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Exploring the mechanism of dishabituation

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ABSTRACT

In this study we explored elicitation and habituation of the orienting reflex (OR) in the context of indifferent and significant stimuli, particularly aiming to clarify the mechanism driving dishabituation. An in-depth analysis of the mechanisms of electrodermal habituation and dishabituation was conducted, focusing on the role of state measures as determinants of the phasic response profile. Twenty-four young adult participants completed an auditory dishabituation task while electrodermal activity was recorded. Participants listened to a series of 10 innocuous tones of the same frequency (standards), followed by a deviant tone of a different frequency, and succeeded by 2–4 tones of the same frequency as the initial 10 stimuli. All stimuli had a random stimulus onset asynchrony of 5–7 s. Participants completed an indifferent condition in which there was no task in relation to the stimuli, and a significant condition where instruction was given to count the stimuli silently; order was counterbalanced between participants. As predicted, both skin conductance responses (SCRs) and skin conductance levels (SCLs) were larger for the significant than the indifferent condition. The initial phasic ORs were dependent on pre-stimulus arousal level, and there were significant decreases in both SCR and SCL over the first 10 standards in both conditions. Phasic response recovery was apparent to the deviant stimulus, and dishabituation to the following standard stimulus; both effects were enhanced in the significant condition. Sensitisation was apparent in SCL following the initial and deviant stimuli, but the extent of this was confounded with incomplete resolution of the preceding phasic OR in the significant condition. In the indifferent condition, dishabituation was independent of deviant-related sensitisation; this could not be tested in the significant condition. These findings suggest that dishabituation is not a process of sensitisation, but rather, a disruption of the habituation process.

1. Introduction

The process of habituation is selective and has specific characteristics, which distinguishes it from other forms of response decrement attributed to fatigue or neuronal refractory periods (Thompson, Berry, Rinaldi, & Berger, 1979; Thompson & Spencer, 1966). In a recent re-examination of the characteristics of habituation, Rankin et al. (2009) note that for response decrement to be identified as habituation, it is necessary to demonstrate response recovery and dishabituation. Response recovery can be observed as an increase in response magnitude when a series of repetitive stimuli is interrupted by a deviant stimulus (Webster, Dunlop, & Simons, 1965), and subsequent dishabituation is demonstrated by amplified responding to the re-presentation of an habituated stimulus following an interpolated deviant (Barry & James, 1981; Siddle & Packer, 1987).

Response habituation has been extensively explored in the context of the orienting reflex (OR), which is conceptualised as the unit of attentional processing responsible for directing an organism towards changes in its environment (Barry, 2009). The OR is believed to serve an adaptive purpose that "ensure[s] optimal conditions for [the] perception of a stimulus" (Sokolov, 1963b, p. 11), and has been linked to learning mechanisms. Typically, Western psychophysiological research has focused on quantifying the OR as a rapid, short-term (or phasic) reaction by an organism in response to an innocuous novel stimulus (Barry, 2004).

Sokolov (1960, 1963a, 1963b) explored habituation in phasic electrodermal activity (now measured by the skin conductance response, SCR), in conjunction with its tonic electrodermal counterpart (now measured as skin conductance level, SCL). Tonic electrodermal changes are longer, slower, and state-related, and have been associated with the arousal level of the organism (Barry & Sokolov, 1993). Sokolov's (1963b) neuronal model mechanism of the phasic OR included this tonic state measure as an amplifier of the phasic reflex.

In a different theoretical account of the OR, the dual-process theory of habituation, Groves and Thompson (1970) describe two theoretical processes (habituation [H] and sensitisation [S]), which are elicited by a stimulus, and interact to determine OR magnitude.

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H is a pathway-specific decremental process that reflects the novelty of a stimulus, and S is a state process that demonstrates an initial increment to the presentation of a novel stimulus. The S process regulates the outcomes of the H-process and, essentially, can act to amplify response magnitude. Dual-process theory has a unique interpretation of the mechanism driving dishabituation. Thompson's (2009) recent overview reiterates that dishabituation is "not a disruption of habituation but rather an independent superimposed process of sensitization" (p. 130). This position is different from that of Sokolov (1963b), who suggests that dishabituation is a disturbance in the process of habituation.

Sokolov (1963b) reported that significant stimuli yield larger OR amplitudes, which habituate more slowly (compared to when stimuli are indifferent[1]) in the context of heightened arousal, and this has been confirmed in other research (e.g. Barry, 2004). Neither Sokolov's neuronal model, nor dual-process theory, entirely account for the response characteristics associated with significant stimuli (Barry, 2004). Although there has been at least one attempt to extend Sokolov's neuronal model to account for the effects of stimulus significance (Gati & Ben-Shakar, 1990), the neuronal model does not contain a mechanism to generate the observed significance-related arousal increases. Similarly, dual-process theory is unable to predict the arousal difference associated with significant stimuli. In contrast, Maltzman's (1979a, 1979b, 1990) concept of the voluntary OR predicts the significance effects observed by Sokolov (1963b). The voluntary OR is the outcome of cortical activation related to an individual's differential pre-existing response tendencies (not necessarily conscious) in relation to a particular stimulus, and may reflect instructions, conditioning, prior attitudes, interests, etc. This cortical activation is reflected in the increased arousal and phasic responding associated with significant stimuli.

