Cross-Cultural Comparison in the Emotional Responses Elicited by Wine Odors

Aimee Hasenbeck

University of Arkansas, Fayetteville

Follow this and additional works at: http://scholarworks.uark.edu/etd

Part of the Applied Behavior Analysis Commons, and the Food Chemistry Commons

Recommended Citation


http://scholarworks.uark.edu/etd/2026

This Thesis is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of ScholarWorks@UARK. For more information, please contact scholar@uark.edu, ccmiddle@uark.edu.
Cross-Cultural Comparison in the Emotional Responses Elicited by Wine Odors
Cross-Cultural Comparison in the Emotional Responses Elicited by Wine Odors

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Food Science

by

Aimee R. Hasenbeck
University of Arkansas
Bachelor of Science in Food Science, 2011

December 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

_______________________________________________
Dr. Han-Seok Seo
Thesis Director

_______________________________________________
Dr. Jean-Francois Meullenet
Committee Member

_______________________________________________
Dr. Robert Harrington
Committee Member

_______________________________________________
Dr. Andy Mouramoustakos
Committee Member
Abstract

To remain competitive in the wine market, wine companies must strive for a deeper understanding of the factors that influence consumers at an emotional level in order to sustain consumer satisfaction. Evaluating the wine odor-induced emotional response, in addition to hedonic response and descriptive analysis, may provide valuable information into the perspective of the consumer and potentially insight to repeat purchases. The objectives of this research were to measure the emotional responses elicited by odor attributes in wine samples and determine whether these emotional responses vary as function of cultural and experiential backgrounds, as well as sensory characteristics of wine odors. In Study 1 (Chapter 3), 10 trained panelists evaluated odor attributes of the five pre-selected wine samples; four specific odorants, linalool, 2,3-butanedione (diacetyl), 2,4,6-trichloroanisole (TCA), and acetaldehyde, were added to the base wine to maximize the odor effect of sensory perception. The five wine samples were found to differ in the odor intensities of sulfur, moldy/musty, honey, and leather attributes. In Study 2 (Chapter 4), French (N = 86) and U.S. (N = 89) participants rated their emotional responses elicited by the odors of five wine samples on the Geneva Emotion and Odor Scale (GEOS). There were significant interactions between country and wine sample for the ratings of “well-being” and “excited” in emotional response. Significant cross-cultural differences were obtained in the emotional responses evoked by the wines for 19 of the 36 terms, which led to the difference in the distribution of wine samples as shown by principal component analysis between two countries. In addition, the emotional responses elicited by wine odors were different as a function of gender and previous reading of wine-related literature. Furthermore, the odor of wine sample including TCA was rated at the least pleasant in both countries. This study shows that emotional responses and hedonic responses, as well as sensory attributes can be modulated as a
function of the odor of wine samples and consumer characteristics such as gender and culture. A better understanding of the emotional effects of odors found in wine, and how these effects vary among consumers, will allow the wine industry to develop products with specific emotional impacts on users of different consumer groups.
Acknowledgements

I would first like to express my sincere gratitude to my advisor, Dr. Han-Seok Seo, for his time, patience and intellectual guidance in sensory. I have learned so much through this experience, much of which I owe to you. Thank you for your endless encouragement and determination throughout my path to becoming a sensory scientist.

I would also like to express my abundant appreciation to all my committee members: Dr. Jean-Francois Meullenet, Dr. Andy Mouramoustakos and Dr. Robert Harrington. Each of you provided endless knowledge and guidance throughout this process. Further, I would like to thank the staff and fellow graduate students at the Department of Food Science and Sensory Service Center.

My very special thanks also go to the other researchers who helped with my project: Dr. Renee Threlfall, Dr. Jordi Ballester and Dr. Christelle Pecher. Renee, thank you so much for constantly encouraging me over the years and helping so much with planning the initial portion of my research. Without you, this would not be possible. Further, thank you for all the scholarship opportunities you provided me with and your guidance with those applications. Jordi and Christelle, I cannot tell you how thankful I am for my time with you in France. Both of you went above-and-beyond with accommodating me and seeing my research through in France.

To my husband, Thomas, thank you so much. Your patience, understanding, motivation and unconditional love made this thesis possible. Thank you for believing in me and making me believe in myself. I know, at times, it was not an easy challenge. Last, but certainly not least, I would also like to express my deep gratitude to my family whose constant love and encouragement helped me achieve my goal.
Dedication

This thesis is dedicated to the loving memory of Dr. Justin Morris, or “Doc,” who provided me with endless educational opportunities, encouragement and—best of all—laughter.
Table of Contents

Chapter 1 – Introduction..................................................................................................................1

Literature Cited.................................................................................................................................4

Chapter 2 – Review of Literature....................................................................................................7
  1. Affective terms, responses, and model.......................................................................................8
     1.1. Models.................................................................................................................................9
     1.1.1. Basic emotion models.................................................................................................9
     1.1.2. Dimensional feeling models.......................................................................................10
     1.1.3. Componential appraisal models..................................................................................11
     1.2. Clarification of affective terms.........................................................................................13
  2. Olfaction......................................................................................................................................15
     2.1. Anatomy and physiology of the olfactory system............................................................16
     2.2. Sources of variation in olfactory perception.....................................................................19
        2.2.1. Demographic factors...............................................................................................19
        2.2.2. Cultural background...............................................................................................21
  3. Emotional effect of odors..........................................................................................................23
     3.1. Odor hedonic tone..............................................................................................................24
     3.2. Effects of odors on cognition and behavior.......................................................................25
     3.3. Physiological impacts of odors involved in emotional response.....................................26
     3.4. Link between odor, memory, and emotion.......................................................................27
     3.5. Cultural specificity of odor-induced emotional response...............................................29

Literature Cited..................................................................................................................................31

Chapter 3 – Descriptive Analysis of Odor Attributes in Wine

Samples.............................................................................................................................................43

Abstract...........................................................................................................................................44

  1. Introduction..............................................................................................................................45
  2. Materials and methods..............................................................................................................46
     2.1. Samples and preparation....................................................................................................47
     2.2. Descriptive sensory analysis............................................................................................49
     2.3. Data analysis......................................................................................................................50
  3. Results and Discussion..............................................................................................................51
List of Tables

TABLE 2.1. Relationships between organismic subsystems and the functions and components of emotions ................................................................. 14

TABLE 3.1. Chemical profile of 2010 Georges DuBœuf Mâcon-Villages Chardonnay wine (Burgundy, France) .................................................................. 47

TABLE 3.2. Profiles of four odorants added into the base white wine in this study.... 48

TABLE 3.3 Aroma attributes and their definitions in the wine samples used in this study ........................................................................................................... 51

TABLE 3.4. Mean (± standard deviation) intensity ratings of the odor attributes in the five wine samples .......................................................................................... 53

TABLE 4.1. Comparisons between American and French participants in their demographic profiles and wine consumption ................................................... 65

TABLE 4.2. Main effects of country and wine sample and their interaction in the emotional responses elicited by the five wine odors ................................. 71

TABLE 4.3. Mean ratings (± standard deviation) in the emotional responses as a function of country and wine samples ........................................................................... 73

TABLE 4.4. Mean hedonic ratings (± standard deviation) in the hedonic responses to the five wine odors as a function of country ........................................... 83
List of Figures

FIGURE 3.1. A spider-web plot of the descriptive sensory analysis for the odors of the five wine samples. * and ** represent a significant difference at $P < 0.05$ and $P < 0.01$, respectively .................................................. 54

FIGURE 3.2. Principal component analysis (PCA) for the odor attributes of the five wine samples ................................................................. 55

FIGURE 4.1. Interactions between country and wine sample in the emotional responses: well-being (a) and excited (b) .................................................. 69

FIGURE 4.2. Cross-cultural difference between French and American participants in the emotional responses elicited by wine odors ........................................... 75

FIGURE 4.3. Differences in the emotional responses elicited by the odors of five wine samples ................................................................. 76

FIGURE 4.4. Principal component analyses in the emotional responses elicited by the odors of five wine samples as a function of country: (a) France and (b) U.S.A ................................................................. 77

FIGURE 4.5. Dendrograms drawn by agglomerative hierarchical clustering (AHC) in the emotional responses elicited by the odors of five wine samples as a function of country: (a) France and (b) U.S.A .................................................. 78

FIGURE 4.6. Gender-differences in the emotional responses elicited by the odors of five wine samples ................................................................. 79

FIGURE 4.7. Differences in the emotional responses elicited by the odors of five wine samples as a function of previous reading of wine-related literature ....... 80

FIGURE 4.8. Differences in the emotional responses elicited by the odors of five wine samples as a function of wine training .................................................. 81

FIGURE 4.9. Differences in the emotional responses elicited by the odors of five wine samples between the participants with and without their own wine Cellar ................................................................. 82
FIGURE 4.10. A superimposed bi-plot of the partial least squares regression (PLSR) analysis in French participants. Blue squares represent the five wine samples.

FIGURE 4.11. A superimposed bi-plot of the partial least squares regression (PLSR) analysis in American participants.
List of Appendix Contents

APPENDIX 1.1. An informed consent form for assessments of sensory attributes and emotional responses to wine odors.................................................................95

APPENDIX 1.2. IRB protocol approval.................................................................98

APPENDIX 1.3. Geneva Emotion Wheel..............................................................100

APPENDIX 1.4. Geneva Emotion and Odor Scale (GEOS) questionnaire...............103

APPENDIX 1.5. A questionnaire for demographics, health status, and wine consumption.................................................................107

APPENDIX 1.6. Distraction task questionnaire.......................................................113
Chapter 1 – Introduction
Emotion is an integral part of human beings. To understand the overall nature of human emotion, researchers have proposed categorizing systems or models to organize emotions into structural model, framework or dimensions and attempted to identify the stimuli or components essential to each emotional response (Frijda, 1986; Izard, 1977; Mayer & Gaschke, 1988; Plutchik, 1980; Rosch, 1978; Russell, 1980; Thayer, 1978; Watson & Tellegen, 1985). The concept of emotion is frequently debated among emotion theorists. Scherer (2005) defined emotion as “an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism.” This suggests that the external experiences humans perceive through the five senses assert influential impact on emotional reactions.

In the past few decades, research investigating the emotional effects of odors has been conducted with increasing frequency (for reviews, see Ehrlichman & Bastone, 1992; Herz, 2002). Odors have the powerful ability to stimulate emotional autobiographical memories (Chu & Downes, 2000). After an odor has been associated with an emotional experience, it has the ability to conjure the associated emotions when encountered on another occasion. This incident can ultimately lead to an alteration of thoughts and behaviors (Epple & Herz, 1999; Millot & Brand, 2001). These effects have been credited by the interdependence of olfaction and emotion on overlapping neural systems (Phillips & Heining, 2002), which has been supported with neuroimaging studies (Herz, et al., 2004; Royet et al., 2003). In addition, odor experiences can elicit changes in physiological parameters, such as heart rate or skin conductance, which are related to emotional response (Alaouï-Ismaili et al., 1997; Bensafi et al., 2002a, 2002b, 2002c; Heuberger et al., 2001; Possel et al., 2005). Research has also shown that odor experience is
inextricably intertwined with hedonic tone of the odor. Therefore, odors are likely to influence moods. For example, pleasant odors can induce positive moods, whereas unpleasant odors can induce negative moods (Schiffman et al., 1995a, 1995b; Rétiveau et al., 2004).

Previous studies have focused on hedonic responses to odors and whether these responses are influenced by cultural-background (Ferdenzi et al., 2011). One study (National Geographic Smell Survey) of 1.4 million participants across five continents found geographic variation in hedonic ratings of six odorants, which supports the idea that hedonic responses to odors are dependent on culture (Wysocki et al., 1991). Findings such as these, along with those that demonstrate the link between odor experience and hedonic tone (Rétiveau et al., 2004; Schiffman et al., 1995a, 1995b), illustrate the need for additional research regarding emotional response to odors. For example, odor-induced emotional response can provide a more complete perspective on consumer behavior. Those emotions are likely to be the underlying dimensions for liking and satisfaction (Thomson et al., 2010).

In the competitive wine market, wine companies must strive for a deeper understanding of the factors that influence consumers at an emotional level in order to sustain consumer satisfaction. Evaluating the wine odor-induced emotional response, in addition to hedonic response and descriptive analysis, may provide valuable information into the perspective of the consumer and potentially insight to repeat purchases. Building on previous findings, this study aimed to determine whether emotional responses elicited by wine odors can vary as a function of sensory attributes and culture, focusing on the North American (Fayetteville, AR, U.S.A.) and French (Dijon, France) consumers.
Literature Cited


Chapter 2 – Review of Literature
1. Affective terms, responses, and models

Emotions have been researched extensively across many disciplines; however, the definition and categorization of emotions remains heavily contested among researchers. Numerous theories have been developed with an attempt to define emotion and refine the terms it entails. Mood and emotion scales have been constructed to measure and evaluate the state of mental processes when experiencing stimuli. In olfaction literature, scholars have not reach a consensus regarding the number of terms used to target feelings, which may vary from 6 (anger, disgust, fear, sadness, surprise, happiness; Alaoui-Ismaili et al., 1997; Vernet-Maury et al., 1999) when authors adapt the strict definition of a basic, or discrete, emotion (Matsumoto & Ekman, 2009) to 22 (shame, jealousy, fear, anger, sadness, pride, hope, relief, boredom, contempt, admiration, disgust, desire, disappointment, love, dissatisfaction, amusement, stimulation, satisfaction, unpleasant surprise, enjoyment, pleasant surprise; Desmet, 2005; Desmet & Schifferstein, 2008) when authors accept a comprehensive definition (Delplanque et al., 2012). Most modern emotion researchers have coalesced towards defining emotion as a complex phenomenon involving different subsystems - cognitive, physiological, action tendencies, motor expression, and subjective feeling- of the organism’s functioning (Frijda, 1994; Izard, 1991; Roseman, 1984; Scherer, 1984a). Componential theories of emotion (Ellsworth & Scherer, 2003; Frijda, 1987; Lazarus, 1991b; Roseman, 1984; Roseman et al., 1996; Scherer, 1984a; Scherer, 1988, 1999; Smith & Ellsworth, 1985; VanReekum & Scherer, 1997) embody this definition and provide the theoretical basis on which the present research relies.

Componential models, specifically the Component Process Model (Scherer, 1984, 2001), will be discussed in depth, as it is most relevant to our research on emotion. When studying emotions, it is important to note the differences among the terms “emotion”, “feeling”, “mood”,
and “affect,” which are often used interchangeably.

1.1. Models

1.1.1. Basic emotion model

Basic emotion theory suggests the existence of a small number of basic emotions that are based on evolutionarily continuous neuromotor programs (Matsumoto & Ekman, 2009). The fundamental elements of basic emotion models originate from Tomkin’s (1962, 1963) interpretation of Darwin’s (1872, 1998) account of the evolutionary functions of emotions and their expression. Izard (1977, 1993) and Ekman’s (1992, 1999) theories of basic emotions are among the most renowned. In their proposed models, emotions are considered affect programs that are sparked by appropriate eliciting events to produce response patterns that are emotion-specific, such as physiological reactions, action tendencies, and prototypical facial expressions (Grandjean et al., 2008). Although the number and nature of basic emotions is frequently debated among theorists, anger, joy, sadness, fear and disgust are typically included. These basic emotions function in the adaptation and adjustment of an individual to events that have potentially important outcomes for their physical and psychological integrity. Additional emotions are either hypothesized mixtures of basic emotions (e.g., contempt is a blend of anger and disgust) or given a different status; For example, shame is considered a complex social emotion (Grandjean et al., 2008).

One limitation of the basic emotion theory as a leading emotion model is the lack of clear predictions on the conditions that trigger basic emotions. In addition, there is a lack of precise hypotheses for the predicted prototypical patterning of emotion-specific responses (prototypes are frequently designated inductively from observation). The vague criterion used to define basic
and non-basic emotions is another drawback in basic emotion theories. Discrete theories also lack experimental evidence for the production of emotion-specific response patterns in facial/vocal expression or physiological reactions (Griffiths, 1997; Scherer & Ellgring, 2007; Stemmler et al., 2001). However, the most notable issue of discrete theories involves the lack of specification for affect programs (Grandjean et al., 2008).

