

PRELIMINARY EVIDENCE FOR TWO INDEPENDENT LEARNING MECHANISMS
VIA ELECTRODERMAL RESPONSES TO VISUAL STIMULI

A Thesis
by
ANDREW J. GRAVES

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APPROVED BY:

Kenneth M. Steele, Ph.D.
Chairperson, Thesis Committee

Mark C. Zrull, Ph.D.
Member, Thesis Committee

James C. Denniston, Ph.D.
Member, Thesis Committee

James C. Denniston, Ph.D.
Chairperson, Department of Psychology

Max C. Poole, Ph.D.
Dean, Cratis D. Williams School of Graduate Studies

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Abstract

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Andrew J. Graves
B.A., B.S., Appalachian State University
M.A., Appalachian State University

Chairperson: Kenneth M. Steele

There is debate among learning theorists regarding the mechanisms underlying human associative learning (Mitchell, De Houwer, & Lovibond, 2009). Some researchers argue a single-process drives human associative learning, a propositional model guided by higher-order reasoning (Mitchell et al., 2009). Other researchers argue for a dual-process model, in which two independent processes drive human associative learning, one propositional and sensitive to stimulus prediction, the other automatic and sensitive to stimulus pairing (Sloman, 1996). The current study tested if the single-process model made either correct or incorrect predictions in the Perruchet paradigm (Perruchet, 1985). The Perruchet paradigm induces a state of uncertainty regarding stimulus prediction, dissociating participants' expectancy of an unconditioned stimulus (US) and physiological/ behavioral response to a conditioned stimulus (CS), which results in unexplainable predictions in the context of the single-process model (Mitchell et al., 2009). Influenced by the work of McAndrew, Jones, McLaren, and McLaren (2012), the adapted Perruchet paradigm for the current study predicted an opposite linear pattern between expectancy of the US and skin

conductance response (SCR) to the CS as a function of sequential stimulus pairing. The results generally supported this hypothesis, expanding the Perruchet effect to a visual stimulus paradigm and to a phasic SCR analytic procedure previously unexamined in this experimental context. Future experiments will address limitations of the current study, notably stimulus timing, stimulus intensity, and weak stimulus contiguity.

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Dedication

I dedicate this thesis to my mom, Virginia Pharaoh.

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Preliminary Evidence for Two Independent Learning Mechanisms via Electrodermal

Responses to Visual Stimuli

Andrew J. Graves

Appalachian State University

Author Note

Andrew J. Graves, Department of Psychology, Appalachian State University

Correspondence concerning this article should be addressed to Andrew J. Graves,
Department of Psychology, Appalachian State University, Boone, NC 28608. Email:
gravesaj@appstate.edu

Abstract

There is debate among learning theorists regarding the mechanisms underlying human associative learning (Mitchell, De Houwer, & Lovibond, 2009). Some researchers argue a single-process drives human associative learning, a propositional model guided by higher-order reasoning (Mitchell et al., 2009). Other researchers argue for a dual-process model, in which two independent processes drive human associative learning, one propositional and sensitive to stimulus prediction, the other automatic and sensitive to stimulus pairing (Sloman, 1996). The current study intended to collect evidence supporting either the single-process model or dual-process model. We tested if the single-process model made either correct or incorrect predictions in the Perruchet paradigm (Perruchet, 1985). The Perruchet paradigm induces a state of uncertainty regarding stimulus prediction, dissociating participants' expectancy of an unconditioned stimulus (US) and physiological/ behavioral response to a conditioned stimulus (CS), which results in unexplainable predictions in the context of the single-process model (Mitchell et al., 2009). Influenced by the work of McAndrew, Jones, McLaren, and McLaren (2012), the adapted Perruchet paradigm for the current study predicted an opposite linear pattern between expectancy of the US and skin conductance response (SCR) to the CS as a function of sequential stimulus pairing. The results generally supported this hypothesis, expanding the Perruchet effect to a visual stimulus paradigm and to a phasic SCR analytic procedure previously unexamined in this experimental context. Future experiments will address limitations of the current study, notably stimulus timing, stimulus intensity, and weak stimulus contiguity.

