Understanding olfaction and emotions and the moderating role of individual differences

Meng-Hsien (Jenny) Lin
College of Business, California State University, Monterey Bay, Seaside, California, USA, and

Samantha N.N. Cross and Terry L. Childers
Department of Marketing, Iowa State University, Ames, Iowa, USA

Received 17 May 2015
Revised 26 April 2016
15 December 2016
17 October 2017
Accepted 16 November 2017

Abstract

Purpose – The purpose of this paper is to explore the mediating role of emotions in processing scent information in consumer research, using event-related potential (ERP)-based neuroscience methods, while considering individual differences in sense of smell.

Design/methodology/approach – Prior research on olfaction and emotions in marketing has revealed mixed findings on the relationship between olfaction and emotion. The authors review earlier studies and present a neuroscience experiment demonstrating the benefits of ERP methods in studying the automatic processing of emotions.

Findings – Results demonstrate how emotional processes occurring within 1s of stimulus exposure differ across individuals with varying olfactory abilities. Findings reveal an automatic suppression mechanism for individuals sensitive to smell.

Research limitations/implications – Scent-induced emotions demonstrated through the use of ERP-based methods provide insights for understanding automatic emotional processes and reactions to ambient scents by consumers in the marketplace.

Practical implications – Findings show an automatic suppression of emotions triggered by scent in individuals sensitive to smell. Marketers and retailers should consider such reactions when evaluating the use of olfactory stimuli in promotional and retail strategies.

Originality/value – The authors review past literature and provide an explanation for the disparate findings in the olfaction–emotion linkage, by studying individual differences in response to scent in the marketplace. This is one of the first papers in marketing to introduce the application of ERP in studying consumer-relevant behavior and provide technical and marketing-specific considerations for both academic and market researchers.

Keywords Emotions, Individual differences, Event-related potential, Olfaction, Scent

Paper type General review

Popular press accounts of olfaction point toward the fundamental connection between scent and emotions in everyday life. In total, four out of five Americans say they know from experience that scent can have a positive effect on their mood (Johnson, 2013). According to Byron (2013), increased flavor, a greater sense of safety and even happiness are influenced by a keen sense of smell. Estimates maintain that 75 per cent of the emotions we experience on a daily basis are generated by what we smell (Bell, 2006). Indeed, Bosmans (2006) maintains that the primary reaction to scent is one of like/dislike. This is partly attributable to the close connection between olfaction and the limbic part of the brain, which governs the processing of emotions, in contrast to cortex-based connections for our other sensory

European Journal of Marketing
Vol. 52 No. 3/4, 2018
pp. 811-836

0309-0566
DOI 10.1108/EJM-05-2015-0284

abilities. Scent also has a close connection to our memories. For example, 84 per cent of Americans believe that scent aids in tapping vivid memories and enables the re-experience of the joy of a specific place, person or event (Johnson, 2013). Although all senses are reported to evoke memories equally accurately, more emotional memories are evoked by scent (Herz, 1998).

Bone and Ellen (1999) report that while scent has a strong effect on marketing behavior, there is an inconsistency in the effect scent has been reported to have on emotions. In our study, we find support for the olfaction–emotion linkage in only about one-third of the 33 prior studies reviewed. As discussed, one reason is that emotions are more fleeting and subject to moment-to-moment fluctuations. A second reason is that scents often require little cognitive effort to be experienced and reactions to scents can occur without conscious attention (Ehrlichman and Halpern, 1988). Individuals may be implicitly and unconsciously processing scent-related emotions. Consistent with this, Herrmann *et al.* (2012) demonstrate how ease of processing (processing fluency) accounts for the processing of simple scents, in a retailing context. These more effortless automatic emotional responses to scent are not readily captured by retrospective measures, like self-report questionnaires (Kahneman, 2000). Yet, as our paper reports, self-report scales administered through questionnaires dominate the literature studying the link between olfaction and emotions. As a result, the power of the methods used to detect the fleeting and implicit nature of scent-related emotions is questioned.

Neuroscientific methods can be particularly insightful in studying underlying mechanisms and individual differences in consumer research (Plassmann *et al.*, 2015). Our paper diverges from extant research on the olfaction–emotion link by utilizing a well-grounded neuroscientific method referred to as event-related potentials (ERPs). ERPs are physiological measures of brain activity derived from electroencephalographic (EEG) data. ERP measures using EEG data provide an advantage over other neuroscience techniques such as functional magnetic resonance imaging (fMRI), in that it has the temporal precision to capture internal processes occurring within milliseconds of a stimulus' onset (Luck, 2005). In particular, ERP has proven advantageous in studying the automatic processing of emotions (Lin *et al.*, 2017).

Our study focuses on the following research questions:

RQ1. What are the emotional reactions of consumers when they encounter odors?

RQ2. How might differences in emotional responses to odors vary across individuals depending on their olfactory sensitivity?

A review of 24 olfactory-related marketing and consumer research papers published to date, encompassing 33 studies, reveals inconsistent findings regarding the olfaction–emotion relationship. One possible reason for the lack of consistency in previous findings is that existing individual differences in olfactory sensitivity have been overlooked. Further, in the meta-analysis conducted in this paper, studies in the analysis that reported a significant relationship between scent and emotions revealed moderate effect size characterized with high heterogeneity between studies. Hence, this individual difference factor is included in our study. This study uses neuroscience methods to investigate the impact of individual differences in olfactory sensitivity on the scent and emotion relationship, and highlights the implications for retailers, marketers and public policymakers. Our findings reveal a link between olfaction and automatically induced emotion regulation processing in participants. Furthermore, our results demonstrate differing emotional processes across individual difference groups with varying olfactory orientations. These findings are especially important given the increased use of scents to attract consumers in shopping malls and other retail venues (Nassauer, 2014).

An analysis of olfactory studies in marketing

A review of olfactory-related papers in the marketing literature confirms the powerful effects of scent on marketing practice and consumer behavior. Scent plays a positive role in increasing customer satisfaction and evaluation of various shopping venues such as stores (Walsh *et al.*, 2011) and malls (Morrin and Chebat, 2005). Scent can also increase consumption levels, such as in-store spending (Herrmann *et al.*, 2012), food intake (Hansen *et al.*, 2006) and gambling (Hirsch, 1995). These increases are reflected by sales (Spangenberg *et al.*, 2006), intent to visit stores (Spangenberg *et al.*, 1996), purchase intentions (Spangenberg *et al.*, 2005), willingness to eat (Hansen *et al.*, 2006) or willingness to pay (Fiore *et al.*, 2000). Scent also is found to have an impact on shopping behaviors such as variety-seeking (Mitchell *et al.*, 1995), product search (Morrin and Chebat, 2005), impulse buying (Matilla and Wirtz, 2001) and choice behaviors (Mitchell *et al.*, 1995). The use of scent further affects other important marketing variables, such as increased brand recall (Morrin and Ratneshwar, 2000, 2003), product recall (Morrin *et al.*, 2011), increased attention (Morrin and Ratneshwar, 2003), haptic perceptions (Krishna *et al.*, 2010a) and time spent in the store (Morrison *et al.*, 2011). Indeed, the overall shopping experience can be enhanced by scent, as reflected in increased positive ratings of brands (Bosmans, 2006) and satisfaction with the shopping environment (Michon *et al.*, 2005).

Antecedent, and in contrast, to the studies noted above, Bone and Ellen (1999) conducted a meta-analysis and reported that only 16 per cent of the 22 studies examined, testing the effects of scent on mood or arousal, found statistically significant relationships. To examine this scent-emotion connection more closely, our paper reviews 24 papers published in selected marketing journals, studying smell and olfaction ranging from Laird's (1932) study to more recently published works. These papers report on 33 empirical studies. Of the 33 studies summarized, 20 (or 60 per cent) specifically examined emotions or mood (Table I), along with the effect of scent. Examining those studies by the significance of their support, 14 report that emotions or mood are not directly related to scent. Thus, only 8 of these 20 studies report a direct effect (Bosmans, 2006; Fiore *et al.*, 2000; Hansen *et al.*, 2006; Morrison *et al.*, 2011), a partial effect (Michon *et al.*, 2005; Walsh *et al.*, 2011) or a weak effect (Chebat and Michon, 2003; Matilla and Wirtz, 2001) of scent on emotions or mood.

The increased percentage of papers (40 per cent) supporting an olfaction–emotion linkage is an improvement over the 16 per cent in the Bone and Ellen (1999) review and may be due in part to changes in methodological procedures or techniques. An examination of the 20 studies on scent and emotion finds that only 23 per cent of the laboratory experiments and 33 per cent of the field experiments report significant effects. Thus, the type of study, lab versus field studies, only revealed marginal statistical differences. All 20 of the studies also used questionnaire-based instruments to collect data on the scent's effect on emotions. Of these, 15 studies used the Mehrabian and Russell (1974) pleasure-arousal-dominance (PAD) scale or an adaptation of the scale. Thus, most of the studies reviewed only used scale items to measure the pleasure and arousal dimensions (Table I). In fact, Morrin and Ratneshwar (2003, p. 23) note that:

> This null finding may be due to the self-report measuring instrument we employed. Perhaps the PAD scale is not sensitive enough to detect the small alterations in mood or arousal as state variables.

They go on to recommend that physiological indicators may be better able to capture emotional reactions induced by scent. These would include the ERP methods used in our study.