1.1.2. Dimensional feeling model

Dimensional feeling theory assumes that all affective phenomena are described via positions in a two-dimensional valence by arousal space or a three-dimensional space, which includes an additional dimension of dominance or potency (e.g., Barrett & Russell, 2009; Lang et al., 1993; Mehrabian & Russell, 1974; Russell, 1980; Russell & Mehrabian, 1977; Wundt, 1909). Dimensional feeling theory is based on Wundt’s (1905) proposal that feelings, which he distinguished from emotions, can be described according to the following bi-polar dimensions: “pleasantness–unpleasantness”, “excitement–inhibition”, and “tension–relaxation.” Another fundamental aspect of these theories comes from Osgood et al.’s (1975) work on the dimensions of affective meaning (arousal, valence, and potency). In recent models, the focus is on valence and arousal; thus, most current models are two-dimensional (Grandjean et al., 2008).

Emotion experts continue to debate characteristics of dimensional models. The exact nature of the axes and the existence of a circumplex distribution- where affective terms are spread relatively evenly around the perimeter of the defined space- of central feeling states are center to the their debate (Lang, 1984; Russell, 1980; Tellegen et al., 1999). In dimensional models, emotions typically operate as verbal reports of subjective feeling along the positive–negative and active–passive dimensions (Grandjean et al., 2008). The inclusion of feelings in
these models is problematic and results in misunderstanding when researchers study emotional processes and their association with the development of a conscious feeling. In addition, the definition of emotion as a subjective feeling in dimensional feeling theories creates an issue and is most often expressed exclusively as verbal self-report. The reduction of emotion differentiation to a two-dimensional valence-arousal space is also problematic. For example, anger is very close to fear in dimensional circumplex models, although the two are very distinct responses (Grandjean et al., 2008). Other deficiencies of dimensional feeling theories according to Grandjean et al. (2008) include: “lack of a functional perspective in terms of the adaptive functions of emotion”, “absence of attempts to theoretically predict the determinants of emotion differences (even in a reduced two-dimensional space)”, and “no explanatory mechanism allowing prediction of response patterning.”

The following characteristics of emotions are key to their understanding: 1) emotions are phenomena with many components; they consist of extremely organized arrangements of event eliciting and response profile appraisals; 2) they develop over time and may be rapidly altered 3) their underlying processes may vary according to the individual and cultural background, despite similar eliciting events (Grandjean et al., 2008). Aside from inadequate specification of the mechanisms underlying the elicitation and differentiation of emotion, the basic and dimensional models disregard the previously mentioned fundamental aspects of emotion; thus, both models are inadequate for evaluating the emotional response to odors, or the cross-cultural differences between emotional responses elicited by odors (Grandjean et al., 2008).

1.1.3. Componential appraisal models

Componential appraisal models capture emotion as a dynamic episode that involves a
process of continuous change in all of its subsystems (e.g., cognition, motivation, physiological reactions, motor expressions, and feeling—the components of emotion) that is highly adaptable to events of extreme relevance and potentially significant consequences for an individual (adopting a functional approach in the Darwinian tradition; Ellsworth & Scherer, 2003; Grandjean et al., 2008; Scherer, 1984, 2001). Notably, feeling is viewed as a component of emotion and has a monitoring function to facilitate regulation under these models (Scherer, 2004).

According to the pioneering work of Arnold (1960) and Lazarus (1966, 1991), the fundamental mechanism of emotion is appraisal. Appraisal is the continuous, repeated evaluation of an event for criteria such as novelty, intrinsic pleasantness, goal conduciveness, coping potential, and normative significance. The result of the appraisals from different criteria is expected to directly drive response patterning of physiological reactions, motor expression, and action preparation. For example, anger is viewed as a consequence of an event being appraised as an obstruction to reaching a goal or meeting a need. This may be produced by an unfair, deliberate act of another person that could be eliminated by powerful action with a corresponding response pattern consisting of aggressive action tendencies, involving sympathetic arousal, furrowed eyebrows, clenched teeth, and loud, forceful vocals (Grandjean & Scherer, 2008).

Appraisal processing involves the subjective evaluation of the individual, thus allowing for variation between age groups, personal dispositions, and cultural contexts. Consequently, componential appraisal theories avoid many of the faults seen with the previously mentioned models. More specifically, the Component Process Model (Scherer, 1984, 2001) is advantageous as a guiding model for empirical research because it (a) defines emotions as complex, multicomponent, dynamic processes that require extensive measurement of changes in the
different components; (b) makes highly specific predictions about the determinants that elicit and differentiate emotions; (c) suggests a concrete mechanism underlying emotional response patternning, allowing specific hypotheses (predicts appraisal-driven responses from functional considerations; see Scherer, 2001); and (d) accounts for the richness of emotion differentiation, especially in humans, allowing researchers to model individual differences and emotional disorders (Scherer, 2004). In light of the above attributes, the component process model provides the theoretical basis on which our research relies.

1.2 Clarification of affective terms

Defining “emotion” is a notorious problem among emotion theorists and researchers. Consensus on a conceptual and functional level for affective labeling is imperative to determine the phenomenon under investigation and for future advancement in emotion research; however, the nature and complexity of semantics makes this a particularly difficult problem (Kreibig, 2010; Scherer, 2005). The following clarification of various affective terms and phenomena is provided according to definitions most suitable to our study.

In the context of the component process model, emotion is defined as “an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism (Scherer, 1987, 2001).” The components of an emotion episode are the respective states of the five subsystems, and the process consists of the coordinated changes over time. Table 1 illustrates the association between components and subsystems as well as the presumed substrata and functions. Three components- expression, bodily symptoms/arousal, and subjective experience- have consensus as modalities of emotion. The elicitation of action
tendencies and the preparation of actions are thought to be associated with emotional arousal (e.g., fight-or-flight responses). The cognitive information-processing component has not obtained consensus by emotion theorists, as many prefer to see emotion and cognition as independent but interacting systems (Scherer, 2001). Scherer (2004b) contends “all subsystems underlying emotion components function independently much of the time and the special nature of emotion as a hypothetical construct consists of the coordination and synchronization of all of these systems during an emotion episode, driven by appraisal.”

Table 2.1. Relationships between organismic subsystems and the functions and components of emotions

<table>
<thead>
<tr>
<th>Emotion function</th>
<th>Organismic subsystem and major substrata</th>
<th>Emotion component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of objects and events</td>
<td>Information processing (CNS)</td>
<td>Cognitive component (appraisal)</td>
</tr>
<tr>
<td>System regulation</td>
<td>Support (CNS, NES, ANS)</td>
<td>Neurophysiological component (bodily symptoms)</td>
</tr>
<tr>
<td>Preparation and direction of action</td>
<td>Executive (CNS)</td>
<td>Motivational component (action tendencies)</td>
</tr>
<tr>
<td>Communication of reaction and behavioral intention</td>
<td>Action (SNS)</td>
<td>Motor expression component (facial and vocal expression)</td>
</tr>
<tr>
<td>Monitoring of internal state and organism environment interaction</td>
<td>Monitor (CNS)</td>
<td>Subjective feeling component (emotional experience)</td>
</tr>
</tbody>
</table>

CNS = central nervous system; NES = neuro-endocrine system; ANS = autonomic nervous system; SNS = somatic nervous system (Scherer, 2004).

Emotions, as defined above, are distinguishable from other affective phenomena such as feelings and moods. The term “feeling” represents the subjective emotional experience component of emotion and is thought to play a major role in monitoring and regulation under the Component Process Model. Scherer (2004b) proposed that “feelings integrate the central
representation of appraisal-driven response organization in emotion;” thus, feelings indicate the complete pattern of cognitive appraisal as well as motivational and somatic response patterning that underlies the subjective experience of an emotional episode. Using feeling, a single component representing the process of subjective experience, and emotion, the complete multicomponent process, as synonyms obstructs understanding of the emotion phenomena (Scherer, 2005). In summary, feelings should be considered a distinct, single component of the complex multimodal process of emotions.

Moods and emotions can be discriminated by intensity and duration. Emotions prepare adaptive action tendencies and their motivational foundation and are believed to have consequences in behavior. Thus, emotion response patterns and their corresponding experiences are relatively high in intensity. Emotions require substantial response mobilization and synchronization, as part of certain action tendencies and their duration is generally brief in order to conserve the resources of an individual and allow for behavioral adaptation. In contrast, moods are generally low in intensity and involve little response synchronization. In comparison to emotions, moods are thought to be long-lasting subjective feelings that influence the experience and behavior of an individual (Scherer, 2005). Moods may arise without an apparent cause, such as an event or specific appraisal, and can persist over hours or days. Emotions, on the other hand, tend to be much more fleeting. Examples of mood states include being cheerful, gloomy, or depressed. In summary, low intensity moods exert minute influence on behavior and can be sustained for a considerable period of time without adverse effects when compared to emotions.

2. Olfaction
The sense of smell, or olfaction, predates all other sensory modalities. In humans, the pleasantness of odors is a major contributor to social relationships and food intake. Smells evoke approach and avoidance responses, reflecting the hedonic value of odors (Mandairon et al., 2009). Scented products constitute an annual market of over $25 billion dollars in the United States alone, demonstrating the economic importance of the sense of smell (Keller et al., 2004). Humans can detect more than 10,000 odors and discriminate between approximately 5,000 of these. The mechanism by which the vast number of odors is recognized and discriminated has not been fully determined. Thus, the mechanisms that guide central olfactory processing and form the odor percept remain a mystery (Keller et al., 2004). However, the fact that odor perception is highly influenced by memory, experience, and input from other sensory modalities makes the problem even more intriguing (Keller et al., 2004).

2.1. Anatomy and physiology of the olfactory system

Olfaction, or the sense of smell, depends on sensory receptors that respond to volatile compounds. Volatile compounds (odorants) can reach the neurons in the olfactory epithelium either directly, via the nostrils (orthonasal olfaction), or indirectly, from the back of the throat (retronasal olfaction). Retronasal olfaction is central to flavor, the perception generated from the integrated modalities of taste, olfaction, touch, vision, and occasionally audition; the chemical senses of smell and taste are the main contributors to flavor (Jackson, 2009). Smell is a dual sense, and the perception of an odor varies according to the route of olfaction, either orthonasally or retronasally (Rozin, 1982). Not only is identification of odorants poorer retronasally, but also threshold values are generally higher (Halpern, 2004).
In humans, olfactory receptors are located in the olfactory epithelium. The olfactory epithelium covers an area 2-10 m² and is located in the upper portion of the nasal cavity below the cribriform plate. The olfactory epithelium is comprised of three types of cells: receptor, supporting, and basal cells (Bakari & Usman, 2012). Basal cells differentiate into receptor neurons and replace them as they degenerate. Supporting cells electrically isolate adjacent receptor cells and are thought to maintain normal cell function (Jackson, 2009).

The receptor cells, or neurons, each have a primary cilium that carries odor sensitive receptors on its surface membrane (Bakari & Usman, 2012). Olfactory receptors converge at the glomerulus, a structure that transmits signals to the olfactory bulb. The olfactory bulb is divided into two distinct structures: the main olfactory bulb and the accessory factory bulb. From either structure, the olfactory neurons extend through a porous bone-the cribriform plate- and interact with the environment inside the nose (Nolte, 2002). From the olfactory bulb, fibers of the olfactory nerve project to the amygdala, prepiriform cortex, anterior olfactory nucleus, entorhinal cortex, as well as the hippocampus, hypothalamus and thalamus (Jones & Rog, 1998).

Transduction of odorants into electrical impulses occurs in the receptors on the olfactory cilia. Odor molecules diffuse to the receptor sites in the cell membrane causing ionic channels to open. Electric current flows across the membrane and establishes a receptor potential that disperses from the cilia to the cell body. Depolarization of the cell body triggers action potentials that begin the transmission of electrical impulses to the olfactory bulb (John, 1996).

The olfactory mucosa receives efferent projections from the olfactory cortical areas, basal forebrain, and midbrain. Within the cortex, the two bulbs are connected by the anterior olfactory nucleus through the anterior commissure. The piriform (olfactory) cortex projects to the medio-lateral thalamus, which then projects to the orbito-frontal cortex (Bakari & Usman, 2012).
The piriform cortex is thought to enable the developing and coding of odor memories. Identification appears to take place in the anterior portion, whereas qualitative grouping—e.g., fruity/floral or edible versus nonedible—appears to be localized in the posterior portion (Gottfried et al., 2006). The thalamus serves as an integrator in odor processing. Connections to the amygdala likely generate the emotional memories often associated with odors. Individual cortical neurons can be associated with both specific odor memories and their perceived quality (Rolls, 1999). The entorhinal cortex is involved in memory consolidation. Neurons from taste, odor and visual centers of the brain converge and interact at the orbitofrontal cortex, allowing multisensory perception (Jackson, 2009).

The distinguishing character (quality) of a particular odor is believed to arise from the differential sensitivity of receptor neurons and the learning of their response pattern (Jackson, 2009). Sensitivity refers to the presence of a unique family of odor-binding proteins produced by the olfactory epithelium (Buck & Axel, 1991). Some experiments suggest that the right hemisphere of the olfactory bulb possesses greater odor discrimination than the left hemisphere (Zucco & Tressoldi, 1988). However, this may be the result of better airflow past the olfactory epithelium in the right nostril compared to the left nostril (Zhao et al., 2004). Odor detection is influenced by odorants’ absorption, solubility, and reactivity (Hadley et al., 2004).

Odor perceptions are greatly influenced by memories, experiences, and input from other sensory modalities (Keller et al., 2004). Synergistic effects of odors across sensory modalities have been observed. For example, a combination of sub-threshold concentrations of olfactory and gustatory compounds can result in the detection of both (Dalton et al., 2000). This phenomenon appears to only occur with sensations that have been integrated through experience (Jackson, 2009). Reactions such as these, combined with human inconsistency in sensitivity,
experiences and memories are just a few of the reasons why human responses to odors are so highly variable (Jackson, 2009).

2.2. Sources of variation in olfactory perception

Numerous factors assert influence on odor quality and perception, including age (Doty et al., 1984; Hummel et al., 2001, 2007; Lehrner et al., 1999a, 1999b; Venstrom & Amoore 1968), gender (Choudhury et al., 2003; Öberg et al., 2002), personality (Larsson et al., 2000), cognitive ability of the individual (Haehner et al., 2007), and culture (Ayabe-Kanamura et al., 1998; Barber, 1997; Distel & Hudson, 2001). In regards to our research, we place emphasis on individual factors such as age and gender and the environmental factor of culture, which have been shown to influence olfactory sensitivity and perception (Ferdenzi et al., 2008).

2.2.1. Demographic factors

Age can be considered both an individual (e.g., level of cognitive development; thus, ability to process information) and environmental factor (e.g., odor experience and exposure). In light of this, many studies have shown the ability to detect, discriminate and identify odors improves throughout childhood (Hummel et al., 2007; Lehrner et al., 1999b; Richman et al. 1995). During the very early stages of development, the olfactory environment can become meaningful (e.g., Schaal et al., 2000), which highlights the importance of the effect of odor exposure throughout the lifespan on olfactory aptitude (Ferdenzi et al., 2008). While olfactory skill most can improve in early life, it has been widely recognized that sensory and cognitive properties of olfaction deteriorate as individuals’ age (Doty et al., 1984). Typically, older adults have elevated thresholds and perceive odors as less intense compared to young adults (Hummel
et al., 2002). Furthermore, cognitive olfaction tasks, free identification (Schemper et al., 1981) and multiple choice identification (Larsson et al., 2004a), are influenced by age. However, it is important to note that considerable differences exist between individuals with respect to olfactory decline over the lifespan. Possible explanations for the observed variation include influence from other demographic factors (Larsson et al., 2004), neuropsychological functioning (Larsson et al., 2004), and psychosocial variables (Corwin et al., 1995). In addition, inter-individual differences for olfactory sensitivity and odor identification exist due, at least to some extent, to genetic diversity (Konstantinidis et al., 2006). Additionally, the degree of variation in odor identification as a function of age has been found to depend on the specific odor, and odor sensitivity or resistance to aging is associated with the hedonic tone of the given odor (Konstantinidis et al., 2006). Thus, olfactory variation between individuals with respect to age arises from a multitude of factors.