Keywords: Perruchet effect, associative learning models, classical conditioning, expectancy, skin conductance response

Introduction

Associative learning is the process of making connections between two events (De Houwer, Thomas, & Baeyens, 2001). There is debate among learning theorists regarding the mechanisms underlying human associative learning (Mitchell et al., 2009). Some researchers argue a single-process model drives human associative learning, a propositional model guided by higher-order reasoning. Other researchers propose a dual-process model, in which two independent processes drive human associative learning, one propositional in nature and sensitive to stimulus prediction, the other automatic and sensitive to stimulus pairing, sometimes defined as the forming of a link between two events (Sloman, 1996).

The common component to both the single-process model and dual-process model is that both incorporate a propositional element, requiring and utilizing cognitive resources. The single-process model presumes all learning effects in humans are explainable through higher-order reasoning and cognitive processes, and that learned associations do not automatically form through lower-order processes. The unique component to the dual-process model is that links between two events form when stimuli are contiguous, or connected by time. The links presumably form independently from cognition and contribute to learned associative responses (Perruchet, Cleeremans, & Destrebecqz, 2006).

To illustrate, if a heroin addict felt withdrawal symptoms at the sight of a syringe, the single-process model would predict the addict was consciously aware of the relationship between the syringe and heroin as well as aware of the associative cause of the withdrawal symptoms simply by viewing the syringe. The dual-process model would predict that cognitive processes factored into the associative cause of the withdrawal symptoms, but also would uniquely factor the formation of a link between the syringe and heroin through lower-

order processes, and this supposed link would form independently from cognitive processes. While the two supposed processes would operate independently, they would naturally manifest behaviorally in similar ways. In this example, it is not clear how the association formed, as both processes resulted in the same consequence, withdrawal.

Researchers agree that cognitive processes factor into human associative learning, but there is not consensus on the existence of a link-based learning mechanism (Mitchell et al., 2009). This is due to the confounding nature of the two models, that is the single-process model and dual-process model make identical predictions in most experimental designs. Take for example Pavlov's (1927) salivation experiments. In these experiments, Pavlov presented a tone and then subsequently presented food to dogs in a trial-by-trial fashion. After consistent pairings of the tone and food, dogs salivated to the tone before food presentation, producing digestive responses to the tone itself.

The dogs' salivation to tones prior to presentation of food can be interpreted two ways. One interpretation, although difficult to represent empirically, is the dogs were consciously aware the tone predicted food and thus produced a digestive response directly in anticipation of the food. If the tone sounded, and food reliably followed, the tone became a useful signal or predictor. This illustrates a propositional interpretation of the learning effect. Another interpretation is the experimenter paired tone and food on enough trials such that the tone adopted the same digestive effect as food. Because the tone and food were temporally connected, the excitation of the digestive response passively transferred to the tone. This illustrates a link-based interpretation of the learning effect. It is difficult to determine which interpretation is correct in this simple experimental design. If a tone reliably predicts the presentation of food, and food is only presented in the context of the tone, the tone is both

predictive of food and contiguous with food. The predicative component strengthens the propositional connection between the two events while the contiguous component strengthens the link between the two events, thus in this design the single-process model and dual-process model would predict similar outcomes.

Albeit limited, some research suggests people can learn associations through a lower-order link-based mechanism alone (see Mitchell et al., 2009, for a review). The limited amount of research supporting this argument is again largely due to the confounding nature of most conditioning experimental designs, in which the single-process model and dual-process model make similar predictions. There are at least two research areas that produce evidence supporting the dual-process model over the single-process model (Mitchell et al., 2009). Literature from the Evaluative Conditioning (EC) research area and the Perruchet paradigm research area provide some evidence for two independent learning systems. The EC research area influenced the rationale to conduct the current study, while the Perruchet paradigm influenced the experimental design for the current study.

Evaluative Conditioning

EC is the transfer of emotional valence from one stimulus to another through stimulus pairing. Through EC, the perception of a neutral valence stimulus acquires a negative valence when paired with another negative valence stimulus, and the perception of a neutral valence stimulus acquires a positive valence when paired with another positive valence stimulus (Walther, Weil, & Langer, 2011). EC is an associative learning effect similar to Pavlovian Conditioning (PC) (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). However, EC often differs from PC in terms of procedure. In the EC paradigm, the conditioned stimulus (CS) is a neutral stimulus and the unconditioned stimulus (US) is a stimulus with

positive or negative valence. In the PC paradigm, the CS is a neutral stimulus and the US is a biologically relevant stimulus (e.g., electric shock). EC research usually measures self-reported beliefs towards a CS, while PC research usually measures physiological responses towards a CS. The current study will combine elements from the EC and PC paradigm, using stimulus sets that fit more under the EC paradigm but measuring responses that fit more under the PC paradigm.