Following the guidelines and criteria provided by Laroche and Soulez (2012) on conducting meta-analysis in marketing research, a final set of seven studies from six papers

Table I. Review of papers on olfaction in marketing

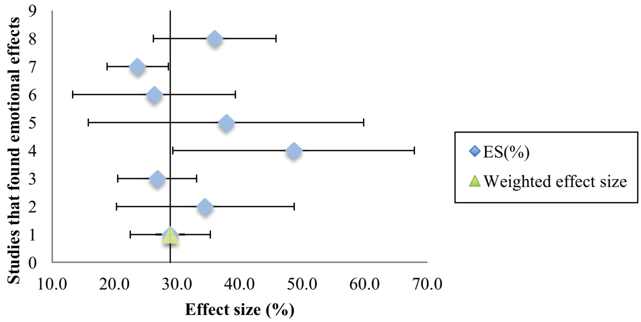
Article	Method: data collection/form	Type/Source of scent	Findings (scent-emotion link)	Measuring emotions (PAD scale)	Analysis method
Bosmans (2006)	Laboratory experiment/ Questionnaire	Ambient (pleasant): citrus (congruent), lavender scent (incongruent)	Yes, congruency matters	No. Used scale: depressing/cheerful, ugly/ beautiful, irritating/nice	SEM
Fiore *et al.* (2000)	Laboratory experiment/ Questionnaire	Ambient (pleasant): "Lily of the Valley" (appropriate), "Sea Mist" (inappropriate)	Yes	Yes	ANOVA (and regression)
Hansen *et al.* (2006)	Laboratory experiment/ Questionnaire	Ambient (pleasant): potato chip odour (congruent), grape fruit odour (incongruent)	Yes, product congruency matters	Yes	SEM
Morrison *et al.* (2011	Field experiment/ Questionnaire	Product scent (pleasant): vanilla scent	Yes	Yes	MANOVA/ ANOVA
Chebat and Michon (2003	Field experiment/ Questionnaire	Ambient (pleasant): citrus vapor	Yes, but partially	Yes	SEM/EQS
Walsh *et al.* (2011)	Survey (in-store)/ Questionnaire	Ambient (pleasant)	Yes, pleasure increased but not arousal	Yes	SEM
Matilla and Wirtz (2001)	Field experiment/ Questionnaire	Ambient (pleasant): lavender (low arousal), grapefruit (high arousal)	Yes, but weak ($p < 0.1$)	Yes	ANOVA
Michon, Chebat and Turley (2005)	Field experiment/ Questionnaire	Ambient (pleasant): lavender (neutral), citrus (pleasing)	Yes, but weak ($p < 0.1$)	Yes	SEM
Spangenberg, Grohmann and Sprott (2005)	Laboratory experiment/ Questionnaire	Ambient (pleasant): "Enchanted Christmas Spray" produced by Greenleaf	Only with music	Yes	ANOVA
Krishna *et al.* (2010b)	Laboratory experiment/ Questionnaire	Product scent (pleasant): Orange blossom	No	Yes	MANOVA/ MANCOVA
Mitchell *et al.* (1995)	Laboratory experiment/ Questionnaire	Ambient (pleasant)	No	Yes	No effects, hence no report of methods

(*continued*)

Article	Method: data collection/form	Type/Source of scent	Findings (scent-emotion link)	Measuring emotions (PAD scale)	Analysis method
Morrin and Chebat (2005)	Field experiment/ Questionnaire	Ambient (pleasant): citrus (a combinantion of lemon, bergamot, and orange)	No	Yes	ANOVA
Morrin and Ratneshwar (2003)	Laboratory experiment/ Questionnaire	Ambient (pleasant): geranium (congruent), cloves (incongruent)	No	Yes	ANOVA
	Laboratory experiment/ Questionnaire	Ambient (pleasant): geranium (congruent)	No	Yes	ANOVA
Morrin and Ratneshwar (2000)	Laboratory experiment/ Questionnaire	Ambient (pleasant): geranium scent	No	Yes	ANOVA
Spangenberg *et al.* (1996)	Laboratory experiment/ Questionnaire	Ambient (pleasant): lavender and ginger (neutral), spearmint and orange (pleasing)	No	Yes	No effects, hence no report of methods
Herrmann *et al.* (2012)	Laboratory experiment/ Anagram task	Ambient (pleasant): orange (simple), basil-orange with green tea (complex)	No	No. used scale from Peterson and Sauber	ANOVA
	Laboratory experiment/ Anagram task	(Same as above)	No	No (same as above)	ANOVA
	Laboratory experiment (simulation)/Questionnaire	(Same as above)	No	No. used self-assessment manikin (SAM) (Bradley and Lang)	ANOVA
Teller and Dennis (2012)	Field experiment/ Questionnaire	Ambient (pleasant): mixture of orange, grapefruit, bergamot, cinnamon, cardamom, ginger, pimento and other additives	No	No. evaluated emotional state based on 52 attributes (Teller, Reutterer and Schnedlitz)	n/a

Table I.

was aggregated and included for a meta-analysis. These papers (Figure 1) all investigated the influence of scent on emotions or affect and were selected based on the criteria depicted in Table II. (Table I for study details). Note, studies were omitted due to insufficient details provided. This should be considered when interpreting the meta-analysis results reported below.



1	*Weighted effect size across studies*
2	Spangenberg *et al.* 2005
3	Morrison *et al.* 2011
4	Morrin and Ratneshwar 2000
5	Morrin and Ratneshwar (Study 2) 2003
6	Morrin and Ratneshwar (Study 1) 2003
7	Morrin and Chebat 2005
8	Fiore *et al.* 2001

Figure 1.
Tree plot displaying meta-analysis results (for seven studies)

Table II.
Overview of meta-analysis methodological steps

Methodological steps	Results	References
1. Review and select common DV	Scent induced emotions: 19 studies	Laroche and Soulez (2012)
2. Review and select common measurement scales	PAD scale: 15 studies Other: 4 studies	
3. Review and analytic methods	ANOVA: 9 studies SEM: 4 studies No details: 2 studies	
4. Review and report statistical results	2 studies did not provide details	
5. Calculate mean effect size (ES)	Calculated weighted Cohen's d, ES = 0.29, CI (0.26, 0.35), suggests moderate ES	Cohen (1992)
6. Homogeneity test using Q statistics	Q = 16.57, suggests heterogeneity (Q statistic close to 1 indicates homogeneity)	Durlak (1995, 2008), Hedges and Olkin (1984)
7. Statistical heterogeneity	I2 = 0.64, confirms moderate to substantial heterogeneity	Higgins *et al.* (2003), Higgins and Green (2011)

The mean effect size (ES) using Cohen's d calculations was ES = 0.33 (range of 0.27-0.49). Considering the varying sample size across the studies, a weighted Cohen's d was calculated and resulted in an effect size of ES = 0.29, CI (0.26, 0.35), across the seven studies (Figure 1 for the Forest plot of the ES across the studies). Based on the criteria provided by Cohen (1992), this reflects a relatively small (ES = 0.2) to medium (ES = 0.5) effect size.

Further homogeneity tests of the Q statistics (Hedges and Olkin, 1984) were calculated, arriving at Q = 16.57. A Q statistic close to 1 indicates homogeneity within the studies, whereas the greater the value of Q suggests systematic differences among the studies (implying heterogeneity), in addition to sampling error (Durlak, 1995, 2008). Statistical heterogeneity is tested using Higgins *et al.* (2003) procedures in calculating I2, resulting in I2 = 0.64, suggesting moderate to substantial heterogeneity (Higgins and Green, 2011). The statistical results suggest positive and small to moderate effect size as expected, noting that these results represent fewer than 50 per cent of the studies (7 out of 19) that measured emotions in some form.

In sum, the heterogeneity, plus the lack of consistency in the findings and the lack of methodological detail provided across prior studies, further support the need for additional studies investigating the olfaction–emotion linkage. However, these results also provide some validation for the impact of scent on emotions, while supporting both the consideration of other factors, such as individual differences in the sense of smell, and the use of alternative and complementary research approaches to deepen our understanding of the nature of the impact.

Literature review and hypotheses

Olfactory-associated emotions and information processing

Among the five senses, olfaction is the phylogenetically oldest and most primitive sense (Herz, 2010), closely connected to emotions. There are only two synapses between the olfactory nerve and the amygdala, which are intrinsically connected to emotion processing (Herz and Engen, 1996). In addition to the functional purposes that are essential for human survival, for example, safety (Stevenson, 2010), one of the powerful roles of olfaction is the hedonic experience of emotions associated with detection of odors (Yeshurun and Sobel, 2010). Odors can elicit pleasant or unpleasant emotions (Herz *et al.*, 2004) and memories (Ehrlichman and Halpern, 1988), which in turn can influence decisions and behaviors (Chebat and Michon, 2003).

Emotions can be defined in hedonic valence in terms of pleasant emotions, such as happiness and relaxing, and unpleasant emotions, such as disgust, fear and anxiety (Chrea *et al.*, 2009; Porcherot *et al.*, 2010). These emotions can be associated with, or induced by, odors that represent different hedonic valences. For example, unpleasant odors such as sulfate-based chemicals can induce the disgust emotion which is a biological mechanism that can help humans avoid disease (Oaten *et al.*, 2009). On the other hand, hedonic scents such as fragrances, which are perceived as pleasant, can stimulate positive emotions (Warrenburg, 2005). The associations between pleasant scent and positive emotions can attract us, while unpleasant odors may elicit negative emotions that can warn us (Hummel and Nordin, 2005). However, the same scent may elicit positive emotions in one individual and negative emotions in another (Nordin *et al.*, 2003). This highlights the need to consider individual differences, like olfactory sensitivity, when studying the olfaction–emotion link.

Individual differences in olfactory sensitivity

In developmental psychology, smell is one of the many sensory stimuli that can be overpowering, particularly for sensitive individuals. Research has explored the concept of individual sensory defensiveness (a negative reaction to sensory stimuli in the environment) and coping strategies for over-stimulated individuals (Heller, 2003). A total of 20 per cent of the US population falls under the category of "highly sensitive person" (HSP) (Aron, 1998). In particular, sensory sensitivity plays a major role in shaping such individuals, which is evidenced by survey items included in the HSP scale, such as "I am easily overwhelmed by strong sensory input" or "I am easily overwhelmed by things like bright lights, strong smells, coarse fabrics, or a siren close by" (Aron and Aron, 1997). In another study, specifically exploring individual differences in olfactory sensitivity, approximately 20 per cent of the population self-reported as having a heightened sensitivity to scent, in comparison to 70 per cent who self-categorized their sense of smell as normal (Cross *et al.*, 2015). Combined, these findings suggest that a significant proportion of the population is sensitive to smell.

Using the affective impact of odor (AIO) scale to measure the importance of smell on an individual's liking of people, places and products, Wrzesniewski *et al.* (1999) found that high AIO scores (i.e. smell played a more significant role) were associated with odor-related memory, attention to odor and influenced their liking or disliking of people based on their odors. Lin *et al.* (2015) investigated these effects across individuals based on their olfactory sensitivity, and found that odors play a significantly stronger role in individuals sensitive to smell (vs normal) on perceptions of place (shopping environment) and people (sales personnel) in a service setting, as well as on cognitive processes such as attention, memory and emotions.

In contrast to the research on the olfactory impaired (Aschenbrenner *et al.*, 2008; Miwa *et al.*, 2001), there are limited medical reports on individuals with a heightened sense of smell (known as hyperosmia); mainly in patients undergoing chemotherapy (Bernhardson *et al.*, 2008) and in pregnant women (Cameron, 2007). Research on hyperosmics usually had a singular focus on odor intolerance (Dalton, 1999; Nordin *et al.*, 2003). One exception is Olofsson *et al.*'s (2005) study which uses EEG methods to understand perceptual versus cognitive processing of odors across individuals during pregnancy. Their ERP study suggests that the processing of odors is enhanced by the cognitive processing (top-bottom response) in pregnant women who have self-reported to be sensitive to smell. Until these recent studies, the sense of smell had not been widely studied in the marketing literature as an individual difference factor. Herrmann *et al.* (2012) note that although scents are easy and inexpensive to use, "One concern levied against the use of olfactory cues is that odors can become overwhelming to customers who may be hypersensitive to olfactory stimuli" (Herrmann *et al.*, 2012, p. 12). These authors advocate for additional research on the interaction between consumer olfactory sensitivity and scent fluency. Our study incorporates individual differences and illustrates one condition under which the olfaction–emotion link is likely to vary.