A number of studies have demonstrated that females outperform males in olfactory performance. In fact, research indicates, in general, females are superior to males in olfaction related abilities throughout the human lifespan (Dorries, 1992; Doty et al., 1984; Ship & Weiffenbach, 1993). Frasnelli and Hummel (2005) and Croy et al. (2010) contend that females’ superior olfactory abilities may be the reason females are prone to react to an impairment of olfactory function more strongly than males. Another facet of olfaction that females appear to be more skillful in than males is their consideration of odors. Seo et al. (2011) reported findings that females generally have more attentive and consistent attitudes toward olfaction than males, which was consistent with previous research outcomes (Ferdenzi et al., 2008; Frasnelli & Hummel, 2005; Herz & Cahill, 1997; Schleidt et al., 1981). A survey conducted by Croy et al. (2010) demonstrated the sense of smell may be more important to females than males, which
could provide one explanation as to why females consider and report smells with more expertise than males.

Still, one group of researchers found that smell identification for men might decline more drastically and earlier in life as compared to females, which indicates an age by gender interaction may exist for olfactory tasks (Ship et al., 1996). However, in general, olfactory performance tends to decrease with age, regardless of gender (Doty et al., 1984; Hummel et al. 2007; Shu et al. 2009; Wysocki & Gilbert 1989) and females tend to outperform males in olfactory tasks (Dorries, 1992; Doty et al., 1984; Ship & Weiffenbach, 1993).

2.2.2. Cultural background

Another particularly important influence on olfactory performance is exerted by experience. Experience, specifically, cultural experience asserts influence on basic perceptual ratings as well as odor classifications. Numerous studies have acknowledged that odor quality perception is considerably influenced by experience and have demonstrated this relation in cross-cultural comparisons (Ayabe-Kanamura et al., 1998; Chrea et al., 2004; Pangborn et al., 1988; Seo et al., 2011; Wysocki et al., 1991). Pangborn et al. (1988) and Wysocki et al. (1991) demonstrated the link between odor hedonic tone and culture. In the study led by Pangborn et al. (1988), participants from 16 regions responded to 22 odorants; the results demonstrate a positive correlation between hedonic liking and the rate with which the respondents encountered the odorants in their daily lives. Similarly, the “National Geographic Smell Survey” based on 1.42 million participants across 76 countries of 9 regions established that olfactory responses to 6 odorants varied according to geographic, regional, and individual differences of the participants. For example, in the United States the odor of wintergreen was more appreciated as compared to
Europe. This can be explained by wintergreen’s positive connotation with candy in the United States and its negative connotation with medication in Europe (Wysocki et al., 1991). Hedonic ratings also show variability among cultures according to their perceived pleasantness. For instance, Schaal et al. (1998) and Schleidt et al. (1988), found higher variability between cultures for the hedonic ratings of relatively pleasant odors (i.e., odors from nature, hygiene, or food). On the other hand, Schleidt et al. (1988) and Schaal et al. (1998) found cultural agreement for the unpleasant aspect of certain odor hedonics; specifically, a negative evaluation independent of culture for of decaying organic matter, feces, and body odors (Japanese vs. German participants in Schleidt et al., 1988; Indonesian vs. Canadian participants in Schaal et al., 1998). In another study, Ayabe-Kanamura et al. (1998) asked German and Japanese participants to smell 18 everyday odorants (6 familiar to Japanese, 6 familiar to Germans, 6 familiar to both groups) and to judge them against several perceptual characteristics. For 10 odors, significant differences in familiarity ratings were found between both groups. Well-known odors were usually rated as more pleasant and in many cases as edible in each of the two populations. Their results suggest that humans show preference to smells they have regularly experienced. This can be attributed to one’s cultural-specific eating habits, which can consequently demonstrate a substantial impact of cultural experience on perceptual ratings of odors. Distel et al. (1999) extended the research of Ayabe-Kanamura et al. (1998) by adding Mexican subjects to the German–Japanese sample. Again, a correlation between the ratings of pleasantness and familiarity was observed.

Cultural experience has also been shown to modulate classification of odors (Chrea et al., 2004, 2005; Ueno, 1993). Ueno (1993) instructed Japanese and Nepalese (Sherpa) participants to sort 20 Japanese food flavors according to their perceived similarity and found significant variations between cultures. Unlike the Japanese participants, Sherpa participants did not
distinctly categorize “fishy” odorants. Ueno credited the categorization differences to the participants’ culture-specific experiences, namely, the fact that Sherpa do not often come in contact with fish odors in their daily lives. Chrea et al. (2004, 2005) used a similar approach to conduct a more comprehensive study that investigated the perceptual categories of 3 cultural groups: the United States, France, and Vietnam. Participants were asked to sort 40 odorants according to their perceptual similarity in as many groups as they felt necessary. The results revealed various culture-specific odor arrangements that were related to differences in nutrition and domestic life. However, the differences were mainly found in the assignment of single odors to classes; thus, the general arrangement of the 3 cultural groups’ olfactory spaces was similar. Thus, Chrea et al. (2004, 2005) offered empirical evidence for the basic universality of odor perception that has been proposed in the past (Carrasco & Ridout, 1993; Carrie et al., 1999; Dawes et al., 2004).

Given these findings, it can be assumed that environmental factors such as culture, learning, and experience can assert influence on olfactory performance to some degree (Hudson, 1999; Seo et al., 2011). However, cross-cultural research has shown that cultural-specific experience mainly influences the evaluation of familiar versus unfamiliar odors rather than perceptual processes in general. Therefore, one can assume a basic universality in odor perception for people at comparable ages, with similar cultural backgrounds, and without olfactory deficiencies (Kaeppler & Mueller, 2013).

3. Emotional effect of odors

The assertion that odor is powerful elicitor of emotions is rarely debated. In the past several decades, a growing scientific literature has documented the various emotional effects of
odors (for reviews, see Ehrlichman & Bastone, 1992 and more recently Herz, 2002). Through a variety of approaches, research investigating the relation between odor and affective phenomena has shown (1) odor experience is inextricably linked to odor hedonic tone; thus, odor hedonic tone is likely to influence mood such that pleasant odors tend to induce positive moods whereas unpleasant odors tend to induce negative moods (Rétiveau et al. 2004; Schiffman et al., 1995a, 1995b); (2) odors produce effects on cognition and behavior that are similar to those produced by emotional stimuli in other perceptual modalities (Chebat & Michon, 2003; Degel & Köster, 1999; Epple & Herz, 1999; Ilmberger et al., 2001; Ludvigson & Rottman, 1989; Millot & Brand, 2001); (3) odor experience provokes changes in physiological parameters, such as heart rate or skin conductance, which are directly involved in the emotional response (Alaoui-Ismaïli et al. 1997; Bensafi et al. 2002a, 2002b, 2002c; Heuberger et al. 2001; Pössel et al. 2005; Robin et al. 1999); and (4) odors can evoke autobiographical memories that are emotionally intense and longstanding (for a review, see Chu & Downes, 2000). These effects are typically interpreted as an interdependence of olfaction and emotion on overlapping neural systems (Phillips & Heining, 2002), which has recently been confirmed with neuroimaging evidence (Herz et al. 2004; Royet et al. 2003). In addition, researchers have examined whether hedonic responses to odors are universal or dependent on an individual’s experience and culture (Guinard, & Davis, 1988; Schaal et al., 1997; Schleidt et al., 1988; Wysocki et al., 1999).

3.1. Odor hedonic tone

Many studies have focused on the bipolar hedonic valence dimension of olfactory perception. Odor hedonic valence refers to the propensity of an odor to be pleasant, liked, agreeable, and pleasurable (or, on the contrary, unpleasant, disliked, disgusting, and repulsive).
Most of these studies (and, particularly, in the unpleasant pole, see Ehrlichman & Bastone, 1992, for a review) report that unpleasant odors have negative impacts and pleasant odors have positive impacts on moods (e.g., Degel & Köster, 1999; Herz, 2002; Schiffman et al., 1995a, 1995b). For example, Schiffman and Sattely (1995) found that pleasant fragrances could improve the mood of men and females at midlife under real-life conditions and over a period of one month. More recently, Rétiveau et al. (2004) found that pleasant fragrances positively affected the mood of females at midlife both overall and in the vigor-activity dimension. This study provided valuable insight on the link between specific sensory characteristics of fragrances and distinct mood patterns, as well as the ability of pleasant fragrances to positively influence mood (Rétiveau et al., 2004).

3.2. Effects of odors on cognition and behavior

Associative learning, the process by which an event or object becomes linked to another through experience, is critically involved in human cognition and behavior (Wasserman & Miller, 1997). It has been suggested that associative learning principles can explain human perceptual responses to odors (Engen, 1988, 1991; Herz, 2001). Specifically, odor hedonic perception (e.g., liking/pleasantness) is the result of a learned association with the emotional context in which that odorant was first encountered. That is, one would dislike the smell of rose if it were first encountered in an unpleasant setting (e.g., a funeral).

Several studies found that infants of mothers who consumed volatiles with a distinct smell (e.g., garlic, alcohol, cigarette smoke) during pregnancy or lactation showed preferences for these smells compared to infants who had not been exposed to these scents (Mennella, 1995; Mennella & Beauchamp, 1991, 1993). Another study found the smell of eugenol ("clove" odor
used in dental cement) was evaluated negatively and elicited autonomic fear responses among patients who were afraid of dental procedures; however, autonomic fear responses were not seen in patients who were unafraid of the dentist (Robin et al., 1998). Additionally, Herz et al. (2004) demonstrated hedonic evaluation of a novel odor directionally changed (positively and negatively) as a function of the emotional experience that it had been paired with. In another study, researchers concluded ambient scent contributes to the building of a favorable perception of a mall environment, and indirectly of product quality (Chebat & Michon, 2003) Therefore, it is likely that experience can become conditioned to odors and, in turn, influences behavior.

3.3. Physiological impacts of odors involved in emotional response

Odor experience has been shown to provoke changes in physiological parameters, such as heart rate or skin conductance, which are directly involved in the emotional response (Alaoui-Ismaïli et al. 1997; Bensafi et al. 2002a, 2002b, 2002c; Heuberger et al. 2001; Pössel et al. 2005; Robin et al. 1999). Heart rate variations are considered to be a relevant physiological indicator of pleasantness, and several studies have indicated that subjects’ heart rate decreased as an odor became more pleasant (Alaoui-Ismaili et al., 1997; Bensafi et al., 2002a, 2002b; Robin, et al., 1999; Vernet-Maury, et al., 1997). Generally, unpleasant odors lead to an increase in heart rate, whereas pleasant odors lead to a decrease (Alaoui-Ismaili et al., 1997; Brauchli et al., 1995) Furthermore, it has been demonstrated that skin conductance can be modulated by the perception of an odorant (Robin et al., 1999; van Toller et al., 1983). More specifically, electro-dermal response variations (skin resistance and ohmic perturbation duration) could be modulated by odor pleasantness (Alaoui-Ismaili et al., 1997).

In addition, Alaoui-Ismaili et al. (1997) found that basic emotions could be associated
with different odorants from the global autonomic response pattern induced by the inhalation of each odorant. Using this approach, Robin et al. (1999) studied the autonomic response patterns of subjects to eugenol, an odor that is characteristic of dental offices. Non-fearful dental subjects rated eugenol as pleasant, and their autonomic responses were mainly associated with positive basic emotions (happiness and surprise); however, fearful dental subjects rated eugenol as unpleasant and showed autonomic response patterns associated with negative basic emotions (fear, anger, disgust).

The association between odors and emotions is most often attributed to the interdependence of olfaction and emotion on overlapping neural systems (Phillips & Heining, 2002). The neural substrates of chemosensory perception, or more specifically olfaction, are the limbic and para-limbic hetero-modal regions (i.e. regions that are not specific to any one sensory modality) that are also involved in emotional processing, memory, and homeostatic regulation (Rouby et al., 2009). Pleasant and unpleasant odors activate areas in the primary olfactory cortex, the insula, anterior cingulate cortex, orbitofrontal cortex and anteromedial temporal lobe, which includes the amygdala (Anderson et al., 2003; Bensafi et al., 2007a; Bensafi et al., 2008a; Gottfried et al., 2002; Rolls et al., 2003; Royet et al., 2003; Sobel & Khan, 2007a; Zald & Pardo, 1997; Zelano et al., 2007). These areas are also known to be sensitive to the reward value of a stimuli, chemosensory or not (Gottfried et al., 2003; Kringelbach, 2004, 2005; Small, 2002). Thus, the overlap between the olfactory areas, reward, and emotion has a clear impact on odor processing.

3.4. Links between odor, memory and emotion

Odors can evoke vivid autobiographical memories that produce powerful emotions (for a
review, see Chu & Downes, 2000). The first empirical study on this phenomenon was conducted by Rubin et al. (1984), who drew comparisons between odors and label cues in his first experiment and between odors, photographs, and label cues in his second experiment. In each study, subjects were asked to describe specific autobiographical memory brought to mind by each cue, to date the memory, and to rate each memory in terms of vividness, pleasantness, and the number of times that the episode had been thought of or spoken of prior to the experiment. Results from both studies showed that odor-cued memories were thought of and spoken of with less frequency than those cued by other stimuli. Another study carried out by Herz and Cupchik (1992) investigated the characterization of odor-evoked memories. Their results characterize odor-evoked memories as highly emotional, vivid, specific, rare, and relatively old. More recently, Aggleton and Waskett (1999) provided a demonstration of the potency of olfactory cues. Results showed the importance of congruent over incongruent olfactory cues. The process of olfaction is mediated by a number of anatomical structures that are also heavily implicated in memory and emotion, which provides an explanation for odor-evoked biographical memories. The olfactory bulb, for example, projects to a number of structures including the amygdala, hippocampus, and thalamus (Nieuwenhuys et al., 1999; Dodd & Catellucci, 1991), structures which have been shown to be involved in memory function and the modulation of emotions. Studies suggest that memory for odor is persistent (for a review see White, 1998). Thus, the fact that odors persist when memory traces from other stimuli degrade implies that the olfactory components of autobiographical memories may be longer lasting than other facets of the same experience.

In addition, Hinton and Henley (1993) found that when they compared reactions to stimuli presented in visual, lexical, and olfactory modalities, odors elicited by far the most
affective reactions. Several researchers (Aggleton & Waskett, 1999; Herz 1997b) have attributed the efficacy in of odors in memory retrieval, at least in part, to the accepted link between emotional arousal and the information associated with such affective reactions (Guy & Cahill, 1999). This link is likely mediated by the amygdala, which is involved in olfaction, memory, and emotion (Cahill et al., 1995, 1996).

3.5. Cultural specificity of odor-induced emotional response

It is widely purported that emotional response toward odors can be influenced by cultural background (Ayabe-Kanamura et al., 1998; Wysocki et al., 1991). In each culture, exposure to specific odorants varies greatly. Additionally, exposure frequencies of odorants differ between cultures, inducing differences in categorizations of odorants across countries (Chrea et al., 2004). Schaal et al. (1997) tested this hypothesis in three groups of children from different cultural environments (French Canadian, Sundanese Indonesian, and Syrian), who were asked to evaluate a set of odorants: consensus was observed for odorants perceived as unpleasant; however, the three groups diverged for their hedonic evaluation of pleasant odors.