The pioneering study for EC used a picture-picture paradigm. In this study, Levey and Martin (1975) presented contiguous pairings of pictures to participants. The contiguous pairings consisted of neutral valence pictures with positive valence pictures or neutral valence pictures with negative valence pictures. Participants evaluated neutral valence pictures more positively when paired with positive valence pictures, and participants evaluated neutral valence pictures more negatively when paired with negative valence pictures. The contiguous pairing of pictures caused changes in perceived valence. Levey and Martin (1975) argued these findings were not the result of cognitive propositions, given participants did not report awareness of how the stimulus pairings affected their judgments when asked. However, whether or not this survey measurement was sufficiently sensitive is ambiguous, and researchers debate whether EC actually operates in absence of awareness of stimulus pairings (Hofmann et al., 2010). Davey (1994) argued that inappropriate statistical analyses within the EC paradigm explained the lack of evidence for conscious awareness of stimulus pairings. The selected statistical analyses for awareness of stimulus pairings may not have been sensitive enough for detection of participants' awareness of complex covariation between experimental stimuli.

Despite ambiguity regarding the role of conscious awareness of stimulus relationships, EC seems to influence participants in many experimental contexts. In addition to visual stimuli (Levey & Martin, 1975), the remaining four basic senses exhibit EC effects, the general finding being EC operates within-sensory modes and across-sensory modes (De Houwer, Baeyens, Vansteenwegen, & Eelen, 2000; Hammerl & Grabitz, 2000; Van Reekum, Van den Berg, & Frijda, 1999; Zellner, Rozin, Aron, & Kulish, 1983). EC also can cause residual influence, such that a neutral stimulus can acquire valence through pairing, and then subsequently influence perceptions of other stimuli. In one study, Blair and Shimp (1992) manipulated between-subjects whether participants listened to a pleasant song while completing a boring task, the experimental group, or completed a boring task in silence, the control group. The experimental group rated the song as more unpleasant than the control group. Several days later, when the newly unpleasant song played during marketing presentations of specific brand names, the experimental group evaluated specific brand names as more unpleasant than the control group. The pleasant song became more unpleasant through its pairing with a boring task, and that unpleasantness extended to a different stimulus situation during an experimental session that occurred days later. A propositional interpretation of this effect requires participants in the experimental group to have realized their diminished liking of the song was due to its pairing with a boring task. A propositional interpretation also requires participants in the experimental group to have realized their diminished liking of the brand names was due to its pairing with the newly unpleasant song.

Hebl and Mannix (2003) reported negative inferences were made towards interviewees sitting next to an obese person compared to interviewees sitting by themselves. These results suggested EC operates through stereotypes as well. A propositional explanation

of this effect requires participants to have realized their diminished liking of the interviewee proximal to the obese person was due to the proximity of the obese person. Interestingly, EC does not seem to be limited to laboratory judgments. EC can produce subtle changes in behavior, such as diminishing racial stereotypes (Olson & Fazio, 2006), changing stable attitudes towards foods (Dwyer, Jarratt, & Dick, 2007; Lascelles, Field, & Davey, 2003), and mitigating alcoholic drinking behavior (Houben, Havermans, & Wiers, 2010).

The ability to detect EC effects in the absence of participant self-report awareness of stimulus pairings supports the argument that EC may not be entirely dependent on cognitive propositions (see Hofmann et al., 2010, for a review). Some researchers argue this characteristic of EC research is merely an artifact of the paradigm (Field & Davey, 1999), thus the evidence is not conclusive. EC research also may not inform whether PC learning effects can also form without awareness of stimulus relationships, as some researchers consider EC to be a separate process from PC (De Houwer et al., 2001).