Neuroscience and the processing of emotions. Emotions are elicited quickly, automatically and are less subject to deliberate control (Russell, 2003). This puts self-reported mood scales such as the PAD scale at a disadvantage. Furthermore, evidence shows that the amygdala is responsible for this automaticity in the elicitation of emotions (Cardinal *et al.*, 2002), and neuroanatomy confirms that sensory processing inputs to the amygdala are faster than semantic processing from the hippocampus and cortex (LeDoux, 1996). This gives neuroscience methods an edge when it comes to studying sensory and emotional processing, as Lin *et al.* (2017) explain in their discussion of the application of an EEG approach in consumer neuroscience. Neuroscientific methods have gained attention over the past two decades as important tools for conducting research on the processing of emotions. Researchers applying EEG techniques to study emotions have focused on two primary parameters of affect (Hajcak *et al.*, 2012),namely, direction (movement toward or away from a stimulus) and intensity (strength, speed or vigor of the movement) (Bradley and Lang, 2000). This is based on the assumption that emotions are rooted in motivational states, which are governed by the above dimensions. Effects of stimuli are based on the motivational systems that support either pleasantness, which reflect appetitive activation, or unpleasantness ratings which reflect defensive activation (Bradley *et al.*, 2001; Lang *et al.*, 1998). The automaticity of emotions is associated with the unconscious formation of emotions. Therefore, the utilization of time-sensitive ERP methods to evaluate emotions has received much attention as a form of objective measure, in addition to other physiological measures including heart rate, skin conductance, facial muscle activity and functional neuroimaging (Bradley and Lang, 2000; Lang *et al.*, 1998).

Late positive potentials

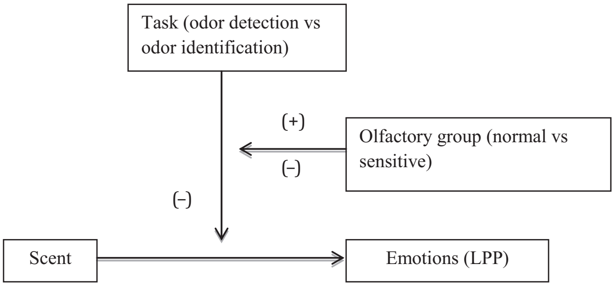
ERP studies utilize what are referred to in the literature as "components". These components have both temporal and spatial characteristics. One such component is the late positive potential (LPP), which is commonly identified spatially in the brain as a midline centroparietal activation that temporally occurs after 300 ms post stimulus and may last up to 1,500 ms [Figure 2(a) for an example of LPP scalp distribution]. LPP evidences information processing operations associated with emotions and arousal. Researchers have used the LPP component for studying emotion-relevant stimuli in comparison to neutral stimuli (Cunningham *et al.*, 2005; Hajcak *et al.*, 2006b; Lang *et al.*, 1998; Schupp *et al.*, 2006). As it is modulated by motivational relevance (Schupp *et al.*, 2000), LPP is enhanced regardless of valence, while also reflecting a negativity bias, that is, there is a stronger LPP among negative stimuli versus positive or neutral stimuli (Cacioppo and Berntson, 1994). This negativity bias may be rooted in our evolution, as negative emotion-relevant stimuli may be highly motivationally salient (Weinberg *et al.*, 2013) for survival purposes (e.g. smoke).

Hypotheses

Smeets and Dalton (2005) propose a model of chemosensory perception differentiating between bottom-up processes used in detection of odors, and a top-down process used in elaboration and memory of odor experiences. This distinction is addressed by administering two tasks in our experiment: an odor detection task (bottom-up processing) is compared to a more active elaborative odor identification task (top-down processing) (Hajcak *et al.*, 2006a). Cognitive effortful tasks have been shown to down-regulate emotional responses to negative stimuli (Van Dillen *et al.*, 2009). In their study, co-activation of brain activity in the two areas, amygdala and frontal cortex, provide evidence that emotional and cognitive processes are interrelated (Van Dillen *et al.*, 2009). Further, increased cognitive load also reduces coping strategies used in consumers' risk avoidance situations (Drolet and Luce, 2004). Investigation of the varying cognitive strenuous levels of tasks (detect vs identify) is expected to influence the impact level of scent on triggering emotions [Figure 3(a)].

Differences in olfactory ability across consumers can have an impact on the intensity of the emotions perceived. This emotional intensity may be manipulated depending on the level of cognitive effort required for the task [Figure 3(a) and (b)]. As noted, a detection task is used where individuals need to discern whether there is an ambient scent present. For example, detection of smoke or rotting food serves as an early warning to individuals that there may be something dangerous or harmful in the air (Stevenson, 2010). In contrast, an identification task is more cognitively focused and oriented toward identifying "what" ambient scent is present.

It is expected that exposure to odors during the detection task will elicit increased emotions (as reflected in the LPP) compared to non-odor conditions (blank trials) in



(a)

	Normal	**Sensitive**
Odor detection	LPP increase (*H1*)	LPP suppressed (*H2*)
Odor identification	LPP down regulate (*H1*)	LPP suppressed (*H2*)

(b)

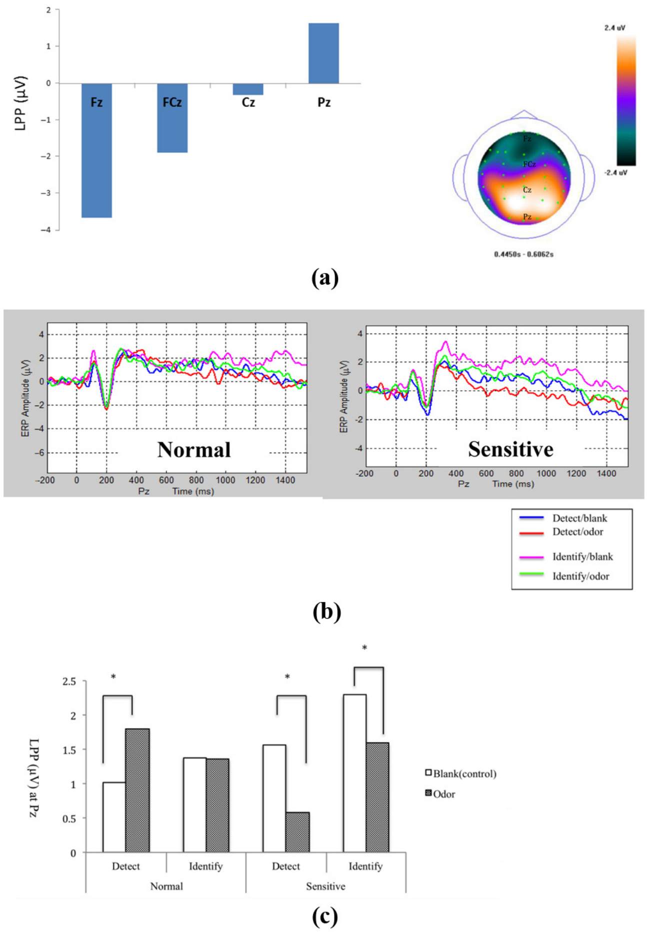
Figure 2.
(a) Framework proposed for the relationship between scent and emotions, moderated by task and olfactory group; and (b) corresponding hypotheses (*H1, H2*)

individuals with a normal sense of smell. They will engage their hot system (Matcalfe and Mischel, 1999) to automatically monitor their environment for any signs of harm or danger. In contrast, during an identification task where the focus is on distinguishing the scent, the cold system (rational) will be triggered and the hot system (emotional) will be reduced. This more cognitive task should result in similar levels of LPP during both the odor and non-odor trials, displaying a down-regulation of emotions [Figure 3(b)], as reported in previous studies (Van Dillen *et al.*, 2009).

However, individuals who are more sensitive to smell are more attuned to the adverse effects of ambient scent. It is expected that individuals with greater olfactory ability will be constantly monitoring the environment for the presence of dangerous and harmful chemicals that can produce negative effects (e.g. headaches and nausea). For these individuals, there is an automatic increase in cognitive activity, even during situations such as detection of scent. Hence, the rational is expected to override the emotional during both the detection and identification tasks for sensitive individuals. This prediction is supported by Lin *et al.* (2012), who reported that odor-sensitive individuals responded to olfactory-related words (e.g. stink) with a diminished emotional response reflected in a reduced LPP. This finding demonstrates that odor-sensitive individuals are hyper-vigilant, as odors are experienced more intensely. Their natural reaction is to avoid or reduce the exposure and effect of ambient odors. Even seemingly pleasant odors can stimulate a negative reaction (Lin *et al.*, 2012). Thus, it is predicted that sensitive individuals should exhibit reduced levels of LPP during odor trials (vs blank trials) across odor detection and identification tasks [Figure 3(b)]:

H1. Elevated emotions (reflected in an increased LPP) will occur during odor trials (vs control) during a detection task in individuals with a normal sense of smell. Similar levels of emotions will occur during an identification task.

H2. Reduced levels of emotions (reflected in a suppression of LPP) will occur during odor trials (vs control) during both detection and identification tasks in individuals with a heightened sense of smell.



Notes: (a) Characteristics of LPP are identified: LPP peaks at 450-600 ms and is distributed along the midline electrodes (Fz, FCz, Cz and Pz) (left) and shown in a topographic map (right), indicating the electrode sites. Larger amplitudes (µV) reflect strong emotional main effects; (b) ERP wave graph for LPP is measured at Pz, a posterior site typical for measuring LPP, displayed by olfactory group: normal (left) vs sensitive (right). Note that LPP amplitudes, reflecting processing of emotions, are elevated for sensitive individuals in identification and blank conditions; (c) LPP bar graphs (measurements from the wave graph) for normal vs sensitive: task (detect vs identify) × condition (blank vs odor), *$p < 0.05$

Figure 3.
Emotion processes reflected by LPP in the two olfactory groups

An ERP study on olfaction and emotions

Research design, materials and participants

A 2 (odor: neutral [control] vs odor) within subject × 2 (olfactory group: normal vs hyperosmics) between subject × 2 (task: odor detection vs odor identification) within subject mixed design was used. A survey was distributed across campus to approximately 800 students (undergraduate and graduate) and staff members in a large university in the Midwest, to recruit participants from the two olfactory categories for the purpose of the study. A self-reported screener question, validated by Lin *et al.* (2015), asked individuals to select a category that best described their sense of smell such as heightened sense of smell, normal sense of smell, decreased sense of smell and impaired with no sense of smell. A balanced group of 20 participants recruited from each of the two groups, normal and heightened, were randomly invited to participate in the study. A final number of 17 and 18 participants (57 per cent female, mean participant age was 22), respectively, completed the study. The study took approximately 1 h, including experiment set-up, data collection and a follow-up survey. Appreciation for participants' time was acknowledged with $10 gift cards.