More recently, Ferendzi et al. (2011) developed self-report scales unique to the UK, Singapore, and Switzerland following the same procedure as used in the past to develop the Geneva Emotion and Odor Scale (GEOS: Chrea et al., 2009). Ferendzi et al. (2011) aimed to determine if affective responses to odor vary as a function of culture. Their results illustrated that, although there were three dimensions shared by the three cultures, culture specific dimensions emerged. Furthermore, through a comparison approach they found that the dimensional organization of odor-related affective terms in a given culture better explained data variability for that culture than data variability for the other cultures, thus highlighting the
importance of culture-specific tools in the investigation of odor-related affect (Ferendzi et al., 2011).
Literature Cited


Öberg C., Larsson M., Bäckman L. (2002) Differential sex effects in olfactory functioning:


Chapter 3 – Descriptive Analysis of Odor Attributes in Wine Samples
Abstract

Wine is a complex beverage in terms of olfaction, which is critical to consumer choice. To remain competitive in the wine market, it is important to identify the odor attributes of wine, as they can be used to gain consumer insight. Also, flavored wines are gaining more popularity in the wine market. This study aimed to understand the odor characteristics of five pre-selected wine samples using descriptive analysis (DA) with trained descriptive panelists (N=10). Four specific odorants, linalool, 2,3-butanedione (diacetyl), 2,4,6-trichloroanisole (TCA), and acetaldehyde, were added to the base wine to maximize the odor effect of sensory perception. Training sessions were conducted to re-familiarize panelists with common wine odor attributes and their evaluation. Wine samples were found to differ in the odor intensities of sulfur, moldy/musty, honey, and leather attributes. The odors of wine sample containing TCA were more closely associated with “moldy/musty” and “leather” attributes, while the odors of those containing diacetyl were more closely related to “buttery” and “honey” attributes. In addition, the odor attributes were found to be similar among the two wine samples: acetaldehyde and base wine. Findings from this study will be used to investigate the relationship between sensory attributes, hedonic and emotional responses in odors of wine products in Chapter 4.
1. Introduction

The global wine market is experiencing significant changes. Previous global leaders in Europe have experienced a decline in wine production and consumption, while the rest of the world is increasingly embracing wine (Mintel, 2014). In 2013, U.S. consumers bought 784 million gallons of wine, making U.S. the biggest wine market in the world in terms of volume (International Vine and Wine Organization, 2014). In this highly competitive marketplace, it is advantageous for producers to identify and measure sensory characteristics that can influence perceived wine quality and consumer acceptance.

Wine is a complex beverage in terms of sensory and chemical components (Thorngate, 1997). Researchers estimate wine contains more than 800 volatile odorant compounds (Marti et al., 2003; Rapp, 1990). The volatile compounds in wine are classified as primary, secondary or tertiary aroma. Primary aroma is comprised of volatile compounds derived directly from the grape or during grape processing and includes numerous floral and fruity aromas, as well as tobacco and vegetative aromas. Linalool, for example, is a primary aroma responsible for the floral character in white varieties such as Muscat and Chardonnay. Secondary aromas in wine are mostly fermentation by-products. Diacetyl, a secondary aroma, imparts a buttery aroma in wine. Tertiary aromas are produced during wine aging. One example, acetaldehyde, contributes a pungent, oxidized character to aged wine (Villamor & Ross, 2013).

The human olfactory system is highly sensitive and has the ability to detect odors at levels more sensitive than instrumental and chemical analyses (Lawless & Heymann, 1998). The term olfaction refers to the sense of smell, whereby volatile odorants reach olfactory receptor cells embedded in the olfactory epithelium either by sniffing through the nostrils (orthonasal olfaction), or from the mouth and nasopharynx (retronasal olfaction) (Jackson, 2009). Amerine
and Roessler (1976) found sniffing to be the best way for panelists to accurately judge a wine because it diverts odors accurately to the olfactory region of the nose. Olfaction produces the most diverse and complex perceptions in wine and contributes to its expert market appeal (Jackson, 2009).

The primary sensory tool for identifying the characteristics of a complex aroma, fragrance, flavor or other odorous mixture of volatiles is descriptive analysis (Lawless, 1999). Descriptive analysis uses a trained panel to specify the intensities of specific attributes, based on a psychophysical model for intensity scaling (Lawless, 1999). Wine researchers have widely used descriptive analysis to evaluate both the qualitative and quantitative characteristics of wine (Guinard & Cliff, 1987; Heymann & Noble, 1989; Carlucci & Monteleone, 2001; Koussissi et al., 2002; Varela & Gàmbaro, 2006; Parr et al., 2007). In these studies, descriptive analysis exhibited the ability to show how products vary among themselves and implied that a comparison could be made among the products (Carlucci & Monteleone, 2008). Therefore, the objective of the present study was to determine odor attributes of pre-selected wine samples, which will be used to examine relationships between sensory attributes, hedonic and emotional responses in the next chapter. In addition, it is worth noting that the market of flavored wine is growing.

2. Materials and Methods

This study was conducted according to the Declaration of Helsinki for studies on human subjects. The protocol (#12-09-093) was approved by the University Institutional Review Board of the University of Arkansas (Fayetteville, AR, U.S.A.). Prior to the experimentation, an informed written consent (Appendix I) was obtained from each participant.
2.1. Samples and preparation

The odors of five white wines, including a base wine (i.e., no added odorant) and four wines spiked with different odorants, were used as odor stimuli. As the base wine, a white wine (2010 Georges DuBœuf Mâcon-Villages Chardonnay, Burgundy, France) was selected due to its un-oaked and relatively neutral aroma profile. Table 3.1 shows the chemical profile of the base wine provided from the producer.

<table>
<thead>
<tr>
<th>Alcohol (% vol)</th>
<th>Sugar (g/L)</th>
<th>T.A. (g/L)</th>
<th>Volatile Acidity (g/L)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.40</td>
<td>1.60</td>
<td>3.50</td>
<td>0.26</td>
<td>3.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Free SO₂ (mg/L)</th>
<th>Total SO₂ (mg/L)</th>
<th>Malic (g/L H₂SO₄)</th>
<th>Lactic (g/L)</th>
<th>%FML</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>89</td>
<td>0.52</td>
<td>1.91</td>
<td>80%</td>
</tr>
</tbody>
</table>

To allow for consistent concentrations of one dominant odor per wine sample throughout the study, the odorants that best represented a range of olfactory notes commonly found in white wine were added to the base wine. The four odorants selected for addition to the base wine were linalool, 2,3-butanedione (diacetyl), 2,4,6-trichloroanisole (TCA), and acetaldehyde. All odorants were purchased from Sigma-Aldrich Co., LLC. (Sigma-Aldrich Co. LLC, St. Louis, MO, U.S.A.). Linalool (“floral/citrus-like”) and diacetyl (“buttery”) represent pleasant and unpleasant odors, respectively (Deplanque et al., 2008). Presence of TCA (“cork-taint” or “musty”) in wine is considered a fault and is indicative of spoilage among winemakers; therefore, wine consumers may consider wine with TCA to have an unpleasant odor. Finally,
acetaldehyde (“oxidized”) was selected for its potential to produce either a pleasant or unpleasant odor. The concentrations of the odorant solutions added to the wine were supra-threshold and adjusted to reach an iso-intensity among spiked wine samples (Table 3.2). In a preliminary test, six individuals experienced in sensory evaluation matched the intensities of spiked wine samples each other.

Table 3.2. Profiles of four odorants added into the base white wine in this study.

<table>
<thead>
<tr>
<th>Aromatic compound</th>
<th>Source (purity)</th>
<th>Conc.(^a) (ethanol)</th>
<th>Concentration (wine)</th>
<th>Odor descriptor</th>
<th>ODT(^a)</th>
<th>References for ODT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>Sigma-Aldrich (≥ 99%)</td>
<td>10 g/L</td>
<td>30 mg/L</td>
<td>sherry, bruised apple</td>
<td>100 mg/L</td>
<td>Sweiggers et al., 2005</td>
</tr>
<tr>
<td>2,3-butanedione</td>
<td>Sigma-Aldrich (97%)</td>
<td>5 g/L</td>
<td>10 mg/L</td>
<td>buttery</td>
<td>5 µg/L</td>
<td>Lawless et al., 1994</td>
</tr>
<tr>
<td>Linalool</td>
<td>Sigma-Aldrich (≥ 97%)</td>
<td>10 g/L</td>
<td>7 mg/L</td>
<td>floral, citrus</td>
<td>6 µg/L</td>
<td>Buttery et al., 1990</td>
</tr>
<tr>
<td>2,4,6-trichloroanisole</td>
<td>Sigma-Aldrich (99%)</td>
<td>1 mg/L</td>
<td>80 ng/L</td>
<td>cork</td>
<td>0.3-5 ng/L</td>
<td>Teixeira et al., 2006</td>
</tr>
</tbody>
</table>

\(^a\) Concentration; \(^b\) Odor detection threshold

The odorous solutions were prepared prior to conducting the study by adding the appropriate amount of odor compound to 100 mL of pure ethanol. The solutions were then mixed and stored at 4°C in airtight glass containers. Each morning, prior to the experiment, the amounts of each odorous solution to be added to the base wine were calculated according to the number of schedule participants that day.

The appropriate amounts were added to airtight glass jars and labeled with their corresponding three-digit blinding codes. Prior to pouring the samples, the glass jars were inverted five times each for mixing. Samples were stored at 16 °C between each use and poured
30 min before the participant’s arrival. Thirty-milliliters of sample were poured into 190 mL pear-shaped wine glasses at room temperature, which were immediately covered with plastic petri dishes to limit aromatic contamination of the immediate environment. Three-digit random numbers were used to code each sample.

2.2. Descriptive sensory analysis

Ten highly trained descriptive panelists (2 males and 8 females) from the University of Arkansas Sensory Service Center (Fayetteville, AR, U.S.A.) participated in the descriptive analysis of wine aroma. All panelists had been trained for the Spectrum® method (Sensory Spectrum Inc., Chatham, NJ, U.S.A.) and had extensive experience (e.g., 7 to 20 years) with descriptive analysis of various food products; however, they had limited experience in evaluating wine odors.

During 3 orientation/training sessions (3 hours per session), panelists were trained to be familiar with wine odors and their sensory attributes. In the first two sessions, panelists were introduced to odor references for odors commonly found in white wine, which included both positive and negative odor attributes. Using a commercially available wine aroma kit, panelists discussed sensory terms and practiced scaling in relation to the intensity of the aroma attributes. During the first two sessions, panelists were also exposed to a subset of samples to be evaluated. In the final session, the five selected wine samples were used to develop a lexicon for wine odor evaluation. Panelists refined the list of 24 sensory attributes via consensus during panel discussion (Table 3.3).

Following the training sessions, descriptive analysis was conducted for the odors of the five wine samples (i.e., control and four spiked wine samples) in duplicate on the same day. Prior
to serving the actual wine samples, another wine sample was provided as a warm-up stimulus to increase reliability of the test (Plemmons & Resurreccion, 1998). A warm-up sample was found to minimize the first sample bias so that reliability of ratings can be increased (Plemmons & Resurreccion, 1998). Following the warm-up sample, panelists received the five wine samples, as mentioned above, one after another in an irregular order. A five-min. break was given between the sample presentations.

After sniffing the odors of each wine sample, panelists were asked to rate perceived intensity of the 24 odor attributes, respectively, on a 15-point numerical scale ranged from 0 (not detectable) to 15 (extremely strong).

2.3. Data analysis

Data analysis was conducted using JMP pro (version 11.0, SAS Institute Inc., Cary, NC, U.S.A.) and XLSTAT software (Addinsoft, New York, NY, U.S.A.). For data of descriptive sensory analysis, a two-way analysis of variance (ANOVA), treating wine sample as a fixed effect and panelist as a random effect, was performed to determine whether perceived intensities of odor attributes were statistically different among the five wine samples. Post hoc comparison tests were performed using least square difference (LSD) tests. Principal component analysis (PCA) with covariance matrix was also conducted to determine whether odor attributes could be associated with a smaller set of sensory components. A statistically significant difference was defined as $P < 0.05$. 
Table 3.3.
Aroma attributes and their definitions in the wine samples used in this study

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol/Ethanol</td>
<td>Aromatic characteristic of the chemical class of compounds known as alcohols; more specifically ethanol, isopropanol, etc.</td>
</tr>
<tr>
<td>Acetone</td>
<td>Aroma characteristic of ketones, specifically acetone.</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Aromatic associated with hydrogen sulfide, rotten egg.</td>
</tr>
<tr>
<td>Petroleum</td>
<td>Aromatic reminiscent of hydrocarbons such as gasoline or kerosene.</td>
</tr>
<tr>
<td>Earthy/Dirty</td>
<td>Aromatic characteristic of damp soil, wet foliage, or slightly undercooked boiled potato/ aromatic characteristic of dry mud, dirt, or soil; geosmin</td>
</tr>
<tr>
<td>Moldy/Musty</td>
<td>Aromatic associated with closed air spaces such as attics and closets (dry) and basements (wet).</td>
</tr>
<tr>
<td>Woody</td>
<td>Aromatic associated with dry fresh cut wood; balsamic or bark-like.</td>
</tr>
<tr>
<td>Vanilla</td>
<td>Aromatic blend of sweet, vanillin, woody, browned notes, sometimes having chocolate, tobacco, floral or spicy components.</td>
</tr>
<tr>
<td>Caramelized</td>
<td>Aromatic blend of sweet, vanillin, woody, browned notes, sometimes having chocolate, tobacco, floral or spicy components.</td>
</tr>
<tr>
<td>Honey</td>
<td>The sweet caramelized floral and woody aromatic associated with honey.</td>
</tr>
<tr>
<td>Buttery</td>
<td>Aromatic associated with fresh butterfat, sweet cream; aromatic associated with artificial butter (diacetyl).</td>
</tr>
<tr>
<td>Nutty</td>
<td>Aromatic associated with nuts or nutmeats.</td>
</tr>
<tr>
<td>Leather</td>
<td>Aromatic associated with tanned animal hides.</td>
</tr>
<tr>
<td>Veggie Note</td>
<td>A general term that describes the aromatic of vegetables, in general.</td>
</tr>
<tr>
<td>Green Pepper</td>
<td>An aroma note associated with fresh bell pepper.</td>
</tr>
<tr>
<td>Green Grass</td>
<td>Green, slightly sweet aromatic associated with cut grass.</td>
</tr>
<tr>
<td>Fruity</td>
<td>Aromatic associated with a mixture of non-specific fruits: berries, apples/pears, tropical, melons; usually not citrus fruits.</td>
</tr>
<tr>
<td>Citrus</td>
<td>Aromatic associated with general impression of citrus fruits.</td>
</tr>
<tr>
<td>Spicy/Bl. Pepper</td>
<td>An overall aroma term associated with pungent spices; spicy, pungent aroma characteristic of freshly ground black pepper.</td>
</tr>
<tr>
<td>Floral</td>
<td>A sweet aromatic associated with flowers.</td>
</tr>
<tr>
<td>Lactic</td>
<td>Characteristic taste of lactic acid (a sour aroma note.).</td>
</tr>
<tr>
<td>Dirty Socks</td>
<td>Aroma similar to old dirty socks. Sour.</td>
</tr>
<tr>
<td>Yeasty</td>
<td>Aromatics associated with fresh yeast and yeast fermentation</td>
</tr>
<tr>
<td>Oxidized</td>
<td>A general non-specific term related to various characteristics of oxidized foods—such as stale, cardboard, rancid, painty, tallow.</td>
</tr>
</tbody>
</table>

3. Results and Discussion

As shown in Table 3.4 and Figure 3.1, the five wine samples significantly differed in four of the 24 odor attributes evaluated by the trained panelists: “sulfur” \( F (4, 36) = 2.95, P = 0.03 \),
“moldy/musty” \( [F (4, 36) = 4.83, P = 0.003] \), “honey” \( [F (4, 36) = 4.07, P = 0.008] \), and “leather” \( [F (4, 36) = 4.59, P = 0.004] \). For the “sulfur” odor attribute, wine samples containing diacetyl were perceived as significantly more intense, compared to both base wine and the wine containing acetaldehyde \( (P < 0.05) \). At low concentrations, diacetyl imparts a buttery, nutty, or toasty flavor; however, at levels far above its sensory threshold, diacetyl can generate a buttery, lactic off-odor that often occurs in association with lactic acid bacteria spoilage (Jackson, 2009). Bertrand et al. (1984) found that people can be separated into two distinct groups based on their response to diacetyl: those that find it desirable and those that find it highly undesirable, which may be related to its association with trace amount of contaminants possessing a vile, pungent odor (Jackson 2009). Sulfur compounds, such as hydrogen sulfide, are described as rotten eggs, putrid, or pungent. Thus, one possible explanation for the higher intensity of “sulfur” in the diacetyl samples is that panelists perceived diacetyl odor negatively and perceived it as a sulfur odor attribute. The wine sample containing TCA was found to have the greatest perceived “moldy/musty” odors \( (P < 0.05) \), whereas there were no differences among the other samples for the “moldy/musty” odor attribute. For the odor attribute, “honey”, the wine sample including diacetyl was rated significantly more intense compared to those including acetaldehyde, linalool and TCA \( (P < 0.05) \). Finally, the odor attribute identified as “leather” was detected in all of the samples; however, the “leather” attribute was perceived significantly higher in wine sample containing TCA than in the other four samples \( (P < 0.05) \).

