



Comparing measurements for emotion evoked by oral care products

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ABSTRACT

The flavor of foods or oral care products can affect consumers' emotions and experience. We compared different methods for measuring emotion evoked by flavors, including self-report measures (Self-Assessment Manikin, or SAM and EsSense), electroencephalography (EEG), electromyography (EMG), and cardiovascular measures (HR and HRV). The results indicate that the difference of α/β power spectral density (PSD) ratios at AF4 and AF3 EEG channels can reflect emotion valence and produce the most consistent result for the 3 repetitions of the same stimulus. P8 β PSD and HR are reliable and valid for measuring emotion arousal. The two self-report measures, Self-Assessment Manikin (SAM) and selected items in EsSense Profile, can distinguish emotion evoked by five flavors. The divergent validity of self-reporting measures, however, is inadequate, which may be attributed to the halo effect, i.e., the strong perception of one emotional property influences people's perception of other emotional properties.

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1. Introduction

With the rapid proliferation of new products, customers' emotional responses to a product has been found more and more important to the success of product success (Helander, 2001; Hsiao and Chen, 2006; Khalid, 2004). For oral care products, the flavor has a direct impact on emotional responses of customers. The sense of flavor is related to both the taste and the smell sensation. The chemicals in these products stimulate the taste buds and smell receptors, and the signals are sent to the insular cortex and the olfactory bulb in the brain. Close to the insular cortex and the olfactory bulb, an area involving emotions, called the amygdala, also receives signals. In this way, specific emotions are evoked by different flavors. Flavor-evoked emotions can further influence consumers' decisions to purchase oral care products (Damasio, 2006). The manipulation of product flavors is therefore an important way through which designers elicit desired emotional response from consumers.

To design product flavors that evoke specific positive emotions, being able to measure flavor-evoked emotions is an important step. Emotions, however, are complicated and difficult to measure

accurately. So far, self-report measures are the most widely used tool. They are good for assessing mixed emotions and gathering rich interpretable opinions from consumers at low costs (Desmet, 2003; Paulhus and Vazire, 2007). To depict an accurate and comprehensive picture of customers' emotional response to a flavor, however, self-reporting measures have a couple of limitations. First, self-report measures cannot measure the emotion at exactly the moment when the emotion is evoked, whereas flavor-evoked emotion decays in seconds. Second, flavor stimuli can evoke unconscious or subtle emotion changes. Such subtle emotions may induce subliminal facial expressions, activate amygdala and other brain areas, and evoke skin conductance responses. But it is difficult to measure these by self-reporting because customers are not conscious of them (Berridge and Winkelman, 2003). Third, the results from self-reporting methods are affected by individual characteristics, such as cultural backgrounds (Desmet, 2003), one's the ability of reading and comprehension, and the ability to detect and be aware of one's emotions (Lane et al., 1997; Mauss and Robinson, 2009). These factors may confound self-reporting results. In addition, people may not be able to accurately describe their emotional feelings or they may deliberately modify their opinions if they do not want to express their true feelings, feel inhibited, or are unconsciously influenced by the circumstance, e.g., the experimenter and the design of questions (Mauss and Robinson, 2009; Paulhus and John, 1998; Czerwinski et al., 2001;

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Nielsen and Levy, 1994).

To seek alternative measurement of emotions, a number of researchers have endeavored to develop emotion measures based on people's psychophysiological responses to the product (Guo et al., 2016; Hill and Bohil, 2016; Laparra-Hernández et al., 2009; Lee and Cho, 2009; Liu and Sourina, 2012; Peck et al., 2013; Qie et al., 2017; van den Broek and Westerink, 2009). The underlying rationale is straightforward: psychophysiological measures directly access people's primary response to an emotional stimulus without involving conscious processes (Kramer, 2006; Motte, 2009; Trimmel et al., 2009). By monitoring directly psychophysiological responses, we may infer about their emotional state. A major advantage of psychophysiological measures is that people cannot easily control their physiological signals voluntarily. In addition, they provide a continuous and real-time description of consumers' internal state, which is not possible with self-reporting methods, which are in nature retrospective.

Commonly used physiological measures for emotions include central nervous system measures (e.g., electroencephalography and neuroimaging), peripheral nervous system measures (e.g., skin conductance responses, heart rate, and heart rate variability), and facial measures (e.g., facial expressions and electromyography) (Maus and Robinson, 2009). The feasibility of using these physiological methods to measure flavor-related emotions has been explored by a number of researchers (Brown et al., 2012; Hu et al., 1999; Park et al., 2011). These studies, however, focused on one to two specific physiological measures, used different flavor stimuli, and adopted different criteria for assessing the effectiveness of measurements. Thus, there is not a common ground for comparing these measures in terms of (1) the sensitivity to the difference in flavors used in foods and oral products, (2) the reliability to produce consistent results for the same stimulus, and (3) the validity to measure flavor-related emotions. Such knowledge is useful for flavor designers to choose suitable measures when evaluating products.