The rationale of this study was to explore the role of arousal in modulating phasic OR amplitudes. Aiming to replicate the novelty and significance effects in electrodermal activity reported by Barry (2004), it was thus hypothesised that SCR would show a systematic response decrement with repetition of a stimulus, response recovery to a deviant stimulus, and dishabituation to the re-presentation of the habituated stimulus, whether or not the stimuli were significant. In addition, it was anticipated that SCRs would demonstrate effects due to significance akin to those described by Sokolov (1963b).

Barry and Sokolov (1993) had identified pre-stimulus SCL as an index corresponding to Sokolov's arousal/amplifier, and as demonstrating the initial enhancement characteristic of dual-process theory's sensitisation. Hence it was predicted that pre-stimulus SCLs would decrease with stimulus repetition, and, in line with Barry (2004), be enhanced for the significant compared to the indifferent condition. An interruption in the systematic decrement of SCL was expected to be apparent as an increase in arousal (sensitisation) at trial 2, following the initial stimulus, and at trial 12, following the deviant. This hypothesis is in line with properties of the S process, described in dual-process theory. Barry (2004) reported that the initial enhancement was independent of the phasic response to trial 1, an important prerequisite for identifying an arousal increase as sensitisation rather than an incomplete resolution of the preceding phasic response.

Furthermore, in accordance with both Sokolov's (1963b) neuronal model and dual-process theory, it was predicted that the initial phasic OR would be dependent upon initial arousal level.

To clarify the mechanism of dishabituation, a unique prediction derived from dual-process theory was tested. Groves and Thompson (1970) contend that "dishabituation is simply an instance of sensitization, a superimposed increase in responsiveness that does not in fact disrupt the process of habituation" (p. 420). This implies that the increase in SCR associated with dishabituation will directly depend upon the corresponding increase in SCL associated with the deviant-related sensitisation. If this prediction were shown to be false, it would argue against this aspect of dual-process theory, and suggest that dishabituation is instead, a disruption of the habituation process (Sokolov, 1963b).

[1] The effects of indifferent stimuli are determined solely by their physical properties.

2. Method

2.1. Participants

Twenty-four undergraduate students participated in this study in return for course credit. The sample included 12 males and 12 females (21 right-handed and 3 left-handed), who had a mean age of 19.2 ($SD = 2.2$) years. All provided written consent prior to commencing the experiment, and were free to withdraw at any time without penalty. Individuals taking psychotropic medication were excluded, as were those with self-reported neurological or psychiatric illnesses. Participants had refrained from psychoactive substances for at least 12 h, and from tea, coffee, alcohol, and tobacco for at least 2 h prior to testing. All participants had normal or corrected-to-normal vision.

2.2. Procedure

After providing informed consent, participants were required to complete a demographic and screening questionnaire, and were fitted with electrodermal recording apparatus.

Participants were seated in an air-conditioned room 600–800 mm in front of a 19" Dell LCD monitor (REV A00) and instructed to fixate on a 10 × 10 mm grey cross displayed in the centre of a black background. Acoustic stimuli were delivered binaurally through Sony MDR V700 circumaural stereo headphones, and consisted of 1000 and 1500 Hz tones of 50 ms duration (15 ms rise/fall time), at 80 dB SPL, with a random stimulus onset asynchrony (SOA) of 5–7 s. The paradigm included 10 standard tones of the same frequency, followed by a deviant tone of a different frequency, and succeeded by 2–4 tones of the same frequency as the initial 10 stimuli. Standard and deviant stimuli were counterbalanced between 1000 and 1500 Hz. All participants completed two conditions presented approximately 3 min apart. In the indifferent condition, participants were instructed that there was "no task in relation to the sounds", while in the significant condition, participants were directed to "silently count the sounds and report to the experimenter at the end of the experiment". Order of conditions was also counterbalanced between subjects.

This procedure was approved by the joint University of Wollongong and South Eastern Sydney/Illawarra Area Health Service Health and Medical Human Research Ethics Committee.

2.3. Materials and apparatus

Electrodermal data were recorded from the distal volar surface of digits II and III of the non-dominant hand using sintered silver/silver-chloride (Ag/AgCl) electrodes, filled with isotonic electrode paste of 0.05 M NaCl in an inert ointment base. Skin conductance was sampled using a constant voltage device (UFI Bioderm model 2701) at 0.5 V. The DC-coupled skin conductance output was sampled at 1000 Hz using a Neuroscan Synamps 2 digital signal-processing system and Neuroscan 4.3.1 Acquire software, and were stored on a Dell Optiplex 755 computer. Stimulus presentation was controlled by a linked stimulus computer using Neurobehavioral Systems Inc. Presentation V 13.0 Build 01.23.09 software.