0.057$). Consequently, it was decided to conduct a post hoc analysis on heart rate scores. The Tukey post hoc results ($p < 0.05$) revealed that Diacetyl led to the greatest increase in heart rate which was significantly higher in comparison to the non-aroma water sample (Figure 3.8). No other comparisons were found to be statistically significant. When only the beer

Table 3.5. Mean values (and standard error of the mean) and number of subjects for physiological measures (two replicates). Values are baseline corrected (response values divided by baseline values). bpm = beats per minute

Sample	No. of subjects		Heart rate (bpm)	No. of subjects		Skin temperature (˚C)
	Rep1	Rep2		Rep1	Rep2	
Water	-	58	1.003 ±0.004	-	59	0.999851 ±3.5x10^{-5}
Control	58	59	1.013 ±0.005	59	59	0.999843 ±4.1x10^{-5}
Diacetyl	59	59	1.021 ±0.005	59	59	0.999864 ±3.3x10^{-5}
Lightstruck	58	59	1.020 ±0.005	58	59	0.999897 ±3.9x10^{-5}
Hoppy	59	59	1.012 ±0.005	59	59	0.999901 ±3.6x10^{-5}
Isoamyl acetate	59	59	1.019 ±0.005	59	59	0.999877 ±3.1x10^{-5}
Hydrogen sulphide	59	59	1.016 ±0.005	59	59	0.999923 ±3.4x10^{-5}
Mercaptan	57	59	1.016 ±0.005	58	59	0.999911 ±3.6x10^{-5}

aromas were analysed, no significant main effects could be found for heart rate or skin temperature (Table 3.6).

Table 3.6. P-values from mixed model ANOVAs' main effects of sample, replicate and sample x replicate for physiological measures towards beer aromas and water samples and beer aromas only.

	Physiological measure	Sample	Replicate	Sample x replicate
Beer aromas & water sample	Heart rate	0.056	0.478	0.881
	Skin temperature	0.543	0.733	0.893
Beer aromas only	Heart rate	0.657	0.577	0.829
	Skin temperature	0.525	0.784	0.796

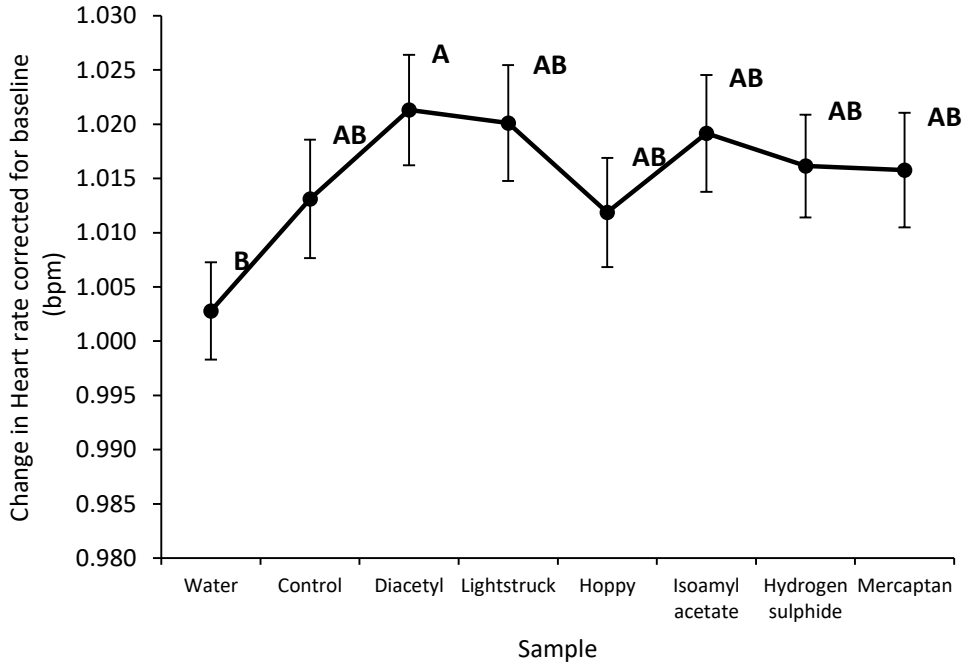


Figure 3.8. Mean change in heart rate (and standard error of the mean) in response to beer and water samples. Letters above bars represent Tukey HSD groupings ($p < 0.05$).

3.5.2. Facial expression responses

Mean scores and S.E.M for corrugator and zygomatic responses towards water and beer samples are displayed in Table 3.7. Firstly concerning the beer and water samples, the analysis intended to identify whether less corrugator activity (and consequently less frowning activity) would be produced when smelling no aroma, compared to smelling beer aromas. The mixed model ANOVA revealed there was a significant effect of aroma and replicate (Table 3.8) and post hoc analysis revealed the water sample evoked the least corrugator activity which was significantly lower than the responses observed towards the Diacetyl, Hoppy, Hydrogen sulphide and Mercaptan samples (Figure 3.9). When only the beer aromas were included within the analysis, the mixed model ANOVA showed that there was a significant effect of both sample and replicate on corrugator activity (Table 3.8).

Table 3.8. P-values from mixed model ANOVAs' main effects of sample, replicate and sample x replicate for facial expression measures towards beer aroma and water samples and beer aroma only.

	Facial expression measure	Sample	Replicate	Sample x replicate
Beer aroma inc water	Corrugator supercilii	**<0.0001**	**0.0001**	0.276
	Zygomatic major	0.423	0.128	0.518
Beer aroma only	Corrugator supercilii	**<0.0001**	**<0.0001**	0.331
	Zygomatic major	0.331	0.078	0.521

With regards to variation in corrugator activity in response to beer aroma, the Mercaptan and Hydrogen sulphide samples resulted in the largest increase in frowning activity and post hoc analysis ($p < 0.05$) (Figure 3.10) revealed that

the frowning activity observed towards the Mercaptan sample was significantly larger compared to all other aromas except for Hydrogen sulphide.

Table 3.7. Mean values (and standard error of the mean) and number of subjects for facial expression measures (two replicates). Values are baseline corrected and log10 transformed.

Sample	No. of subjects		Corrugator activity (mV)	No. of subjects		Zygomatic activity (mV)
	Rep1	Rep2		Rep1	Rep2	
Water	-	59	-0.029 ±0.01	-	59	0.065 ±0.014
Control	59	59	0.033 ±0.02	59	59	0.046 ±0.013
Diacetyl	59	59	0.030 ±0.02	59	59	0.051 ±0.017
Lightstruck	58	59	0.033 ±0.018	58	59	0.071 ±0.019
Hoppy	59	59	0.069 ±0.021	59	59	0.068 ±0.013
Isoamyl acetate	59	59	0.046 ±0.021	59	59	0.066 ±0.015
Hydrogen sulphide	59	59	0.144 ±0.027	59	59	0.076 ±0.020
Mercaptan	58	59	0.112 ±0.025	58	59	0.090 ±0.023

The Hydrogen sulphide sample was also found to increase frowning activity significantly in comparison to the Control, Lightstruck and Isoamyl acetate samples which elicited the smallest frowning responses. However no significant differences were found between the Control, Lightstruck and Isoamyl acetate samples and the Diacetyl and Hoppy samples. Further post hoc analysis ($p < 0.05$) on the replicate factor indicated that frowning responses were recorded as being larger the second time a subject smelt an aroma (mean and S.E.M of second replicate = 0.092 mV ±0.012) in comparison to the first time they smelt an aroma (mean and S.E.M of first replicate = 0.041 mV±0.011). However there was no significant interaction between

samples and replicates, consequently it is not possible to identify whether replicate effects were restricted to particular samples or not.

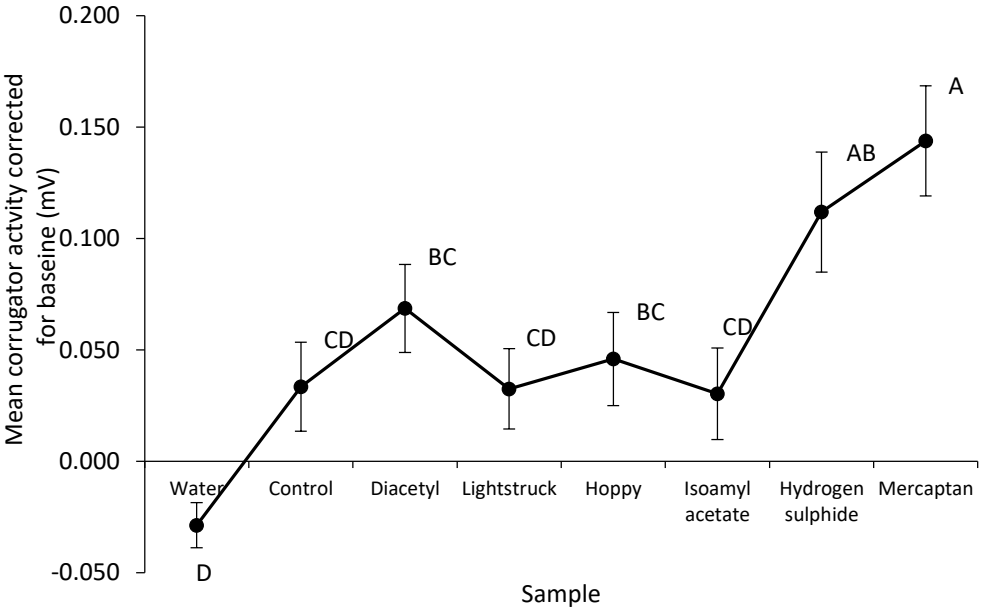


Figure 3.9. Mean change in heart rate (and standard error of the mean) in response to water and beer samples. Letters above bars represent Tukey HSD groupings ($p < 0.05$).

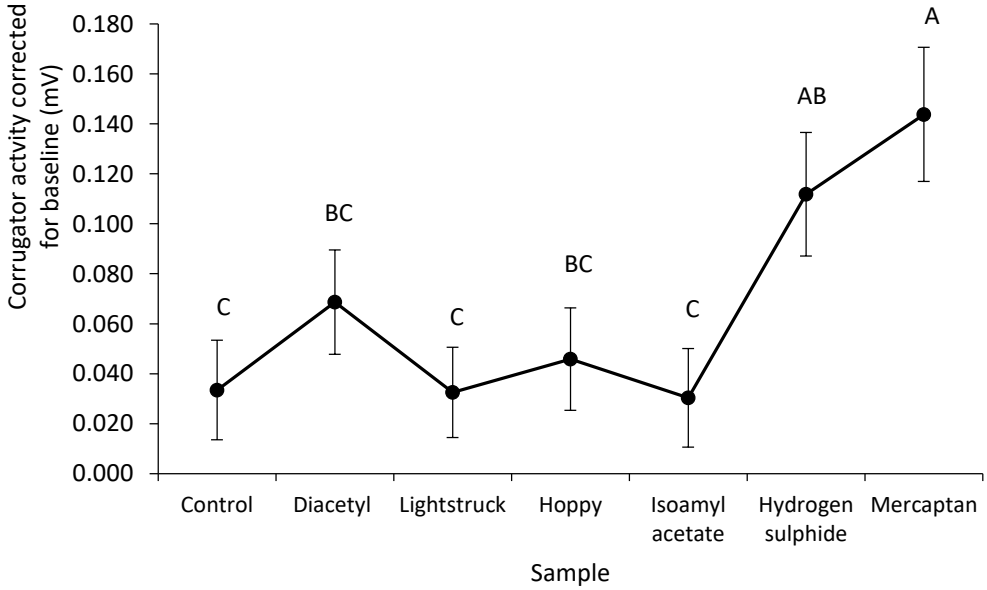


Figure 3.10. Mean change in heart rate (and standard error of the mean) in response to beer samples. Letters above bars represent Tukey HSD groupings ($p < 0.05$).

The analysis of zygomatic activity intended to identify whether subjects smiled more in response to some samples than others. Concerning the effect of sample aroma on zygomatic activity, the mixed model ANOVA revealed that there was no significant effect of sample, replicate or interaction between samples and replicates on zygomatic responses. Indeed this was the case when both water and beer samples were considered as well as when only beer samples were included in the analysis (Table 3.8). However given the large variations in response values, zygomatic activity was also analysed non-parametrically, using a Friedman test, in order to determine if there were significant differences on the ranking of samples. When both water and beer samples were analysed, there was significant difference between samples, with the p value slightly exceeding the $p < 0.05$ threshold level. When the analysis was performed on beer samples only, the Freidman test found that zygomatic activity did vary with beer aroma $X^2 = 15.57$, $d.f. = 6$, $p = 0.016$. Post hoc analysis using Nemenyi's procedure ($p < 0.05$) revealed that the Mercaptan sample (mean rank = 4.71) evoked significantly greater zygomatic and hence smiling activity in comparison to the Control (mean rank = 3.46) and Diacetyl (mean rank = 3.53) samples.

3.5.3. Self-reported emotional response

The mixed model ANOVA revealed that there was a significant effect of sample within each of the 10 emotion categories (Table 3.9). In order to determine which samples were significantly different from each other, Tukey post hoc tests were carried out on each of the emotion categories to identify sample groupings and have been displayed alongside the mean scores in

Table 3.9. Water sample data was not included because the emotional lexicon was developed for assessing emotional response towards beer and not water samples. Inspection of the post hoc groupings revealed that the majority of emotion categories distinguished between aromas in a similar way; being broadly divided into emotion categories associated with displeasure/unpleasantness (shocked, bored, disconfirmed and underwhelmed) and emotion categories associated with pleasure/pleasantness (content, excited, tame/safe and nostalgic).

With regards to the emotion categories associated with displeasure/unpleasantness, the categories shocked and bored were highly discriminating towards the samples Mercaptan and Hydrogen sulphide, which received significantly higher scores compared to all other samples. The Mercaptan and Hydrogen sulphide samples were also somewhat well described by the disconfirmed and underwhelmed categories, receiving significantly higher scores than the Lightstruck, Hoppy and Isoamyl acetate samples. However both Mercaptan and Hydrogen sulphide shared post hoc groupings with the Control and Diacetyl samples in the case of the underwhelmed category, whilst only Hydrogen sulphide shared these groupings within the disconfirmed category. Consequently the Mercaptan and Hydrogen sulphide samples were the most unpleasant samples as they were best described by emotion categories associated with displeasure/unpleasantness.

The Lightstruck, Hoppy and Isoamyl acetate samples were well discriminated by the emotion categories associated with pleasure/pleasantness and received significantly higher scores than the Hydrogen sulphide and Mercaptan samples within the content, excited and tame/safe categories (except within the tame/safe category where Isoamyl acetate and Hydrogen sulphide shared groupings). Consequently the Lightstruck, Hoppy and Isoamyl acetate samples were the most pleasant samples as they were best described by the emotion categories associated with pleasure/pleasantness.

The Control and Diacetyl samples shared post hoc groupings with both pleasant and unpleasant samples in many emotional categories and were consistent with more emotionally neutral samples. The curious and bored emotion categories discriminated between samples in slightly different ways compared to other eight emotion categories. For example within the bored category, the Hydrogen sulphide, Diacetyl, Lightstruck, Hoppy and Isoamyl acetate could not be discriminated from each other, whilst the Lightstruck sample could not be discriminated from the unpleasant Hydrogen sulphide and Mercaptan samples within the curious category.

3.5.4. Liking and familiarity scores

There was a significant effect of sample within both the liking and familiarity ratings (Table 3.9) and consequently Tukey post hoc analysis was conducted to identify which samples were significantly different from one another. Post hoc groupings are displayed alongside mean scores in Table 3.9. Post hoc groupings on liking scores revealed that the Lightstruck, Hoppy, Isoamyl acetate, Diacetyl and Control samples were liked significantly more than the Hydrogen sulphide and Mercaptan samples. Furthermore, the Lightstruck sample was additionally liked significantly more than the Control and Diacetyl samples but no other comparisons were found to be significant. With regards to the familiarity ratings, Lightstruck was rated significantly more familiar than all other samples, whilst similar post hoc groupings were shared between Control, Diacetyl and Isoamyl acetate samples as well as between Diacetyl, Hoppy and Hydrogen sulphide samples.