Researchers have argued EC is less sensitive to contingencies, extinction, and potentially contingency awareness than PC (De Houwer et al., 2001, Olson & Fazio, 2001). Contingency is the percentage of CS-US pairings relative to the presentations of the CS alone. For example, a 75% contingency means 75% of the trials are CS-US pairings and 25% of the trials are the CS alone. PC depends on the strength of the contingency, meaning a 50% contingency will produce a weaker conditioned response (CR), or response to the CS, than a 100% contingency. Contingency awareness is participant's conscious knowledge regarding contingencies, and is analogous to conscious propositions in this context. Extinction refers to weakening a learned association by consistently presenting the CS without the US. If a stimulus relationship follows a 50% contingency, the predictive value of the CS is relatively

weak. However, US presentation can be strongly contiguous with CS presentation in a 50% contingency. In a simple 50% contingency, the CS precedes the US 100% of the time, meaning the US is never presented unless the CS is presented, establishing a 100% contiguous relationship while maintaining a 50% contingent relationship. These three characteristics of EC suggest reinforcement between two stimuli, experimentally manipulated by presenting the CS and US together, seems to be the primary contributor to the EC learning effect.

Whether or not contingency or contiguity differentially drives specific learning effects becomes a question of theoretical importance. Since researchers have argued EC relative to PC is less dependent upon contingency strength, extinction, and potentially contingency awareness, EC may be more dependent upon contiguity than PC, and less dependent on the predictive value of the CS than PC (De Houwer et al., 2001; Vansteenwegen, Francken, Vervliet, De Clercq, & Eelen, 2006). These counterintuitive characteristics of EC, however, do not sufficiently provide a solution to the theoretical question of which model, the single-process model or the dual-process model, has more explanatory scope for human associative learning as a whole. The mere absence of predictability is not enough. Predictions regarding stimuli presentation and behavioral responses to those stimuli should manifest orthogonally in order to argue for two independent learning systems. Strong CRs in the context of strong predictions that a US will not be presented as well as weak CRs in the context of strong predictions that a US will be presented should be measured within a PC paradigm to counter the single-process model persuasively.

Perruchet Effect

The most convincing evidence for the dissociation of predictive strength and CR strength of stimuli is the Perruchet effect (Perruchet, 1985). Developed by Pierre Perruchet, the Perruchet effect induces a state of uncertainty regarding the prediction of US presentation. In the Perruchet paradigm, the researcher explains to participants that the experiment follows a 50% contingency, such that half the trials are CS+ and half the trials are CS-. A CS+ trial is a reinforcement trial, or presentation of the CS and the US together, while a CS- trial is an extinction trial, or presentation of the CS without the US. In the original study examining the Perruchet effect, there were sequential runs of reinforcement (CS+) trials and extinction (CS-) trials with lengths of 4, 3, 2, and 1 (Perruchet, 1985). Runs represented the number of sequential trials of the same trial type. For example, CS+4 runs represented four CS+ trials occurring in a row, and CS-4 runs represented four CS- trials occurring in a row. Run value directly corresponded to the absolute numerical value of the run, such that CS+4 runs represented the strongest reinforcement while CS-4 runs represented the strongest extinction.

Knowing the contingency is 50%, participants are more likely to guess that a CS+ trial will not occur after experiencing a CS+4 run, and are more likely to guess that a CS+ trial will occur after experiencing a CS-4 run. This decrease in expectancy as run value increases regarding the likelihood that a CS+ trial will occur is generally linear across run value. While this reasoning is somewhat rational, Perruchet argues that it is similar to the gambler's fallacy (Perruchet, 2015). The gambler's fallacy is easily illustrated by example. People tend to predict a coin landing on tails after watching it land on heads several times in a row, even though both heads and tails are always equally likely on a fair coin (Burns &

Corpus, 2004). In the coin-flip example, the propositional mechanism would predict tails after a run of several heads because a person expects an equal number of heads and tails. The link mechanism would predict the strengthening of the connection between the coin-flip and heads after a run of several heads, making heads the expected outcome at that moment in time. Thus, the two mechanisms would make opposite predictions in situations when a certain event unexpectedly occurs in sequence, contrary to most conditioning designs in which the two mechanisms would make near identical predictions. This is why the Perruchet effect is a viable way to contribute to the associative learning debate, as the paradigm effectively pits the two models against each other.