The EMSE® software (Cortech Solutions, Inc.) was used to clean the raw data and remove any noise and artifacts from muscle movement and eye blinks. To limit the possibility of distorting the data due to overcorrecting measures, average trials rejected (per condition) were below 10 per cent of the total trials. Participant data with too much noise and artifacts were excluded from the final set of participants. Hence, the final data set included 13 individuals with a normal sense of smell and 13 individuals with a heightened sense of smell, resulting in a total of 26 participants. This sample size is above the norm for neuroscience studies (whether fMRI or EEG), which range from 6 to 20 subjects (Hirsch, 2010). In addition, an 80-trials-per-participant design (1,040 trials per olfactory condition) was used in this study to maximize statistical power.

Scents released from a manufactured smell kit, Sniffin Sticks (Burghart, Germany), were used as odor stimuli (Appendix 1). Many of these scents were similar to the common scents used in prior consumer research; for example, citrus scents such as orange and lemon, and spices such as cinnamon and cloves (Table I). Participants were asked to sniff the odors presented to them, while their brain activity was recorded using EEG methods (Appendix 2).

Each task, odor detection and odor identification, consisted of 40 trials, namely, 20 odor trials and 20 unscented trials, presented in quasi-randomized order (Appendix 1). Interstimulus interval (ISI) included a 3-s instruction screen plus a 1-s visual fixation. In the odor identification task, participants were prompted on the computer screen to identify the odor presented by selecting from five options – four odor options and a "blank". For both tasks, a trained experimenter presented the stimuli to the participant. See Appendix 2 for description of lab setup.

Data processing

The mean voltage data were analyzed in a series of 2 (task: detection vs identification) × 2 (olfactory group: normal vs heightened) between subject × 2 (condition: control vs odor) × 4 (midline electrodes: Fz, FCz, Cz and Pz) within subject ANOVAs. The electrodes included in these analyses were based upon previous research on LPP (Hajcak *et al.*, 2006b) and inspection of the grand-averaged ERPs plotted in MATLAB. To correct for violations of sphericity, the Greenhouse–Geisser correction was applied where appropriate. Background variables (e.g. gender, age and smoking habits) were captured and included as control variables. Refer to Appendix 2 for equipment and data recording details.

Results and discussion

Behavioral outcome. During the odor identification task, behavioral responses revealed an average accuracy rate of 83 per cent across all individuals. Furthermore, accuracy rates were higher for detecting a presence of scents than correctly identifying the nature of the scent [$M_{detect} = 0.868$ vs $M_{identify} = 0.785$, $t(38) = 2.97$, $p < 0.01$]. As we mentioned earlier, bottom-up detection is less cognitively intense than top-down identification. This finding is similar between both smell groups, for detection trials [$M_{detection/normal} = 0.873$ vs $M_{detection/sensitive} = 0.863$, $t(37) = 0.188$, $p > 0.1$] and for identification trials [$M_{identification/normal} = 0.783$ vs $M_{identification/sensitive} = 0.787$, $t(37) = -0.100$, $p > 0.1$]. This suggests that behavioral responses in terms of detection do not seem to differentiate the two smell groups as reflected in equivalent accuracy responses in odor detection results. In fact, the smell kit was designed only to screen out individuals with an impaired sense of smell. Hence, this finding was not unexpected.

Physiological outcome. Odor-induced emotion is measured and reflected through the component of interest, LPP, which can be confirmed by its characteristic posterior scalp distribution [Figure (2a)]. LPP is distributed along the midline electrodes (Fz, FCz, Cz and Pz), with increasing amplitudes from the negative frontal site (Fz) to the positive posterior site (Pz) as represented here. This finding is consistent with prior studies on LPP (Hajcak *et al.*, 2006a). LPP also can be characterized by its temporal characteristics, which involve offsetting around 300 ms post stimuli, peaking early at 450-650 ms and sustaining a slow wave up to 1,500 ms [depicted in Figure 2(b)]. After confirming the "identity" of the component of interest based on these characteristics demonstrated in Figure 2(a) and (b), measurements were taken across the window of 450-600 ms at the midline sites (Fz, FCz, Cz, Pz)[1]. The LPP is visibly presented at the midline parietal areas of the brain. The topological map of brain activity [Figure 2(a)], where larger positive amplitudes (depicted in light shading) indicate higher emotional activity confirms a pattern consistent with the characteristics of LPP during this time window. The map also locates the largest positive activity at site Pz where the follow up analyses are performed [Figure 2(c)].

The following tests were conducted to examine *H1* and *H2*. Analyses were performed using MANOVA, utilizing a task (odor detection vs identification) × condition (control vs odor) × electrode (Fz, FCz, Cz and Pz) within subject × group (normal vs heightened) between subject mixed design. Data are reported in microvolts (μV). Results from early LPP revealed significant main effects of electrode [$M_{FZ} = -2.13$ vs $M_{FCz} = -1.57$ vs $M_{Cz} = -0.15$ vs $M_{Pz} = 1.10$, $F(3, 69) = 14.116$, $p < 0.001$] and condition [$M_{control} = -0.28$ vs $M_{odor} = -1.09$, $F(1, 23) = 15.66$, $p < 0.001$]. This further confirms the linear distribution of the LPP amplitudes measured along the midline electrodes. Odor trials triggered significantly stronger LPP in comparison to control conditions.

LPP was further analyzed using site Pz which evidences the maximal amplitude of LPP [$M_{FZ} = -1.91$ vs $M_{FCz} = -1.43$ vs $M_{Cz} = 0.75$ vs $M_{Pz} = 1.27$, $F(3, 69) = 14.116$, $p < 0.001$] [Figure 2(a)]. Overall group [$M_{normal} = 1.39$ vs $M_{sensitive} = 1.51$, $F(1, 23)= 0.017$, $p > 0.1$], task [$M_{detection} = 1.24$ vs $M_{identify} = 1.66$, $F(1, 23) = 1.335$, $p > 0.1$] and condition [$M_{control} = 1.56$ vs $M_{odor} = 1.33$, $F(1, 23) = 0.814$, $p > 0.1$] main effects were not significant. See Table III for summary of MANOVA results. However, there were moderate interaction effects between condition × task [$F(1, 23) = 3.195$, $p < 0.07$], indicating the effect of odor in eliciting emotions was dependent on the task (detection vs identification). During the identification task, emotion (reflected by LPP) was higher during blank versus odor conditions [$M_{control} = 1.83$ vs $M_{odor} = 1.41$, $F(1, 23) = 1.85$, $p < 0.05$] whereas there was no significant effect between the two conditions during the detection task [$M_{control} = 1.29$ vs $M_{odor} = 1.18$, $F(1, 23) = 0.92$, $p > 0.1$].

Further, the two-way interaction for group × condition was significant [$F(1, 23) = 5.6$, $p < 0.01$], suggesting the effect of odor in eliciting emotions was moderated by group (normal vs sensitive). For normal individuals, the identification task elicited higher emotions (measured with LPP) in comparison to the detection task [$M_{detection} = 1.20$ vs $M_{identify} = 1.58$, $F(1, 23) = 1.97$, $p < 0.05$]. While for sensitive individuals, LPP was higher in the detection task compared to the identification task [$M_{detection} = 1.93$ vs $M_{identify} = 1.08$, $F(1, 23) = 2.56$, $p < 0.05$]. Three-way interaction was not significant [$F(1, 23) = 0.74$, $p > 0.1$].

The following analyses were conducted to test for the individual differences predicted in *H1* and *H2*. Results revealed that for individuals with a normal sense of smell, there is a significant interaction between task × condition [$F(1, 12) = 3.73$, $p < 0.05$]. Contrast tests supporting *H1* confirm that under the detection task, LPP is significantly increased during odor trials compared to blank trials [$M_{detection/control} = 1.02$ vs $M_{detection/odor} = 1.79$, $t(12) = -2.05$, $p < 0.05$]. When instructed to identify the odor presented, LPP levels are comparable between the two conditions [$M_{identify/control} = 1.38$ vs $M_{identify/odor} = 1.36$, $t(12) = 0.05$, $p > 0.1$], which also supports *H1* [Figure 2(b) and (c)].

In contrast, individuals sensitive to smell displayed lower LPP during odor conditions compared to blank conditions [$M_{control} = 1.93$ vs $M_{odor} = 1.08$, $F(1, 11) = 3.87$, $p < 0.05$], confirming *H2* [Figure 2(b)]. This suppression effect of LPP occurred during both the detection task [$M_{detection/control} = 1.57$ vs $M_{detection/odor} = 0.58$, $t(12) = -2.24$, $p < 0.05$] and the identification task [$M_{identify/control} = 2.29$ vs $M_{identify/odor} = 1.59$, $t(12) = -1.71$, $p < 0.05$] (Figure 2c).

In sum, when passively detecting a scent (Task 1), the emotions of normal individuals are automatically generated as reflected by the elevated LPP magnitudes occurring less than 600 ms, following exposure to the scent stimuli. However, during the more cognitively effortful identification task, emotions were not elevated, reflecting possible engagement in other cognitive processing activities and less immediate emotional responses. For individuals who are sensitive to smell, results reflect an automatic suppression of emotions as indicated by the attenuated LPP levels during both odor tasks. These findings suggest a more automatic cognitive-based mechanism may be involved in regulating their emotional responses.

General discussion

Our results suggest an automatic allocation of attentional resources devoted to olfactory cues in normal individuals, as well as suppressing mechanisms in individuals who have a heightened sensitivity to smell. Our results reinforce earlier findings that emotions automatically experienced by highly olfactory sensitive individuals (hyperosmics) are in fact negative and protective in nature (Cross *et al.* 2015). Moreover, this regulatory mechanism is absent in normal individuals; perhaps because individuals with a normal

Table III. Summary of MANOVA results for LPP measured at electrode Pz

Independent variables	*F*-value	df	Significance (*p*-value)
Task	1.336	(1, 23)	>0.1
Condition	0.814	(1, 23)	>0.1
Group	0.017	(1, 23)	>0.1
Task × Condition	3.195	(1, 23)	<0.07
Task × Group	1.567	(1, 23)	>0.1
Condition × Group	5.600	(1, 23)	<0.01
Task × Condition × Group	0.740	(1, 23)	>0.1

ability to smell do not suffer the level of negative consequences (e.g. headaches, nausea, dizziness) from intense odors as do hyperosmics. Consistent with their hyper-vigilant nature, individuals with a high sensitivity to smell report paying more attention to smell and indicate that scent is a more salient sensory factor for them, compared to normal individuals, as evidenced by a questionnaire study investigating individual differences in sense of smell (Lin *et al.*, 2012).

