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Electrodermal responses during appetitive conditioning are sensitive to contingency instruction ambiguity

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ABSTRACT

Studies on human appetitive conditioning using food rewards can benefit from including psychophysiological outcome measures. The present study tested whether the skin conductance response can function as a measure of differential responding in an appetitive conditioning paradigm including an acquisition and extinction phase, and examined which time window during a trial is most sensitive to conditioning effects. As a secondary aim, the effects of ambiguous vs. non-ambiguous contingency instructions on conditioned responses (skin conductance responses, US expectancies, chocolate desires, and CS evaluations) were assessed. Results indicated differential skin conductance responses in an anticipatory time window and during unexpected omission of the US in early extinction. Interestingly however, anticipatory responses were only found for participants who received ambiguous contingency instructions – possibly indicating a call for additional processing resources in response to the ambiguous CS+. Further, ambiguous instructions slowed the extinction of US expectancies but did not influence chocolate desires and CS evaluations. It is concluded that skin conductance can function as a sensitive measure of differential responding in appetitive conditioning, though its sensitivity might depend on the specific task context.

1. Introduction

The prevalence of overweight and obesity has reached epidemic proportions. Currently, more than two-thirds of all U.S. adults are either overweight or obese (Ogden et al., 2014). Experts agree that the changed food environment is largely responsible for this (Swinburn et al., 1999), since its abundant food cues can easily elicit appetitive responses such as food cravings that promote overeating. Pavlovian learning has been proposed to play an important role in the development of these appetitive responses: after repeated pairings of a stimulus (e.g., the sight and smell of food, or a certain context) with food intake, the stimulus becomes a predictor (food cue) for intake that promotes appetitive responses and food intake (Bouton, 2011; Jansen, 1998; Jansen et al., 2011).

In line with a learning-based account, conditioning studies have shown that after a few pairings of a neutral stimulus (e.g., a box) with food intake (e.g., eating a piece of chocolate; unconditioned stimulus or US), this stimulus (conditioned stimulus + or CS+) elicits conditioned appetitive responses (CRs), relative to a stimulus not followed by intake (CS−). These responses generally diminish when the CS+ is no longer followed by the US during extinction (e.g., Jansen et al., 2016; van den Akker et al., 2014; van den Akker et al., 2015; Van Gucht, Vansteenwegen, Beckers, & Van den Bergh, 2008). CRs that have been examined in these human appetitive conditioning studies often include psychological (self-reported US expectancies, cravings or desires to eat, and CS evaluations) and sometimes behavioural responses (food consumption or choice, and computer tasks) (Bongers et al., 2015; van den Akker et al., 2013; Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008). There are limitations, however, to relying solely on self-report and behavioural measures. For example, their assessment may alter responses on subsequent measurements (Gawronski et al., 2015; Lipp and Purkis, 2006), and self-report measures in particular can be sensitive to experimental demand (e.g., Lipp, 2006). In addition, verbal/cognitive and behavioural measures likely do not cover all indices of (appetitive) learning, since multiple response systems are thought to be involved in conditioning (Beckers et al., 2013; Delamater and Oakeshott, 2007).

Psychophysiological measurement of conditioned appetitive responding may overcome at least some of these limitations. Although several psychophysiological measures may be suitable for measuring differential responding in appetitive conditioning (Blechert et al., 2016; Franken et al., 2011; Meyer et al., 2015; O'Doherty et al., 2003), one particularly promising, easy-to-use, and nonintrusive measure is skin conductance. Skin conductance measures activity of the sympathetic

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nervous system which is thought to reflect arousal (Dawson et al., 2007). Such arousal can originate from various cognitive and emotional processes (Critchley, 2002). Skin conductance is heightened during exposure to the sight and smell of palatable food and other appetitive substances (e.g., Carter and Tiffany, 2001; Nederkoorn et al., 2000), and it is widely used as a measure of differential responding in fear conditioning studies, in which it may primarily index explicit learning about the CS-US contingencies (Hamm and Weike, 2005). In the appetitive field, several conditioning studies have examined skin conductance, reporting a successful acquisition of conditioned skin conductance responses to reward-associated CSs (e.g., Andreatta and Pauli, 2015; Glautier et al., 1994; Klucken et al., 2015; Kruse et al., 2017; but see Field and Duka, 2001). The USs that were used in these studies rarely involved *food intake*, however. One study that used a food US reported differential skin conductance responses during exposure to a food-associated CS + (a shape; Andreatta and Pauli, 2015). However, this CS + (but not the CS −) was always accompanied by a picture of the food US. Since food pictures are potent CSs on their own that elicit appetitive responses (Boswell and Kober, 2016), it is impossible to determine whether differential responding was due to presentation of the existing cue (food picture) or due to the newly conditioned cue – i.e., it is unclear whether differential skin conductance responses reflected conditioning effects.