The majority of research studying the Perruchet effect has used an eye blink conditioning paradigm (Perruchet, 2015), and various laboratories have replicated this effect (Clark, Manns, & Squire, 2001; Weidemann, Broderick, Lovibond, & Mitchell, 2012). Eye blink conditioning involves a neutral CS, usually a tone, a bothersome air puff to the eye as the US, and eye blinking as the CR. The apparatus directs an air puff towards the eye, which produces a reflexive eye-blink. Pairing of the tone with the air puff eventually produces eye blinking in reaction to the tone before the presentation of the air puff.

Participants blinked the most in reaction to the tone after experiencing a CS+4 run, and blinked the least in reaction to the tone after experiencing a CS-4 run. Thus, the CR between tone and air puff was strongest after a CS+4 run, and weakest after a CS-4 run. This change in eye blink frequency was generally linear across run value, such that more recent reinforcement of tone and air puff resulted in more blinking and more recent extinction of tone and air puff resulted in less blinking. Participants' predictions, however, followed the opposite pattern. Participants' expectancy to experience an air puff after a CS+4 run was

lowest, and expectancy to experience an air puff after a CS-4 run was greatest. Thus, the proposition between tone and air puff was strongest after a CS-4 run, and weakest after a CS+4 run. This expectancy trend was generally linear across runs, such that more recent reinforcement of tone and air puff resulted in lower expectancy, and more recent extinction of tone and air puff resulted in greater expectancy. This provided evidence effectively dissociating participant's prediction of the US and physiological response to the CS. The pairing of tone and air puff, not tone predicting air puff, produced consistent robust CR's (Perruchet, 1985). This orthogonal linear pattern between conscious expectancy and physiological anticipation of an event as a function of run value does not fit the single-process model's predictions of associative learning effects.

There is not much research expanding the Perruchet effect to other paradigms, but there is some evidence of the Perruchet effect occurring in cognitive tasks, using response times as dependent measures rather than physiological responses (Barrett & Livesey, 2010; Moore & Obhi, 2012). Response time in the Perruchet paradigm is similar to the CR. When the researcher instructed participants to respond to a target stimulus (e.g. an arrow on a computer screen) which was sometimes but not always presented after a non-target stimulus, response times operated in the opposite direction of expectancy to view the target stimulus. In other words, the Perruchet paradigm induced uncertainty via stimulus run sequences, causing participants to respond quickest to the target stimulus when they least expected to view the target stimulus and respond slowest to the target stimulus when they most expected to view the target stimulus (Barrett & Livesey, 2010). Within associative learning literature, there is magnetoencephalographic evidence that shows brain activity and expectancy operating in opposite directions for participants in a Perruchet task, with light as the CS and

loud noise as the US (Moratti & Keil, 2009). There has also been relative success for the Perruchet effect within the electrodermal paradigm, which involves measuring changes in electrical properties of the skin. Some efforts have been successful (McAndrew et al., 2012), while some efforts have not been successful (Williams & Prokasy, 1977). The research conducted by McAndrew et al. (2012) influenced the hypotheses and Perruchet design within the electrodermal paradigm for the current study.

In the target study, which the current study attempted to replicate, McAndrew et al. (2012) conducted an experiment with 44 conditioning trials. For each CS+ trial, participants viewed a brown cylinder (CS) for 5 s, and were administered a moderately painful electric shock (US) for the last 500 ms of CS presentation. In conditioning terms, this design was a delay procedure, as presentation of the CS and US overlapped in time and terminated together. During the inter-trial interval (ITI), participants rated their expectancy of being shocked on the next trial on a scale of 1 (*there will definitely not be a shock*) to 5 (*there will definitely be a shock*). On every trial, the apparatus recorded tonic electrodermal activity (EDA), or slow-moving changes in the skin's electrical conductivity. The calculation for the CR measured the difference between the mean tonic EDA during CS presentation and mean tonic EDA 5 s prior to CS presentation. The experiment followed a Perruchet design with a 50% contingency, but participants were not instructed that the trials followed a 50% contingency. The trials were organized into two runs of CS+/-3, four runs of CS+/-2, and eight runs of CS+/-1. The presentation of runs was pseudorandom. The researchers pooled run data into three levels: Level 1 (CS-3, CS+1), Level 2 (CS-2, CS+2), and Level 3 (CS-1, CS+3). Increase in level represented increase in the recent reinforcement value of the CS. Results revealed that participant's expectancy to experience a shock and their tonic EDA

followed contrasting linear patterns of runs collapsed across levels. Increased EDA occurred when participants least expected a shock to occur, and decreased EDA occurred when participants most expected a shock to occur. This trend was generally linear as a function of level. This was the first electrodermal experiment to produce results similar to the effects of Perruchet's eye blink conditioning studies (McAndrew et al., 2012).