Suppression is one form of emotion regulation strategy that is more response focused (Gross and Thompson, 2009). We found that such a strategy is employed to reduce the emotion response to the elicited scent, rather than using an antecedent form of emotion regulation (Gross, 1998), such as situation avoidance and situation selection (Cross *et al.*, 2015). The suppression of emotions is also widely studied in non-sensory contexts where negative emotions are experienced at both social and individual levels, such as stereotype threat (Keller and Dauenheimer, 2003), prejudice (Amodio *et al.*, 2007) and obesity and eating behavior (Vohs and Heatherton, 2000). Experiencing such negative emotions can affect decision-making and performance (Inzlicht and Kang, 2010), again supporting the interaction between emotion, cognitive processes and behavior.

Findings from our study complement the small subgroup of past behavioral studies reporting significant effects between the olfaction–emotion link (Table I). Results also provide an explanation for the large number of studies reporting a *lack* of significant effects of scent on emotions when self-reported measures, such as the PAD scale, were used. The behavioral results in our paper suggest that individuals with a sensitive sense of smell are not necessarily more accurate in detecting or identifying odors. However, our neuroscience findings, enabled by the time-specific and high sampling frequency characteristics of the EEG data, reveal that olfactory sensitivity is driven by differential cognitive and emotional effects. These findings provide an explanation for Dalton *et al.*'s (1999) findings of no evidence of physiological differences among people who report that they are more sensitive to smell.

Outcome reactions of automatic emotions are often expressed and studied through facial expressions (Öhman, 2002). Here we demonstrate that EEG could also be used to reveal the fast occurring and automatic emotion processing induced from scents, especially for individuals who are highly sensitive to smell. Thus, the results of our study advocate the use of neuroscience methods in consumer research to better extend our knowledge of the influence of odor stimuli on emotion processes. Yet, while there has been a slow but steady increase in the number of fMRI studies over the past decade (Hedgcock and Rao, 2009; Reimann *et al.*, 2011, 2012; Yoon *et al.*, 2006), there are far fewer ERP studies (Boksem and Smidts, 2014; Jones *et al.*, 2012; Pozharliev *et al.*, 2015) in business journals, despite the considerable history of ERP studies in neuroscience and psychology (Luck, 2005). However, industry consultants and corporate researchers, such as Nielsen Neuro and GE, use EEG methods to provide solutions to help companies understand consumer shopping and consumption behavior, (ABC News Internet Ventures, 2016), as well as consumer preferences and advertising evaluations, (The Nielsen Company, 2016). Our study is one of the first to apply EEG methods in marketing research and illustrates one of the many potential uses of ERP measures to study consumer relevant topics and their underlying cognitive processes. Marketing researchers should also consider the use of neuroscience methods as a complement to existing research methods. See Lin *et al.* (2017) for a detailed discussion of the use of EEG in consumer neuroscience.

Implications and limitations

Recognizing that individuals vary in their sensitivity to scent is important to advancing our understanding of the role of olfaction for consumers, which is particularly relevant to marketing and retail managers. The use of ambient scent or scenarios where the consumers are asked to think about "what" the particular scents are may trigger cognitive processes in consumers. This may in turn arouse (as in the detection task for normal individuals) or dampen emotions (as demonstrated in the identification task for normal individuals, and in both the detection and identification tasks for sensitive individuals). The latter outcome is concerning, as it may lead to diminished marketplace enjoyment or consumer's disengagement with the store and the brand, counteracting the initial marketing intention – to get potential consumers excited about the product and the brand, while creating positive brand and shopping experiences. Given the differential impact of sensory influences on individual perception, reaction and consumption, the increased use of ambient scent in stores, hotels and other public venues should be prudently monitored. Future practice should also consider the selective use of scratch and sniff inserts in magazines, sample sprays or other tactics, where a focused attention is placed on discerning the scent. Instead, a multi-sensory design without placing an emphasis on scent might be better.

As we noted earlier, ambient scents have been widely used in retail settings based on conventional knowledge of their effect on mood (Bosmans, 2006; Herrmann *et al.*, 2012; Spangenberg *et al.*, 2005). They enhance positive purchase experiences and increase positive product evaluations (Bosmans, 2006). However, despite the positive impact that scent can have on purchase intentions and evaluations, Bosmans (2006, p.41) also acknowledges that "as long as the scent is not too salient [. . .] these scents will have a positive impact on product evaluations".

Our findings support the assertion that saliency *does* matter. Some retail stores have started to recognize that ***more*** scent (not just the intensity, but the variety and pervasiveness of scent) is not necessarily better and use ventilation systems to prevent ambient scent from overwhelming customers. For other retailers, such as Abercrombie and Fitch, it is a continuous struggle not to drive away customers, as their signature ambient scent is reported to increase the feeling of anxiety (Stampler, 2014). Having not only scent-free products, but also scent-free aisles or sections in stores, could alleviate any adverse effects of ambient scent on consumers who are sensitive to smell. Simply relocating the perfume counter or other scent-heavy areas away from the main entrances would also reduce purchase anxiety for these consumers (Cross *et al.*, 2015). Based on the results of our study, retailers and service providers should consider creating entirely scent-free shopping environments, or partitioning off scent-free areas within stores and other venues (e.g. massage studios, museums, theaters) where individual use of fragrances or scented products is either subtle or not permitted at all. These simple actions could prevent shoppers and patrons from being distracted (Nassauer, 2014) and provide a different experience for consumers, highlighting other forms of sensory stimuli, such as visual, auditory or tactile. This, in turn, would attenuate the possible suppression effect we saw in our study and could make the consumption experience more pleasurable for the olfactory sensitive individual.

Yet, scent-free spaces and policies should not be confined to places consumers shop, but should also include the workplace and other public places. In Broward County, FL, a "Fragrance Free Workplace" edict was instituted in the sheriff's office (Mayo, 2010). In Canada and California, voluntary fragrance-free policies have been enacted in several workplaces (Mayo, 2010). Churches in Kirkland and Bellevue, WA, have fragrance free campaigns, and designated fragrance free zones to provide relief for olfactory sensitive members (Peeples, 2013); and in Japan, anti-fragrance advocates, such as the members of the Society Demanding Fragrance Restraint, raise public awareness about fragrance allergies and scent sensitivity (Negishi and Dvorak, 2013). Scent-free spaces within the marketplace, workplace and other public venues, would cater not just to the highly olfactory sensitive (hyperosmics), but also to those consumers who may simply prefer a less scented environment.

Scent marketing has been described as "the business of emotional transportation" (Lewis, 2014). In Lewis' (2014) article, Aradhna Krishna asserts that "no other cue is as potent as a scent-based cue". After all, researchers at the Rockefeller Institute have shown that the nose can potentially distinguish over a trillion different smells (Bushdid *et al.*, 2014). However, others point out that because "scent affects emotion" and "works without you having the opportunity to filter it", scent marketing, even if the outcome is to enhance the consumer experience, crosses the ethical line (Lewis, 2014). Our study adds another dimension to this ethical debate and demonstrates that *scent marketing* is not just about *getting the scent right* through developing signature scents, but also *getting the scent to the right individuals*, those who may actually enjoy the experience. It is clear from our study that sensory stimuli that attract can also repel (Lin *et al.*, 2015), influencing the overall marketplace experience. Marketers need to be aware that scents which are favorably viewed by some, may be less agreeable, and potentially physiologically or psychologically harmful, to the highly sensitive consumers, who comprise approximately 20 per cent of the population. For these consumers, the inability to filter out scent, whether ambient or from other individuals, in public spaces and the marketplace, can also be viewed as unethical, or, at the very least, unjust and unfair. Marketers who show greater awareness and sensitivity to the varying needs, preferences and limitations of all their consumers in product assortment, policies and guidelines, and retail and marketplace design, will be seen as more inclusive and attract a wider customer base.

In the current study, we used actual scent; yet, recent studies in olfaction have explored the power of olfactory imagery (Stevenson and Case, 2005), that is, imagining the scent related to a product without the actual scent being present, and found an impact on hunger levels (Krishna *et al.*, 2014) and ad evaluations (Lin *et al.*, 2015). Marketers and researchers should continue to explore the use of olfactory imagery as an alternative form of communicating odor information, without the use of actual scents to possibly minimize the outcomes of emotional suppression from encountering scent.

Our study also has implications for a richer understanding of the degree to which consumers process smell-related information through automatic versus controlled strategies. There is a widespread assumption of positive associations triggered from scent. As a result, sensory sensitivity or negative scent-related associations are sometimes seen merely as an artifact (Dalton, 1999; Olofsson *et al.* 2005), rather than as a physiological condition. In our study respondents who reported themselves as being more sensory sensitive were in fact no better at either detecting or identifying odors. Our findings show that olfactory sensitivity is not driven mainly by the physiological aspects of smell (accuracy in identifying the scent) but by the regulation of emotions, as revealed in the ERP data. Thus, it seems highly likely that sensory sensitivity can also be a psychological rather than just a physiological condition, which supports Dalton's (1999) findings. However, our studies also demonstrate that individual differences in sense of smell may cause individuals to react emotionally differently to the same scent, implying that outcomes related to judgment and choice may also differ across individuals and contexts.

A potential limitation is that our research used a self-report prescreen survey to recruit participants for the olfactory categories. Although smell tests have been used to group individuals into different olfactory groups (Kremer *et al.*, 1998), there is also evidence supporting the validity of using self-reports for this type of categorization (Gent *et al.*, 1987; Leon *et al.*, 2007). Not only were the self-reported categorizations validated by our results, but in additional studies, we also found further validation through cluster analysis (Lin *et al.*, 2016). In addition, high consistency between self-reported categorizations and participants' responses were found when participants were interviewed about the importance and significance of smell in their lives (Cross *et al.*, 2015).

Despite the many advantages ERP provides as an alternative to measuring emotions, there are also limitations to this approach. EEG recordings are limited when it comes to identifying the source of origin in the brain. Hence, while the ERP waves provide insight to cognitive and emotional processes, results must be interpreted with caution when pinpointing specific brain regions. However, the use of the LPP component and its link to emotion processing has been validated in a more recent study by Liu *et al.* (2012), who compared fMRI and ERP results, and demonstrated that LPP modulation is valence specific and is modulated by brain areas that govern emotional processing.

Selected scents, similar to those used in retail settings and prior studies, were included in our study (Appendix 1) to expand the generalizability of our findings. However, given the nature of ERP experimental design, the effects of the different scents were analyzed in aggregate, therefore limiting us in separating the effects of individual scents. Future research could examine the effects of the different scents by including multiple trials for each type.