As shown in Figure 3.1, the wine sample containing diacetyl showed higher intensity of “buttery” attribute than other wine samples, but there was no significance \( (P = 0.11) \).
Table 3.4.
Mean (± standard deviation) intensity ratings of the odor attributes in the five wine samples.

<table>
<thead>
<tr>
<th>Odor attributes</th>
<th>Base wine</th>
<th>Acetaldehyde</th>
<th>Diacetyl</th>
<th>Linalool</th>
<th>TCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol/Ethanol</td>
<td>4.47 (± 0.69)</td>
<td>4.33 (± 0.67)</td>
<td>4.37 (± 0.68)</td>
<td>4.42 (± 0.70)</td>
<td>4.36 (± 0.57)</td>
</tr>
<tr>
<td>Acetone</td>
<td>1.87 (± 1.58)</td>
<td>1.71 (± 1.61)</td>
<td>1.42 (± 1.64)</td>
<td>2.12 (± 1.81)</td>
<td>1.68 (± 1.74)</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.20 (± 0.89)bc</td>
<td>0.00 (± 0.00)c</td>
<td>0.89 (± 1.58)a</td>
<td>0.84(± 1.50)ab</td>
<td>0.34 (± 1.03)abc</td>
</tr>
<tr>
<td>Petroleum</td>
<td>1.14 (± 1.81)</td>
<td>1.13 (± 1.80)</td>
<td>0.57 (± 1.42)</td>
<td>1.41 (± 1.82)</td>
<td>1.20 (± 1.70)</td>
</tr>
<tr>
<td>Earthy/Dirty</td>
<td>1.59 (± 1.82)</td>
<td>1.38 (± 1.75)</td>
<td>1.35 (± 1.71)</td>
<td>1.56 (± 1.80)</td>
<td>1.05 (± 1.65)</td>
</tr>
<tr>
<td>Moldy/Musty</td>
<td>0.96 (± 1.51)b</td>
<td>0.60 (± 1.23)b</td>
<td>0.48 (± 1.18)b</td>
<td>0.82 (± 1.47)b</td>
<td>2.09 (± 1.77)a</td>
</tr>
<tr>
<td>Woody</td>
<td>0.97 (± 1.52)</td>
<td>0.49 (± 1.20)</td>
<td>0.76 (± 1.36)</td>
<td>0.74 (± 1.32)</td>
<td>0.63 (± 1.29)</td>
</tr>
<tr>
<td>Vanilla</td>
<td>1.52 (± 1.73)</td>
<td>1.65 (± 1.71)</td>
<td>1.14 (± 1.63)</td>
<td>0.80 (± 1.43)</td>
<td>0.93 (± 1.46)</td>
</tr>
<tr>
<td>Caramelized</td>
<td>1.51 (± 1.72)</td>
<td>1.57 (± 1.78)</td>
<td>1.67 (± 1.73)</td>
<td>1.15 (± 1.61)</td>
<td>0.66 (± 1.36)</td>
</tr>
<tr>
<td>Honey</td>
<td>1.01 (± 1.59)ab</td>
<td>0.82 (± 1.41)bc</td>
<td>1.60 (± 1.69)a</td>
<td>0.32(± 0.99)bc</td>
<td>0.20 (± 0.89)c</td>
</tr>
<tr>
<td>Buttery</td>
<td>0.55 (± 1.34)</td>
<td>1.22 (± 1.72)</td>
<td>1.64 (± 1.71)</td>
<td>0.78 (± 1.39)</td>
<td>0.71 (± 1.46)</td>
</tr>
<tr>
<td>Nutty</td>
<td>0.40 (± 0.98)</td>
<td>0.56 (± 1.15)</td>
<td>0.16 (± 0.72)</td>
<td>0.29 (± 0.88)</td>
<td>0.41 (± 1.02)</td>
</tr>
<tr>
<td>Leather</td>
<td>0.26 (± 0.82)b</td>
<td>0.51 (± 1.24)b</td>
<td>0.66 (± 1.35)b</td>
<td>0.83 (± 1.48)b</td>
<td>1.57 (± 1.81)a</td>
</tr>
<tr>
<td>Veggie Note</td>
<td>0.20 (± 0.89)</td>
<td>0.00 (± 0.00)</td>
<td>0.20 (± 0.89)</td>
<td>0.00 (± 0.00)</td>
<td>0.33 (± 1.00)</td>
</tr>
<tr>
<td>Green Pepper</td>
<td>0.17 (± 0.74)</td>
<td>0.15 (± 0.67)</td>
<td>0.00 (± 0.00)</td>
<td>0.44 (± 1.08)</td>
<td>0.47 (± 1.16)</td>
</tr>
<tr>
<td>Green Grass</td>
<td>1.56 (± 1.61)</td>
<td>1.28 (± 1.62)</td>
<td>1.14 (± 1.60)</td>
<td>1.49 (± 1.70)</td>
<td>1.37 (± 1.72)</td>
</tr>
<tr>
<td>Fruity</td>
<td>1.82 (± 1.71)</td>
<td>1.85 (± 1.74)</td>
<td>1.85 (± 1.57)</td>
<td>2.26 (± 1.54)</td>
<td>1.77 (± 1.67)</td>
</tr>
<tr>
<td>Citrus</td>
<td>0.63 (± 1.29)</td>
<td>0.45 (± 1.10)</td>
<td>0.78 (± 1.38)</td>
<td>0.66 (± 1.36)</td>
<td>0.30 (± 0.92)</td>
</tr>
<tr>
<td>Spicy/Bl. Pepper</td>
<td>0.34 (± 1.05)</td>
<td>0.35 (± 1.08)</td>
<td>0.33 (± 1.02)</td>
<td>0.33 (± 1.02)</td>
<td>0.35 (± 1.08)</td>
</tr>
<tr>
<td>Floral</td>
<td>1.41 (± 1.65)</td>
<td>1.47 (± 1.76)</td>
<td>0.76 (± 1.37)</td>
<td>1.27 (± 1.61)</td>
<td>1.33 (± 1.75)</td>
</tr>
<tr>
<td>Lactic</td>
<td>0.47 (± 1.15)</td>
<td>0.45 (± 1.10)</td>
<td>0.49 (± 1.20)</td>
<td>0.33 (± 1.00)</td>
<td>0.56 (± 1.41)</td>
</tr>
<tr>
<td>Dirty Socks</td>
<td>0.00 (± 0.00)</td>
<td>0.00 (± 0.00)</td>
<td>0.35 (± 1.09)</td>
<td>0.00 (± 0.00)</td>
<td>0.48 (± 1.48)</td>
</tr>
<tr>
<td>Yeasty</td>
<td>0.91 (± 1.44)</td>
<td>1.06 (± 1.48)</td>
<td>1.11 (± 1.60)</td>
<td>1.25 (± 1.57)</td>
<td>1.47 (± 1.67)</td>
</tr>
<tr>
<td>Oxidized</td>
<td>0.16 (± 0.72)</td>
<td>0.31 (± 0.95)</td>
<td>0.51 (± 1.26)</td>
<td>0.15 (± 0.67)</td>
<td>0.47 (± 1.15)</td>
</tr>
</tbody>
</table>

Mean ratings with different letters show a significant difference between the samples ($P < 0.05$)
A principal component analysis (PCA) was conducted to further visually examine whether the 24 odor attributes could be associated with a smaller set of sensory components. The PCA accounted for 79.09% of the total variance, with PC1 and PC2 explaining 55.55% and 23.54%, respectively (Figure 3.2.). The odors of wine sample containing TCA were more closely associated with “moldy/musty” and “leather” attributes, whereas the odors of those containing diacetyl were more closely associated with “buttery” and “honey” attributes. In addition, the odor attributes appear to be relatively similar among the two wine samples: acetaldehyde and base wine.
Diacetyl (2,3-butanedione) and linalool were added to characterize “buttery” and “floral” attributes in wine samples. As shown in a spider-web plot (Fig. 3.1), the wine samples with diacetyl and linalool appear to have stronger “buttery” and “floral” attributes, respectively; although, no significant difference was found ($P > 0.05$). A lack of significance may indicate that the concentration of added compounds was not high enough to make a noticeable difference in the attributes; although, it should be noted, the levels were chosen based on a preliminary test. In contrast, the wine sample including TCA was obviously differentiated from the other 4 wine samples. Knowing that unpleasant odors, in comparison to pleasant odors, are more likely to be detected at low concentration, this result can be understandable. Further, it has been questioned whether descriptive analysis is an adequate tool for sensory analysis of complex and well-blended aromas. Lawless (1999) stated, “humans do not have an unlimited capacity to judge the
intensities of individual odor notes in complex smells using a long list of odor descriptors.” Therefore, different or additional methods, such as chemical analysis, may provide more discrimination among samples and better identify wine odor attributes for future research.

4. Conclusion

Descriptive sensory analysis aided in differentiation among the wine samples used in this study. The odor attributes, “sulfur”, “moldy/musty”, “honey”, and “leather”, were significantly different among the five wine samples. In addition, PCA provided additional into the odor attribute intensities detected among the five wine samples. In particular, the five wine samples were well differentiated on the bi-plot of PCA, which means that certain wine can be differently characterized by adding specific odorant into the wine.
Literature Cited


Chapter 4 – Cross-Cultural Comparisons in the Emotional Responses Elicited by Wine Odors
Abstract

Odors produce the most diverse and complex perceptions in wine, which may play a key role in modulating consumer choice and perception. Understanding how wine odors elicit emotional responses and how they vary by individuals’ experiences and cultural backgrounds may provide an insightful guidance in product development and marketing strategy for wine producers. However, limited research has dealt with this subject. The objectives of this study were to: (1) investigate the impact of common wine odor attributes on consumers’ odor-induced emotional responses and (2) determine whether these emotional responses vary between different cultural and experiential backgrounds. This study was held in France (N = 86) and the United States (N = 89). Using the Geneva Emotion and Odor Scale (GEOS), emotional responses elicited by the odors of five wine samples (see Chapter 3) were measured. There were significant interactions between country and wine sample for the ratings of “well-being” and “excited” in emotional response. Significant cross-cultural differences were obtained in the emotional responses evoked by the wines for 19 of the 36 terms. Consensus between countries was found for the hedonic valence of 2,4,6-trichloroanisole, which was rated as the least pleasant. A better understanding of the emotional effects of odors found in wine, and how these effects vary among consumers, will allow the wine industry to develop products with specific emotional impacts on users of different consumer groups.
1. Introduction

The link between olfaction and affective phenomena has been widely reported in scientific literature. Previous studies have shown odors can lead to pleasant and unpleasant experiences (Schleidt et al., 1988). Further, odor experience is related to the hedonic determination of an odor, which has been purported as the main function of olfaction (Yeshurun & Sobel, 2010). The hedonic tone of an odor is likely to influence mood, such that positive moods are induced by pleasant odors and negative moods by unpleasant odors (Rétiveau et al., 2004; Schiffman et al., 1995a, 1995b). Numerous studies report the influence of odors on cognition and behavior (Chebat & Michon, 2003; Degel & Köster, 1999; Epple & Herz, 1999; Ilmberger et al., 2001), as well as the physiological parameters linked to emotional response—such as heart rate and skin conductance (Alaoui-Ismaïli et al., 1997; Bensafi et al., 2002a, 2002b, 2002c; Pössel et al., 2005).

Memory associations between odors are particularly strong, in regards to both the autobiographical events (Chu & Downes, 2000) and context in which they are encountered (Robin et al., 1999); therefore, odors are likely to elicit a range of emotional responses that vary as a function of culture due to markedly different contexts to which odors are associated (Ferdenzi et al., 2011). Numerous studies have shown the influence of culture on both perceptual ratings and classifications of odors (Ayabe-Kanamura et al., 1998; Chrea et al., 2004; Pangborn et al., 1988; Wysocki et al., 1991; Seo et al., 2011; Chrea et al., 2004, 2005). In addition, researchers have acknowledged that odor quality perception is considerably influenced by experience and have demonstrated this relation in cross-cultural comparisons. For example, Seo et al. (2011) found that Mexican participants had significantly higher general attitudes toward olfaction in comparison to Korean, Czech and German participants using the importance of
olfaction questionnaire (Croy et al., 2010). In addition, Wysocki et al. (1991) demonstrated the odor of wintergreen was more appreciated in United States as compared to Europe, which can be explained by the positive connotation of wintergreen with candy in the United States and negative connotation with medication in Europe. In another study, Chrea et al. (2004) asked participants from the United States, France and Vietnam to sort 40 odorants according to their perceptual similarity in as many groups as they felt necessary and revealed various cultural-specific odor arrangements that were related to differences in nutrition and domestic life.

Marketing studies have shown ambient odors can provide positive impacts on product evaluations and time in consumption contexts (Spangenberg et al., 1996; Morrin & Ratneshwar, 2000; Guéguen & Petr, 2006). One explanation could be that pleasant odors have a positive impact on mood by triggering positive memory associations from previous odor encounters, which may lead to approach behaviors; thus, odors may generally facilitate initial product interaction. Human-product interactions are not only influenced by environmental odors, but also by the olfactory properties of the product itself (Ferdenzi, 2013). Thus, measuring affective responses to odors can be extended to products for which odors are a key attribute (e.g., in the food, beverage and personal care industries).

Although the food and personal care industries increasingly include emotions in sensory testing (Seo et al., 2009; Thomson et al., 2010; Rousset et al., 2005; Ferrarini et al., 2010), few studies have focused on the emotional response elicited by product odors. In one such study, Porcherot et al. (2010) found the odor-elicited emotional profiles of perfumery oils discriminated between products that were similarly liked. Mandarin and jasmine oils scored 7.1 and 6.9 on the nine-point hedonic liking scale, respectively. However, the mandarin odor was associated with consumers feeling energetic, invigorated, clean and more romantic, in love and desire; whereas,
jasmine lead to more relaxed, serene and reassured emotions. Therefore, studying the odor-induced emotional response may be beneficial for products where aroma is a key attribute to quality and consumer acceptance.

Wine is often consumed for pleasure among diverse populations. Further, aroma is considered one of the most important intrinsic factors in perceived wine quality (Villamor & Ross, 2013). Exploring the relationship between preferences and emotional response of wine odors among consumers might be advantageous for wine producers and researchers worldwide. The global wine industry is highly competitive and consumers are faced with vast choices of wine products; thus, odor evoked emotional responses could be significant in beneficially discriminating wines with similar characteristics in other sensory modalities, packaging, and price. Building on previous findings, this study aimed to determine whether wine odor-elicited emotional responses could be modulated by odor attributes and culture.

2. Materials And Methods

2.1. Participants

This study was conducted at two locations: University of Arkansas (Fayetteville, AR, U.S.A.) and University of Burgundy (Dijon, Burgundy, France). A total of 89 North American participants (all Caucasians; 34 males and 55 females) and 86 French participants (32 males and 54 males) were recruited from the University of Arkansas communities and the University of Burgundy communities, respectively. The participants were screened based on their self-reporting of the consumption frequency of wine; only participants who consume any wine products at least once per week were required in order to qualify as a wine consumer. As shown in Table 4.1, the two cultural groups were not significantly different in terms of gender ratio ($P = \ldots$)
and mean age ($P = 0.89$). All participants reported no clinical histories of major diseases and no olfactory disturbance. The participants were asked to self-rate their health and olfactory function on the two five-point Likert scales ranging from 1 (very bad) to 5 (very good). The two cultural groups did not differ in self-ratings of health status ($P = 0.26$). However, self-ratings of olfactory function were significantly higher in the American group than the French group ($P < 0.001$). To further confirm acceptable olfactory function of participants, the “Sniffin’ Sticks” screening test (Burghart Instruments, Wedel, Germany; for details, see Hummel et al., 2001) was administered; no participants with olfactory impairment were observed in both either groups.