EDA is a measure of sweat gland secretions and is a product of sympathetic branch activity within the autonomic nervous system (Handler, Nelson, Krapohl, & Honts, 2010). Within EDA, there are several components, the one of particular interest here being skin conductance response (SCR). SCR, in units of microsiemens (μS), is a measurement of change in electrical current flow which indicates change in arousal. Arousal is readiness for activity in reaction to an external stimulus. The brain sends signals down efferent nerve fibers that reach the palmar and plantar eccrine sweat glands. When eccrine sweat glands moisten the epidermal tissue, the ions in the sweat produce an increased conductivity in the skin (Handler et al., 2010). Applying a weak constant voltage through electrodes attached to fingers detects and measures this change in conductivity. SCR is sensitive to the characteristics of stimuli, for example increasing biological significance of stimuli results in increased SCR (Critchley, 2010).

Current Study

The intent of the current research was to collect evidence supporting either the single-process model or dual-process model, by testing if the single-process model made either correct or incorrect predictions in the Perruchet paradigm (Mitchell et al., 2009). Influenced by the work of McAndrew et al. (2012), I hypothesized an orthogonal linear pattern of expectancy of the US and SCR to the CS as a function of run value. This hypothesis follows

predictions of the dual-process model and contrasts predictions of the single-process model. The dual-process model predicts expectancy of the US and SCR to the CS to manifest orthogonally while the single-process model predicts expectancy of the US and SCR to the CS to manifest in parallel. The dual-process model predicts successive reinforcement and successive non-reinforcement of CS-US pairings will cause the contiguous link mechanism to drive the CRs despite participants' opposite expectation. The current study implemented a new stimulus paradigm, an alternate delay procedure, an expanded expectancy scale, a phasic SCR analysis, and no collapsing of run value into levels, to test if the Perruchet effect is generalizable to a different set of experimental protocols.

Instead of electric shock as the US, the USs were arousing images. Electric shock maps on to fear learning, while arousing images broaden the scope from specifically fear learning to both positive valence learning and negative valence learning. Strategic image selection from the International Affective Picture System (IAPS), in which images and their respective emotional content are normatively scaled (Lang, Bradley, & Cuthbert, 2008), allowed for a stimulus set with controlled emotional qualities. The measured emotional content of the images includes arousal, the quality necessary to produce SCR (Lang et al., 2008). Selecting moderately arousing images of predatory animals, humans wounds, attractive humans (same sex and opposite sex), and romantic couples allowed for a stimulus set with controlled arousal across images (see Appendix A). These image categories produce SCR to a greater degree than other categories in the IAPS (Bradley, Codispoti, Sabatinelli, & Lang, 2001). Since images are biologically innocuous, as opposed to electric shock, images offered a less invasive alternative to study the Perruchet effect. The intent of using unique

images on every trial was to attenuate habituation to the imagery and to facilitate attention towards the stimuli.

Instead of a visual brown cylinder as the CS, the CS was a fixation cross (McAndrew et al., 2012). The CS was a fixation cross because the USs were arousing images, keeping the CS and USs within the same sensory mode but distinctive through visual complexity. Stimulus presentation was a delay procedure in which the US immediately followed termination of the CS. The fixation cross terminated immediately before US presentation so the CS would not superimpose the US, potentially changing the USs' natural arousal qualities.

The two dependent measures were participant's expectancy of a US and participant's SCR to the CS. Expectancy indicated the prediction that the following trial was a CS-US pair and was measured on a 9-point scale instead of a 5-point scale to allow more variability in response selection. Two separate waveforms, phasic and tonic, operationalized SCR. The tonic waveform represented slow moving changes in EDA while the phasic waveform represented rapid changes in EDA. Analyzing both waveforms added more information pertaining to participant's responses, as different waveforms yielded different response magnitudes and frequencies. For the phasic waveform, specific responses to stimuli were moments when EDA crossed from negative phase to positive phase, while non-responses were moments that did not elicit this phasic activity. For the tonic waveform, specific responses to stimuli were moments when the maximum amplitude during stimulus presentation exceeded minimum amplitude before stimulus presentation, while non-responses were moments that did not elicit this tonic activity.