Scents, and their interaction with other environmental stimuli, such as music (Matilla and Wirtz, 2001) and retail density (Michon *et al.*, 2005) have also been explored. We investigate only one sensory modality in this study. However, individuals with high olfactory sensitivity are often reported to have heightened sensitivity in other senses as well (Aron, 1998), creating a potentially powerful multi-sensory impact on their consumption preferences and purchase experiences. Future research should further investigate the interaction of scent and other sensory stimuli or cognitive taxing tasks such as price and discount calculations in a retail setting or task-oriented shopping environment, such as grocery stores.

Philosopher, Michael Marder (2017) argues that sensory bombardment (continuous sensory pollution that, in the case of scent, can "overwhelm and confuse our olfactory register") will limit the range of our possible experiences, as one or two stimuli will "outshine, outsmell or outshout the rest". He cautions that we are in danger of becoming victims of both sensory *over*load and sensory *under*load, which he likens to "impoverishment through surplus"; limiting our awareness, diminishing the scope of our experiences and impairing our well-being. Based on his assertions, we will all eventually be affected by too much sensory stimuli. Based on our findings, this suggests that the suppression effect on emotions and negative scent-related associations may eventually be more widespread. Thus, it is imperative that marketing researchers continue to study the impact of sensory sensitivity on purchase behavior, decision-making, consumer well-being and the overall consumption experience.

Notes

1. We focus on the early temporal window of the LPP so as to demonstrate the earliest onset of effects. Nevertheless, significant differences persist into the later LPP up until around 1,000 ms and are visible in Figure 4(b).
2. 33-electrode array include VEO1, VEO2, Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, FT7, FC3, FCz, FC4, FT8, T7, C3, Cz, C4, T8, TP7, CP3, CPz, CP4, TP8, P7, P3, Pz, P4, P8, O2, Oz, O1.

References

ABC News Internet Ventures (2016), "How your brain reacts to barbeque", available at: http://abcnews.go.com/Nightline/video/nightline-brain-reacts-barbeque-29716028 (accessed February 18, 2016)

Amodio, D.M., Devine, P.G. and Harmon-Jones, E. (2007), "A dynamic model of guilt implications for motivation and self-regulation in the context of prejudice", *Psychological Science*, Vol. 18 No. 6, pp. 524-530.

Aron, E.N. (1998), *The Highly Sensitive Person: How to Thrive When the World Overwhelms You*, Thee Rivers Press, New York, NY.

Aron, E.N. and Aron, A. (1997), "Sensory-processing sensitivity and its relation to introversion and emotionality", *Journal of Personality and Social Psychology*, Vol. 73 No. 2, p. 345.

Aschenbrenner, K., Hummel, C., Teszmer, K., Krone, F., Ishimaru, T., Seo, H. and Hummel, T. (2008), "The influence of olfactory loss on dietary behaviors", *The Laryngoscope*, Vol. 118 No. 1, pp. 135-144.

Bell, S. (2006), "Future sense: defining brands through scent", *GDR Creative Intelligence*, Vol. 21, pp. 1-5.

Bernhardson, B., Tishelman, C. and Rutqvist, L.E. (2008), "Self-reported taste and smell changes during cancer chemotherapy", *Supportive Care in Cancer*, Vol. 16 No. 3, pp. 275-283.

Boksem, M. and Smidts, A. (2014), "Brain responses to movie-trailers predict individual preferences for movies and their population-wide commercial success", *Journal of Marketing Research*, Vol. 52 No. 4, pp. 482-492.

Bone, F.P. and Ellen, P.S. (1999), "Scents in the marketplace: explaining a fraction of olfaction", *Journal of Retailing*, Vol. 75 No. 2, pp. 243-262.

Bosmans, A. (2006), "Scents and sensibility: when do (in) congruent ambient scents influence product evaluations?", *Journal of Marketing*, Vol. 70 No. 3, pp. 32-43.

Bradley, M.M. and Lang, P.J. (2000), "Measuring emotion: behavior, feeling, and physiology", *Cognitive Neuroscience of Emotion*, Vol. 25, pp. 49-59.

Bradley, M.M., Codispoti, M., Cuthbert, B.N. and Lang, P.J. (2001), "Emotion and motivation I: defensive and appetitive reactions in picture processing", *Emotion (Washington, D.C.)*, Vol. 1 No. 3, pp. 276-298.

Bushdid, C., Magnasco, M.O., Voshall, L.B. and Keller, A. (2014), "Humans can discriminate more than 1 trillion olfactory stimuli", *Science*, Vol. 343 No. 6177, pp. 1370-1372.

Byron, E. (2013) "Uncork the nose's secret powers", available at: http://online.wsj.com/news/articles/SB10001424127887323696404578300182010199640 (accessed July 23, 2014).

Cacioppo, J.T. and Berntson, G.G. (1994), "Relationship between attitudes and evaluative space: a critical review, with emphasis on the separability of positive and negative substrates", *Psychological Bulletin*, Vol. 115 No. 3, pp. 401-423.

Cameron, L.E. (2007), "Measures of human olfactory perception during pregnancy", *Chemical Senses*, Vol. 32 No. 8, pp. 775-782.

Cardinal, R.N., Parkinson, J.A., Hall, J. and Everitt, B.J. (2002), "Emotion and motivation: the role of the amygdala, ventral striatum, and prefrontal cortex", *Neuroscience & Biobehavioral Reviews*, Vol. 26 No. 3, pp. 321-352.

Chebat, J. and Michon, R. (2003), "Impact of ambient odors on mall shoppers' emotions, cognition, and spending: a test of competitive causal theories", *Journal of Business Research*, Vol. 56 No. 7, pp. 529-539.

Chrea, C., Grandjean, D., Delplanque, S., Benedicte, I.C., Calve, L., Aymard, L., Velazco, M.I., Sander, D. and Scherer, K.R. (2009), "Mapping the semantic space for the subjective experience of emotional responses to odors", *Chemical Senses*, Vol. 34 No. 1, pp. 49-62.

Cohen, J. (1992), "A power primer", *Psychological Bulletin*, Vol. 112 No. 1, pp. 155-159.

Cross, S.N.N., Lin, M.H. and Childers, T.L. (2015), "Sensory identity: the impact of olfaction on consumption", in Belk, R., Murray, J., Thyroff, A. (Eds), *Research in Consumer Behavior Series*, Emerald Publishing Group.

Cunningham, W.A., Espinet, S.D., DeYoung, C.G. and Zelazo, P.D. (2005), "Attitudes to the right-and left: frontal ERP asymmetries associated with stimulus valence and processing goals", *NeuroImage*, Vol. 28 No. 4, pp. 827-834.

Dalton, P. (1999), “Cognitive influences on health symptoms from acute chemical exposure”, *Health Psychology*, Vol. 18 No. 6, pp. 579-590.

Drolet, A. and Luce, M.F. (2004), “The rationalizing effects of cognitive load on emotion-based trade-off avoidance”, *Journal of Consumer Research*, Vol. 31 No. 1, pp. 63-77.

Durlak, J.A. (1995), “Understanding meta-analysis”, in Grimm, R.G. and Yarnord, P.R. (Eds), *Reading and Understanding Multivariate Statistics*, American Psychological Association, Washington, DC, pp. 319-352.

Durlak, J.A. (2008), “Chapter ten: basic principles of meta-analysis”, in Roberts, M.C. and Ilardi, S.S. (Eds), *Handbook of Research Methods in Clinical Psychology*, Blackwell, Malden, MA, pp. 196-209.

Ehrlichman, H. and Halpern, J.N. (1988), “Affect and memory: effects of pleasant and unpleasant odors on retrieval of happy and unhappy memories”, *Journal of Personality and Social Psychology*, Vol. 55 No. 5, pp. 769-779.

Fiore, A.M., Yah, X. and Yoh, E. (2000), “Effects of a product display and environmental fragrancing on approach responses and pleasurable experiences”, *Psychology and Marketing*, Vol. 17 No. 1, pp. 27-54.

Gent, J.F., Goodspeed, R.B., Zagraniski, R.T. and Catalanotto, F.A. (1987), “Taste and smell problems: validation of questions for the clinical history”, *Yale Journal of Biology and Medicine*, Vol. 60 No. 1, pp. 27-35.

Gross, J.J. (1998), “The emerging field of emotion regulation: an integrative review”, *Review of General Psychology*, Vol. 2 No. 3, pp. 271-299.

Gross, J.J. and Thompson, R.A. (2009), “Emotion regulation: conceptual foundations”, in Gross, J.J. (Ed.), *Handbook of Emotion Regulation*, The Guilford Press, New York, NY, pp. 3-26.

Hajcak, G., Moser, J.S. and Simons, R.F. (2006a), “Attending to affect: appraisal strategies modulate the electrocortical response to arousing pictures”, *Emotion*, Vol. 6 No. 3, pp. 517-522.

Hajcak, G., Moser, J.S., Holroyd, C.B. and Simons, R.F. (2006b), “The feedback-related negativity reflects the binary evaluation of good versus bad outcomes”, *Biological Psychology*, Vol. 71 No. 2, pp. 148-154.

Hajcak, G., Weinberg, A., MacNamara, A. and Foti, D. (2012), *ERPs and the study of emotion*, Oxford Handbook of ERP Components, pp. 441-474.

Hansen, T., Bruun-Christensen, A. and Schauman, J. (2006), “Consumers’ emotions, cognition and approach/avoidance behavior in relation to scented food products”, paper presented at The 5th International Congress Marketing Trends, Venice, 20-21 January.

Hedgcock, W. and Rao, A.R. (2009), “Trade-off aversion as an explanation for the attraction effect: a functional magnetic resonance imaging study”, *Journal of Marketing Research*, Vol. 46 No. 1, pp. 1-13.

Hedges, L.V. and Olkin, I. (1984), “Nonparametric estimators of effect size in Meta-analysis”, *Psychological Bulletin*, Vol. 96 No. 3, p. 573.

Heller, S. (2003), *Too Loud, Too Bright, Too Fast, Too Tight: What to Do If You Are Sensory Defensive in an Overstimulating World*, Harper Collins, New York, NY.

Herrmann, A., Zidansek, M., Sprott, D.E. and Spangenberg, E.R. (2012), “The power of simplicity: processing fluency and the effects of olfactory cues on retail sales”, *Journal of Retailing*, Vol. 458, pp. 1-14.

Herz, R. (2010), *The Emotional, Cognitive and Biological Basics of Olfaction*, Routledge, New York, NY.

Herz, R.S. (1998), “Are odors the best cues to memory? a cross-modal comparison of associative memory stimuli”, *Annals of the New York Academy of Sciences*, Vol. 855 No. 1, p. 670.

Herz, R.S. and Engen, T. (1996), “Odor memory: review and analysis”, *Psychonomic Bulletin & Review*, Vol. 3 No. 3, pp. 300-313.