Table 3.9. Main effect P-values from mixed model ANOVA on the effects beer aroma had on emotion categories (and liking and familiarity) where sample was fixed factors and subject was included as a random factor. Mean scores (on 10 point scale) are displayed for samples across emotion categories as well as liking and familiarity with Tukey HSD post hoc groupings.

Emotion category	p-value	Sample						
		Control	Diacetyl	Lightstruck	Hoppy	Isoamyl acetate	Hydrogen sulphide	Mercaptan
Shocked	**<0.0001**	2.91 B	2.94 B	2.00 B	2.97 B	2.92 B	4.63 A	4.88 A
Bored	**<0.0001**	3.38 AB	2.94 ABC	2.41 C	2.31 C	2.50 BC	2.99 ABC	3.66 A
Content	**<0.0001**	4.75 BCD	4.66 CD	6.40 A	5.80 AB	5.60 ABC	3.71 DE	3.06 E
Excited	**<0.0001**	4.48 BC	4.35 BC	6.11 A	5.67 A	5.29 AB	3.53 CD	2.82 D
Nostalgic	**<0.0001**	3.79 B	3.77 B	5.42 A	3.83 B	3.81 B	3.22 BC	2.41 C
Disconfirmed	**<0.0001**	3.63 BC	3.58 BC	2.12 D	2.73 CD	2.80 CD	4.66 AB	5.74 A
Disgusted	**<0.0001**	2.96 B	3.02 B	1.76 C	2.41 BC	2.27 BC	4.62 A	5.47 A
Tame/Safe	**<0.0001**	4.62 ABC	4.80 AB	5.51 A	4.94 AB	4.55 BC	3.74 CD	3.44 D
Underwhelmed	**<0.0001**	3.82 AB	3.47 AB	3.06 B	3.07 B	2.94 B	4.26 A	4.14 A
Curious	**<0.0001**	4.88 C	4.99 BC	5.39 ABC	6.38 A	5.99 AB	5.13 BC	4.55 C
Liking	**<0.0001**	5.27 BC	5.13 C	6.84 A	6.15 ABC	6.31 AB	3.88 D	3.21 D
Familiarity	**<0.0001**	6.11 B	5.73 BCD	7.43 A	4.68 DE	5.87 BC	4.83 CDE	3.87 E

ABCDE: letters within the same row indicate post hoc groupings by Tukey HSD ($p < 0.05$).

3.5.5. Correlation analysis

In order to assess the relationship between physiological, facial expression and self-report measures a Pearson's Product Moment Analysis was performed (Table 3.10). Categories associated with pleasure/pleasantness (excited, content, nostalgic and tame/safe) had a strong positive correlation with one another (>0.8) and categories associated with displeasure/unpleasantness (shocked, disconfirmed, disgusted and underwhelmed) were also highly positively correlated with one another (>0.8). Emotion categories associated with pleasure/pleasantness and

displeasure/unpleasantness respectively was negatively correlated with one another (except for nostalgic and underwhelmed). Bored, nostalgic and curious shared the least relation to other emotion categories. Comparison of emotion categories with liking and familiarity scores revealed that liking scores had a strong relation with all 10 emotion categories as well as familiarity, whilst familiarity itself had a strong relation with six of the 10 emotion categories with a particularly strong positive correlation with the nostalgic category.

Corrugator activity was the only physiological/facial expression measure that had any relationship with self-reported emotional response, liking and familiarity. Corrugator activity had a strong negative relation with emotion categories associated with pleasure/pleasantness and a strong positive correlation with emotion categories associated with displeasure/unpleasantness. Corrugator was also positively associated with the bored category (but was the least significant association) whilst there was no significant relationship between curious and corrugator activity. In contrast, zygomatic activity, heart rate or skin temperature had no significant relationship with any emotion category or with familiarity or liking. However when the correlations between physiological/face expression measures were assessed amongst themselves, only skin temperature and zygomatic activity were found to have strong positive correlation with one another.

Table 3.10. Pearsons Product Moment correlation coefficients between physiological, facial expression and self-reported emotional response (and liking and familiarity). Statistically significant correlation are highlighted in bold. * denotes significance at $p < 0.05$, and ** $p < 0.01$ levels.

Variable	Liking	Familiarity	Shocked	Bored	Content	Excited	Nostalgic	Disconfirmed	Dis-gusted	Tame/Safe	Under-whelmed	Curious	Corrugator	Zygomatic	Heart rate	Skin temp
Liking	**1**	**0.773***	**-0.936****	**-0.862***	**0.995****	**0.991****	**0.891****	**-0.992****	**-0.990****	**0.936**	**-0.946****	**0.777***	**-0.964****	-0.545	0.214	-0.308
Familiarity	**0.773***	**1**	**-0.874****	-0.498	**0.755***	0.724	**0.927****	**-0.773***	**-0.794***	**0.796***	-0.623	0.239	**-0.834***	-0.395	0.469	-0.461
Shocked	**-0.936****	**-0.874***	**1**	0.671	**-0.918****	**-0.901****	**-0.911****	**0.936****	**0.956****	**-0.957****	**0.851***	-0.534	**0.939****	0.637	-0.301	0.549
Bored	**-0.862***	-0.498	0.671	**1**	**-0.880****	**-0.898****	-0.735	**0.882****	**0.835***	**-0.769***	**0.832***	**-0.877****	**0.755***	0.301	-0.222	-0.122
Content	**0.995****	**0.755***	**-0.918****	**-0.880****	**1**	**0.998****	**0.901****	**-0.991****	**-0.975****	**0.946****	**-0.930****	**0.789***	**-0.943****	-0.494	0.187	-0.232
Excited	**0.991****	0.724	**-0.901****	**-0.898****	**0.998****	**1**	**0.886****	**-0.990****	**-0.971****	**0.939****	**-0.923****	**0.818***	**-0.937****	-0.503	0.150	-0.206
Nostalgic	**0.891****	**0.927****	**-0.911****	-0.735	**0.901****	**0.886****	**1**	**-0.909****	**-0.887****	**0.933****	-0.738	0.481	**-0.875****	-0.368	0.380	-0.242
Disconfirmed	**-0.992****	**-0.773***	**0.936****	**0.882****	**-0.991****	**-0.990****	**-0.909****	**1**	**0.991****	**-0.955****	**0.915****	**-0.767***	**0.954****	0.563	-0.223	0.290
Disgusted	**-0.990****	**-0.794***	**0.956****	**0.835***	**-0.975****	**-0.971****	**-0.887****	**0.991****	**1**	**-0.936****	**0.926****	-0.738	**0.976****	0.634	-0.237	0.404
Tame/Safe	**0.936****	**0.796***	**-0.957****	**-0.769***	**0.946****	**0.939****	**0.933****	**-0.955****	**-0.936****	**1**	**-0.827***	0.609	**-0.884****	-0.531	0.238	-0.331
Underwhelmed	**-0.946****	-0.623	**0.851***	**0.832***	**-0.930****	**-0.923****	-0.738	**0.915****	**0.926****	**-0.827***	**1**	**-0.800***	**0.875****	0.470	-0.279	0.294
Curious	**0.777***	0.239	-0.534	**-0.877****	**0.789***	**0.818***	0.481	**-0.767***	-0.738	0.609	**-0.800***	**1**	-0.696	-0.423	-0.188	0.067
Corrugator	**-0.964****	**-0.834***	**0.939****	**0.755***	**-0.943****	**-0.937****	**-0.875****	**0.954****	**0.976****	**-0.884****	**0.875****	-0.696	**1**	0.664	-0.153	0.464
Zygomatic	-0.545	-0.395	0.637	0.301	-0.494	-0.503	-0.368	0.563	0.634	-0.531	0.470	-0.423	0.664	**1**	0.211	**0.787***
Heart rate	0.214	0.469	-0.301	-0.222	0.187	0.150	0.380	-0.223	-0.237	0.238	-0.279	-0.188	-0.153	0.211	**1**	-0.087
Skin temp	-0.308	-0.461	0.549	-0.122	-0.232	-0.206	-0.242	0.290	0.404	-0.331	0.294	0.067	0.464	**0.787**	-0.087	**1**

3.5.6. Principal component analysis

The Principal Component Analysis (PCA) was run using all 10 emotion categories as active variables and included liking, familiarity and physiological/facial expression measures as supplementary variables. The first two principal components (PC) accounted for 97.64% of the total variance in the data (Figure 3.11). PC1 accounted for the majority of the data variation (93.20%) and was highly positively correlated with the emotion categories associated with displeasure/unpleasantness (disgusted, disconfirmed, underwhelmed and disconfirmed) as well as shocked and bored to a lesser degree. PC1 was also highly positively correlated with emotion categories associated with pleasure/pleasantness (content, excited, tame/safe and nostalgic). Shocked, bored and curious also had some relation with PC2 but only curious had moderate positive correlation (0.647) with PC2, however, PC2 only accounted for a much smaller amount (4.43%) of the total data variation and no emotional categories loaded onto this PC with a correlation coefficient above 0.70. As a consequence this PCA is dominated by PC1 which describes the pleasantness/unpleasantness dimension of emotion, usually referred to as valence but also receives some influence from the activation dimension, reflecting a circumplex model of emotion (see section 1.2.2) (Larsen and Diener, 1992; Russell, 1980).

Figure 3.12 shows the sample observations and reflects the post hoc groupings revealed from the mixed model ANOVA. The Hydrogen sulphide and Mercaptan are highly positively correlated with PC1 and load strongly onto the displeasure/unpleasant dimension of emotion. Lightstruck was

highly negatively correlated with PC1 as were both Hoppy and Isoamyl acetate to a lesser extent. These three samples were therefore well represented by the pleasure/pleasantness dimension of emotion. The Diacetyl and Control samples do not load strongly onto either PC1 or PC2 therefore are more consistent with a neutral emotional response.

Liking was negatively associated with PC1 and hence with the pleasantness dimension of emotion and Lighstruck, Hoppy and Isoamly acetate samples, whilst Familiarity scores showed some correlation towards both PC1 and PC2, with a stronger relation with PC1, which is likely explained by its strong correlation with nostalgic scores. Corrugator scores were positively associated with PC1 and hence better represented by the displeasure/unpleasant emotion categories and Hydrogen sulphide and Mercaptan samples, which also loaded well onto this PC. Zygomatic major activity was also positively correlated with PC1 but did not load well onto this PC. Finally the variation in both skin temperature and heart rate was not explained well by either PC1 or PC2.

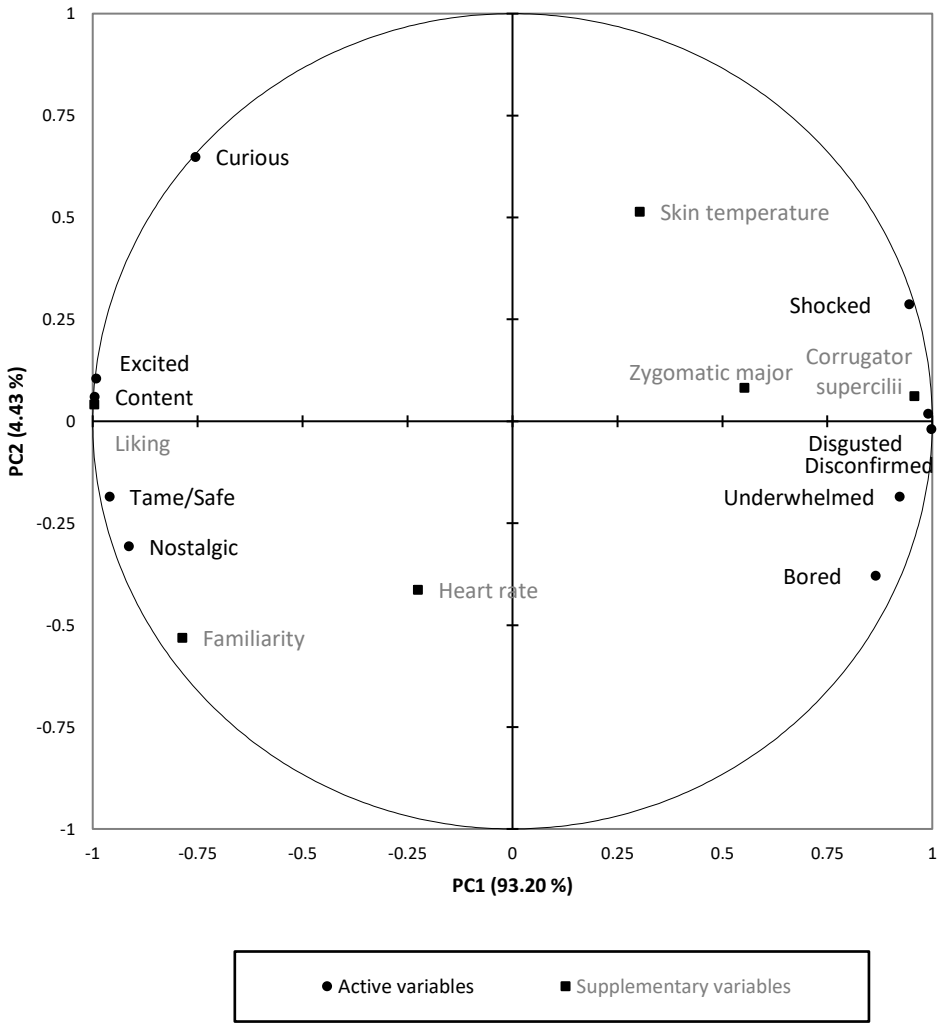


Figure 3.11. Correlation graph for PC1 and PC2. Active variables include 10 emotion categories from consumer-led lexicon. Physiological and facial expression measures included as supplementary variables.

3.5.7. Comparison between implicit and explicit measures

The PCA and post hoc groupings from the mixed model ANOVAs allowed a useful comparison between self-reported emotional response, physiological/facial expression response and liking scores. Comparison of the significant facial expression variables, corrugator and zygomatic activity, with self-reported emotional response revealed both similarities and differences in discrimination ability between explicit and implicit measures.

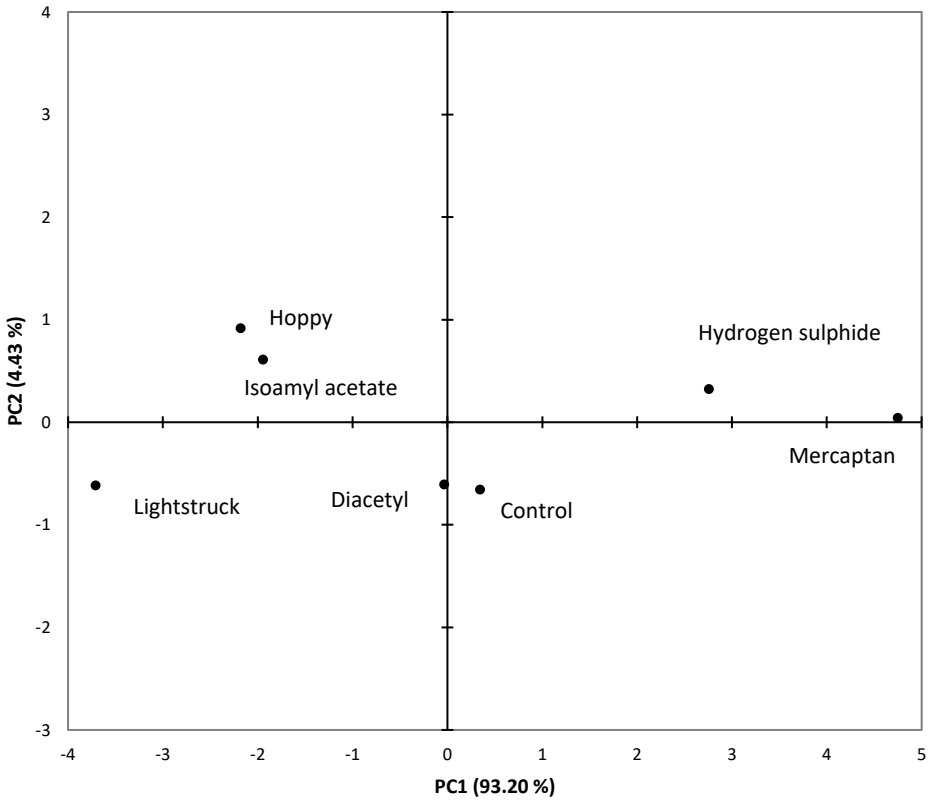


Figure 3.12. Observation plot displaying position of beer samples within PC1 and PC2.