2.2. Geneva Emotion Wheel (GEW)

Prior to exposure to wine odors, participants’ current emotions were measured using the Geneva Emotion Wheel (Scherer, 2005; Appendix II). Participants were asked to indicate the emotions they were experiencing at the present time by choosing intensities for a single emotion or a mixture of emotions out of 20 distinct emotion families arranged in the shape of a wheel. Two major appraisal dimensions defined the axes of the wheel: 1) high control/power to no control/power and 2) unpleasant/obstructive to pleasant/conducive. Five degrees of intensities were available to choose from for each emotion family. Circles were provided, which were proportional to the intensity of the emotion felt; as the circles increased in size, the intensity of the selected emotion increased. “No emotion felt” and “other emotion felt” were also provided as options.

The GEW was used as a precautionary measure for data analyses. It served as a measurement tool to explain potential outliers in the data resulting from participants with extreme emotional states prior to the objective portion of the study.
Table 4.1.
Comparisons between American and French participants in their demographic profiles and wine consumption.

<table>
<thead>
<tr>
<th>Demographic profiles</th>
<th>American</th>
<th>French</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (Males : Females)</td>
<td>34 : 55</td>
<td>32 : 54</td>
<td>0.89</td>
</tr>
<tr>
<td>Mean age (± SD)</td>
<td>38 (± 13)</td>
<td>38 (± 12)</td>
<td>0.89</td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
<td>0.14</td>
</tr>
<tr>
<td>No education to High school</td>
<td>14</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>2-year college</td>
<td>17</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>4-year college</td>
<td>35</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Graduate school</td>
<td>23</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Mean self-rating of health status (± SD)</td>
<td>4.4 (± 0.6)</td>
<td>4.3 (± 0.7)</td>
<td>0.26</td>
</tr>
<tr>
<td>Mean self-rating of olfactory function (± SD)</td>
<td>4.6 (± 0.6)</td>
<td>3.7 (± 0.8)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

| Wine consumption                                                                 |          |        |         |
| Frequency of white wine consumption                                                |          |        | 0.28    |
| Fewer than once per month                                                           | 17       | 22     |         |
| Once per month                                                                      | 12       | 15     |         |
| 2-3 times per month                                                                 | 26       | 24     |         |
| Once per week                                                                       | 13       | 15     |         |
| Two times or more per week                                                          | 21       | 10     |         |
| Mean hedonic rating of white wine (± SD)                                            | 7.7 (± 1.3)| 7.0 (± 1.2)| 0.001 |
| Reading of wine-related magazine or book                                            |          |        |         |
| Yes                                                                                  | 51       | 38     | 0.08    |
| No                                                                                   | 38       | 48     |         |
| Training in enology or wine tasting                                                 |          |        | < 0.001|
| Yes                                                                                  | 4        | 30     |         |
| No                                                                                   | 85       | 56     |         |
| Wine cellar                                                                          |          |        | < 0.001|
| Yes                                                                                  | 2        | 53     |         |
| No                                                                                   | 87       | 33     |         |

SD = standard deviation

2.3. Geneva Emotion and Odor Scale (GEOS)

The subjective emotional responses elicited by odors of wine samples were verbally assessed using GEOS (Chrea et al., 2009). GEOS consists of 36 affective terms classified in six emotional dimensions: disgust/irritation, happiness/well-being, sensuality/desire, energizing/re-freshing, peacefulness/soothed and sensory pleasure. To validate the appropriateness of the
French terms for describing odor-related emotional response for participants in France, French citizens, who were bilingual in French and English approved the terms. The English translation of GEOS was found in Chrea et al. (2009). The same bilingual speakers, as well as American citizens, approved the translation of the terms in English. In addition, both groups (Americans and French citizens) discussed the meaning of the terms in both languages to assure they carried similar, if not the same, meaning in both languages. To measure the intensity of the emotional responses, a 10-cm line scale ranging from 0 (not at all intense) to 10 (extremely intense) for each term was used (Appendix III).

2.4. Hedonic rating of wine odors

Participants were asked to rate their hedonic response to odors in five wine samples on a nine-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely).

2.5 Survey of demographic profile and wine consumption habits

Participants’ demographics (e.g., age, gender, education level) and their wine consumption were assessed (Appendix IV). The consumption frequency and acceptance of wines were also asked. Additionally, wine consumption-related questions, whether or not the consumers had 1) experience of reading magazines or books about wine, 2) training in enology or wine tasting, and 3) keeping wine at a wine cellar, were asked.

2.6. Procedure

The experiment took place in two well-ventilated rooms with consistent ambient temperature (20-22°C) at University of Arkansas Sensory Service Center and University of
Burgundy, respectively. To avoid distractions, which could alter participants’ emotional response, one participant was assigned per room for each session. Thus, two participants could be scheduled during each 60-min session. Environmental conditions were kept as identical as possible between rooms, as well as between countries.

After rating their current emotional status using the GEW, participants received 30-mL of the five different wine samples (i.e., a control and four spiked wines) which were assigned random 3-digit codes, covered with petri dishes. The sequences of sample presentation were randomized for each consumer according to the William Latin Square design (Williams, 1949) to minimize first-order-carry-over effect (Macfie et al., 1989). After swirling the wine glass and sniffing odors of each wine sample, participants were asked to rate their emotional responses evoked by the wine odors using GEOS. The time interval between wine samples was approximately 5 to 10-min. During a break, participants were asked to read a brief text and answer two questions irrelevant to this study, which served as a distraction task to minimize emotional carry-over from the previous wine sample (see Appendix V).

After completing the GEOS portion of the study, participants were asked to evaluate the samples again and provide their overall impression for each wine sample on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). Consumers were allowed to re-sniff the wine sample. Lastly, all consumers were asked to complete supplementary questionnaires regarding their demographic profiles and wine consumption habit.

2.7. Data analysis

Data analysis was conducted using JMP pro (version 11.0, SAS Institute Inc., Cary, NC, U.S.A.) and XLSTAT software (Addinsoft, New York, NY, U.S.A.). For data of emotional and
hedonic responses elicited by wine odors, a three-way analysis of variance (ANOVA) was performed treating wine sample and country as fixed effects and panelist as a random effect. If a significant difference in means was indicated by ANOVA, post hoc comparison tests were performed using LSD tests. A PCA was conducted to determine whether emotional responses evoked by wine odors could be associated with a smaller set of emotional components. Additionally, a hierarchical cluster analysis (AHC) using Ward’s method (Ward Jr., 1963) was used to examine relationships of the five wine samples based on their odor-elicited emotional responses.

Finally, a partial least squares regression analysis (PLSR; Tenenhaus et al., 2005) was used to further identify relationships among the odor attributes, emotional responses, and hedonic ratings for the wine odors. The explanatory variables were odor attributes and emotional responses, and the dependent variable was hedonic ratings for the wine odors. A statistically significant difference was defined as $P < 0.05$.

3. Results and Discussion

3.1. Cross-cultural comparisons in the emotional responses elicited by wine odors

A three-way ANOVA, treating country and wine sample as fixed effects and panelist as a random effect, revealed a significant interaction (country x wine sample) in the two emotional response terms: “well-being” and “excited” (Figure 4.1 and Table 4.2).

As shown in Figure 4.2, overall, French participants’ odor-elicited emotional response ratings were significantly higher than American participants. One explanation could be the positive correlation between odor familiarity and pleasantness (Engen & Ross, 1973; Lawless & Cain, 1975; Ayabe-Kanamura et al., 1998; Royet et al., 1999). While French participants were recruited in the world-renowned winemaking region of Burgundy, American participants were recruited in Arkansas, a U.S. region where wine is not prevalent. In 2013, while the District of Columbia showed the highest wine consumption with 25.7 liters per capita, while Arkansas had 7 liters of wine consumption per capita (Statista, 2014). Moreover, French people reported more involvement with wine and a higher level of training on average compared to American people.
For example, while 5% of American participants had training in enology or wine tasting, 35% of French participants reported training (Table 4.1); herein, it should be noted that most French participants were recruited from Burgundy, France—an area rich in wine culture—while American participants were recruited from the University of Arkansas Sensory Service Center Database ($N = 6,200$) and lived close to Fayetteville, Arkansas. Therefore, the possibility that French participants might have greater experience with wine due to the history of wine in the region they were recruited from cannot be ruled out. In addition, more than half (62%) of French participants reported having wine cellars, whereas only 2% of American participants ($N = 2$) had wine cellars. The higher level of training and product involvement among French participants suggests their overall familiarity and knowledge of wine is likely greater than American participants. Charters (2006) suggested that knowledge facilitates the ability to understand the nuances of and distinctions of different types of wine, thereby possibly impacting preference selection. The case could be the same for knowledge level and emotional response.

Another possible factor for the significant effect of culture on emotional response ratings could be the region-dependent use of rating scales, known as “cultural response set” (Matsumoto & Juang, 2004; Seo et al., 2011) For example, French people used the scale in this study in a wider range than American people. However, it seems that the difference between North Americans and Europeans in the usage of scale is not a large difference, as compared to that between North Americans and Asians (Chen et al., 1995).
Table 4.2.  
Main effects of country and wine sample and their interaction in the emotional responses elicited by the five wine odors.

<table>
<thead>
<tr>
<th>Emotional responses</th>
<th>Country</th>
<th>Wine sample</th>
<th>Country x Wine sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-ratio</td>
<td>P-value</td>
<td>F-ratio</td>
</tr>
<tr>
<td>Dirty</td>
<td>4.50</td>
<td>0.04</td>
<td>13.94</td>
</tr>
<tr>
<td>Irritated</td>
<td>15.34</td>
<td>&lt; 0.001</td>
<td>6.82</td>
</tr>
<tr>
<td>Unpleasant</td>
<td>13.25</td>
<td>&lt; 0.001</td>
<td>9.28</td>
</tr>
<tr>
<td>Unpleasantly surprised</td>
<td>14.13</td>
<td>&lt; 0.001</td>
<td>15.34</td>
</tr>
<tr>
<td>Dissatisfaction</td>
<td>15.13</td>
<td>&lt; 0.001</td>
<td>12.11</td>
</tr>
<tr>
<td>Sickening</td>
<td>6.54</td>
<td>0.01</td>
<td>12.46</td>
</tr>
<tr>
<td>Disgusted</td>
<td>16.70</td>
<td>&lt; 0.001</td>
<td>11.89</td>
</tr>
<tr>
<td>Angry</td>
<td>12.53</td>
<td>&lt; 0.001</td>
<td>6.20</td>
</tr>
<tr>
<td>Pleasant</td>
<td>4.13</td>
<td>0.045</td>
<td>11.00</td>
</tr>
<tr>
<td>Well-being</td>
<td>19.41</td>
<td>&lt; 0.001</td>
<td>7.48</td>
</tr>
<tr>
<td>Happiness</td>
<td>1.76</td>
<td>0.19</td>
<td>8.86</td>
</tr>
<tr>
<td>Attracted</td>
<td>24.89</td>
<td>&lt; 0.001</td>
<td>11.95</td>
</tr>
<tr>
<td>Feeling awe</td>
<td>25.81</td>
<td>&lt; 0.001</td>
<td>6.72</td>
</tr>
<tr>
<td>Pleasantly surprised</td>
<td>18.81</td>
<td>&lt; 0.001</td>
<td>12.08</td>
</tr>
<tr>
<td>Sexy</td>
<td>0.003</td>
<td>0.96</td>
<td>10.43</td>
</tr>
<tr>
<td>Desire</td>
<td>3.33</td>
<td>0.07</td>
<td>5.79</td>
</tr>
<tr>
<td>Sensual</td>
<td>1.35</td>
<td>0.25</td>
<td>6.71</td>
</tr>
<tr>
<td>Excited</td>
<td>0.03</td>
<td>0.86</td>
<td>3.89</td>
</tr>
<tr>
<td>In love</td>
<td>3.65</td>
<td>0.06</td>
<td>5.79</td>
</tr>
<tr>
<td>Romantic</td>
<td>1.98</td>
<td>0.16</td>
<td>9.61</td>
</tr>
<tr>
<td>Admiration</td>
<td>3.85</td>
<td>0.053</td>
<td>5.17</td>
</tr>
<tr>
<td>Invigorated</td>
<td>15.10</td>
<td>&lt; 0.001</td>
<td>3.73</td>
</tr>
<tr>
<td>Refreshed</td>
<td>0.32</td>
<td>0.58</td>
<td>5.05</td>
</tr>
<tr>
<td>Revitalized</td>
<td>2.58</td>
<td>0.11</td>
<td>4.17</td>
</tr>
<tr>
<td>Energetic</td>
<td>13.33</td>
<td>&lt; 0.001</td>
<td>3.51</td>
</tr>
<tr>
<td>Clean</td>
<td>3.21</td>
<td>0.08</td>
<td>6.83</td>
</tr>
<tr>
<td>Shivering</td>
<td>34.50</td>
<td>&lt; 0.001</td>
<td>1.21</td>
</tr>
</tbody>
</table>
Table 4.2.
Main effects of country and wine sample and their interaction in the emotional responses elicited by the five wine odors (Cont.).

<table>
<thead>
<tr>
<th>Emotional responses</th>
<th>Country</th>
<th>Wine sample</th>
<th>Country x Wine sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-ratio</td>
<td>P-value</td>
<td>F-ratio</td>
</tr>
<tr>
<td>Stimulated</td>
<td>6.03</td>
<td>0.02</td>
<td>7.48</td>
</tr>
<tr>
<td>Serene</td>
<td>3.78</td>
<td>0.055</td>
<td>8.93</td>
</tr>
<tr>
<td>Reassured</td>
<td>8.58</td>
<td>0.005</td>
<td>12.10</td>
</tr>
<tr>
<td>Soothed</td>
<td>0.43</td>
<td>0.52</td>
<td>8.45</td>
</tr>
<tr>
<td>Light</td>
<td>2.45</td>
<td>0.12</td>
<td>6.34</td>
</tr>
<tr>
<td>Relaxed</td>
<td>0.06</td>
<td>0.81</td>
<td>10.70</td>
</tr>
<tr>
<td>Nostalgic</td>
<td>0.28</td>
<td>0.60</td>
<td>1.74</td>
</tr>
<tr>
<td>Amusement</td>
<td>11.66</td>
<td>0.001</td>
<td>4.75</td>
</tr>
<tr>
<td>Mouth-watering</td>
<td>1.06</td>
<td>0.33</td>
<td>8.88</td>
</tr>
</tbody>
</table>
Table 4.3.
Mean ratings (± standard deviation) in the emotional responses as a function of country and wine samples.