Skin conductance can be measured in different time windows during a conditioning trial (Boucsein, 2012; Prokasy and Kumpfer, 1973). In fear conditioning studies, it is often measured directly after presentation of a CS (first-interval response or FIR), or, in case of longer CS-US intervals, in the period prior to US delivery (second-interval response or SIR; Lovibond et al., 2008; Prokasy and Ebel, 1967). In addition to measuring skin conductance during an anticipation period, one may also observe differential responding after unexpected omission of a shock US (i.e., on a non-reinforced CS + trial after CS offset; Dunsmoor and LaBar, 2012; Grings et al., 1962; Spoormaker et al., 2011). This has been termed 'third-interval omission response' (TOR) or offset SCR'(skin conductance response)', and possibly reflects "surprise" or "relief" upon unexpected omission of the aversive US (Grings et al., 1962; Rescorla and Wagner, 1972; Spoormaker et al., 2011). In appetitive conditioning, measuring skin conductance responses during an expectancy mismatch (e.g., during extinction) could provide an additional measure of learning, possibly reflecting surprise, or frustration/disappointment, about the non-occurrence of the US (Amsel, 1992; Papini and Dudley, 1992; Spoormaker et al., 2011).

Conditioned responses (including skin conductance) are likely not solely based on physical pairings between a CS and a US. Studies have shown that contingency instructions can have a big impact on responding as well. For example, verbal instructions about the CS-US contingency (e.g., that the CS + predicts a shock) can establish conditioned fear responses in the absence of actual CS-US pairings (e.g., Cook and Harris, 1937; Raes et al., 2014), and information suggesting a reversal of CS-US contingencies after conditioning (e.g., informing participants that the CS + is no longer followed by a shock) can reverse fear responses (e.g., Cook and Harris, 1937; Mertens and De Houwer, 2016). In many conditioning studies, contingency instructions are provided prior to acquisition, guiding a participant's attention towards the CS-US relationship (e.g., "one of these boxes will sometimes contain something to eat, whereas the other box will never contain anything"). This is done because US expectancies are likely necessary for the development of conditioned (appetitive) responses (Hogarth and Duka, 2005; Lovibond and Shanks, 2002; van den Akker et al., 2013). The precise wording of the contingency instruction might however impact subsequent learning. Specifically, using an ambiguous contingency instruction like "the box will *sometimes* contain chocolate" (which may be used to account for the fact that the stimulus is not followed by the US during extinction) could result in a pattern of responding similar to that induced by a partial reinforcement schedule, in which the CS-US contingency is < 100%, thereby leading to an attenuated CR during acquisition (e.g., interfering with a successful acquisition of differential skin conductance responses; Dunsmoor et al., 2007), and a slowed extinction (i.e., the partial reinforcement extinction effect; e.g., van den Akker et al., 2014). In the present study, we investigated the effects of a subtle difference in the wording of contingency instructions on conditioning by omitting the word *sometimes* in one condition.

The primary aim of the present study was to examine whether skin conductance can be used as a measure of conditioned responding in a differential appetitive conditioning paradigm, and to examine which time window provides the most sensitive measure for differential responding – after CS onset (FIR), right before the US is imminent (SIR), or after CS offset (TOR). In addition, the influence of an ambiguous contingency instruction (either including the word *sometimes* or not) on conditioned responses (US expectancies, desires for chocolate, CS evaluations, and skin conductance) was examined. It was expected that skin conductance would be heightened in response to CS + vs. CS − trials after acquisition, and especially in the time window when the US was imminent. It was also hypothesized that an US omission response in CS + vs. CS − trials would occur when the US was unexpectedly not provided, particularly in early extinction when US omission would be most surprising. Finally, it was expected that relatively ambiguous instructions (ambiguous condition) would attenuate both the acquisition and extinction of conditioned responses, compared with a condition in which the word "sometimes" was omitted (non-ambiguous condition).

2. Methods and materials

2.1. Participants

Sixty-four participants took part in the study. Of these, four participants were excluded: three because they were not aware of the contingency between the CS and US, and one due to technical errors. These participants were replaced by four additional participants to ensure full counterbalancing. Participants were eligible to participate in the study if they were undergraduate female students, right-handed, aged between 17 and 25 years, and had indicated to like chocolate. It was ensured that none of the participants had previously participated in an appetitive conditioning study. Only females were included to reduce variability in responding. All participants were instructed to have a small meal (such as a sandwich) two hours prior to participation and to refrain from calorie intake thereafter. As a cover story, participants were told the study was about attention and taste perception. Participants received either a monetary reward (€ 7,50) or course credit for participation. The study was approved by the local ethical committee.

2.2. Stimuli

Two geometrical shapes [a blue square (9.3 cm wide) and a yellow circle (10.4 cm in diameter)] were used as conditioned stimuli. These were displayed on a computer screen in front of the participant. Which shape served as CS + and CS − was counterbalanced between participants. A small piece of Belgian milk chocolate (approximately 1.3–1.5 g, Rousseau chocolate) placed in a small cup functioned as US.

2.3. Measures

Skin conductance: Electrodermal activity was recorded using Ag/AgCl electrodes (8 mm) which were attached to the volar surfaces of the medial phalanges of the index and middle fingers of the left hand (leaving the right hand to give US expectancy and chocolate desire ratings). The electrodes were filled with isotonic electrode paste (0.5% saline in a neutral base). The skin conductance signal was amplified using a BrainAmp ExG device and passed to Brain Vision Recorder 2.0 software (Brain Products, Gilching, Germany). The sampling rate was 500 Hz.