Both corrugator activity and emotion categories associated with displeasure (shocked, disconfirmed, disgusted and underwhelmed) showed higher activity/scores to the unpleasant aromas Hydrogen sulphide and Mercaptan. However whilst corrugator post hoc groupings could not discriminate Control, Diacetyl, Lightstruck, Hoppy and Isoamyl acetate samples, post hoc groupings in seven out of the 10 emotion categories (bored, content, excited, nostalgic, disconfirmed, disgusted and curious) were able to show some discrimination between these samples. For example the disconfirmed and disgusted categories allowed the Lightstruck sample to be discriminated from the Control and Diacetyl samples. Zygomatic activity post hoc groupings could

separate unpleasant Mercaptan samples from Control and Diacetyl samples. However no significant differences were found between any other samples.

As with emotion response categories, liking scores were able to provide greater discrimination between pleasant and neutral samples than corrugator and zygomatic responses. For example, the Lightstruck sample was significantly more liked than the Diacetyl and Control samples and both unpleasant aromas could be discriminated from pleasant and neutral samples with liking scores (whereas this was only the case with Mercaptan in the case of corrugator activity).

Concerning the comparison between self-reported emotional responses with liking scores, pleasant emotion categories were able to reveal subtle differences between pleasant aromas which were not distinguishable on the basis of liking scores alone. For example the Hoppy sample could be discriminated from the Control and Diacetyl samples within the excited category but could not be on the basis of liking scores alone. Furthermore nostalgia category was able to discriminate Lightstruck from Hoppy and Isoamyl acetate samples, whilst the tame/safe category allowed the Lightstruck sample to be discriminated from Isoamyl acetate, despite these samples sharing post hoc groupings within liking scores. Emotion categories such as bored and curious had post hoc grouping which appeared to be less related to liking and pleasantness compared to other emotional categories. Within the curious category, this allowed the Hoppy sample to once again be

discriminated from the Control and Diacetyl samples, despite Lightstruck not being significantly different from any other sample.

3.5.8. Effects of gender

Concerning physiological and facial expression measures, the univariate analysis with ANOVA allowed the effect of gender and replicate to be investigated with respect to each aroma independently. No significant effect of gender, replicate or interaction between gender and replicate was found towards beer aroma within heart rate, skin temperature or zygomatic responses. However a significant effect of replicate was observed towards corrugator activity in response to Hydrogen sulphide samples ($F_{(1,114)} = 5.86$, $p = 0.017$) with greater frowning activity observed in the second (0.171 mV S.E.M±0.035) compared to the first presentation (0.052 mV S.E.M±0.033) of a sample. As no other effects of replicate were observed towards any other sample, it is likely that the significant replicate effects observed within the mixed model ANOVA were partly determined by the higher responses obtained towards the second presentation of hydrogen sulphide samples.

With regards to self-reported emotional response, liking and familiarity a series of independent T-tests were conducted with respect to each beer aroma and a number of significant gender effects were found. In particular male (shocked = 2.43 ±0.35, bored = 2.83 ±0.31) subjects rated the Lightstruck sample higher in shocked ($t_{(57)} = -2.84$, $p = 0.033$) and bored ($t_{(57)} = -2.08$, $p = 0.042$) categories compared to females (shocked = 1.5 ±0.21, bored = 1.89 ±0.35). Furthermore males (bored = 3.08 ±0.39, disconfirmed = 3.34 ±0.45)

also rated the Hoppy sample as significantly higher in bored ($t_{(57)}$ = -3.59, p = 0.001) and disconfirmed ($t_{(57)}$ = -2.19, p = 0.33) categories than females (bored = 1.43 ± 0.21, disconfirmed =2.03 ±0.38). With regards to the Isoamyl acetate sample, males (4.39 ±0.45) rated the aroma as significantly more nostalgic ($t_{(57)}$ = -2.02, p = 0.048) compared to females (3.15 ±4.17). However females (5.69 ±0.45) found the Diacetyl ($t_{(57)}$ = 2.23, p = 0.030) sample significantly more curious compared to males (4.39 ±0.38). No significant effects of gender were found on liking or familiarity scores.

3.6. Discussion

Emotional response towards beer aromas were assessed using physiological and facial expression measures as well as self-reported emotional response using a consumer defined emotional lexicon specific to beer as well as liking and familiarity ratings. Based on the results of this investigation, the beer aromas could be broadly categorised into pleasant aromas, (Lightstruck, Hoppy and Isoamyl acetate spiked beer samples) unpleasant aromas (Mercaptan and Hydrogen sulphide spiked beer samples) and emotionally neutral samples (Diacetyl spiked beer sample and a non-spiked Control beer). The overall aim of this investigation was to investigate whether self-reported emotional response or physiological and facial expression measures of emotion were more discriminating towards beer aroma and whether either of these measures were more discriminating than liking.

3.6.1. Physiological and facial expression responses

Neither of the physiological measures; heart rate and skin temperature, were affected by sample aroma. With regards to heart rate, this does not support the results obtained from previous studies on aroma, where heart rate has been found to respond to the valence (pleasantness/ unpleasantness) dimension of aroma stimuli, increasing in response to unpleasant aromas (Bensafi et al., 2002a, 2002c; Brauchli et al., 1995; Delplanque et al., 2009; He et al., 2014; Pichon et al., 2015) and decreasing in response to pleasant ones (Bensafi et al., 2002c; Brauchli et al., 1995). A recent study by Pichon et al (2015) which compared heart rate (amongst other responses) towards a selection of i) pleasant aromas and ii) pleasant and unpleasant aromas has suggested that physiological measures are not sensitive enough to distinguish between samples which have similar pleasantness scores but can be used to distinguish between aromas which have large differences in pleasantness scores. However within the present investigation, samples were found to be well discriminated on the basis of both liking and emotional response but it is also possible that samples were still too similar/pleasant to elicit a physiological response.

The majority of studies which have investigated emotional response towards aroma stimuli have done so using pure aroma compounds. However within the present study, aromas were presented within the context of beer and consequently consumers may have not only judged whether an aroma was pleasant/unpleasant but also its appropriateness within beer. Introducing the opportunity for cognitive appraisal alongside affective judgements, may have

influenced implicit responses such as heart rate. For example, previous research has shown that heart rate responses are less pronounced towards aromas when subjects are required to perform a cognitive evaluation immediately after smelling an aroma (Bensafi et al., 2002c). Neuroimaging studies have also demonstrated that cognitive evaluations of different properties of an aroma an individual focuses on (e.g. aroma intensity or pleasantness) influences which brain regions respond to the stimulus (Rolls et al., 2008). As autonomic responses such as heart rate are under the influence of higher neural processes, (Beissner et al., 2013; Shields Jr, 1993) changes in activate neural regions as a result of cognitive or contextual evaluations may influence changes in physiological activity (Farrow et al., 2012). However such an effect has not been explored widely with respect to product evaluations within Sensory Science.

Skin temperature was also not affected by sample aroma within this study. Comparative studies within the olfactory modality have also revealed that skin temperature is unaffected by sample aroma (Heuberger et al. 2001; He et al. 2014; Glass et al. 2014; but see de Wijk et al. 2012). However mixed results have been observed when taste and flavour stimuli have been evaluated, with some research indicating that skin temperature increases with unpleasant tastes (Rousmans and Robin, 2000) whilst others report a greater increase in skin temperature for liked samples (de Wijk et al., 2014, 2012). Whilst these differences between olfactory and taste stimuli may be the result of different responses towards sensory modalities (Kreibig, 2010b) it is acknowledged that the changes observed in skin temperature are very small

(Landowska, 2014) (as was the case in this study) and consequently skin temperature may not be a reliable or sensitive enough indicator of emotional response.

In comparison to physiological responses, facial expression changed in response to beer aroma. With respect to corrugator activity, greater frowning activity was observed towards the unpleasant aromas Mercaptan and Hydrogen sulphide. The increase in corrugator activity in response to olfactory stimuli has been reported previously in response towards aroma stimuli (Bensafi et al., 2002b; Delplanque et al., 2009; Pichon et al., 2015) and well as towards other sensory stimuli such as visual and audio stimuli (Alvarado, 1997; Dimberg, 1990; Dimberg and Karlsson, 1997; Lang et al., 1993; Tan et al., 2011) confirming the results of previous studies that corrugator activity is a reliable indicator of sample unpleasantness across modalities. However zygomatic activity which is generally perceived to be an indicator of smiling activity in response to pleasant stimuli (Dimberg et al., 2000; Dimberg and Thunberg, 1989; Lang et al., 1993) was also found to increase in response to the unpleasant Mercaptan sample. Previous research has suggested that there is a quadratic relation between zygomatic activity and sample valence, increasing in response to both pleasant and unpleasant stimuli (Larsen et al., 2003). This was also applicable within the present study where significantly lower zygomatic activity was observed in response to the neutral Control and Diacetyl samples, whilst comparisons between pleasant and unpleasant samples did not reach significance. Previous studies within the olfactory modality have also failed to find an expected increase in

zygomatic activity in response to pleasant aromas (Delplanque et al., 2009) and studies using FaceReader technology have highlighted that the basic emotion, "happy" (which also involves smiling activity) can be associated with both liked and disliked samples (Danner et al., 2014a; de Wijk et al., 2014, 2012; He et al., 2016). Furthermore Zeinstra et al (2009) and Soussignan and Schall (1996) found that negative facial action coding (FAC) units which were associated with unpleasant flavours and aromas but both positive and negative FAC units were associated with pleasant stimuli. Consequently it is likely that the increased zygomatic activity observed in response to the Mercaptan sample was also due to smiling activity and supports the notion of "display rules" where individuals smile to hide, mask or cover up unpleasant feelings towards unpleasant stimuli (Ekman and Friesen, 1982; Soussignan and Schall, 1996). Consequently this investigation supports previous findings where facial expressions are a good indicator of pleasant but not unpleasant samples (Zeinstra et al., 2009).

Comparison of facial expression and liking post hoc groupings revealed that liking scores could provide greater discrimination between samples than corrugator and zygomatic responses. In particular, liking scores could provide discrimination between some pleasant and neutral samples, whilst corrugator and zygomatic responses could not. Considering the recent studies conducted on whole consumption products, this is in accordance with the results of Danner at al (2014a) who found that implicit facial expressions could only discriminate between disliked, neutral and liked samples but could not discriminate between liked and neutral samples. Concerning the comparison

between physiological measures and liking, these results do not support the results of de Wijk et al (2012) who found that finger temperature increased with liking scores or that liked samples caused an increase in heart rate and skin temperature (de Wijk et al., 2014). Within the latter study, these heart rate and skin temperature changes were observed despite not finding any differences in liking scores however the research group point out the larger differences observed in heart rate scores for flavour compared to olfactory stimuli (which was measured in separate study) (de Wijk et al., 2014; He et al., 2014).

3.6.2. Self-reported emotional response

The second objective of this investigation was to determine the discrimination ability of self-reported emotional response towards beer aroma. Inspection of the emotional space generated by the PCA revealed that the samples were structured primarily according to their valence (93%), with a much smaller, second dimension accounting for sample activation (4%) and is consistent with a circumplex model of emotion (Larsen and Diener, 1992; Russell, 1980; Watson and Tellegen, 1985). This bi-dimensional structure (with greater weighting towards the pleasantness/unpleasantness dimension) has also been observed within other investigations measuring emotional response towards consumption stimuli (Chaya et al., 2015a, 2015b; Eaton, 2015; Ng et al., 2013). The consumer-led emotion lexicon developed specifically for beer was able to find a significant effect of beer aroma within each of the 10 emotion categories. In particular, post hoc groupings revealed emotion categories which were associated with displeasure (disconfirmed, disgusted, shocked

and underwhelmed) allowed clear discrimination between the unpleasant Hydrogen sulphide and Mercaptan samples from the pleasant Lightstruck, Hoppy and Isoamyl acetate samples. This was a similar case within the emotion categories associated with pleasure (content, excited and tame/safe) where pleasant samples could be discriminated from the unpleasant Hydrogen sulphide and Mercaptan samples, except within the tame/safe group where Hydrogen sulphide and Isoamyl acetate shared post hoc groupings. Evidently the emotional lexicon allowed clear discrimination between pleasant and unpleasant aromas.

Liking scores showed strong, significant correlations with all 10 of the emotion categories and shared similar post hoc groupings with the pleasant emotion categories (curious, nostalgic, tame/safe, content and excited) which liking was positively correlated with. Previous research has suggested that emotional response is influenced by the positioning of liking or overall acceptability scores before or after emotional lexicons (King et al., 2013). Within the present study the strong correlation observed between liking and emotion categories may reside in the fact that liking was asked before subjects self-reported their emotional response which may influenced emotional scores. Despite the strong correlations between liking and emotional response, four of the 10 emotion categories (excited, nostalgia, tame/safe and curious) were able to provide greater discrimination between samples than liking scores could alone. Consequently emotional response was more discriminating than liking and provided additional insight into why some aromas were preferred to others. These emotion categories had the

weakest association with liking scores and in the case of bored and curious, also partially loaded on the activation dimension (PC2) of the PCA. As previously described by Gutjar et al (2014) it is the emotions associated with the activation dimension which can provide the greatest discrimination beyond liking scores.

Finding that emotional response is more discriminating than liking alone is not unique to this study, (Chaya et al., 2015a; Porcherot et al., 2010; Spinelli et al., 2014), for example, Ng et al (2013) found that 21 out of 36 terms included in a product specific lexicon were more discriminating than liking to black current squash. Similarly emotions such as aggressive and friendly have been found more discriminating towards the taste and packaging of beer respectively (Chaya et al., 2015b).

The Lightstruck sample induced significantly greater feelings of nostalgia compared to other aromas. However highly comparable studies on beer flavour, using an earlier version of the same emotion lexicon, have found Nostalgia to be less discriminating towards Lightstruck samples but significantly higher ratings were observed within individuals aged between 18-34 compared to individuals aged over 35 (Chaya et al., 2015a; Eaton, 2015). Within the present study, the mean age of subjects was 26 years old and consequently the bias towards younger individuals may have increased nostalgia ratings towards the Lightstruck sample. The higher ratings for Lightstruck within this category may also be explained by fact that the present study measured response to aroma and not taste stimuli. The olfactory cortex

shares close connections with the limbic system and structures such as the hippocampus directly involved in learning and memory formation (Cahill et al., 1995; Yeshurun et al., 2009). Consequently as the Lightstruck sample was also the most familiar it is possible that smelling as opposed to just tasting the sample influenced the emotional response to this aroma. It is also interesting to note that brewers perceive Lightstruck to be an off-flavour note and employ various methods to prevent Lightstruck flavours and aromas from developing in beers (Huvaere and Skibsted, 2015; Stephenson and Bamforth, 2002). However contrary to brewers' perceptions, the Lightstruck sample was liked by the subjects in this study and rated as highly familiar within the present study as well as being associated with pleasant emotion categories, particularly nostalgia.

3.6.3. Comparison between implicit and explicit measures

All 10 of the emotion categories were able to discriminate between beer samples, whilst only two of the four implicit measures were able to discriminate between the same set of samples and was restricted to the zygomatic and corrugator facial expression measures. With regards to corrugator activity and self-reported emotional response, both types of measurement primarily reflected sample valence. Zygomatic activity was also able to discriminate the unpleasant sample, Mercaptan from the more neutral samples, Control and Diacetyl.