To address this void, this study compared self-report measures, EEG (electroencephalography), EMG (electromyography), heart rate (HR), and heart rate variability (HRV) in terms of their capability to measure emotion evoked by flavors. We collected 24 participants' emotional response to five flavors that are common in oral care products. The EEG, EMG, HR, and HRV were evaluated in terms of (1) the sensitivity to distinguish emotions evoked by flavors, (2) the reliability, and (3) the validity to reflect flavor-evoked emotions. Furthermore, by incorporating physiological measures, we attempted to develop an integrative model that can predict consumers' overall attitude towards and purchase intention of oral products.

2. Literature review

2.1. Theoretical model of emotions

A widely used model to describe emotions is the valence and arousal model proposed by Russell (1979). This model depicts emotions from the perspectives of valence (the direction of behavioral activation associated with emotion, either toward (positive) or away from (negative) a stimulus), and arousal (the extent or amount of physical response, from low to high). For example, the emotion of "happiness" is characterized by positive valence and high arousal. Using this model, however, "surprise" is also defined as a positive valence and high arousal emotion, though the two emotions are largely different. Mehrabian (1980) expanded this model by adding a dominance dimension (a feeling of being in control to a feeling of being controlled) and proposed the valence-arousal-dominance (VAD) mode. Using this model, "happiness" is

defined as a positive, high arousal, high dominance emotion, whereas "surprise" is defined as a positive, high arousal, low dominance emotion.

2.2. Measures of emotion

Emotion measures fall into mainly two categories: self-report measures and physiological measures. By building upon VAD models, researchers have developed a number of emotion instruments, such as the Self-Assessment Manikin (SAM) (Hodes et al., 1985) and PAD (pleasure arousal dominance) emotion scales (Mehrabian, 1995). They assess emotions from the three state dimensions – pleasure (valence), arousal and dominance. Other emotion instruments, such as the Geneva Emotions Wheel (Scherer, 2005) and the Product Emotion Measurement instrument (PrEmo) (Desmet, 2003), measure emotional responses by directly specifying emotions such as "desired", "inspired", "satisfied", and "bored". In addition, researchers from different product domains developed specific instruments for typical emotions evoked by a specific type of stimuli, such as GEMS-25 (Zentner et al., 2008) for music-evoked emotions and ScentMove (Porcherot et al., 2010) for odor-evoked emotions. To measure emotion evoked by flavors, King and Meiselman developed the EsSense Profile (2010), which contains 39 terms (35 positive and 4 negative terms, such as "pleasant" and "disgusted"). The EsSense Profile has been widely applied in measuring emotion evoked by flavors of foods and beverages (de Wijk et al., 2012; Ferrarini et al., 2010).

Among physiological measures, EEG measures have attracted the most research attention. Traditionally, the feature extraction and electrode selection are based on neuro-scientific assumptions. Neurology and clinical research has indicated associations between emotional states and EEG powers in various frequency bands. Beta waves have been found to be associated with an active state of mind, whereas alpha waves are more dominated in a relaxed state. Therefore, prior research has used high levels of β wave power, low levels of α wave power, or large ratios of β/α to indicate high-level arousal (Choppin, 2000; Bos, 2006). Neurology findings suggests that hemispherical asymmetry can reflect emotion valence (Schmidt and Trainor, 2001). Left frontal inactivation indicates a withdrawal response and a negative emotion, whereas right frontal inactivation indicates an approach response and a positive emotion. Researchers have developed a number of measures of the asymmetry of α and β band power in the two hemispheres to indicate emotion valence (Bos, 2006; Brown et al., 2012; Davidson, 1992; Niemic and Warren, 2002). Davidson (1992) and Brown et al. (2012) measured valence using the differential asymmetry, e.g., the difference in α wave power between the left and right hemispheres of the frontal lobe. Bos (2006) measured valence using the rational asymmetry, e.g., the ratios of alpha or beta wave power between the left and right hemispheres. Furthermore, Ramirez and Vamvakousis (2012) estimated valence values by comparing the difference of α/β ratio between left and right hemispheres. In addition to this neuro-scientific approach for feature extraction and electrode selection, some researchers adopted a data-driven approach by applying computational methods (e.g., machine learning) to optimize the selection of features and electrodes from a vast amount of possible features captured by advanced signal processing technologies. Some advanced feature extraction methods, such as fractal dimension features (Liu and Sourina, 2012; Liu et al., 2011; Sourina and Liu, 2011), higher order crossings (Petrantonakis and Hadjileontiadis, 2010) and higher order spectra (Jenke et al., 2014) have been developed and found successful applications in emotion recognition.

EEG has been used to measure taste-related emotions in a limited number of studies. Park et al. (2011) used EEG to monitor

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