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Neurophysiological responses during cooking food associated with different emotions

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ABSTRACT

Neurophysiological correlates of affective experience could potentially provide continuous information about a person's experience when cooking and tasting food, without explicitly verbalizing this. Such measures would be helpful to understand people's implicit food preferences and choices. This study examined for the first time the relation between neurophysiological variables and affective experiences under real cooking and tasting circumstances, using ingredients that were a priori expected to evoke different affective reactions. 41 participants cooked and tasted two stir-fry dishes in random order following an identical, strictly timed protocol. Once the main ingredient was chicken and the other time mealworms. EEG, ECG and skin potential were recorded continuously. Participants scored subjective valence and arousal after each cooking and tasting session. Frontal EEG alpha asymmetry showed the expected effect throughout the whole cooking and tasting session, consistent with 'approach' motivation for chicken and 'avoidance' for mealworms. Skin potential effects differed between cooking intervals but were in the expected direction. ECG variables showed an interaction with order of cooking the different dishes. Based on EEG alpha asymmetry, ECG and skin potential variables, we can estimate with 82% accuracy whether a single participant is preparing a dish with mealworms or with chicken. Our study provides evidence that it is possible to estimate experienced emotion during real-life cooking and tasting. We argue that it is important to consider that different neurophysiological and subjective measures reflect different underlying affective processes, to map them out more precisely, and to take advantage of these differences.

1. Introduction

Positive emotions are critical for the success of food products in the market place. Yet, surprisingly little is known about emotional processes during consumer-product interactions in food preparation and cooking. Recent years have witnessed a growing body of research on the development of measurement tools to capture emotional responses towards foods. These tools include a range of explicit (self-reported) questionnaires to measure food product-evoked emotions (King & Meiselman, 2010; Cardello et al., 2012; Laurans & Desmet, 2012; Jaeger & Hedderley, 2013; Den Uijl, Jager, Zandstra, De Graaf, & Kremer, 2016), implicit measures that rely on reaction times to capture approach-avoidance motivations to food stimuli (Davies, El-Deredy, Zandstra, & Blanchette, 2012; Piqueras-Fiszman, Kraus, & Spence, 2014; Kraus & Piqueras-Fiszman, 2016), and autonomic nervous system responses on the sight, smell and taste of odors and foods (De Wijk, Kooijman, Verhoeven, Holthuysen, & De Graaf, 2012; He, Boesveldt, De Graaf, & De Wijk, 2014, 2016; De Wijk, He, Mensink, Verhoeven, & De Graaf, 2014). However, despite these developments, this area of research is still in a stage of relative infancy and additional research is needed to develop valid measures of emotions evoked by dynamic continuous interactions and experiences with food (*i.e.*, throughout cooking). So far, research in the area of cooking and food preparation investigated mainly functional aspects such as cooking skills and home cooking equipment in relation to healthy eating behavior (Short, 2003; Larson, Perry, Story, & Neumark-Sztainer, 2006; Bongoni, Steenbekkers, Verkerk, van Boekel, & Dekker, 2013; Bongoni, Verkerk, Dekker, & Steenbekkers, 2015). New methods need to be developed that quantify people's emotional experiences in

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response to food stimuli throughout dynamic cooking processes. Acquiring such methods is essential if we want to be able to successfully deliver emotional benefits and health to consumers by making nutritious cooking and eating desirable, enjoyable, easy to understand and do.

If we want to know people's emotions or feelings, we can simply ask them. However, verbalizing emotions can be difficult and will be affected by cognitive and memory processes. Verbal reports will only include conscious experience that the individual chooses to share. Asking people about their affective processes can even change their normal way of affective evaluation and behavior as indicated by Wilson et al. (1993). They asked participants to verbalize and motivate their liking of art posters, after which they could choose a poster of their liking. Compared to a control group, these participants chose a different poster and were less satisfied about this choice three weeks later. Neurophysiological correlates of affective experience could add information to subjective ratings because they do not require verbalization and in principle provide continuous information without requiring distracting questions about currently felt emotions.

Reviews on reported associations between emotions and physiological signals show that these links are far from clear-cut (Kreibig, 2010; Dockray & Steptoe, 2010). This is not surprising when one considers that the function of physiological processes is not to inform us about experienced emotions but rather to prepare for relevant action. These can coincide (*e.g.* the emotion of anger is likely to be associated with implicitly preparing to fight) but this is not always clearly the case. As long as we do not know the exact mapping between psychological concepts and physiological processes yet (Cacioppo & Tassinary, 1990), it is important to look at this within the context and under the circumstances of interest. In the present study, we investigated the association between emotion and physiological signals during cooking and tasting. We examined whether estimating emotions on the basis of these signals is possible on the level of an individual person, given the noise that movements will introduce into the signal. Different physiological signals and their combinations were explored.