Corrugator activity was greatest in response to the two most unpleasant aromas, Hydrogen sulphide and Mercaptan, which also received the highest

scores within emotion categories associated with displeasure (disgust, underwhelmed, shocked and disconfirmed). Emotion categories associated with pleasure (excited, content, tame/safe and nostalgic) also clearly discriminated the majority of pleasant aromas (Lightstruck, Hoppy and Isoamyl acetate) from unpleasant ones. This is in accordance with the results obtained by He et al (2016) who reported that facial responses detected by FaceReader technology and self-reported emotional response were primarily structured according to sample valence. However unlike corrugator and zygomatic activity, the emotional lexicon allowed greater discrimination between pleasant and neutral samples and between the pleasant samples themselves (for example within the curious, excited and nostalgia categories). Consequently self-reported emotional response was more discriminating than physiological and facial expression measures.

Like many studies on facial expression or physiological response, this study measured the average activity of a response after stimulation (Alaoui-Ismaïli et al., 1997b; Bensafi et al., 2002a; Danner et al., 2014b; Glass et al., 2014; Pichon et al., 2015). However some studies have also investigated the "sequential unfolding" of responses by looking at how both facial expressions and physiological responses change over a series of milliseconds (Delplanque et al., 2009; He et al., 2016, 2014) or seconds (de Wijk et al., 2014). For example Delplanque et al (2009) found that facial EMG activity responded to aroma novelty in first 100ms and aroma pleasantness at 400-500ms, whilst heart rate responded to novelty and pleasantness at 2-4 seconds and 5-8 seconds respectively. He et al (2014) found that disgusted, anger, surprised,

scared and sad expressions differentiate between odours faster than happy expressions (He et al., 2014) and found that facial expressions, depending on their timing, could be related to either pleasantness (occurring at 1250ms) or intensity (2000ms) (He et al., 2016). Analysis of the current results over a period of seconds (1,2 and 3 seconds for EMG activity and 5,10 and 15 seconds for heart rate) did not reveal a changing dynamic response to aroma (data not shown) but it likely that a richer source of information could be gained by inspecting how physiological and facial expression responses change over a period of milliseconds.

Comparisons between implicit and explicit measures should also be made with regard to the ease of data collection. As with liking data, the emotional lexicon could be collected on computer tablets using a series of visual analogue scales. Consequently this style of questionnaire is familiar to consumers and can be implemented using standard data collection software used in Sensory Science. However physiological and facial expression measures require the investment in dedicated recording equipment and software to collect and process data. Furthermore subjects could only be assessed one at a time due to controlled nature of sample delivery and current limitations of recording devices that typically only allow recordings from one or a few subjects. This is in comparison to single sessions involving multiple consumers (depending on facility capabilities) available when only self-reported responses are collected. Finally it is well established that the processing and extraction physiological data per consumer frequently takes the same amount of time invested in data collection, (Gratton, 2007) an

additional step often not required in computer based questionnaire. Consequently the ease of data collection afforded by self-report is of particular relevance to industry. It should be noted that central location tests conducted within industry require affective tests to be conducted on a large number of consumers (often under tight time constraints) thus within an industrial application, self-report is superior to physiological and facial expressions of emotion.

Overall the results from this study confirm previous findings that facial EMG data can be a useful measure of unconscious emotional response. It is a useful measure to employ if an unconscious measure of response in subjects is desired. However it should be restricted to investigations where products are known to show a high variability of valence, as facial EMG shows limited ability to discriminate between pleasant products (Pichon et al., 2015). However if the discrimination between a selection of well-liked or pleasant products is required, it is recommended to employ self-reported emotional response techniques. In particular, single or closely related product categories are frequently assessed within industry and the subjects recruited are generally consumers of the product(s). Indeed as most commercial products are designed to be well liked and product consumers are generally regarded to like the product, it is essential that the measurement used to assess products can provide high discrimination between a set of potentially well liked products (King and Meiselman, 2010; Meiselman, 2015). Consequently in industrial applications using commercial products self-reported emotional response is recommended.

3.6.4. Effects of gender on emotional response

Four of the seven beer aromas were found to have a significant effect of aroma within at least one emotion category. Of the six significant effects of gender found within the emotion categories, males give significantly higher scores than females in five of these categories. This result was surprising as females are generally found to rate aromas as more intense than males (Olofsson and Nordin, 2004) and are reported at being better at identifying aromas as well (Ferdenzi et al., 2013). Some evidence also suggests that females have lower odour detection thresholds than males (Koelega and Köster, 1974). When considering emotional response to aromas, females have also reported a greater number and more intense emotions than men (Brody and Hall, 2008; Martin et al., 2001). However finding higher scores for males in response to beer samples is not unique to this product category; Eaton (2015) previously demonstrated (using an earlier version of the same emotion lexicon) that males rated beer samples higher in the emotion categories disconfirmed, shocked, nostalgia, excitement, bored and underwhelmed. This corresponds to the findings within the present study where all except excitement were also found to be rated higher by males than females. Furthermore using a Spanish version of the lexicon, Chaya et al (2015a) found that Spanish men rated samples higher in the emotion categories: classic, desire, disappointment, indifference, intensity, mildness, and nostalgia compared to Spanish women.

However finding higher emotion scores for men is not unique to beer either: Ferdenzi et al (2013) found Swiss men gave higher scores than women in four

out of six emotion categories. The authors attributed this to evidence that males associated more aromas (such as honey) with unpleasant descriptors (such as ammonia or urine) compared to females, despite not finding any differences in liking and familiarity scores between males and females (Ferdenzi et al., 2013) (as was the case in the present study). Consequently males may have been poorer at identifying aromas or interpreted aromas as more unpleasant within the present study as well. Alternatively, as beer is traditionally associated with being a male beverage, (Landrine et al., 1988) Chaya et al (2015a) suggested that prior conceptions of beer and gender roles may have caused males to give higher ratings than females (Grossman and Wood, 1993; Kring and Gordon, 1998). However male specific gender roles have rarely been investigated and warrant further investigation.

3.7. Conclusions

Concerning implicit measures, only facial expression and not physiological responses could distinguish between beer aromas, however, by extending the analysis to include a comparison with a sample with no aroma, differences in heart rate could be found. Both implicit and explicit emotional responses towards beer aroma could primarily be structured according to sample valence. In the case of implicit measures, this allowed the distinction between unpleasant samples from pleasant and neutral samples but did not allow the distinction between pleasant and neutral samples or between pleasant samples themselves. In contrast, self-reported emotional response was able to show the distinction between pleasant, neutral and unpleasant samples and permitted additional distinction between pleasant samples.

When relating both implicit and explicit measures to liking scores, liking allowed the discrimination of the one of the pleasant samples from the neutral samples, making liking more discriminating than implicit measures. Comparison of self-reported emotional response with liking revealed that four of the emotion categories could provide greater discrimination between beer aromas than liking. Gender effects were also observed within this study but were limited to self-report assessments and found a tendency for males to score specific samples higher than females. Overall the results of this investigation reveal that a product specific, consumer derived emotion lexicon provides greater discrimination between beer aromas compared to implicit or liking measures.

4. Chapter four: General discussion, conclusions and future work

The main aim of this thesis was to assess the discrimination ability of physiological (heart rate and skin temperature), behavioural (changes in facial muscle activity of the corrugator supercilii and zygomatic major) and self-reported emotional response, as well as liking, towards a set of aroma attributes within beer. Two preliminary investigations were run prior to conducting the main investigation where methodological, beer aroma and emotional lexicon parameters were developed and decided. This resulted in the selection of six (pleasant and unpleasant) beer samples with elevated aroma attributes as well as a non-manipulated base beer sample which were assessed in the main investigation. Within this chapter, a summary of the main findings from this research is presented, together with suggestions for where these findings could be implemented and expanded within future research.

4.1. Main findings

The first phase involved conducting two preliminary investigations in order to develop a set of methodological protocols which could be applied to a larger main investigation as well as determine whether an initial set of beer samples were emotionally distinct from one another. The pilot study was the first of two preliminary investigations and had several objectives spanning both methodological and sample considerations. Relating to methodological objectives, the pilot study enabled a suitable methodological protocol to be developed that was trialled on nine individuals as well as giving experience as

to how the physiological and facial expression measures should be extracted and processed. Additional objectives of the pilot study were to determine if physiological/facial expression and self-report measures could discriminate between the two concentrations of spiked (Isoamyl acetate, Lightstruck, Hoppy A and Hoppy B) and non-spiked beer samples (base beer control). Analysis of the physiological and facial expression measures revealed that skin temperature, corrugator and zygomatic activity did not change significantly in response to any of the aromas selected. However there was a decrease in heart rate when smelling the high compared to the low concentration of Isoamyl acetate but heart rate did not change in response to smelling any other aroma. In comparison there was a significant difference in at least one of the self-reported ratings for valence, activation, intensity and familiarity for each of the aromas used and suggested that self-report was more discriminating than physiological/facial expression measure of emotion. The superior discrimination of the self-report ratings also allowed suitable aroma concentrations to be chosen for the main investigation. Further inspection of the self-reported responses revealed that the samples were very similar in pleasantness and a more comprehensive comparison of physiological/facial expression measures and self-report ratings would require the inclusion of both pleasant and unpleasant aromas. Furthermore, owing to the higher discrimination of self-report responses it was deemed appropriate to use an emotional lexicon in the main investigation in order to potentially reveal even greater discrimination between samples.

Further comparison of physiological/facial expression and self-report measures using Pearson correlation analysis and principal component analysis, revealed that there was some association between the measurement types. In particular, corrugator activity had a negative association with valence scores and heart rate was positively associated with intensity and familiarity scores. Although there was no correlation between heart rate and valence, the increase in pleasantness ratings for Isoamyl acetate corresponded with a decrease in heart rate, a finding which has been found in previous studies (Bensafi et al., 2002a; Brauchli et al., 1995; Muroni et al., 2011). Furthermore comparisons of responses between sessions revealed both measurement types were sensitive to session effects which were explored further before proceeding to the main study.

The pilot investigation highlighted the need to explore a greater range of pleasant and unpleasant aromas, the appropriateness of an emotional lexicon specific to beer, as well as to investigate the effect multiple sessions and within session replicates had on physiological/facial expression and self-reported emotional response scores. These were investigated as part of the validation study. The validation study confirmed that the revised set of seven beer aromas (non-manipulated beer and six manipulated beer with elevated aroma attributes) contained a mix of both pleasant and unpleasant aromas which would be assessed using the product specific emotion lexicon. Furthermore, based on the large variation of physiological/facial expression responses between sessions, it was decided to limit replicates within the main study to within a single session. However self-reported emotional response

would only be assessed once due to the limited variation in responses between sessions and replicates.

Chapter three detailed the results of the main investigation where the emotional response of 60 consumers was assessed towards the revised set of seven beer samples. The overall aim of this main investigation was to determine whether self-reported emotional response or physiological and facial expression measures of emotion were more discriminating towards beer aroma and whether either of these measures was more discriminating than liking. Owing to the limited discrimination ability of the physiological and facial expression measures in the pilot investigation, the heart rate and facial expression responses of 10 individuals were analysed prior to conducting the full analysis to identify the most appropriate sections from a temporal perspective for data analysis. Subsequent analysis of the full data set revealed that beer aromas were broadly divided into pleasant aromas (Lightstruck, Hoppy and Isoamyl acetate spiked beer samples), unpleasant aromas (Mercaptan and Hydrogen sulphide spiked beer samples) and emotionally neutral samples (Diacetyl spiked beer sample and a non-spiked Control beer).

Analysis of physiological measurements revealed that neither heart rate nor skin temperature changed in response towards beer aroma. As the aromas used within the study were shown to include a mixture of both pleasant and unpleasant aromas, this was an unexpected finding as heart rate has been previously shown to respond to odour valence, increasing in response to

unpleasant stimuli (Bensafi et al., 2002a, 2002c; Brauchli et al., 1995; Delplanque et al., 2009; He et al., 2014; Pichon et al., 2015) and decreasing in response to pleasant stimuli (Bensafi et al., 2002a; Brauchli et al., 1995). This suggested that heart rate may not be as discriminating towards aromas as initially suggested within the pilot investigation. Furthermore no effect of beer aroma was found on skin temperature; yet this was not wholly unexpected given the small changes recorded and the limited effect aroma has had on skin temperature in previous investigations (Glass et al., 2014; He et al., 2014; Heuberger et al., 2001).

Regarding facial expression responses, corrugator activity was found to increase with sample unpleasantness and showed clear discrimination between the unpleasant Mercaptan sample and all other samples except for Hydrogen sulphide. Non-parametric analysis of zygomatic activity revealed that individuals "smiled" most in response to the unpleasant Mercaptan sample, a response which was significantly larger compared to the Diacetyl and Control samples. These results concurred with previous findings that corrugator activity was a good indicator of unconscious displeasure (Bensafi et al., 2002b; Delplanque et al., 2009; Pichon et al., 2015) and support findings that subjects will also hide feelings of displeasure by smiling in response to unpleasant stimuli (Ekman and Friesen, 1982; Soussignan and Schall, 1996).

Self-reported emotional response revealed that beer aromas could be distinguished by their pleasantness, with unpleasant samples such as Mercaptan and Hydrogen sulphide being well discriminated by emotion

categories associated with displeasure (shocked, disgusted, disconfirmed and underwhelmed). Pleasant samples such as Lightstruck, Hoppy and Isoamyl acetate were better described by emotion categories associated with pleasure, (content, excited, nostalgic and tame/safe) whilst Control and Diacetyl samples could be better described as emotionally neutral samples, not scoring highly in emotion categories associated with pleasure or displeasure.

A comparison of physiological, facial expression, liking and self-reported emotional response using correlation and PCA analysis further supported that samples were primarily structured according to sample valence, where emotion categories associated with pleasure and displeasure had a strong negative correlation. However corrugator activity was the only physiological/facial expression measure to show any relationship to self-report and liking variables (showing a positive association with unpleasant emotion categories and a negative association with liking and pleasant emotion categories). Comparison of post hoc groupings of facial expression and self-reported emotional response revealed that self-reported emotional response allowed superior discrimination between pleasant and neutral samples in comparison to the corrugator and zygomatic facial expression measures. In particular, seven emotion categories (bored, content, excited, nostalgic, disconfirmed, disgusted and curious) were able to show some discrimination between at least one pleasant and one neutral sample. Consequently self-reported emotional response was found to be more discriminating than physiological/facial expression measures of emotion.

Liking scores were also found to be more discriminating than physiological and facial expression measures, allowing increased discrimination between pleasant and neutral samples. However self-reported emotional response was found to be more discriminating than liking in four out of 10 emotion categories, supporting previous reports that emotion response can provide enhanced product discrimination compared to liking scores alone (Chaya et al., 2015b; Ng et al., 2013; Spinelli et al., 2014).

Analysing the results with regards to gender revealed that significant effects of gender were only found with respect to self-reported emotional response. In particular several significant effects were found, with a tendency for males to score higher than females. This did not support previous research where women are generally found to be more emotive (Olofsson and Nordin, 2004) but do concur with previous investigations on beer (Chaya et al., 2015a; Eaton, 2015) and suggests possible gender roles associated with beer for males (Landrine et al., 1988) or that males may be poorer at identifying aromas compared to females, possibly accounting for the differences in scores (Ferdenzi et al., 2013).