<table>
<thead>
<tr>
<th>Emotional Dimensions</th>
<th>Emotional Responses</th>
<th>Country</th>
<th>Wine Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>France</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>Disgust/ Irritation</td>
<td>Dirty</td>
<td>1.89 (± 2.49) *</td>
<td>1.44 (± 2.24) *</td>
</tr>
<tr>
<td></td>
<td>Irritated</td>
<td>2.04 (± 2.55) *</td>
<td>1.24 (± 1.93) *</td>
</tr>
<tr>
<td></td>
<td>Unpleasant</td>
<td>2.46 (± 2.84) *</td>
<td>1.75 (± 2.49) *</td>
</tr>
<tr>
<td></td>
<td>Unpleasantly surprised</td>
<td>2.60 (± 3.03) *</td>
<td>1.80 (± 2.52) *</td>
</tr>
<tr>
<td></td>
<td>Dissatisfaction</td>
<td>2.59 (± 2.96) *</td>
<td>1.81 (± 2.53) *</td>
</tr>
<tr>
<td></td>
<td>Sickening</td>
<td>1.69 (± 2.40) *</td>
<td>1.21 (± 1.98) *</td>
</tr>
<tr>
<td></td>
<td>Disgusted</td>
<td>1.82 (± 2.55) *</td>
<td>1.13 (± 1.88) *</td>
</tr>
<tr>
<td></td>
<td>Angry</td>
<td>1.23 (± 2.17) *</td>
<td>0.65 (± 1.23) *</td>
</tr>
<tr>
<td>Happiness/ Well-being</td>
<td>Pleasant</td>
<td>4.91 (± 2.74) *</td>
<td>4.42 (± 2.92) *</td>
</tr>
<tr>
<td></td>
<td>Well-being</td>
<td>4.31 (± 2.66) *</td>
<td>3.06 (± 2.75) *</td>
</tr>
<tr>
<td></td>
<td>Happiness</td>
<td>3.97 (± 2.72) *</td>
<td>3.59 (± 2.82) *</td>
</tr>
<tr>
<td></td>
<td>Attracted</td>
<td>3.77 (± 2.94) *</td>
<td>2.41 (± 2.52) *</td>
</tr>
<tr>
<td></td>
<td>Feeling awe</td>
<td>2.81 (± 2.54) *</td>
<td>1.58 (± 2.11) *</td>
</tr>
<tr>
<td></td>
<td>Pleasantly surprised</td>
<td>4.22 (± 2.96) *</td>
<td>3.12 (± 2.98) *</td>
</tr>
<tr>
<td>Sensuality/ Desire</td>
<td>Sexy</td>
<td>2.72 (± 2.65) *</td>
<td>2.70 (± 2.79) *</td>
</tr>
<tr>
<td></td>
<td>Desire</td>
<td>3.10 (± 2.64) *</td>
<td>2.56 (± 2.59) *</td>
</tr>
<tr>
<td></td>
<td>Sensual</td>
<td>3.03 (± 2.64) *</td>
<td>2.71 (± 2.61) *</td>
</tr>
<tr>
<td></td>
<td>Excited</td>
<td>3.25 (± 2.62) *</td>
<td>3.20 (± 2.64) *</td>
</tr>
<tr>
<td></td>
<td>In love</td>
<td>2.50 (± 2.58) *</td>
<td>1.97 (± 2.34) *</td>
</tr>
<tr>
<td></td>
<td>Romantic</td>
<td>2.90 (± 2.71) *</td>
<td>2.49 (± 2.69) *</td>
</tr>
<tr>
<td></td>
<td>Admiration</td>
<td>2.55 (± 3.50) *</td>
<td>2.01 (± 2.40) *</td>
</tr>
</tbody>
</table>

Emotional dimensions were drawn by previous research (Chrea et al., 2009).
Mean ratings with different superscripts in the same row represent a significant difference at $P < 0.05$. 
Table 4.3.
Mean ratings (± standard deviation) in the emotional responses as a function of country and wine samples (Cont.).

<table>
<thead>
<tr>
<th>Emotional Dimensions</th>
<th>Emotional Responses</th>
<th>Country</th>
<th>U.S.A.</th>
<th>Base</th>
<th>Acetaldehyde</th>
<th>Diacetyl</th>
<th>Linalool</th>
<th>TCA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>Invigorated</td>
<td>4.45 (± 2.53) ^a</td>
<td>3.41 (± 2.85) ^b</td>
<td>3.84 (± 2.72) ^ab</td>
<td>4.10 (± 2.76) ^a</td>
<td>4.03 (± 2.81) ^ab</td>
<td>4.23 (± 2.75) ^a</td>
<td>3.39 (± 2.64) ^b</td>
</tr>
<tr>
<td></td>
<td>Refreshed</td>
<td>3.57 (± 2.69)</td>
<td>3.41 (± 2.78)</td>
<td>3.46 (± 2.75) ^ab</td>
<td>3.72 (± 2.81) ^a</td>
<td>3.50 (± 2.65) ^ab</td>
<td>3.89 (± 2.79) ^a</td>
<td>2.87 (± 2.61) ^b</td>
</tr>
<tr>
<td></td>
<td>Revitalized</td>
<td>3.50 (± 2.56)</td>
<td>3.05 (± 2.72)</td>
<td>3.21 (± 2.52) ^ab</td>
<td>3.49 (± 2.75) ^a</td>
<td>3.23 (± 2.65) ^ab</td>
<td>3.64 (± 2.70) ^a</td>
<td>2.77 (± 2.57) ^b</td>
</tr>
<tr>
<td></td>
<td>Energetic</td>
<td>4.10 (± 2.57) ^a</td>
<td>3.13 (± 2.62) ^b</td>
<td>3.57 (± 2.52) ^ab</td>
<td>3.84 (± 2.71) ^a</td>
<td>3.64 (± 2.68) ^ab</td>
<td>3.88 (± 2.70) ^a</td>
<td>3.09 (± 2.50) ^b</td>
</tr>
<tr>
<td></td>
<td>Clean</td>
<td>4.22 (± 2.94)</td>
<td>3.62 (± 3.03)</td>
<td>4.08 (± 2.98) ^a</td>
<td>3.93 (± 2.93) ^a</td>
<td>4.07 (± 2.99) ^a</td>
<td>4.34 (± 3.04) ^a</td>
<td>3.14 (± 2.92) ^b</td>
</tr>
<tr>
<td></td>
<td>Shivering</td>
<td>2.03 (± 2.44) ^a</td>
<td>0.75 (± 1.48) ^b</td>
<td>1.25 (± 1.95)</td>
<td>1.58 (± 2.38)</td>
<td>1.42 (± 2.12)</td>
<td>1.37 (± 2.12)</td>
<td>1.28 (± 1.96)</td>
</tr>
<tr>
<td></td>
<td>Stimulated</td>
<td>3.85 (± 2.69) ^a</td>
<td>3.10 (± 2.82) ^b</td>
<td>3.46 (± 2.74) ^a</td>
<td>3.66 (± 2.79) ^a</td>
<td>3.68 (± 2.82) ^a</td>
<td>3.81 (± 2.89) ^a</td>
<td>2.72 (± 2.54) ^b</td>
</tr>
<tr>
<td><strong>Soothing/Peacefulness</strong></td>
<td>Serene</td>
<td>4.23 (± 2.61)</td>
<td>3.68 (± 2.84)</td>
<td>4.05 (± 2.63) ^a</td>
<td>4.24 (± 2.82) ^a</td>
<td>3.96 (± 2.79) ^a</td>
<td>4.40 (± 2.76) ^a</td>
<td>3.10 (± 2.54) ^b</td>
</tr>
<tr>
<td></td>
<td>Reassured</td>
<td>3.65 (± 2.66) ^a</td>
<td>2.75 (± 2.69) ^b</td>
<td>3.20 (± 2.59) ^a</td>
<td>3.41 (± 2.87) ^a</td>
<td>3.51 (± 2.83) ^a</td>
<td>3.55 (± 2.82) ^a</td>
<td>2.29 (± 2.23) ^b</td>
</tr>
<tr>
<td></td>
<td>Soothed</td>
<td>3.73 (± 2.59)</td>
<td>3.56 (± 2.78)</td>
<td>3.62 (± 2.64) ^a</td>
<td>3.96 (± 2.73) ^a</td>
<td>3.68 (± 2.75) ^a</td>
<td>4.12 (± 2.81) ^a</td>
<td>2.85 (± 2.33) ^b</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>3.63 (± 2.58)</td>
<td>3.23 (± 2.87)</td>
<td>3.54 (± 2.74) ^a</td>
<td>3.52 (± 2.75) ^a</td>
<td>3.44 (± 2.67) ^a</td>
<td>3.89 (± 2.76) ^a</td>
<td>2.75 (± 2.69) ^b</td>
</tr>
<tr>
<td></td>
<td>Relaxed</td>
<td>3.79 (± 2.58)</td>
<td>3.73 (± 2.89)</td>
<td>3.83 (± 2.59) ^a</td>
<td>3.95 (± 2.74) ^a</td>
<td>3.92 (± 2.91) ^a</td>
<td>4.29 (± 2.86) ^a</td>
<td>2.82 (± 2.36) ^b</td>
</tr>
<tr>
<td><strong>Sensory Pleasure</strong></td>
<td>Nostalgic</td>
<td>2.09 (± 2.34)</td>
<td>2.24 (± 2.61)</td>
<td>2.03 (± 2.40)</td>
<td>2.30 (± 2.47)</td>
<td>2.25 (± 2.61)</td>
<td>2.37 (± 2.63)</td>
<td>1.89 (± 2.31)</td>
</tr>
<tr>
<td></td>
<td>Amusement</td>
<td>3.73 (± 2.75) ^a</td>
<td>2.70 (± 2.56) ^b</td>
<td>3.20 (± 2.65) ^ab</td>
<td>3.35 (± 2.78) ^a</td>
<td>3.37 (± 2.70) ^a</td>
<td>3.49 (± 2.77) ^a</td>
<td>2.63 (± 2.54) ^b</td>
</tr>
<tr>
<td></td>
<td>Mouth-watering</td>
<td>2.94 (± 2.73)</td>
<td>2.67 (± 2.77)</td>
<td>2.84 (± 2.65) ^a</td>
<td>2.97 (± 2.91) ^a</td>
<td>3.08 (± 2.87) ^a</td>
<td>3.19 (± 2.84) ^a</td>
<td>1.93 (± 2.26) ^b</td>
</tr>
</tbody>
</table>

Emotional dimensions were drawn by previous research (Chrea et al., 2009).
Mean ratings with different superscripts in the same row represent a significant difference at $P < 0.05$. 

---

74
Figure 4.2. Cross-cultural difference between French and American participants in the emotional responses elicited by wine odors. *, **, and *** represent a significant difference at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

The five wine samples significantly differed in all odor-elicited emotional response terms, except “shivering” ($P = 0.31$) and “nostalgic” ($P = 0.14$), as shown in Tables 4.2 and 4.3. Figure 4.3 demonstrates that intensities of the two emotional response terms, “shivering” and “nostalgic”, were very low among the five wine samples’ odors, which might result in a lack of significance. Interestingly, shivering is not included in the newly developed Emotion and Odor Scales (EOS) for the United States or “UniGEOS,” the universal scale to measure olfaction and emotion across cultures. Nostalgic, however, was included in UniGEOS due to its inclusion in three (i.e. Brazil, China and United Kingdom) of seven EOSs from which UniGEOS is developed (Ferdenzi et al., 2013).
Wine samples containing TCA elicited negative emotional responses (e.g., dirty, irritated, unpleasant, unpleasantly surprised, dissatisfaction, sickening, disgusted, and angry) more strongly compared to the odors of other wine samples. By contrast, the odor of wine sample including linalool elicited higher intensities in the positive emotional responses. These results indicate that hedonic tone of the odors added to the wine sample (i.e., base wine) plays a major role in modulating emotional responses.

Figure 4.3. Differences in the emotional responses elicited by the odors of five wine samples. *, **, and *** represent a significant difference at \( P < 0.05 \), \( P < 0.01 \), and \( P < 0.001 \), respectively.

Based on the individual mean ratings of 36 emotional responses to the odors of 5 wine samples, PCAs were performed (Figure 4.4). For French participants, the five wine odors were classified into three groups: Group 1 (TCA), Group 2 (base), and Group 3 (acetaldehyde, linalool, ...
and diacetyl), mainly based on PC 1 (X-axis). Interestingly, the base wine sample (“Base”) is located in the middle of the bi-plot, while the distinctive odorants added to the other wine samples are scattered from the central point. This suggests the odor notes characterized could alter odor-elicited emotional responses wines. Similarly, the characterized odor notes modulating emotional responses in American participants, were classified into three groups: Group 1 (TCA), Group 2 (base, diacetyl, and acetaldehyde), and Group 3 (linalool). The acetaldehyde and diacetyl odors appear not to deviate from the emotional responses elicited by base wine odor in American participants, as compared to the changes in French participants.

The dendrograms drawn by AHCs show a similar pattern in the grouping of the five wine odors based on the odor-elicited emotional responses (Figure 4.5). Figure 4.5 shows that emotional response to the odor of wine samples including TCA is highly different from the emotional responses to other four wine odors.

**Figure 4.4.** Principal component analyses in the emotional responses elicited by the odors of five wine samples as a function of country: (a) France and (b) U.S.A.
Figure 4.5. Dendrograms drawn by agglomerative hierarchical clustering (AHC) in the emotional responses elicited by the odors of five wine samples as a function of country: (a) France and (b) U.S.A.

Gender effects on emotional responses were not country- or wine sample-dependent given that “gender” did not significantly interact with both “country” and “wine sample.” Therefore, focus remained on the main effect of gender on emotional responses. A two-way ANOVA, treating “gender” and “panelist” as fixed and random effects, respectively, revealed that gender could affect emotional responses elicited by different wine odors. Figure 4.6 demonstrates that ratings of the 7 emotional response terms—“attracted”, “desire”, “sensual”, “romantic”, “relaxed”, “amusement” and “mouth-watering”—were significantly higher in males than in females ($P < 0.05$).
Figure 4.6. Gender-differences in the emotional responses elicited by the odors of five wine samples. * and ** represent a significant difference at $P < 0.05$ and $P < 0.01$, respectively.

Since the “wine literature” by “country” and “wine literature” by “wine sample” interactions were not significant in emotional responses, the main effect of wine literature on emotional response was highlighted. A two-way ANOVA, treating “wine literature” as a fixed effect and “panelists” as a random effect, revealed no effect of “wine literature” on emotional responses, with the exception of “shivering” (Figure 4.7). Non-readers of wine literature rated wine odors significantly more “shivering” than those who read wine literature ($P < 0.05$).
Figure 4.7. Differences in the emotional responses elicited by the odors of five wine samples as a function of previous reading of wine-related literature. * represents a significant difference at $P < 0.05$.

As shown in Table 4.1, only a few American participants had training in enology or wine tasting ($N = 4$). Therefore, the effect of “wine training” on emotional response was examined only in French participants. Since there was no significant interaction of “wine training” with “country” or “wine sample”, a two-way ANOVA, treating “wine training” and “panelist” as a fixed effect and a random effect, respectively, was performed to determine whether wine odor-elicited emotional response can be different between the French participants with and without wine training. Figure 4.8 shows that wine-related training had no significant effect on the wine-elicited emotional response ($P > 0.05$).
Because only two American participants reported to have wine cellars, the effect of “wine cellar” on emotional response was examined only in French participants. The effect of “wine cellar” on emotional response was not country- or wine sample-dependent (no significant “wine cellar” by “country” or “wine sample” interaction). Therefore, a two-way ANOVA was conducted with “wine cellar” and “panelist” as fixed and random effects, respectively, to determine whether wine odor-elicted emotional response differed between French participants with and without wine cellars. The wine odor-elicted emotional response did not significantly differ between French participants with and without wine cellars (P > 0.05) (Figure 4.9).
Figure 4.9. Differences in the emotional responses elicited by the odors of five wine samples between the participants with and without their own wine cellar.

3.2. Cross-cultural comparisons in the hedonic responses to wine odors

Hedonic ratings of wine odors were not significantly different by gender, wine training, and wine-related literature reading ($P > 0.05$). In addition, there were no significant interactions of these variables (i.e., gender, wine training, and wine-related literature reading) with country and wine samples ($P > 0.05$). Therefore, the three variables, gender, wine training, and wine-related literature reading, were not included for further data analysis.

A three-way ANOVA, treating “country” and “wine sample” as fixed effects and “panelist” as a random effect, revealed a significant interaction between country and wine sample ($P < 0.001$). There was no significant difference between two countries in the hedonic
ratings of wine odor samples, except the odor of wine sample including TCA. American participants disliked the odor of the TCA-wine sample less than French participants ($P < 0.001$). In addition, French participants liked the odor of wine sample including linalool the most, whereas they liked the odor of wine sample including TCA the least. Similarly, American participants liked the odor of the TCA wine sample the least. However, there was no significant difference in the hedonic ratings among other four wine odor samples ($P > 0.05$).

Table 4.4.
Mean hedonic ratings (± standard deviation) in the hedonic responses to the five wine odors as a function of country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Acetaldehyde</th>
<th>Base</th>
<th>Diacetyl</th>
<th>Linalool</th>
<th>TCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>5.60 (± 1.79)</td>
<td>5.70 (± 1.54)</td>
<td>5.55 (± 1.83)</td>
<td>6.88 (± 2.18)</td>
<td>3.22 (± 2.11)$^b$</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>6.01 (± 1.88)</td>
<td>5.83 (± 1.97)</td>
<td>5.96 (± 2.13)</td>
<td>6.36 (± 1.96)</td>
<td>4.62 (± 2.36)$^a$</td>
</tr>
</tbody>
</table>

Mean ratings with different superscripts in the same column represent a significant difference at $P < 0.05$.