Herz, R.S., Schankler, C. and Beland, S. (2004), “Olfaction, emotion and associative learning: effects on motivated behavior”, *Motivation and Emotion*, Vol. 28 No. 4, pp. 363-383.

Higgins, J.P.T., Thompson, S.G., Deeks, J.J. and Altman, D.G. (2003), "Measuring inconsistency in Meta-analyses", *BMJ: British Medical Journal*, Vol. 327 No. 7414, pp. 557-560.

Higgins, J.P. and Green S. (Eds) (2011), *Cochrane Handbook for Systematic Reviews of Interventions*, Wiley-Blackwell, Chichester.

Hirsch, A.R. (1995), "Effects of ambient odors on slot-machine usage in a las vegas casino", *Psychology and Marketing*, Vol. 12 No. 7, pp. 585-594.

Hirsch, J. (2010), "Brain mapping for neurosurgery and cognitive neuroscience", in, Scott F.H. and Mohamed, F.B. (Eds), *BOLD fMRI: A Guide to Functional Imaging for Neuroscientists*, Springer-Verlag, New York, NY, pp. 119-159.

Hummel, T. and Nordin, S. (2005), "Olfactory disorders and their consequences for quality of life", *Acta Oto-Laryngologica*, Vol. 125 No. 2, pp. 116-121.

Inzlicht, M. and Kang, S.K. (2010), "Stereotype threat spillover: how coping with threats to social identity affects aggression, eating, decision making, and attention", *Journal of Personality and Social Psychology*, Vol. 99 No. 3, p. 467.

Johnson, S.C. (2013), "Glade® encourages Americans to embrace the power of scent: new study shows that consumers link scent to emotion, but may undervalue the positive impact scent has on our quality of life", available at: www.scjohnson.com/en/press-room/press-releases/10-04-2013/Glade-Encourages-Americans-to-Embrace-Power-of-Scent.aspx (accessed July 18, 2014).

Jones, W., Childers, T.L. and Jiang, Y. (2012), "The shopping brain: math anxiety modulates brain responses to buying decisions", *Biological Psychology*, Vol. 89 No. 1, pp. 201-213.

Kahneman, D. (2000), "Experienced utility and objective happiness: a moment-based approach", in Kahneman, D. and Tversky, A. (Eds), *Choices, Values, and Frames*, Cambridge University Press, Cambridge, MA, pp. 6736-6792.

Keller, J. and Dauenheimer, D. (2003), "Stereotype threat in the classroom: dejection mediates the disrupting threat effect on women's math performance", *Personality and Social Psychology Bulletin*, Vol. 29 No. 3, pp. 371-381.

Kremer, B., Klimek, L. and Mösges, R. (1998), "Clinical validation of a new olfactory test", *European Archives of Oto-Rhino-Laryngology : Official Journal of the European Federation of Oto-Rhino-Laryngological Societies (Eufos) : Affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery*, Vol. 255 No. 7, pp. 355-358.

Krishna, A., Elder, R.S. and Caldara, C. (2010a), "Feminine to smell but masculine to touch? Multisensory congruence and its effect on the aesthetic experience", *Journal of Consumer Psychology*, Vol. 20 No. 4, pp. 410-418.

Krishna, A., Lwin, M.O. and Morrin, M. (2010b), "Product scent and memory", *Journal of Consumer Research*, Vol. 37 No. 1, pp. 57-67.

Krishna, A., Morrin, M. and Sayin, E. (2014), "Smellizing cookies and salivating: a focus on olfactory imagery", *Journal of Consumer Research*, Vol. 41 No. 1, pp. 18-34.

Laird, D.A. (1932), "How the consumer estimates quality by subconscious sensory impressions", *Journal of Applied Psychology*, Vol. 16 No. 3, p. 241.

Lang, P.J., Bradley, M.M. and Cuthbert, B.N. (1998), "Emotion, motivation, and anxiety: brain mechanisms and psychophysiology", *Biological Psychiatry*, Vol. 44 No. 12, pp. 1248-1263.

Laroche, P. and Soulez, S. (2012), "Meta-analysis for marketing research", Vol. 27 No. 1, pp. 79-104.

LeDoux, J.E. (1996), *The Emotional Brain*, Simon and Schuster, New York, NY.

Leon, E.A., Catalanotto, F.A. and Werning, J.W. (2007), "Retronasal and orthonasal olfactory ability after laryngectomy", *Archives of Otolaryngology–Head & Neck Surgery*, Vol. 133 No. 1, pp. 32-36.

Lewis, C. (2014), "When scent crosses the ethical line", available at: https://beta.theglobeandmail.com/life/fashion-and-beauty/beauty/when-scent-crosses-the-ethical-line/article20517586/?ref=http://www.theglobeandmail.com& (accessed October 4, 2017).

Lin, M., Cross, S.N.N. and Childers, T.L. (2012), "The smell factor: individual differences in olfaction, memory, judgments and decision-making", *Advances in Consumer Research*, Vol. 40, pp. 236-240.

Lin, M., Cross, S.N.N. and Childers, T.L. (2015), "Olfactory imagery and emotions: neuroscientific evidence", in Krzysztof, K. (Ed.), *Ideas in Marketing: Finding the New and Polishing the Old: Proceedings of the Academy of Marketing Science*, Springer International Publishing, Monterey, pp. 6176-6220.

Lin, M., Cross, S.N.N. and Childers, T.L. (2016), "The scented servicescape: the impact of olfactory sensitivity on the contagion effects of ambient scent", working paper, College of Business, Iowa State University, 8 December.

Lin, M., Cross, S.N.N., Jones, W.J. and Childers, T.L. (2017), "Applying EEG in consumer neuroscience", *European Journal of Marketing*, forthcoming.

Liu, Y., Huang, H., McGinnis-Deweese, M., Keil, A. and Ding, M. (2012), "Neural substrate of the late positive potential in emotional processing", *The Journal of Neuroscience*, Vol. 32 No. 42, pp. 14563-14572.

Luck, S.J. (2005), *An Introduction to the Event-Related Potential Technique*, MIT Press, Cambridge, MA.

Marder, M. (2017), "Our polluted senses", available at: https://www.nytimes.com/2017/10/09/opinion/light-noise-pollution-senses.html?emc=edit_th_20171009&nl=todaysheadlines&nlid=45942977 (accessed October 12, 2017).

Matcalfe, J. and Mischel, W. (1999), "A hot/cool system analysis of delay gratification: dynamics of willpower", *Psychological Review*, Vol. 106 No. 1, pp. 3-19.

Matilla, A.S. and Wirtz, J. (2001), "Congruency of scent and music as a driver of in-store evaluations and behavior", *Journal of Retailing*, Vol. 77 No. 2, pp. 273-289.

Mayo, M. (2010), "Ban on strong scents make sense", available at: http://articles.sun-sentinel.com/2010-05-17/news/fl-cologne-mayocol-b051710-20100517_1_fragrance-free-perfumes-fragrance-free-workplace (accessed December 6, 2016).

Mehrabian, A. and Russell, J.A. (1974), *An Approach to Environmental Psychology*, The MIT Press, Cambridge, MA.

Michon, R., Chebat, J. and Turley, L.W. (2005), "Mall atmospherics: the interaction effects of the mall environment on shopping behavior", *Journal of Business Research*, Vol. 58 No. 5, pp. 576-583.

Mitchell, D.J., Kahn, B.E. and Knasko, S.C. (1995), "There's something in the air: effects of congruent or incongruent ambient odor on consumer decision making", *Journal of Consumer Research*, Vol. 22 No. 2, pp. 229-238.

Miwa, T., Furukawa, M., Tsukatani, T., Costanzo, R.M., DiNardo, L.J. and Reiter, E.R. (2001), "Impact of olfactory impairment on quality of life and disability", *Archives of Otolaryngology-Head &Amp; Neck Surgery*, Vol. 127 No. 5, pp. 497-503.

Morrin, M. and Chebat, J. (2005), "Person-place congruency: the interactive effects of shopper style and atmospherics on consumer expenditures", *Journal of Service Research*, Vol. 8 No. 2, pp. 181-191.

Morrin, M. and Ratneshwar, S. (2000), "The impact of ambient scent on evaluation, attention, and memory for familiar and unfamiliar brands", *Journal of Business Research*, Vol. 49 No. 2, pp. 157-165.

Morrin, M. and Ratneshwar, S. (2003), "Does it make sense to use scents to enhance brand memory?", *Journal of Marketing Research*, Vol. 40 No. 1, pp. 10-25.

Morrin, M., Krishna, A. and Lwin, M.O. (2011), "Is scent-enhanced memory immune to retroactive interference?", *Journal of Consumer Psychology*, Vol. 21 No. 3, pp. 354-361.

Morrison, M., Gan, S., Dubelaar, C. and Oppewal, H. (2011), "In-store music and aroma influences on shopper behavior and satisfaction", *Journal of Business Research*, Vol. 64 No. 6, pp. 558-564.

Nassauer, S. (2014), "Using scent as a marketing tool, stores hope it–and shoppers–will linger: how Cinnabon, Lush Cosmetics, Panera Bread regulate smells in stores to get you to spend more", available at: http://online.wsj.com/news/articles/SB10001424052702303468704579573953132979382 (accessed July 18, 2014).

Negishi, M. and Dvorak, P. (2013), "In Japan, scented fabric softeners wrinkle some noses: Boom in strong fragrances has raided a stink", available at: www.wsj.com/articles/SB10001424052702303332904579223451416639352 (accessed December 6, 2016).

Nordin, S., Millqvist, E., Löwhagen, O. and Bende, M. (2003), "The chemical sensitivity scale: Psychometric properties and comparison with the noise sensitivity scale", *Journal of Environmental Psychology*, Vol. 23 No. 4, pp. 359-367.

Oaten, M., Stevenson, R.J. and Case, T.I. (2009), "Disgust as a disease-avoidance mechanism", *Psychological Bulletin*, Vol. 135 No. 2, pp. 303-321.

Öhman, A. (2002), "Automaticity and the amygdala: nonconscious responses to emotional faces", *Current Directions in Psychological Science*, Vol. 11 No. 2, pp. 62-66.

Olofsson, J.K., Broman, D.A., Wulff, M., Martinkauppi, M. and Nordin, S. (2005), "Olfactory and chemosomatosensory function in pregnant women assessed with event-related potentials", *Physiology & Behavior*, Vol. 86 Nos 1/2, pp. 252-257.

Peeples, L. (2013), "Chemically sensitive find sanctuary in fragrance-free churches", available at: www.huffingtonpost.com/2013/10/26/chemical-sensitivity-fragrance-church_n_4163785.html (accessed December 6, 2016).

Plassmann, H., Venkatraman, V., Huettel, S. and Yoon, C. (2015), "Consumer neuroscience: applications, challenges, and possible solutions", *Journal of Marketing Research*, Vol. 52 No. 4, pp. 427-435.