4.2. Suggestions for future work

4.2.1. Physiological and facial expression recordings

The main findings within Chapter three highlighted that self-reported emotional responses were more discriminating than physiological and facial expression measures. Consequently if the objective of a study is to investigate discrimination between samples (especially between highly

pleasant samples) then self-report as opposed to physiological/facial expression measures should be used. However this does not mean that physiological and facial expression measurements cannot add value to sensory research. For example if the objective of a study is to measures unconscious responses to emotive stimuli then physiological/facial expression responses would be preferable. However researchers would need to take into account the poorer discriminatory power of physiological/facial expression measures and consequently validate a measure to ensure it provides the necessary level of discrimination required for the study. The following sections provide details as to how measurement of some of these implicit responses could be improved or be used in other areas of sensory research.

4.2.1.1. Skin temperature

When skin temperature responses to beer aromas were adjusted using baseline values, the extremely small corrected baseline values suggested that skin temperature showed negligible changes in response to smelling beer aromas. The small temperature changes observed within this investigation may be the because skin temperature recordings were made from the forearm and not from a finger as has been done in previous investigations (Alaoui-Ismaïli et al., 1997b; Danner et al., 2014b; de Wijk et al., 2014, 2012; He et al., 2014; Rousmans and Robin, 2000). Although both glabrous (hairless skin on finger, palms and soles of feet) and non-glabrous skin (hairy skin such as that on forearm) show temperature changes in response to emotional induction, (Machado-Moreira and Taylor, 2011) blood vessels in glabrous sites are more densely innervated by sympathetic nerves which lead to greater

blood vessel vasoconstriction and consequently larger changes in skin temperature (Charkoudian, 2003). However it should also be noted that changes in skin temperature have also been found to be non-significant when measurements are taken from the finger (Danner et al., 2014b; He et al., 2014) and comparisons of skin temperature changes from both glabrous and non-glabrous sites have been shown to be equally small (Landowska, 2014). Consequently skin temperature appears to be an unreliable and poorly discriminating physiological measure. Indeed skin temperature is only an indirect measure of sympathetically mediated changes in blood vessel dilation and constriction and consequently if researchers are interested in investigating vasoconstriction and vasodilation under emotive conditions it is recommended that a more precise measurement of skin blood flow should be used. Skin blood flow can be measured using techniques such as Laser Doppler blood flow to measure changes in the velocity and concentration of blood or Hertzman Photoelectric Plethysmography which used inferred light to measure changes in skin blood flow (Petrofsky and Ph, 2012).

4.2.1.2. Skin conductance response

The PCA generated in Chapter three revealed that the samples were primarily structured according to valence, reflecting how pleasant or unpleasant an aroma was. Sample variation was less well described by the activation dimension, a finding which is shared with other studies which have assessed self-reported emotional response to sensory stimuli (Chaya et al., 2015b; Eaton, 2015; He et al., 2016; Ng et al., 2013). Skin conductance responses are thought to primarily reflect the activation dimension of emotion (Sequeira et

al., 2009) and may have been able to provide greater discrimination between samples along the activation dimension if they had been included within the analysis. Indeed skin conductance level was found to increasing with ratings of aroma arousal (activation) in some studies (Bensafi et al., 2002a) however it should be noted that skin conductance response within the olfactory modality have primarily been found to change in response with aroma valence (Alaoui-Ismaïli et al., 1997b; Delplanque et al., 2009; Distel et al., 1999; He et al., 2014). Nevertheless, the inclusion of skin conductance responses should not be omitted within future studies as they have previously been shown to be discriminating towards samples in sensory studies (Danner et al., 2014b).

4.2.1.3. Facial Electromyography

The findings from Chapter three highlighted that corrugator activity varied with sample pleasantness and can show clear discrimination between liked/pleasant and disliked/unpleasant sample aromas. Future work using facial electromyography could be used to measure the unconscious response towards pleasant and unpleasant stimuli. This would be especially useful in groups which show disturbances in their ability to self-report internal emotions and feelings towards foods, such as individuals with eating disorders (Montebarocci et al., 2006). For example healthy individuals have been found to smile more in response to food cues than individuals with the restrictive eating disorder, anorexia nervosa (AN) (Soussignan et al., 2010) and AN individuals have also been found to frown more in response to subliminal fear cues associated with food (Soussignan et al., 2011). Alternatively facial

electromyography could be used in investigations interested in unconscious responses of individuals with different levels of product use (e.g. heavy or light product users) in order to understand if unconscious valence evaluations differ between these groups (Lang and Yegiyan, 2014).

4.2.2. Self-reported emotional response

4.2.2.1. Emotions beyond aroma stimuli

This thesis demonstrated that beer aroma can influence the emotional response of a consumer and previous investigations have revealed that beer flavour (Chaya et al., 2015a, 2015b; Eaton, 2015; Sester et al., 2013a), bottle packaging (Chaya et al., 2015b; Sester et al., 2013a) and serving temperature (Dorado et al., 2016a) can all influence the emotional response towards beer. However consumers are also known to make quality judgements based on the visual properties of beer; such as colour, height of the foamy head and foamy lace left behind in the glass (Smythe et al., 2002; Smythe and Bamforth, 2003). Indeed qualitative data from previous studies have shown that some consumers can perceive the residual foamy lace on glass to be “dirty” (Bamforth, 2000) implying that there is an emotional component to these assessments as well. Therefore it would be interesting to investigate the emotional profile of these visual characteristics via a series of images where the degree of beer foam, lacing and colour and their various interactions are manipulated. This would be especially interesting to investigate with predominantly lager, ale and stout consumers in order to identify if foam and lace expectations are influenced by preferred beer styles.

The emotional profile of beer has been shown to be dynamic between products (Chaya et al., 2015a, 2015b) but it would also be interesting to investigate the temporal evolution of these emotions within a product. Recently the temporal evolution of dominant emotions was demonstrated using chocolate samples, where consumers selected the dominant emotion they were experiencing at different time points after tasting 10g of chocolate (Jager et al., 2014). This would be particularly interesting to investigate with regards to beer aroma, as odours have previously demonstrated to be subject to a number of evaluation checks and appraisals (such as pleasantness and familiarity) at different time points (Delplanque et al., 2009; He et al., 2014). Along related lines, the emotional response towards beer has typically been assessed using small servings (10-15ml) (Chaya et al., 2015a; Dorado et al., 2016a) and it would be interesting to investigate how the emotional profile of a beer changes over multiple slips of the same sample, such as would occur with a larger serving (such as a half pint measure). This would provide much more comprehensive measurements of how the emotional profile of a beverage changes over the entire consumption experience.

4.2.2.2. Emotions in context

Self-reported emotional response is typically assessed under sensory laboratory conditions which are designed to exclude any environmental influences from the testing environment. However it has been argued that the removal of context in consumer testing is a "situational fallacy" as food and beverage products are removed from the contexts they are usually consumed in, leading to reduced accuracy of rating scores (Köster, 2003). The

studies described in Chapters two and three were conducted in highly controlled conditions partially because this allows the pure emotions related to a sensory variable to be investigated but also allowed the necessary tight control over the physiological and facial expression data. Dorado et al (2016a) found that when consumers were asked to describe a scenario when they drank beer the terms, “friends”, “pub” and “evening” were most frequently cited and Silva et al (2014) found that beer consumption was associated with emotional conceptions of joy, pleasure and socialisation. Consequently, beer consumption has a high association with social contexts as opposed to the isolated assessments made in sensory booths and future investigations should further investigate how the manipulation of context influences emotional response towards beer stimuli.

From a practical perspective, contextual factors can be assessed within a laboratory setting by asking consumers to imagine themselves in specific consumption context using evoked scenarios (Dorado et al., 2016a; Hein et al., 2012, 2010, Piqueras-Fiszman and Jaeger, 2014a, 2014b). Dorado et al (2016a) compared emotional response to a series of beer samples both with and without using an evoked scenario. Evoked scenarios were found to be an effective tool to manipulation the consumption context as beers had different emotional profiles when they were assessed with and without a scenario and led to a greater polarization of responses in positive and negative emotion categories (Dorado et al., 2016a). Alternatively context can be manipulated by creating an immersive environment to reconstruct a typical consumption environment (King et al., 2004; Sester et al., 2013b). By adding elements

typical of a bar or pub, Sester et al (2013b) was able to demonstrate that subsequent consumer beer choice could be influenced by the ambience of the bar (manipulated by changing the furniture and lighting). Future work could further quantify how different contextual cues within an immersive environment influence the emotional response towards beer and subsequently investigate how these are also influenced within natural environments, such as drinking at home or a real bar. Such an approach may allow ultimately allow beer manufactures to understand whether their product is received more positively in some environments than others.

4.2.2.3. Applications of emotions within industry

Within the present study, self-reported emotional response was shown to be highly discriminating and in particular, was found to be more discriminating than liking scores alone. However sensory research conducted within industry is still largely dependent on traditional hedonic tests and may benefit from employing self-reported emotional response measures alongside liking scores to increase discrimination between products. High discriminatory power is particularly relevant within industry where consumption items within the same product category are often compared with one another. Indeed as commercial products, the vast majority of these are designed to be highly appealing to the end user. Furthermore subjects who are consumers of a product are frequently recruited, causing a further bias towards high liking scores. Consequently within a selection of highly liked products, self-reported emotional response may be able to provide reasons as to why some products may be preferred to others.

As highlighted in this study, emotional response may also be able to provide interesting revelations about a product. For example Lightstruck elicited emotions such as nostalgia and was associated with pleasant emotion categories. This is in contrast to the brewer's perspective on Lightstruck, frequently regarding the aroma as an undesirable off-note (Huvaere and Skibsted, 2015). Thus self-reported emotional response may be able to further highlight dissimilarities between consumer and manufacture perspectives towards other commercial products.

4.3. Conclusions

The research presented in this thesis has provided the first comparison between physiological/facial expression, self-reported emotional response and liking scores. Furthermore this project is novel for focusing on beer aroma, allowing specific insight into the response towards a single modality towards a highly emotive product. The comparison between implicit and explicit measures of emotional response towards beer aroma has revealed that self-report measures are more discriminating, time efficient and practical than physiological and facial expression measures of emotion. As with facial expression measures, self-reported emotional response was able to discriminate between pleasant and unpleasant samples. However unlike corrugator activity, self-report was particularly discriminating towards pleasant and neutral samples as well discriminating between the pleasant samples themselves. Furthermore liking scores were also found to be more discriminating than physiological and facial expression measures but the diversity of emotional categories included within the self-report lexicon was

also able to discriminate beyond liking towards beer aroma. The results obtained within this thesis suggest that consumer-led product specific lexicons permit the greatest discrimination between products within sensory science and should be the measurement of choice if a researcher seeks to highlight differences between well liked, pleasant or similar samples. In comparison, if a researcher is interested in understanding the unconscious emotional response of subjects, corrugator major activity has been shown to be a reliable indicator of sample unpleasantness. However researchers should be aware that assessments should be restricted towards sample sets containing both pleasant and unpleasant samples or where limited discrimination between samples which are similar in valence is required. By comparing physiological, facial expression, liking and self-reported emotion response, this thesis has highlighted the limitations and advantages of each measurement. In doing so it is hoped that future researchers can make informed decisions on what measurement type is most suitable for them based on their sample set and study objectives.

References

laoui-Ismaïli, O., Robin, O., Rada, H., Dittmar, A., Vernet-Maury, E., 1997a. Basic emotions evoked by odorants: Comparison between autonomic responses and self-evaluation. Physiol. Behav. 62, 713–720. doi:10.1016/S0031-9384(97)90016-0

Alaoui-Ismaïli, O., Vernet-Maury, E., Dittmar, A., Delhomme, G., Chanel, J., 1997b. Odor hedonics: Connection with emotional response estimated by autonomic parameters. Chem. Senses 22, 237–248. doi:10.1093/chemse/22.3.237

Alvarado, N., 1997. Arousal and valence in the direct scaling of emotional response to film clips. Motiv. Emot. 21, 323–348.

Anderson, A.K., Christoff, K., Stappen, I., Panitz, D., Ghahremani, D.G., Glover, G., Gabrieli, J.D.E., Sobel, N., 2003. Dissociated neural representations of intensity and valence in human olfaction. Nat. Neurosci. 6, 196–202. doi:10.1038/nn1001

Andreassi, J.L., 2007a. The nervous system and measure of its activity, in: Psychophysiology: Human Behaviour and Physiological Response. Lawrence Erlbaum Associates, Mahwah, New Jersey, pp. 43–74.

Andreassi, J.L., 2007b. Heart activity and behaviour I: Development factors, motor and mental activities, perception, attention, and orienting responses, in: Psychophysiology. Mahwah, New Jersey, pp. 336–361.

Andrés-Iglesias, C., Nešpor, J., Karabín, M., Montero, O., Blanco, C.A., Dostálek, P., 2016. Comparison of carbonyl profiles from Czech and Spanish lagers: Traditional and modern technology. LWT - Food Sci. Technol. 66, 390–397. doi:10.1016/j.lwt.2015.10.066

Anttonen, J., Surakka, V., 2005. Emotions and heart rate while sitting on a chair. Proc. SIGCHI Conf. Hum. factors Comput. Syst. 491–499. doi:10.1145/1054972.1055040

Aroxa, 2014. Certified beer flavour standards [WWW Document]. Cara Technol. Ltd. URL http://www.aroxa.com/beer/beer-flavour-standard (accessed 6.15.16).

Bamforth, C.W., 2000. Perceptions of Beer Foam. J. Inst. Brew. 106, 229–238. doi:10.1002/j.2050-0416.2000.tb00062.x

Barrett, L.F., 2006. Solving the emotion paradox : Categorization and the experience of emotion. Personal. Scoial Psychol. Rev. 10, 20–46.

Baumgartner, T., Esslen, M., Jäncke, L., 2006. From emotion perception to emotion experience: Emotions evoked by pictures and classical music. Int. J. Psychophysiol. 60, 34–43. doi:10.1016/j.ijpsycho.2005.04.007

Beissner, F., Meissner, K., Bär, K.-J., Napadow, V., 2013. The autonomic brain: an activation likelihood estimation meta-analysis for central processing of autonomic function. J. Neurosci. 33, 10503–10511. doi:10.1523/JNEUROSCI.1103-13.2013

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., Holley, A., 2002a. Autonomic nervous system responses to odours: the role of pleasantness and arousal. Chem. Senses 27, 703–709. doi:10.1093/chemse/27.8.703

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., Holley, A., 2002b. Psychophysiological correlates of affects in human olfaction. Clin. Neurophysiol. 32, 326–332.

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., Holley, A., 2002c. Influence of affective and cognitive judgments on autonomic parameters during inhalation of pleasant and unpleasant odors in humans. Neurosci. Lett. 319, 162–166. doi:10.1016/S0304-3940(01)02572-1

Berntson, G., Cacioppo, J., Quigley, K., 1995. The metrics of cardiac chronotropism: Biometric perspectives. Psychophysiology 32, 162–171.

Berntson, G., Cacioppo, J., Quigley, K., 1993. Respiratory sinus arrhythmia: autonomic origins, physiological mechanisms, and psychophysiological implications. Psychophysiology 30, 183–196.

Berntson, G.G., Quigley, K.S., Lozano, D., 2007. Cardiovasuclar Psychophsiology, in: Handbook of Psychophysiology. Cambridge University Press, New York, pp. 182–210.

Bhumiratana, N., Adhikari, K., Chambers, E., 2014. The development of an emotion lexicon for the coffee drinking experience. Food Res. Int. 61, 83–92. doi:10.1016/j.foodres.2014.03.008

Boissy, A., Manteuffel, G., Jensen, M.B., Moe, R.O., Spruijt, B., Keeling, L.J., Winckler, C., Forkman, B., Dimitrov, I., Langbein, J., Bakken, M., Veissier, I., Aubert, A., 2007. Assessment of positive emotions in animals to improve their welfare. Physiol. Behav. 92, 375–397. doi:10.1016/j.physbeh.2007.02.003

Boiten, F.A., 1998. The effects of emotional behaviour on components of the

respiratory cycle. Biol. Psychol. 49, 29–51. doi:10.1016/S0301-0511(98)00025-8

Boucsein, W., Fowles, D.C., Grimnes, S., Ben-Shakhar, G., Roth, W.T., Dawson, M.E., Filion, D.L., 2012. Publication recommendations for electrodermal measurements. Psychophysiology 49, 1017–34. doi:10.1111/j.1469-8986.2012.01384.x

Boxtel, A. Van, 2010. Facial EMG as a tool for inferring affective states. Proc. Meas. Behav. August, 104–108.