As a start, we focussed on a case where we expected quite extreme types of emotions: we compared cooking with chicken to cooking with mealworms. While insects are highly valued and considered tasty in some cultures (Hanboonsong, 2010; Ramos-Elorduy, 1997), in Western countries individuals often react with disgust to the idea of eating insects (Looy, Dunkel, & Wood, 2014; Rozin & Fallon, 1987; Tan et al., 2015; Yen, 2009; Verbeke, 2015). In the light of the valence-arousal model of emotions (Russell, 1980), characterizing emotions by respectively their pleasantness and intensity, cooking with mealworms was expected to evoke higher arousal and lower valence than cooking with chicken.

Arousal is a component of emotion that has relatively clear physiological correlates in electrodermal activity (Roth, 1983). Sweat glands, that are mainly responsible for electrodermal activity, are exclusively innervated by the sympathetic 'fight-or-flight' autonomous nervous system. Strong activation of the sympathetic system relative to the parasympathetic 'rest-and-digest' autonomous nervous system reflects physiological arousal. The heart is innervated by both sympathetic and parasympathetic systems. However, high frequency heart rate variability, mainly reflecting the extent to which heart rate is tuned to breathing, is mostly determined by the parasympathetic system. High heart rate variability is reported to be associated with low stress or arousal and vice versa (Grossman & Taylor, 2007; Berntson et al., 1997). In contrast to what is often believed, heart rate and arousal do not seem to be directly associated. Heart rate rises with arousal, *e.g.* in situations with (social) anxiety (Kirschbaum, Pirke, & Hellhammer, 1993; Brouwer & Hogervorst, 2014; Hogervorst, Brouwer, & Vos, 2013), recalling emotional (versus neutral) memories (Vrana & Lang, 1990; Cuthbert et al., 2003; Rainville, Bechara, Naqvi, & Damasio, 2006) or smelling unpleasant odors and tasting disliked foods (He et al., 2014; De Wijk et al., 2012), but the reverse relation has been found as well, *e.g.* in reading emotional sections in a book (Brouwer, Hogervorst, Holewijn, & Van Erp, 2015), and viewing negatively valenced images (Bradley & Lang, 2000). The negative relation between arousal and heart rate is possibly mediated through a negative relation between sensory attention and heart rate (Lacey & Lacey, 1970; Venkatraman et al., 2015).

For valence, there are no clear correlates found in peripheral physiology. While research on viewing emotional images consistently finds that positively valenced images generate heart rate acceleration (*e.g.* Greenwald, Cook, & Lang, 1989; Lang, Greenwald, Bradley, & Hamm, 1993), this does not generalize to other situations (Kreibig, 2010). However, brain signals may provide us with information about experienced valence. Focusing on what we can detect using EEG, a suitable variable would be asymmetric frontal cortical activation where the inverse of EEG alpha power (8–13 Hz) can be taken as an indication of regional brain activation (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998). Originally, strong left activation has been associated with positive valence and strong right activation with negative valence. Later research (reviewed by Harmon-Jones, Gable, & Peterson, 2010) indicated that rather than positive and negative valence, the distinction is more consistent with approach and avoidance motivation (where valence and motivation often overlap, but not always, such as in the case of anger which can be described as a low valence emotion paired with an approach motivation). The approach-avoidance dimension maps perfectly well onto our case of food stimuli, where we expect stronger avoidance for mealworms compared to chicken. Indeed, the literature on disgust has explicitly associated this emotion with avoidance or withdrawal in order to protect the body from possibly harmful elements (Croy et al., 2013; Rozin, Haidt, & McCauley, 2000; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). EEG asymmetry studies on pictures of desserts showed greater left activation for individuals with stronger approach motivation (longer time since eaten, more liking for dessert; Harmon-Jones & Gable, 2009; Gable & Harmon-Jones, 2008).

While the starting point of our study was to examine responses to two foods that differ in valence and arousal, we already referred to two other emotion-related constructs, namely approach-avoidance and disgust. With respect to peripheral measures associated with disgust, both increases in sympathetic activity and parasympathetic activity measures have been found. Relatively strong sympathetic activity may be related to disgust-related avoidance and escape behavior (Ottaviani, Mancini, Petrocchi, Medea, & Couyoumdjian, 2013). Kreibig (2010) proposes a distinction between disgust related to contamination or pollution, and mutilation-related disgust. The former type is closer to our type of disgust, and generally coincides with sympathetic-parasympathetic co-activation (Kreibig, 2010). Kreibig (2010) summarizes published reports on contamination-related disgust as usually showing increased HRV (which might be related to faster, shallow breathing that is also observed), an increase or no change in heart rate and increased electrodermal activity. Note that a disgust-related increased HRV goes in the opposite direction as the arousal-related decrease in HRV (Grossman & Taylor, 2007; Berntson et al., 1997) that we mentioned in earlier in this introduction.

In the present study, each participant cooked and tasted two times a stir-fry dish following a strictly timed protocol. This protocol was exactly the same except for the fact that once, the main ingredient was chicken and the other time it was mealworms. The protocol was divided in distinct phases for which we compared