3.3. Relationships among sensory attributes, emotional responses, and hedonic responses in wine odors

A partial least squares regression (PLSR) analysis showed spatial relationships among sensory attributes, emotional responses, and hedonic responses to the odors of the five wine samples. As shown in Figure 4.10, a large portion of French participants (see the green triangles) tended to like wine odors characterized by “citrus”, “earthy/dirty”, “fruity”, caramelized” notes. These wines were found to be related to positive emotional response terms. By contrast, French participants appeared not to like wine odors characterized by “moldy/musty”, “leather”, “yeasty”, “spicy/black pepper” notes, which were associated with negative emotional responses such as
“dirty”, “dissatisfaction”, “disgusted”, “unpleasant”, and “unpleasantly surprised”, and “irritated”.

**Figure 4.10.** A superimposed bi-plot of the partial least squares regression (PLSR) analysis in French participants. Blue squares represent the five wine samples. Red and black circles represent 24 sensory attributes and 36 emotional responses of the wine odors, respectively. Green triangles represent individual hedonic responses to the wine odors.

Compared to French participants, American participants’ showed little conformity for wine odors they liked (Figure 4.11; see scattered green triangles representing individual hedonic responses). However, like French participants, they did not appear to like wine odors
characterized by “spicy/black pepper”, “leather”, “yeasty”, “moldy/musty” notes, which were associated with negative emotional response terms such as “disgusted”, “angry”, “irritated”, “sickening”, “unpleasant”, “unpleasantly surprised”, “dissatisfaction”, and “dirty”.

Figure 4.11. A superimposed bi-plot of the partial least squares regression (PLSR) analysis in American participants. Blue squares represent the five wine samples. Red and black circles represent 24 sensory attributes and 36 emotional responses of the wine odors, respectively. Finally, green triangles represent individual hedonic responses to the wine odors.
4. Conclusion

Our findings demonstrate that wine odor-elicited emotional responses can vary as a function of 1) sensory attributes, 2) hedonic tones, 3) gender, 4) culture, and 5) wine-related background. Under the current design, the hedonic tone (i.e., liking vs. disliking) of wine odors played a major role in modulating the wine odor-elicited emotional responses. To generalize our findings of this study, further studies are necessary using a variety of wine samples.
Literature Cited


Chapter 5 – Conclusions and Future Research
The goals of this research were to measure the emotional responses elicited by odor attributes in wine samples and determine whether these emotional responses vary as function of cultural and experiential backgrounds, as well as sensory characteristics of wine odors.

The present research provides empirical evidence suggesting that emotional response can vary as a function of culture and odor attributes for wine samples. However, the only affective terms found to significantly interact between country and wine sample were “well-being” and “excited.” Country had a significant effect on attributes in each GEOS affective dimensions: “disgust/irritation,” “happiness/well-being,” “energy,” “soothing/peacefulness,” and “sensory pleasure.” Overall, French participants’ emotional responses elicited by wine odors were significantly higher than American participants. Furthermore, cultural differences were seen in the grouping of wine odors between countries according to principal components analysis. French participants classified wine sample odors in three groups: Group 1 (TCA), Group 2 (base), and Group 3 (acetaldehyde, linalool, and diacetyl). Notably, Group 2, or the base sample, was located in the middle of the bi-plot, while the distinctive odorants added to the other wine samples are scattered from the central point. This lends to the idea that the odor notes characterized could alter emotional response. Americans also classified the characterized odor notes in three groups: Group 1 (TCA), Group 2 (base, diacetyl, and acetaldehyde), and Group 3 (linalool). The acetaldehyde and diacetyl odors appear to elicit emotional responses similar to base wine odor in American participants, as compared to the changes in French participants.

The five wine samples were significantly different for all emotional terms except “shivering” and “nostalgic”. Linalool elicited positive emotional responses with the highest intensities. In contrast, wine samples containing TCA elicited higher intensities in emotional response terms from the “disgust/irritation” dimension than other wine samples. Overall, it
appears TCA had an effect on many of our results, as the emotional responses to TCA wine samples is highly differentiated from the other odors. The hedonic ratings of wine odor samples were not found to significantly differ, with the exception of the wine sample including TCA, which might differentiate the wine sample with TCA from the other wine samples. These results indicate that hedonic tone of the odor-spiked wine samples plays a major role in modulating emotional responses. Future research needs to involve a larger diversity of wine samples with an equal number of odorants with positive and negative hedonic tone. Odor intensity should also be better measured in the future, either by panelists who are highly trained in descriptive analysis of wine or by using chemical analysis to relate to descriptive data.

Gender effect on the odor-elicited emotional response was independent of wine sample and country (i.e., no interactions with either). However, analysis of gender as the main effect of gender on emotional response revealed gender could affect emotional responses elicited by different wine odors. Specifically, the terms “attracted”, “desire”, “sensual”, “romantic”, “relaxed”, “amusement” and “mouth-watering” were found to be significantly higher in males than in females. Similarly, the effect of wine literature was independent of wine sample and country, and it was analyzed as a main effect on emotional responses of French participants. Findings suggest French, non-readers of wine literature found wine odors to be significantly more intense in the “shivering” attribute compared to those who read wine literature. Because too few Americans reported wine-related training or having their own cellars, French data was only analyzed. It was also found that wine-related training and wine cellar had no significant effect on the wine-elicited emotional response.

Future research should further investigate the order effect of emotion terms on the performance of the GEOS questionnaire. This is important because the 36 emotion attributes
tested in this study were presented on paper ballots to create uniform experimental conditions between locations. This could determine if results between randomized or alphabetical orders would convey different results. In addition, the same study could be conducted using sensory booths with computer monitors. It also could be interesting to examine the effects of presenting each GEOS attribute and scale individually, so comparison with the previous attribute would be minimized. Moreover, the newly developed “UniGEOS” could be used to re-examine the relationships between the cultures to determine which scale has the most discriminatory power. In future studies, wines representing a larger range of olfactory characteristics could be used; further, descriptive analysis using a highly trained wine panel coupled with chemical analysis of volatile compounds could provide better insight into exactly what odorants are responsible for eliciting emotional responses.
APPENDIX 1.1.

Informed Consent Form for Assessments of Sensory Attributes and Emotional Responses to Wine Odors
**Title:** Assessments of sensory attributes and emotional responses to wine odors

**Researchers:**
Han Seok Seo, Ph.D., Faculty

**Description:** Considering that odors modulate human emotional responses, it can be thought that wine products with different aroma profiles may induce differences in the emotional response. Therefore, the current project aims to determine whether the emotional response can be altered by wine products with varying aroma profiles. In addition, the sensory attributes of commercial wine products will be assessed by trained panelists.

**Risks and Benefits:** The benefits include contributing to the knowledge base of wine aroma profile and emotional response. Your risk is that you would be exposed to several unpleasant odors in the wine base.

**Voluntary Participation:** Your participation in the research is completely voluntary. There are no college credits for participation. Forty dollars will be paid for the participation reward.

**Confidentiality:** You will be assigned a code number and all information will be recorded anonymously. All information will be kept confidential to the extent allowed by law and University policy. Results from the research will be reported as aggregate data.

**Right to Withdraw:** You are free to refuse to participate in the research and to withdraw from this study at any time. Your decision to withdraw will bring no negative consequences — no penalty to you.

**Informed Consent:** I, ____________________________ (please print), have read the description, including the purpose of the study, the procedures to be used, the potential risks and side effects, the confidentiality, as well as the option to withdraw from the study at any time. Each of these items has been explained to me by the investigator. The investigator has answered all of my questions regarding the study, and I believe I understand what is involved. My signature below indicates that I freely agree to participate in this experimental study and that I have received a copy of this agreement from the investigator.

_________ Date __________

If you have questions or concerns about this study, please contact one of the researchers listed above. For questions or concerns about your rights as a research participant, please contact the University’s IRB Coordinator listed as “Administrator” above.
Appendix 1.2

IRB Protocol Approval
September 18, 2012

MEMORANDUM

TO: Han Seok Seo
    Tonya Tokar

FROM: Ro Windwalker
      IRB Coordinator

RE: New Protocol Approval

IRB Protocol #: 12-09-093

Protocol Title: Assessments of Sensory Attributes and Emotional Responses to Wine Odors

Review Type: ☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 09/18/2012  Expiration Date: 09/17/2013

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form Continuing Review for IRB Approved Projects, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 400 participants. If you wish to make any modifications in the approved protocol, including enrolling more than this number, you must seek approval prior to implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.
Appendix 1.3.

Geneva Emotion Wheel (GEW)
Emotion Wheel

We would like to know how you are feeling at this time.

In order to make it easier for you to report the type of emotion that you are experiencing, 20 different emotion families are arranged in a circular fashion on the following response sheet.

Please note the different emotion families that correspond to your present experience and determine the intensity of the particular emotion(s) you are feeling. To do this, check one of the circles in the spike corresponding to this emotion family -- the bigger the circle, the stronger your emotional experience.

You have the option of choosing one or more different emotions that you might be experiencing. Of course, you can choose different intensities for these emotions.

If you felt no emotion at all, please check the upper half circle in the hub of the wheel with the label “no emotion felt “.

If you did experience an emotion that is very different from any of the emotion families shown please check the lower half circle in the hub of the wheel that is labeled “other emotion felt.”

Please complete the emotion wheel on the next page.
Appendix 1.4.

Geneva Emotion and Odor Scale (GEOS) Questionnaire
**Questionnaire**

We would like you to describe your feelings associated to each odor you are going to smell. We would like you to rate the intensity of different emotional states evoked by the odor using a list of terms corresponding to each type of emotion.

To begin, smell the sample that corresponds with the 3-digit code listed above. In order to smell the sample, lift the lid, swirl the glass, place your nose within the glass, and inhale. After you are done smelling the sample, place the lid back on top of the glass and provide your emotional response. To answer, use the scales presented below. Each scale corresponds with a specific adjective or expression that describes a certain state, emotion, or feeling. The scale is labeled from "not at all" to "extremely".

For each adjective or expression, mark the appropriate place on the scale that represents the intensity of the emotion you have felt. Your answer should be spontaneous. Do not spend too much time on each item. There is neither a correct nor incorrect answer. Be careful: after marking your scale, you will not be able to change your answer.

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Not at all</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dirty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleasant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Invigorated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reassured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soothed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sexy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well-being</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refreshed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unpleasant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not at all</td>
<td>Extremely</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Nostalgic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revitalized</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unpleasantly surprised</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissatisfaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In love</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sickening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disgusted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amusement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happiness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relaxed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shivering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romantic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleasantly surprised</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling</td>
<td>Not at all</td>
<td>Extremely</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Mouth-watering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attracted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling awe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stimulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admiration</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 1.5.

A Questionnaire for Demographics, Health Status and Wine Consumption
Demographics

Please complete all questions on this form.

1. Gender: _____ male     _____ female

2. Age: _____ years

3. What is the highest level of education you have completed?
   _____ No education to Middle school
   _____ High school
   _____ 2-year college
   _____ 4-year college
   _____ Graduate school
**Health Status**

Please complete all questions on this form.

1. How is your health status in general?
   - □ very bad
   - □ bad
   - □ moderate
   - □ good
   - □ very good

2. How is your smell function?
   - □ very bad
   - □ bad
   - □ moderate
   - □ good
   - □ very good

3. Do you have any allergies to foods, odors, or fragrances?
   - _____ No
   - _____ Yes
   - I am allergic to ____________________________

4. Smoking: Are you a smoker?
   - _____ No
   - _____ Yes  In General, I smoke ________ cigarettes per day

5. Have you had surgery on your nose?
   - _____ No
   - _____ Yes  When?____________________

6. Do you have chronic sinusitis?
   - _____ No
   - _____ Yes
Wine Consumption

Please complete all questions on this form.

1. Are you a wine drinker?
   _____ No  _____ Yes

2. How often do you consume **red wine**?
   _____ Never
   _____ fewer than once per month
   _____ Once per month
   _____ 2-3 times per month
   _____ Once per week
   _____ 4-6 times per week
   _____ 2-3 times per week
   _____ Daily

3. How much do you like/dislike **red wine**?

   ![Likert scale](chart.png)

4. How often do you consume **white wine**?
   _____ Never
   _____ fewer than once per month
   _____ Once per month
   _____ 2-3 times per month
   _____ Once per week
   _____ 4-6 times per week
   _____ 2-3 times per week
   _____ Daily
5. How much do you like/dislike white wine?

□ dislike  □ dislike  □ dislike  □ dislike  □ neither  □ like  □ like  □ like  □ like

dislike  very  moderately  slightly  dislike  slightly  moderately  very  extremely

extremely  much  moderately  nor like  moderately  much  extremely

6. How often do you consume rose wine?

_____ Never
_____ fewer than once per month
_____ Once per month
_____ 2-3 times per month
_____ Once per week
_____ 4-6 times per week
_____ 2-3 times per week
_____ Daily

7. How much do you like/dislike rose wine?

□ dislike  □ dislike  □ dislike  □ dislike  □ neither  □ like  □ like  □ like  □ like

dislike  very  moderately  slightly  dislike  slightly  moderately  very  extremely

extremely  much  moderately  nor like  moderately  much  extremely

8. How much do you like/dislike wine that contains a buttery aroma characteristic?

□ dislike  □ dislike  □ dislike  □ dislike  □ neither  □ like  □ like  □ like  □ like

dislike  very  moderately  slightly  dislike  slightly  moderately  very  extremely

extremely  much  moderately  nor like  moderately  much  extremely

9. How much do you like/dislike wine that contains a floral aroma characteristic?

□ dislike  □ dislike  □ dislike  □ dislike  □ neither  □ like  □ like  □ like  □ like

dislike  very  moderately  slightly  dislike  slightly  moderately  very  extremely

extremely  much  moderately  nor like  moderately  much  extremely
10. How much do you like/dislike wine that contains an **oxidized/sherry** aroma characteristic?

- □ dislike
- □ dislike
- □ dislike
- □ dislike
- □ neither
- □ like
- □ like
- □ like
- □ like
- □ like

11. How much do you like/dislike wine that contains a **cork taint** aroma characteristic?

- □ dislike
- □ dislike
- □ dislike
- □ dislike
- □ neither
- □ like
- □ like
- □ like
- □ like
- □ like

12. Have you ever read magazines or books about wine?

- _____ No
- _____ Yes

13. Have you received training in enology or wine tasting?

- _____ No
- _____ Yes If yes, when and for how long? ________

14. Do you have a wine cellar?

- _____ No
- _____ Yes

15. If so how many bottles do you have in your cellar?

- □ <10
- □ 10-50
- □ >50
Appendix 1.6

Distraction Task Questionnaire
Text 1:

The polysaccharides in grapes come from the degradation and the solubilization of part of the pectic substances, which are contained in the cell wall of the grape skin and the pulp. Two families are distinguished: pectins and gums. Gums are soluble polysaccharides, which are obtained after the pectin degradation. They are not only composed of polygalacturonic acids but also neutral sugars, notably arabinose, rhamnose, galactose and xylose.

What are the two families of polysaccharides from the grape?

What are the principal neutral sugars in the composition of gums?

Text 2:

Contrary to the traditional technique of settling, flotation is based on the elevation of particles that are in suspension in grape must. To make these particles rise, two products are necessary: nitrogen and gelatin. The first one, when under pressure, is suddenly distorted and forms gas micro bubbles, which fix on solid particles, and reduce the volumetric mass and rise to the surface.

What are the products necessary for flotation?

In which direction do the solid particles rise due to the gas micro-bubbles?

Text 3:

The viscosity of must is a limiting factor for flotation. The pectolytic enzymes are responsible for the pectin degradation. Subsequently, they reduce the viscosity of the must. They act rapidly with high temperatures, but also act in low temperatures, which is an advantage for this process due to the fact that there is a short delay between pressing and settling by flotation.

What is the limiting factor of flotation?

Does low temperature limit flotation?

Text 4:

After crushing grapes, two tanks of good quality juice with similar volumes are obtained. The method of winemaking will be the same for the two tanks with the exception of the settling method. The control tank has static, classic cold-temperature settling. The experimental tank is settled by flotation via the e-flot system, which is rented by the company Spindal.

How many tanks are obtained?

Which company has rented the e-flot system?