Bradley, M., Lang, P., 1994. Measuring emotion: the self-assessment manikin and the semantic differential. J. Behav. Ther. Exp. Psychiatry 25, 49–59.

Braithwaite, J.J., Watson, D.G., Jones, R., Rowe, R., 2013. A guide for analysing electrodermal activity (EDA) & skin conductance responses (SCRs) for psychological experiments.

Brauchli, P., Ruegg, P.B., Etzweiler, F., Zeier, H., 1995. Electrocortical and autonomic alteration by administration of a pleasant and an unpleasant odor. Chem. Senses 20, 505–515.

Bredie, W.L.P., Tan, H.S.G., Wendin, K., 2014. A comparative study on facially expressed emotions in response to basic tastes. Chemosens. Percept. 7, 1–9. doi:10.1007/s12078-014-9163-6

Brody, R.L., Hall, J.A., 2008. Gender and emotion in context, in: Handbook of Emotion. Guildford Press, New York, pp. 395–408.

Cacioppo, J.T., Berntson, G.G., Larsen, J.T., Poehlmann, K.M., Ito, T.A., 2000. The psychophysiology of emotion, in: Lewis, M., Haviland-Jones, J.. (Eds.), The Handbook of Emotion. Guildford Press, New York.

Cahill, L., Babinsky, R., Markowitsch, H.J., McGaugh, J.L., 1995. The amygdala and emotional memory. Nature 377, 295–296. doi:10.1038/377295a0

Cardoso, D., Olsen, K., 2006. Phenol and terpene quenching of singlet-and triplet-excited states of riboflavin in relation to light-struck flavor formation in beer. J. Agric. … 5630–5636.

Casson, A.J., Yates, D.C., Smith, S.J.M., Duncan, J.S., Rodriguez-Villegas, E., 2010. Wearable electroencephalography. Ieee Eng. Med. Biol. Mag. 29, 44–56. doi:10.1109/MEMB.2010.936545

Catani, M., Dell'acqua, F., Thiebaut de Schotten, M., 2013. A revised limbic system model for memory, emotion and behaviour. Neurosci. Biobehav. Rev. 37, 1724–1737. doi:10.1016/j.neubiorev.2013.07.001

Charkoudian, N., 2003. Skin blood flow in adult human thermoregulation: how it works, when it does not, and why. Mayo Clin. Proc. 78, 603–12. doi:10.4065/78.5.603

Chaya, C., Eaton, C., Hewson, L., Vázquez, R.F., Fernández-Ruiz, V., Smart, K. a., Hort, J., 2015a. Developing a reduced consumer-led lexicon to measure emotional response to beer. Food Qual. Prefer. 45, 100–112. doi:10.1016/j.foodqual.2015.06.003

Chaya, C., Pacoud, J., Ng, M., Fenton, A., Hort, J., 2015b. Measuring the emotional response to beer and the relative impact of sensory and packaging cues. Am. Soc. Brew. Chem. 73, 49–60.

Chrea, C., Grandjean, D., Delplanque, S., Cayeux, I., Le Calvé, B., Aymard, L., Velazco, M.I., Sander, D., Scherer, K.R., 2009. Mapping the semantic space for the subjective experience of emotional responses to odors. Chem. Senses 34, 49–62. doi:10.1093/chemse/bjn052

Christie, I.C., Friedman, B.H., 2004. Autonomic specificity of discrete emotion and dimensions of affective space: a multivariate approach. Int. J. Psychophysiol. 51, 143–153. doi:10.1016/j.ijpsycho.2003.08.002

Codispoti, M., Surcinelli, P., Baldaro, B., 2008. Watching emotional movies: affective reactions and gender differences. Int. J. Psychophysiol. 69, 90–5. doi:10.1016/j.ijpsycho.2008.03.004

Cornelis, W., Grossman, P., 1988. Respiratory psychophysiology as a discipline: Introduction to the special issue. Biol. Psychol. 49, 1–8.

Cram, J.R., Kasman, G.S., Holtz, J., 2011. Atlas for electrode placement, in: 2nd (Ed.), Cram's Introduction to Surface Electromyography. Sudbury, Massachusetts, pp. 245–379.

Criswell, E., 2011. Instramentation, in: Cram's Introduction to Surface Electromyography. Jones and Bartlett, Sudbury, MA, pp. 35–63.

Croy, I., Laqua, K., Süß, F., Joraschky, P., Ziemssen, T., Hummel, T., 2013. The sensory channel of presentation alters subjective ratings and autonomic responses toward disgusting stimuli-Blood pressure, heart rate and skin conductance in response to visual, auditory, haptic and olfactory presented disgusting stimuli. Front. Hum. Neurosci. 7, 510. doi:10.3389/fnhum.2013.00510

Cuthbert, B.N., Lang, P.J., Strauss, C., Drobes, D., Patrick, C.J., Bradley, M.M., 2003. The psychophysiology of anxiety disorder: Fear memory imagery. Psychophysiology 40, 407–422. doi:10.1111/1469-8986.00043

D'Hondt, F., Lassonde, M., Collignon, O., Dubarry, A.-S., Robert, M., Rigoulot, S., Honoré, J., Lepore, F., Sequeira, H., 2010. Early brain-body impact of emotional arousal. Front. Hum. Neurosci. 4, 1–10. doi:10.3389/fnhum.2010.00033

Danner, L., Haindl, S., Joechl, M., Duerrschmid, K., 2014a. Facial expressions and autonomous nervous system responses elicited by tasting different juices. Food Res. Int. 64, 81–90. doi:10.1016/j.foodres.2014.06.003

Danner, L., Haindl, S., Joechl, M., Duerrschmid, K., 2014b. Facial expressions and autonomous nervous system responses elicited by tasting different juices. Food Res. Int. 64, 81–90. doi:10.1016/j.foodres.2014.06.003

Danner, L., Sidorkina, L., Joechl, M., Duerrschmid, K., 2014c. Make a face! Implicit and explicit measurement of facial expressions elicited by orange juices using face reading technology. Food Qual. Prefer. 32, 167–172. doi:10.1016/j.foodqual.2013.01.004

Dawson, M.E., Cacioppo, J.T., Tassinary, L.G., Bernston, G.B., 2001. Handbook of Psychophysiology, Handbook of Psychophysiology. Cambridge Press, Cambridge.

Dawson, M.E., Schell, A.M., Filion, D.L., 2007. The electrodermal system, in: Handbook of Psychophysiology. Cambridge University Press, New York, pp. 159–181.

de Wijk, R.A., He, W., Mensink, M.G.J., Verhoeven, R.H.G., de Graaf, C., 2014. ANS responses and facial expressions differentiate between the taste of commercial breakfast drinks. PLoS One 9, e93823. doi:10.1371/journal.pone.0093823

de Wijk, R.A., Kooijman, V., Verhoeven, R.H.G., Holthuysen, N.T.E., de Graaf, C., 2012. Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods. Food Qual. Prefer. 26, 196–203. doi:10.1016/j.foodqual.2012.04.015

Delplanque, S., Grandjean, D., Chrea, C., Coppin, G., Aymard, L., Cayeux, I., Margot, C., Velazco, M.I., Sander, D., Scherer, K.R., 2009. Sequential unfolding of novelty and pleasantness appraisals of odors: evidence from facial electromyography and autonomic reactions. Emotion 9, 316–328. doi:10.1037/a0015369

Desmet, P.M.A., Hekkert, P., Jacobs, J.J., 2000. When a car makes you smile: Development and application of an instrument to measure product emotions, in: Advances in Consumer Research.

Desmet, P.M. a., Porcelijn, R., Dijk, M.B., 2007. Emotional design; Application of a research-based design approach. Knowledge, Technol. Policy 20, 141–155. doi:10.1007/s12130-007-9018-4

Desmet, P.M., Schifferstein, H.N.J., 2008. Sources of positive and negative emotions in food experience. Appetite 50, 290–301. doi:10.1016/j.appet.2007.08.003

Dimberg, U., 1990. Facial electromyographic reactions and autonomic activity to auditory stimuli. Biol. Psychol. 31, 137–147. doi:10.1016/0301-0511(90)90013-M

Dimberg, U., Karlsson, B., 1997. Facial reactions to different emotionally relevant stimuli. Scand. J. Psychol. 38, 297–303. doi:10.1111/1467-9450.00039

Dimberg, U., Thunberg, M., 1989. Rapid facial reactions to different emotionally relevant stimuli. Scand. J. Psychol. 39, 39–45.

Dimberg, U., Thunberg, M., Elmehed, K., 2000. Unconscious facial reactions to emotional facial expressions. Psychol. Sci. 11, 86–89. doi:10.1111/1467-9280.00221

Dimberg, U., Thunberg, M., Grunedal, S., 2002. Facial reactions to emotional stimuli: Automatically controlled emotional responses. Cogn. Emot. 16, 449–471. doi:10.1080/02699930143000356

Distel, H., Ayabe-Kanamura, S., Martínez-Gómez, M., Schicker, I., Kobayakawa, T., Saito, S., Hudson, R., 1999. Perception of everyday odors--correlation between intensity, familiarity and strength of hedonic judgement. Chem. Senses 24, 191–199. doi:10.1093/chemse/24.2.191

Dobkin, P.L., Pihl, R.O., 1992. Measurement of psychological and heart rate reactivity to stress in the real world. Psychother. Psychosom. 58, 208–210.

Dorado, R., Chaya, C., Tarrega, A., Hort, J., 2016a. The impact of using a written scenario when measuring emotional response to beer. Food Qual. Prefer. 50, 38–47. doi:10.1016/j.foodqual.2016.01.004

Dorado, R., Pérez-Hugalde, C., Picard, A., Chaya, C., 2016b. Influence of first position effect on emotional response. Food Qual. Prefer. 49, 189–196. doi:10.1016/j.foodqual.2015.12.009

Droit-Volet, S., Ramos, D., Bueno, J.L.O., Bigand, E., 2013. Music, emotion, and time perception: the influence of subjective emotional valence and

arousal? Front. Psychol. 4, 1–12. doi:10.3389/fpsyg.2013.00417

Eaton, C., 2015. Developing an effective approach to measure emotional response to the sensory properties of beer. The University of Nottingham.

Ekman, P., 1992. Are there basic emotions? Psychol. Rev. 99, 350–553.

Ekman, P., 1971. Universals and cultural differences in facial expressions of emotion, in: Nebraska Symposium on Motivation. University of Nebraska Press, Lincon, pp. 207–282.

Ekman, P., Friesen, W., 1978. The facial action coding system. Consulting Psychologists Press.

Ekman, P., Friesen, W. V., 1982. Felt, false, and miserable smiles. J. Nonverbal Behav. 6, 238–252. doi:10.1007/BF00987191

Ekman, P., Frisen, W. V, 1986. A new pan cultural expression of emotion. Motiv. Emot. 10, 159–168.

Ekman, P., Levenson, R., Friesen, W., 1983. Autonomic nervous system activity distinguishes among emotions. Science (80-.). 221, 1208–1210.

Ekman, P., Oster, H., 1979. Facial expressions of emotion. Annu. Rev. Psychol. 30, 527–554.

EMedMD, n.d. Diseases Of The Autonomic Nervous System [WWW Document]. eMedMD. URL http://www.emedmd.com/content/diseases-autonomic-nervous-system (accessed 5.19.16).

Esteves, F., Parra, C., Dimburg, U., Ohman, A., 1994. Nonconcious associative learning: Pavlovian conditioing of skin conductance responses to masked fear-relevant facial stimuli. Psychophysiology 31, 375–385.

Evers, C., Adriaanse, M., de Ridder, D.T.D., de Witt Huberts, J.C., 2013. Good mood food. Positive emotion as a neglected trigger for food intake. Appetite 68, 1–7. doi:10.1016/j.appet.2013.04.007

Farrow, T.F.D., Johnson, N.K., Hunter, M.D., Barker, A.T., Wilkinson, I.D., Woodruff, P.W.R., 2012. Neural correlates of the behavioral-autonomic interaction response to potentially threatening stimuli. Front. Hum. Neurosci. 6. doi:10.3389/fnhum.2012.00349

Feldman Barrett, L., Russell, J. a., 1999. The structure of current affect: controversies and emerging consensus. Curr. Dir. Psychol. Sci. 8, 10–14. doi:10.1111/1467-8721.00003

Ferdenzi, C., Roberts, S.C., Schirmer, A., Delplanque, S., Cekic, S., Porcherot, C., Cayeux, I., Sander, D., Grandjean, D., 2013. Variability of affective responses to odors: culture, gender, and olfactory knowledge. Chem. Senses 38, 175–86. doi:10.1093/chemse/bjs083

Fernqvist, F., Ekelund, L., 2014. Credence and the effect on consumer liking of food - A review. Food Qual. Prefer. 32, 340–353. doi:10.1016/j.foodqual.2013.10.005

Ferrarini, R., Carbognin, C., Casarotti, E.M., Nicolis, E., Nencini, A., Meneghini, A.M., 2010. The emotional response to wine consumption. Food Qual. Prefer. 21, 720–725. doi:10.1016/j.foodqual.2010.06.004

Finger, B., Murphy, R.O., 2010. Using skin conductance in judgment and decision making research, in: A Handbook of Process Tracing Methods for Decision Research. Psychology Press, New York, NY.

Fransella, F., Bell, R., Bannister, D., 2004. A manual for repertory grid technique, 2nd ed. John Wiley & Sons Ltd., West Sussex.

Gibbins, I., 2013. Functional organization of autonomic neural pathways. Organogenesis 9, 169–175.

Gilbert, A.N., Fridlund, A.J., Sabini, J., 1987. Hedonic and social determinants of facial displays to odors. Chem. Senses 12, 355–363. doi:10.1093/chemse/12.2.355

Glass, S.T., Lingg, E., Heuberger, E., 2014. Do ambient urban odors evoke basic emotions? Front. Psychol. 5, 1–11. doi:10.3389/fpsyg.2014.00340

Gomez, P., Danuser, B., 2007. Relationships between musical structure and psychophysiological measures of emotion. Emotion 7, 377–87. doi:10.1037/1528-3542.7.2.377

Gratton, G., 2007. Bioprocessing, in: Handbook of Psychophysiology. Cambridge University Press, pp. 834–858.

Greeno, C.G., Wing, R.R., 1994. Stress induced eating. Psychol. Bull. 115, 444–464.

Greimel, E., Macht, M., Krumhuber, E., Ellgring, H., 2006. Facial and affective reactions to tastes and their modulation by sadness and joy. Physiol. Behav. 89, 261–9. doi:10.1016/j.physbeh.2006.06.002

Grossman, M., Wood, W., 1993. Gender differences in judgments of multiple emotions from facial expressions. J. Pers. Soc. Psychol. doi:10.1037/1528-3542.4.2.201

Gutjar, S., Dalenberg, J.R., de Graaf, C., de Wijk, R.A., Palascha, A., Renken, R.J., Jager, G., 2015. What reported food-evoked emotions may add: A model to predict consumer food choice. Food Qual. Prefer. 45, 140–148. doi:10.1016/j.foodqual.2015.06.008

Gutjar, S., Graaf, C. De, Kooijman, V., Nys, A., Horst, G.J. Ter, Jager, G., 2014. The role of emotions in food choice and liking. Food Res. Int. 76, 216–223. doi:10.1016/j.foodres.2014.12.022

Hardestry, T., 1997. Alaska's Wild Denali: Summer in Denali National Park. Alaska Video Postcards, United States.

Hawthorne, D., Shaw, R.D., Davine, D.F., Kavanagh, T.E., Breweries, U., Foster, L., Group, B., Clarke, B.J., 1991. Butyric acid off-flavors in beer: Origins and control 1. Am. Soc. Brew. Chemis 49, 4–8.