Porcherot, C., Delplanque, S., Raviot-Derrien, S., Le Calve, B., Chrea, C., Gaudreau, N. and Cayeux, I. (2010), "How do you feel when you smell this? Optimization of a verbal measurement of odor-elicited emotions", *Food Quality and Preference*, Vol. 21 No. 8, pp. 938-947.

Pozharliev, R., Verbeke, W.J.M.I., Van Strien, J.W. and Bagozzi, R.P. (2015), "Merely being with you increases my attention to luxury products: using EEG to understand consumers' emotional experience of luxury branded products", *Journal of Marketing Research*, Vol. 52 No. 4, pp. 546-558.

Reimann, M., Castaño, R., Zaichkowsky, J. and Bechara, A. (2012), "How we relate to brands: psychological and neurophysiological insights into consumer-Brand relationships", *Journal of Consumer Psychology*, Vol. 22 No. 1, p. 128.

Reimann, M., Schilke, O., Weber, B., Neuhaus, C. and Zaichkowsky, J. (2011), "Functional magnetic resonance imaging in consumer research: a review and application", *Psychology and Marketing*, Vol. 28 No. 6, pp. 608-637.

Russell, J.A. (2003), "Core affect and the psychological construction of emotion", *Psychological Review*, Vol. 110 No. 1, pp. 145-172.

Schupp, H.T., Cuthbert, B.N., Bradley, M.M., Cacioppo, J.T., Ito, T. and Lang, P.J. (2000), "Affective picture processing: the late positive potential is modulated by motivational relevance", *Psychophysiology*, Vol. 37 No. 2, pp. 257-261.

Schupp, H.T., Flaisch, T., Stockburger, J. and Junghofer, M. (2006), "Emotion and attention: event-related brain potential studies", *Progress in Brain Research*, Vol. 156, p. 31.

Smeets, M.A. and Dalton, P.H. (2005), "Evaluating the human response to chemicals: odor, irritation and non-sensory factors", *Environmental Toxicology and Pharmacology*, Vol. 19 No. 3, pp. 581-588.

Spangenberg, E.R., Crowley, A.E. and Henderson, P.W. (1996), "Improving the store environment: do olfactory cues affect evaluations and behaviors?", *Journal of Marketing*, Vol. 60 No. 2, pp. 67-79.

Spangenberg, E.R., Grohmann, B. and Sprott, D.E. (2005), "It's beginning to smell (and sound) a lot like christmas: the interactive effects of ambient scent and music in a retail setting", *Journal of Business Research*, Vol. 58 No. 11, pp. 1583-1589.

Spangenberg, E.R., Sprott, D.E., Grohmann, B. and Tracy, D.L. (2006), "Gender-congruent ambient scent influences on approach and avoidance behaviors in a retail store", *Journal of Business Research*, Vol. 59 No. 12, pp. 1281-1287.

Stampler, L. (2014), "This is reason going into Abercrombie & Fitch gives you anxiety," available at: http://time.com/2799621/abercrombie-fitch-cologne-anxiety-study/ (accessed July 25, 2017).

Stevenson, R.J. (2010), "An initial evaluation of the functions of human olfaction", *Chemical Senses*, Vol. 35 No. 1, pp. 3-20.

Stevenson, R.J. and Case, T.L. (2005), "Olfactory imagery: a review", *Psychonomic Bulletin &Amp; Review*, Vol. 12 No. 2, pp. 244-264.

Teller, C. and Dennis, C. (2012), "The effect of ambient scent on consumer perception, emotions, and behaviour: a critical review", *Journal of Marketing Management*, Vol. 28 Nos 1/2, pp. 14-36.

The Nielsen Company (2016), "Consumer Neuroscience", available at: www.nielsen.com/consumerneuroscience (accessed February 18, 2016).

Van Dillen, L.F., Heslenfeld, D.J. and Koole, S.L. (2009), "Tuning down the emotional brain: an fMRI study of the effects of cognitive load on the processing of affective images", *Neuroimage*, Vol. 45 No. 4, pp. 1212-1219.

Vohs, K.D. and Heatherton, T.F. (2000), "Self-regulatory failure: a resource-depletion approach", *Psychological Science*, Vol. 11 No. 3, pp. 249-254.

Walsh, G., Shiu, E., Hassan, L.M., Michaelidou, N. and Beatty, S.E. (2011), "Emotions, store-environmental cues, store-choice criteria, and marketing outcomes", *Journal of Business Research*, Vol. 64 No. 7, pp. 737-744.

Warrenburg, S. (2005), "Effects of fragrance on emotions: moods and physiology", *Chemical Senses*, Vol. 30 No. 1, pp. 248-249.

Weinberg, A., Ferri, J. and Hacjak, G. (2013), "Interactions between attention and emotion: insights from the late positive potential", in Robinson, M.D., Watkins, E.R. and Harmon-Jones, E. (Eds), *Handbook of Cognition and Emotion*, The Guilford Press, New York, NY, pp. 35-54.

Wrzesniewski, A., McCauley, C. and Rozin, P. (1999), "Odor and affect: individual differences in the impact of odor on liking for places, things and people", *Chemical Senses*, Vol. 24 No. 6, pp. 713-721.

Yeshurun, Y. and Sobel, N. (2010), "An odor is not worth a thousand words: from multidimensional odors to unidimensional odor objects", *Annual Review of Psychology*, Vol. 61 No. 1, pp. 219-241.

Yoon, C., Gutchess, A.H., Feinberg, F. and Polk, T.A. (2006), "A functional magnetic resonance imaging study of neural dissociations between Brand and person judgments", *Journal of Consumer Research*, Vol. 33 No. 1, pp. 31-40.

Further reading

Moser, J.S., Hajcak, G., Bukay, E. and Simons, R.F. (2006), "Intentional modulation of emotional responding to unpleasant pictures: an ERP study", *Psychophysiology*, Vol. 43 No. 3, pp. 292-296.

Smith, C.A. and Ellsworth, P.C. (1985), "Patterns of cognitive appraisal in emotions", *Journal of Personality and Social Psychology*, Vol. 48 No. 4, pp. 813-838.

Appendix 1. Description for Sniffin' Sticks (stimuli)

The detection task included odors provided from the Sniffin' Sticks smell kit; chemical components of the pens are provided along with descriptions of the corresponding odors. Another 15 different scents are included in the discrimination test for the identification task, including such as orange, leather, cinnamon, peppermint, banana, lemon, liquorice, turpentine, garlic, coffee, apple, cloves, pineapple, rose (Fish was excluded because of its strong and unpleasant odor) (Table AI).

Appendix 2. The EEG chamber setup, equipment and data recording

Our study was conducted in a highly sophisticated lab developed for recording EEG including minimization of noise due to lighting, computer monitors and outside sources to reduce impedance (i.e. establish a good connection between a participant's scalp and a recording electrode). The experiment setup was designed specifically for this study, which involved presentation of the scent. Unlike common visual stimuli used in most studies, to:

- ensure odor presentation procedures were implemented in a consistent and controlled manners; and
- to minimize unwanted muscle movements that would introduce noise in the recordings, several precautions were taken to minimize possible confounding factors.

First, we used a head stand with a chin rest, similar to that used by ophthalmologists, to help participants position their heads and keep still (see Plate 1 below). A clamp was attached onto the head stand at a 45° fixed angle for the pens to be inserted, maintaining a consistent 1-inch distance from the inserted pen to the participant's nose. Two trained experimenters presented the Sniffin Sticks to the participants. Each pen was inserted in the clamp, presented for 1.5 s and participants

	Detection task		Identification task	
Pen	Set 1	Set 2	Pen	Odor
1	Octylacetat	Cinnamonaldehyd	1	Orange
2	n-Butanol	2-Phenylethanol	2	Leather
3	Isoamylacetat	Anethol	3	Cinnamon
4	Anethol	Eugenol	4	Peppermint
5	Geraniol	Octylacetat	5	Banana
6	2-Phenylethanol	Isoamylacetat	6	Lemon
7	(+)-Limonen	(+)-Fenchon	7	Liquorice
8	(−)-Carvon	(+)-Carvon	8	Turpentine
9	(−)-Limonen	Citronellal	9	Garlic
10	2-Phenylethanol	(+)-Menthol	10	Coffee
11	(+)-Carvon	Geraniol	11	Apple
12	n-Butanol	(+)-Fenchon	12	Cloves
13	Citronellal	Linalool	13	Pineapple
14	Pyridin	(−)-Limonen	14	Rose
15	Eugenol	Cinnamonaldehyd	15	Anise
16	Eucalyptol	lono	16	Fish

Notes: Octylacetat has a fruity smell, commonly found in grapefruit and other citrus fruits; cinnamonaldehyde gives a cinnamon odor; n-butanol has a banana-like odor; 2-phenylethanol has a floral pleasant odor; isoamylacetat has a banana-like odor; anethol has a anise (licorice) odor; eugenol smells of cloves; geraniol has a sweet rose odor; (+)-limonen smells like oranges and (−)-limonen has a turpentine odor; (+)-fenchon has an odor similar to camphor; R-(−) Carvon smells like caraway and S-(+) Carvon smells like spearmint; citronellal has a lemon-like odor; (+) Menthol has a peppermint odor; pyridine has a fish-like odor; eucalyptol has a camphor-like odor; linalool has a floral odor

Table AI. Description of the scents used

Plate 1.
Set up of EEG data collection chamber

were instructed to take one sniff. A practice trial was included for the participant to become familiar with the procedure. In addition, any lingering scents from the previous trials were minimized by placing odor absorbing rocks in the laboratory.

The electroencephalogram (EEG, filter 0.02-150 Hz, gain 1000, 16-bit A/D conversion) was recorded from an array of 33[2] Ag/AgCl electrodes on an electrode arrays cap (Sands Research, El Paso, TX). These electrodes include the midline sites (Fz, FCz, Cz and Pz), which are of particular interest for the purpose of our study. The electrode arrays cap was interfaced to a DBPA-1 (Sensorium Inc., Charlotte VT) that amplified and digitized the data. High quality recordings were obtained by using low impedance (<10 KΩs) standards. The EEG recording data were sampled at 2,048 Hz; no resampling procedures were taken.

After manually removing the noise sources, an intermediate band-pass filter (high 20 Hz, low 0.1 Hz) was used to remove other out-of-ERP-range noises such as electromyographic signals (EMG) and electrical line noise. Ocular artifacts were corrected using a covariance-based technique, including empirically derived estimates of the EEG associated with artifact and artifact free data (Source-Signal Imaging, San Diego). The ERP epochs, recordings ranging from −200 to 1,500 ms around stimulus onset for this study, were obtained offline for analysis (Luck, 2005).

Corresponding author
Meng-Hsien (Jenny) Lin can be contacted at: jelin@csumb.edu