He, W., Boesveldt, S., de Graaf, C., de Wijk, R.A., 2016. The relation between continuous and discrete emotional responses to food odors with facial expressions and non-verbal reports. Food Qual. Prefer. 48, 130–137. doi:10.1016/j.foodqual.2015.09.003

He, W., Boesveldt, S., de Graaf, C., de Wijk, R.A., 2014. Dynamics of autonomic nervous system responses and facial expressions to odors. Front. Psychol. 5, 1–8. doi:10.3389/fpsyg.2014.00110

Hein, K. a., Hamid, N., Jaeger, S.R., Delahunty, C.M., 2012. Effects of evoked consumption contexts on hedonic ratings: A case study with two fruit beverages. Food Qual. Prefer. 26, 35–44. doi:10.1016/j.foodqual.2012.02.014

Hein, K. a., Hamid, N., Jaeger, S.R., Delahunty, C.M., 2010. Application of a written scenario to evoke a consumption context in a laboratory setting: Effects on hedonic ratings. Food Qual. Prefer. 21, 410–416. doi:10.1016/j.foodqual.2009.10.003

Heuberger, E., Hongratanaworakit, T., Böhm, C., Weber, R., Buchbauer, G., 2001. Effects of chiral fragrances on human autonomic nervous system parameters and self-evaluation. Chem. Senses 26, 281–292. doi:10.1093/chemse/26.3.281

Homma, S., Matsunami, K., Han, X.Y., Deguchi, K., 2001. Hippocampus in relation to mental sweating response evoked by memory recall and mental calculation: a human electroencephalography study with dipole tracing. Neurosci. Lett. 305, 1–4. doi:10.1016/S0304-3940(01)01759-1

Horio, T., 2000. Effects of various taste stimuli on heart rate in humans. Chem.

Senses 25, 149–153. doi:10.1093/chemse/25.2.149

Hu, S., Player, K., Mcchesney, K., Dalistan, M., Tyner, C., Scozzafava, J., 1999. Facial EMG as an indicator of palatability in humans. Physiol. Behav. 68, 31–35. doi:10.1016/S0031-9384(99)00143-2

Huang, C., Chen, C., Chung, H., 2004. The review of applications and aeasurements in facial electromyography. J. Med. Biol. Eng. 25, 15–20.

Huvaere, K., Skibsted, L.H., 2015. Flavonoids protecting food and beverages against light. J. Sci. Food Agric. 95, 20–35. doi:10.1002/jsfa.6796

Izard, C.E., 2007. Basic emotions, natural kinds, emotion schemas, and a new paradigm. Perspect. Psychol. Sci. 2, 260–280. doi:10.1111/j.1745-6916.2007.00044.x

Jaeger, S.R., Cardello, A. V., Schutz, H.G., 2013. Emotion questionnaires: A consumer-centric perspective. Food Qual. Prefer. 30, 229–241. doi:10.1016/j.foodqual.2013.05.015

Jager, G., Schlich, P., Tijssen, I., Yao, J., Visalli, M., de Graaf, C., Stieger, M., 2014. Temporal dominance of emotions: Measuring dynamics of food-related emotions during consumption. Food Qual. Prefer. 37, 87–99. doi:10.1016/j.foodqual.2014.04.010

Johnson, J.M., 1986. Nonthermoregulatory control of human skin blood flow. J. Appl. Physiol. 61, 1613–22.

Jose, A., Collison, D., 1970. The normal range and determinants of the intrinsic heart rate in man. Cardiovasc. Res. 4, 160–167.

Kaneda, H., Kojima, H., 2011. Novel psychological and neurophysiological significance of beer aromas . Part I : aeasurement of changes in human emotions during the smelling of hop and ester aromas using a measurement system for brainwaves. Am. Soc. Brew. Chem. 69, 67–74.

Kaneda, H., Kojima, H., Watari, J., 2011. Novel psychological and neurophysiological significance of beer aromas . Part II : Effects of beer aromas on brainwaves related to changes in human emotions. Am. Soc. Brew. Chem.

Katz, A.M., 2011a. Structure of the heart and cardiac muscle, in: Physiology of the Heart. Lippincott Williams & Wilkins, Philadelphia, PA, pp. 3–32.

Katz, A.M., 2011b. The electrocardigram, in: Physiology of the Heart. Lippincott Williams & Wilkins, Philadelphia, PA, pp. 401–430.

Kimura, K., Low, D., 2007. Cutaneous blood flow and sweat rate responses to exogenous administration of acetylcholine and methacholine. J. Appl. Physiol. 102, 1856–1861.

King, S.C., Meiselman, H.L., 2010. Development of a method to measure consumer emotions associated with foods. Food Qual. Prefer. 21, 168–177. doi:10.1016/j.foodqual.2009.02.005

King, S.C., Meiselman, H.L., Carr, B.T., 2010. Measuring emotions associated with foods in consumer testing. Food Qual. Prefer. 21, 1114–1116.

King, S.C., Meiselman, H.L., Thomas Carr, B., 2013. Measuring emotions associated with foods: Important elements of questionnaire and test design. Food Qual. Prefer. 28, 8–16. doi:10.1016/j.foodqual.2012.08.007

King, S.C., Weber, A.J., Meiselman, H.L., Lv, N., 2004. The effect of meal situation, social interaction, physical environment and choice on food acceptability. Food Qual. Prefer. 15, 645–653. doi:10.1016/j.foodqual.2004.04.010

Koelega, H.S., Köster, E.P., 1974. Some experiments on sex differences in odour perception. Ann. N. Y. Acad. Sci. 237, 234–246.

Koelsch, S., Jäncke, L., 2015. Music and the heart. Eur. Heart J. 36, 3043–3049. doi:10.1093/eurheartj/ehv430

Köster, E.P., 2003. The psychology of food choice: some often encountered fallacies. Food Qual. Prefer. 14, 359–373. doi:10.1016/S0950-3293(03)00017-X

Köster, E.P., Mojet, J., 2015. From mood to food and from food to mood: A psychological perspective on the measurement of food-related emotions in consumer research. Food Res. Int. 76, 180–191. doi:10.1016/j.foodres.2015.04.006

Kreibig, S.D., 2010a. Autonomic nervous system activity in emotion: a review. Biol. Psychol. 84, 394–421. doi:10.1016/j.biopsycho.2010.03.010

Kreibig, S.D., 2010b. Autonomic nervous system activity in emotion: a review. Biol. Psychol. 84, 394–421. doi:10.1016/j.biopsycho.2010.03.010

Kring, A.M., Gordon, A.H., 1998. Sex differences in emotion: Expression, experience, and physiology. J. Pers. Soc. Psychol. 74, 686–703. doi:10.1037//0022-3514.74.3.686

Krogerus, K., Gibson, B., Hytonen, E., 2015. An improved model for prediction of fermentation progress and total diacetyl profile. Am. Soc. Brew. Chem.

73, 90–99.

Kuesten, C., Chopra, P., Bi, J., Meiselman, H.L., 2014. A global study using PANAS (PA and NA) scales to measure consumer emotions associated with aromas of phytonutrient supplements. Food Qual. Prefer. 33, 86–97. doi:10.1016/j.foodqual.2013.11.004

Kuppens, P., Tuerlinckx, F., Russell, J. a, Barrett, L.F., 2013. The relation between valence and arousal in subjective experience. Psychol. Bull. 139, 917–40. doi:10.1037/a0030811

Landowska, A., 2014. Emotion monitoring--verification of physiological characteristics measurement procedures. Metrol. Meas. Syst. 21, 381–394. doi:10.2478/mms-2014-0049

Landrine, H., Bardwell, S., Dean, T., 1988. Gender expectations for alcohol use: A study of the significance of the masculine role. Sex Roles 19, 703–712. doi:10.1007/BF00288986

Lang, A., Yegiyan, N., 2014. Mediated substance cues: Motivational reactivity and use influence responses to pictures of alcohol. J. Health Commun. 19.

Lang, P.J., Reenwald, M.K.C., Bradley, M.M., Hamm, A.O., 1993. Looking at pictures : Affective , facial , visceral , and behavioral reactions. Psychophysiology 30, 261–273.

Lapatki, B., Stegeman, D., Jonas, I., 2003. A surface EMG electrode for the simultaneous observation of multiple facial muscles. J. Neurosci. Methods 123, 117–128.

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, 776–785. doi:10.1111/1469-8986.00078

Larsen, J.T., Norris, J.I., 2009. A facial electromyographic investigation of affective contrast. Psychophysiology 46, 831–42. doi:10.1111/j.1469-8986.2009.00820.x

Larsen, R.J., Diener, E., 1992. Promises and problems with the circumplex model of emotion. Rev. Personal. Soc. Psychol. 13, 25–59.

LeDoux, J., 2012. Rethinking the Emotional Brain. Neuron 73, 653–676. doi:10.1016/j.neuron.2012.02.004

LeDoux, J.E., 1992. Brain mechanisms of emotion and emotional learning.

Curr. Opin. Neurobiol. 2, 191–197. doi:10.1016/0960-9822(92)90530-N

Letarte, a, Dubé, L., Troche, V., 1997. Similarities and differences in affective and cognitive origins of food likings and dislikes. Appetite 28, 115–129. doi:10.1006/appe.1996.0069

Levenson, R.W., 2014. The autonomic nervous system and emotion. Emot. Rev. 6, 100–112. doi:10.1177/1754073913512003

Levenson, R.W., 1988. Emotions and the autonomic nervous system, in: A Prospectus for Research on Autonomic Specificity. Wiley, New York, pp. 17–42.

Levy, M.N., Martin, P.J., 1981. Neural regulation of the heart beat. Annu. Rev. Physiol. 43, 443–453.

Lewinski, P., den Uyl, T.M., Butler, C., 2014. Automated facial coding: Validation of basic emotions and FACS AUs in FaceReader. J. Neurosci. Psychol. Econ. 7, 227–236. doi:10.1037/npe0000028

Liao, L., Corsi, A.M., Chrysochou, P., Lockshin, L., 2015. Emotional responses towards food packaging: a joint application of self-report and physiological measures of emotion. Food Qual. Prefer. 42, 48–55. doi:10.1016/j.foodqual.2015.01.009

Libby, W., Lacey, B., Lacey, J., 1973. Pupillary and cardiac activity during visual attention. Psychophysiology 10, 270–294.

Lidberg, L., Wallin, B.G., 1981. Sympathetic skin nerve discharges in relation to amplitude of skin resistance responses. Psychophysiology 18, 268–270.

Lorig, T., 2007. The respiratory system, in: Handbook of Psychophysiology. Cambridge University Press, New York, pp. 231–234.

Lottridge, P.T.J.A.U., Chignell, D., Yasumura, M., 2011. Identifying emotion through implicit and explicit measures: Cultural differences. Cogn. Load 3, 1949–3045.

Lubin, B., Zuckerman, M., Hanson, P., Armstrong, T., Rinck, C., Seever, M., 1986. Reliability and validity of the Multiple Affect Adjective Check List - Revised. J. Psychopathol. Behav. Assess. 8, 103–117.

Lyman, B., 1982. A psychology of food, more than a matter of taste. Van Nostrand Reinhold, New York.

Macefield, V.G., Wallin, B.G., 1996. The discharge behaviour of single sympathetic neurones supplying human sweat glands. J. Auton. Nerv.

Syst. 61, 277–286. doi:10.1016/S0165-1838(96)00095-1

Machado-Moreira, C.A., Taylor, N.A.S., 2011. Psychological sweating from glabrous and nonglabrous skin surfaces under thermoneutral conditions. Psychophysiology 49, 369–374.

Macht, M., 2008. How emotions affect eating: A five-way model. Appetite 50, 1–11. doi:10.1016/j.appet.2007.07.002

Mangina, C.A., Beuzeron-Mangina, J.H., 1996. Direct electrical stimulation of specific human brain structures and bilateral electrodermal activity. Int. J. Psychophysiol. 22, 1–8. doi:10.1016/0167-8760(96)00022-0

Martin, G.N., Apena, F., Chaudry, Z., Mulligan, Z., Nixon, C., 2001. The development of an attitudes towards the sense of smell questionnaire (SoSQ) and a comparison of different professions' responses. N. Am. J. Psychol. 3, 1527–7143.

Mauss, I.B., Robinson, M.D., 2009. Measures of emotion: A review. Cogn. Emot. 23, 209–237. doi:10.1080/02699930802204677

McCorry, L., 2007. Physiology of the autonomic nervous system. Am. J. Pharm. Educ. 71, 1–11.

McNair, D.M., Lorr, M., Droppleman, L.F., 1971. Manual for the profile of mood states. Educational and Industrial Testing Services, San Diego, CA.

MedicalLibary, n.d. 30 Muscles of the Skull & Face [WWW Document]. URL http://doctorlib.info/medical/anatomy/32.html (accessed 5.19.16).

Mehrabian, A., Russell, J.A., 1974. An approach to environmental psychology. The MIT Press, Cambridge, MA.

Meilgaard, M., Dalgliesh, C., Clapperton, L., 1979. Beer flavour terminology. J. Inst. … 37, 47–52.

Meiselman, H.L., 2015. A review of the current state of emotion research in product development. Food Res. Int. 76, 192–199. doi:10.1016/j.foodres.2015.04.015

Meiselman, H.L., 2013. The future in sensory/consumer research: Evolving to a better science. Food Qual. Prefer. 27, 208–214. doi:10.1016/j.foodqual.2012.03.002

Mojet, J., Dürrschmid, K., Danner, L., Jöchl, M., Heiniö, R.-L., Holthuysen, N., Köster, E., 2015. Are implicit emotion measurements evoked by food unrelated to liking? Food Res. Int. 76, 224–232.

doi:10.1016/j.foodres.2015.06.031

Montebarocci, O., Codispoti, M., Surcinelli, P., Franzoni, E., Baldaro, B., Rossi, N., 2006. Alexithymia in female patients with eating disorders. Eat. Weight Disord. EWD 11, 14–21.

Morecraft, R.J., Louie, J.L., Herrick, J.L., Stilwell-Morecraft, K.S., 2001. Cortical innervation of the facial nucleus in the non-human primate: A new interpretation of the effects of stroke and related subtotal brain trauma on the muscles of facial expression. Brain 124, 176–208. doi:10.1093/brain/124.1.176

Morris, J.O.N.D., Geason, J.A., 2002. The power of affect: Predicting intention. J. Advert. Res. May-June, 7–17.

Muroni, P., Crnjar, R., Tomassini Barbarossa, I., 2011. Emotional responses to pleasant and unpleasant oral flavour stimuli. Chemosens. Percept. 4, 65–71. doi:10.1007/s12078-011-9093-5

Murphy, F.C., Nimmo-Smith, I., Lawrence, a. D., 2003. Functional neuroanatomy of emotions: A meta-analysis. Cogn. Affect. Behav. Neurosci. 3, 207–233. doi:10.3758/CABN.3.3.207

Næs, T., Langsrud, Ø., 1998. Fixed or random assessors in sensory profiling? Food Qual. Prefer. 9, 145–152. doi:10.1016/S0950-3293(96)00050-X

Ng, M., Chaya, C., Hort, J., 2013. Beyond liking: Comparing the measurement of emotional response using EsSense Profile and consumer defined check-all-that-apply methodologies. Food Qual. Prefer. 28, 193–205. doi:10.1016/j.foodqual.2012.08.012

Nikula, R., 1991. Psychological correlates of nonspecific skin conductance responses. Psychophysiology 28, 86–90.

Olofsson, J.K., Nordin, S., 2004. Gender differences in chemosensory perception and event-related potentials. Chem. Senses 29, 629–637. doi:10.1093/chemse/bjh066

Oosthoek, P.W., Virágh, S., Mayen, a E., van Kempen, M.J., Lamers, W.H., Moorman, a F., 1993. Immunohistochemical delineation of the conduction system. I: The sinoatrial node. Circ. Res. 73, 473–481. doi:10.1161/01.RES.73.3.473

Ortony, A., Turner, T., 1990. What's basic about basic emotions? Psychol. Rev. 97, 315–331.

Panksepp, J., 2007. Neurologizing the psychology of affects: How appraisal-

based constructivism and basic emotion theory can coexist. Perspect. Psychol. Sci. 2, 281–296. doi:10.1111/j.1745-6916.2007.00045.x

Pappano, A., 2010. Regulation of the heart and vasculture, in: Physiology. Elsevier, Philadelphia, pp. 370–392.

Petrofsky, J.S., Ph, D., 2012. Resting blood flow in the skin: Does It exist, and what is the influence of temperature, aging, and diabetes? 6.

Phan, K.L., Wager, T., Taylor, S.F., Liberzon, I., 2002. Functional neuroanatomy of emotion: a meta-analysis of emotion activation studies in PET and fMRI. Neuroimage 16, 331–48. doi:10.1006/nimg.2002.1087

Pichon, A.M., Coppin, G., Cayeux, I., Porcherot, C., Sander, D., Delplanque, S., 2015. Sensitivity of physiological emotional measures to odors depends on the product and the pleasantness ranges used. Front. Psychol. 6. doi:10.3389/fpsyg.2015.01821

Piqueras-Fiszman, B., Jaeger, S.R., 2014a. The impact of evoked consumption contexts and appropriateness on emotion responses. Food Qual. Prefer. 32, 277–288. doi:10.1016/j.foodqual.2013.09.002

Piqueras-Fiszman, B., Jaeger, S.R., 2014b. Emotion responses under evoked consumption contexts: A focus on the consumers' frequency of product consumption and the stability of responses. Food Qual. Prefer. 35, 24–31.

Podsakoff, P.M., Mackenzie, S.B., Lee, J., Podsakoff, N.P., 2003. Common method biases in behavioral research : A critical review of the literature and recommended remedies 88, 879–903. doi:10.1037/0021-9010.88.5.879

Poels, K., Dewitte, S., 2006. How to capture the heart? Reviewing 20 years of emotion measurement in advertising. J. Advert. Res. 46, 18–37. doi:10.2501/S0021849906060041

Porcherot, C., Delplanque, S., Raviot-Derrien, S., Calv??, B.L., Chrea, C., Gaudreau, N., Cayeux, I., 2010. How do you feel when you smell this? Optimization of a verbal measurement of odor-elicited emotions. Food Qual. Prefer. 21, 938–947.

Rainville, P., Bechara, A., Naqvi, N., Damasio, A.R., 2006. Basic emotions are associated with distinct patterns of cardiorespiratory activity. Int. J. Psychophysiol. 61, 5–18. doi:10.1016/j.ijpsycho.2005.10.024

Ritz, T., Dahme, B., Claussen, C., 1999. Gradients of facial EMG and cardiac activity during emotional stimulation. J. Psychophysiol. 13, 3–17.

Robin, O., Rousmans, S., Dittmar, a, Vernet-Maury, E., 2003. Gender influence on emotional responses to primary tastes. Physiol. Behav. 78, 385–393. doi:10.1016/S0031-9384(02)00981-2

Rolls, E.T., Grabenhorst, F., Margot, C., de Silva, M.A., Velazco, M.I., 2008. Selective attention to affective value alters how the brain processes olfactory stimuli. Eur. J. Neurosci. 27, 723–729. doi:10.1111/j.1460-9568.2008.06033.x

Rottenburg, J., Ray, R., Gross, J., 2007. Emotion elicitation using films, in: Handbook of Emotion Elicitation and Assessment. New York, pp. 9–28.

Rousmans, S., Robin, O., 2000. Autonomic nervous system responses associated with primary tastes. Chem. Senses 25, 709–718.

Rudolph, M.J., 1995. The food product development process. Br. Food J. 97, 3–11. doi:10.1108/00070709510081408

Russell, J.A., 1980. A circumplex model of affect. J. Pers. Soc. Psychol. 39, 1161–1178.

Russell, J.A., Barrett, L.F., 1999. Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. J. Pers. Soc. Psychol. 76, 805–819. doi:10.1037//0022-3514.76.5.805

Russell, J.A., Weiss, A., Mendelsohn, G.A., 1989. Affect Grid: A single-item scale of pleasure and arousal. J. Pers. Soc. Psychol. 57, 493–502. doi:10.1037//0022-3514.57.3.493

Russell, J. a., 2003. Core affect and the psychological construction of emotion. Psychol. Rev. 110, 145–172. doi:10.1037/0033-295X.110.1.145

Scherer, K.R., 2005. What are emotions? And how can they be measured? Soc. Sci. Inf. 44, 695–729. doi:10.1177/0539018405058216

Schifferstein, H.N.J., Desmet, P.M. a., 2010. Hedonic asymmetry in emotional responses to consumer products. Food Qual. Prefer. 21, 1100–1104. doi:10.1016/j.foodqual.2010.07.004

Schifferstein, H.N.J., Fenko, A., Desmet, P.M. a., Labbe, D., Martin, N., 2013. Influence of package design on the dynamics of multisensory and emotional food experience. Food Qual. Prefer. 27, 18–25. doi:10.1016/j.foodqual.2012.06.003

Sequeira, H., Hot, P., Silvert, L., Delplanque, S., 2009. Electrical autonomic correlates of emotion. Int. J. Psychophysiol. 71, 50–6. doi:10.1016/j.ijpsycho.2008.07.009

Sester, C., Dacremont, C., Deroy, O., Valentin, D., 2013a. Investigating consumers' representations of beers through a free association task: A comparison between packaging and blind conditions. Food Qual. Prefer. 28, 475–483. doi:10.1016/j.foodqual.2012.11.005

Sester, C., Deroy, O., Sutan, A., Galia, F., Desmarchelier, J.-F., Valentin, D., Dacremont, C., 2013b. "Having a drink in a bar": An immersive approach to explore the effects of context on drink choice. Food Qual. Prefer. 28, 23–31. doi:10.1016/j.foodqual.2012.07.006

Shields Jr, R.W., 1993. Functional anatomy of autonomic nervous system. J. Clin. Neurophysiol. 10, 2–13.

Silva, A.P., Jager, G., van Bommel, R., van Zyl, H., Voss, H.-P., Pintado, M., Hogg, T., De Graaf, C., 2014. Emotional and Functional conceptualisations for Beer, Wine and Non-Alcoholic beer consumption in the Netherlands and in Portugal. App 83, 350. doi:10.1016/j.appet.2014.06.055

Smith, C.A., Ellsworth, P.C., 1985. Patterns of cognitive appraisal in emotion. Attitudes Soc. Cogn. 48, 813–838.

Smythe, J.E., Bamforth, C.W., 2003. The path analysis method of eliminating preferred stimuli (PAMEPS) as a means to determine foam preferences for lagers in European judges based upon image assessment. Food Qual. Prefer. 14, 567–572. doi:10.1016/S0950-3293(02)00133-7

Smythe, J.E., Mahony, M.A.O., Bamforth, C.W., 2002. The impact of the appearance of beer on its perception. Insititute Guild Brew. 108, 37–42.

Sokhadze, E.M., 2007. Effects of music on the recovery of autonomic and electrocortical activity after stress induced by aversive visual stimuli. Appl. Psychophysiol. Biofeedback 32, 31–50. doi:10.1007/s10484-007-9033-y

Soussignan, R., Jiang, T., Rigaud, D., Royet, J.P., Schaal, B., 2010. Subliminal fear priming potentiates negative facial reactions to food pictures in women with anorexia nervosa. Psychol. Med. 40, 503–514. doi:10.1017/S0033291709990377

Soussignan, R., Schaal, B., Rigaud, D., Royet, J.P., Jiang, T., 2011. Hedonic reactivity to visual and olfactory cues: Rapid facial electromyographic reactions are altered in anorexia nervosa. Biol. Psychol. 86, 265–272. doi:10.1016/j.biopsycho.2010.12.007

Soussignan, R., Schall, B., 1996. Children's facial responsiveness to odors: Influences of hedonic valence of odor, gender, age, and social presence.

Dev. Psychol. 32, 367–379. doi:10.1037/0012-1649.32.2.367

Spinelli, S., Masi, C., Dinnella, C., Zoboli, G.P., Monteleone, E., 2014. How does it make you feel? A new approach to measuring emotions in food product experience. Food Qual. Prefer. 37, 109–122. doi:10.1016/j.foodqual.2013.11.009

Steiner, J.E., 1979. Human facial expressions in response to taste and smell stimulation. Adv. Child Dev. Behav. 13, 257–295.

Steiner, J.E., 1974. Discussion paper: Innate, discriminative human facial expressions to taste and smell stimulation. Ann. N. Y. Acad. Sci. 273, 229–233.

Stemmler, G., 2004. Physiological processes during emotion, in: The Regulation of Emotion. Mahwah, New Jersey, pp. 33–70.

Stephenson, W., Bamforth, C., 2002. The impact of lightstruck and stale character in beers on their perceived quality: A consumer study. J. Inst. Brew. Distill. 108, 5–8.

Stewart-Knox, B., Mitchell, P., 2003. What separates the winners from the losers in new food product development? Trends Food Sci. Technol. 14, 58–64. doi:10.1016/S0924-2244(02)00239-X

Stockhorst, U., Pietrowsky, R., 2004. Olfactory perception, communication, and the nose-to-brain pathway. Physiol. Behav. 83, 3–11. doi:10.1016/j.physbeh.2004.07.018

Stone, H., Bleibaum, R.N., Thomas, H.A., 2004. Introduction to sensory evaluation, in: Sensory Evaluation Practices. Academic Press, Tokyo, pp. 0–21. doi:10.1016/B978-0-12-382086-0.00001-7

Striegel-Moore, R.H., Morrison, J.A., Schreiber, G., Schumann, B.C., Crawford, P.B., Obarzanek, E., 1999. Emotion-induced eating and sucrose intake in children: The NHLBI growth and health study. Int. J. Eat. Disord. 25, 389–398. doi:10.1002/(SICI)1098-108X(199905)25:4<389::AID-EAT3>3.0.CO;2-4

Takahashi, H., Maehara, K., Onuki, N., 2003. Decreased contractility of the left ventricle is induced by the neurotrausmitter acetylcholine, but not by vagal stimulation in rats. Jpn. Heart J. 44, 257–270.

Tan, J.-W., Walter, S., Scheck, A., Hrabal, D., Hoffmann, H., Kessler, H., Traue, H.C., 2011. Facial electromyography (fEMG) activities in response to affective visual stimulation. 2011 IEEE Work. Affect. Comput. Intell. 2011,

1–5. doi:10.1109/WACI.2011.5953144

Task Force, 1996. Heart rate variability Standards of measurement, physiological interpretation, and clinical use: Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur. Heart J. 17, 354–381.

Tassinary, L.G., Cacioppo, J.T., 1992. Unobservable Facial Actions and Emotion. Psychol. Sci. 3, 28–33. doi:10.1111/j.1467-9280.1992.tb00252.x

Thayer, R.E., 1989. The biopsychology of mood and activation. Oxford University Press, New York, NY.

Thomas, K., 2006. British beers: a survey of cask ale character. Br. Food J. 108, 849–858. doi:10.1108/00070700610702109

Thomson, D.M.H., Crocker, C., Marketo, C.G., 2010. Linking sensory characteristics to emotions: An example using dark chocolate. Food Qual. Prefer. 21, 1117–1125. doi:10.1016/j.foodqual.2010.04.011

Tuorila, H., Meiselman, H.L., Bell, R., Cardello, A. V, Johnson, W., 1994. Role of sensory and cognitive information in the enhancement of certainty and liking for novel and familiar foods. Appetite 23, 231–246. doi:10.1006/appe.1994.1056

van der Zwaag, M.D., Westerink, J.H.D.M., van den Broek, E.L., 2011. Emotional and psychophysiological responses to tempo, mode, and percussiveness. Music. Sci. 15, 250–269. doi:10.1177/1029864911403364

van oyen Witvliet, C., Vrana, S.R., 1995. Psychophysiological responses as indices of affective dimensions. Psychophysiology 32, 436–443. doi:10.1111/j.1469-8986.1995.tb02094.x

Vernet-Maury, E., Alaoui-Ismaïli, O., 1999. Basic emotions induced by odorants: a new approach based on autonomic pattern results. J. Auton. Nerv. Syst. 75, 176–183.

Vos, P., De Cock, P., Munde, V., Petry, K., Van Den Noortgate, W., Maes, B., 2012. The tell-tale: What do heart rate; skin temperature and skin conductance reveal about emotions of people with severe and profound intellectual disabilities? Res. Dev. Disabil. 33, 1117–1127. doi:10.1016/j.ridd.2012.02.006

Wagner, T., Hernandez, L., Jonides, J., Lindquist, M., 2007. Elements of functional neuroimaging, in: Handbook of Psychophysiology. Cambridge

University Press, New York, NY, pp. 19–84.

Watson, D., Clark, L.A., Tellegen, A., 1988. Development and validation of brief measures of positive and negative affect - the PANA scales. J. Pers. Soc. Psychol. 54, 1063–1070. doi:10.1037/0022-3514.54.6.1063

Watson, D., Tellegen, A., 1985. Toward a consensual structure of mood. Psychol. Bull. 98, 219–235. doi:10.1037//0033-2909.98.2.219

Wendin, K., Allesen-Holm, B.H., Bredie, W.L.P., 2011. Do facial reactions add new dimensions to measuring sensory responses to basic tastes? Food Qual. Prefer. 22, 346–354. doi:10.1016/j.foodqual.2011.01.002

Winston, J.S., Gottfried, J.A., Kilner, J.M., Dolan, R.J., 2005. Integrated neural representations of odor intensity and affective valence in human amygdala. J. Neurosci. 25, 8903–7. doi:10.1523/JNEUROSCI.1569-05.2005

WorldPress, 2014. Heart function and physiology [WWW Document]. Excerise Physiol. URL http://ptexphys.utorontoeit.com/cardiovascular-physiology/heart-function-and-physiology/ (accessed 5.19.16).

Yasuma, F., Hayano, J.I., 2004. Respiratory sinus arrhythmia: Why does the heartbeat synchronize with respiratory rhythm? Chest 125, 683–690. doi:10.1378/chest.125.2.683

Yeshurun, Y., Lapid, H., Dudai, Y., Sobel, N., 2009. The privileged brain representation of first olfactory associations. Curr. Biol. 19, 1869–1874. doi:10.1016/j.cub.2009.09.066

Yeshurun, Y., Sobel, N., 2010. An odor is not worth a thousand words: from multidimensional odors to unidimensional odor objects. Annu. Rev. Psychol. 61, 219–41, C1-5. doi:10.1146/annurev.psych.60.110707.163639

Zander, K., Hamm, U., 2010. Consumer preferences for additional ethical attributes of organic food. Food Qual. Prefer. 21, 495–503. doi:10.1016/j.foodqual.2010.01.006

Zatorre, R.J., Jones-Gotman, M., Rouby, C., 2000. Neural mechanisms involved in odor pleasantness and intensity judgments. Neuroreport 11, 2711–6. doi:10.1097/00001756-200008210-00021

Zeinstra, G.G., Koelen, M. a., Colindres, D., Kok, F.J., de Graaf, C., 2009. Facial expressions in school-aged children are a good indicator of “dislikes”, but not of “likes.” Food Qual. Prefer. 20, 620–624. doi:10.1016/j.foodqual.2009.07.002

Zimmer, H., 2006. Habituation of the orienting response as reflected by the skin conductance response and by endogenous event-related brain potentials. Int. J. Psychophysiol. 60, 44–58. doi:10.1016/j.ijpsycho.2005.05.003

Zukerman, M., Lubin, B., 1965. Test manual for the Multiple Affect Adjective Check List (MAACL). Educational and Industrial Testing Services, San Diego, CA.