A magnitude analysis included responses and non-responses, while an amplitude analysis only included responses. While including non-responses attenuated the overall average magnitude of the responses, it added power to the data analysis, as more data points were included. Generally, a magnitude analysis is more suitable to detect subtle EDA changes, while an amplitude analysis is sufficient for large-scale EDA changes (Braithwaite & Watson, 2015). Given the stimulus of interest was an innocuous fixation cross, response magnitudes and frequency were expected to be relatively low, making magnitude the analysis of choice.

The planned analyses did not collapse run value across levels. While pooling six levels of a variable into three levels would have made the analyses more powerful, the resulting three levels would not be representative of the original six levels. CS+ runs represented stronger pairing of the CS and US via recent reinforcement, while CS- runs represented weaker pairing of the CS and US via recent extinction. The absolute numerical value assigned to each run corresponded to the strength of the reinforcement or extinction, meaning the CS+ 3 run represented the strongest reinforcement between the CS and US while the CS- 3 run represented the strongest extinction between the CS and US. McAndrew et al. (2012) organized trials into two runs of CS+/-3, four runs of CS+/-2, and eight runs of CS+/-1. By pooling CS-3 run data with CS+1 run data, the influence of CS-3 run data on the analysis was less clear, as there were four times the amount of data points in the CS+1 run group by design. Additionally, the predictions for CS-3 run data and CS+1 run data were not commensurate, so combining the two did not make sense for a theoretical test or measurement of effect size. The six levels remained independent in the analysis for the current study, such that the group means were separate entities.

Method

Participants

Ninety-five undergraduate students from a university in the Southeastern region of the United States were recruited from psychology courses through the university's online recruitment system and were provided course credit for their participation. Recruiting participants of similar age for this research was advantageous, given that electrodermal conditioning varies across the lifespan (Gao, Raine, Venables, Dawson, & Mednick, 2010). This was the first experiment conducted in a new laboratory, and several unexpected hardware, software, and personnel communication errors impeded the first wave of data collection. While the errors were debugged after they were identified, 17 data files were corrupted and had to be excluded from analysis. This resulted in a participant sample size of 78, of which was further reduced to 68 (Gender: 23 males, 45 females; Age in years: $M = 19.87$, $SD = 1.85$) after 10 EDA hypo responders were excluded from analysis. A hypo responder was a participant who generated zero responses to the CS throughout the experiment based on suggested analysis and location of SCR's on the phasic waveform (Kim, Bang, & Kim, 2004). Approximately 10% of the population are hypo responders, so the collected sample was typical in this regard (Braithwaite, Watson, Jones, & Rowe, 2013). The Institutional Review Board approved the current research on 03/04/2017. IRB approval information is located in Appendix B.

Materials

Conditioned Stimulus. The CS was a fixation cross (Times New Roman, size 32 font) centered on the computer screen (21.7 in). The CS appeared on all trials. For each trial, CS duration was 6 s.

Unconditioned Stimuli. Twenty-two images rated high in arousal were selected from IAPS for the US. The images were centered and stretched to a width of 52.3% (9.94 in) and to a length of 69.4% (7.29 in) of the computer screen. This approximated the clearest display of the image. 22 images allowed for 44 conditioning trials. The US appeared on all CS+ trials. For each CS+ trial, the US duration was 6 s.

Measures

Conditioned Response. The BIOPAC MP36R and *AcqKnowledge* software collected the EDA measurements (BIOPAC, 2008). The BIOPAC MP36R has four channels and a 24-bit analog-to-digital (A/D) converter, able to sample up to 100,000 samples per second (Boucsein et al., 2012). The device was interfaced to the computer running *AcqKnowledge* software. EDA was collected at 1000 Hz. Once collected, the software resampled the signal down to 62.50 Hz to expedite computational analysis. The signal went through a low-pass filter ($f = 1.00$ Hz) for artifact removal and a high pass filter ($f = .05$ Hz, $Q = .707$) for phasic waveform construction (Braithwaite et al., 2013). The measurements captured the magnitude of both tonic and phasic waveforms on every run-commencing trial, resulting in 28 measures of interest for each participant. All of the stimulus-specific SCR data were transformed [$\log(\text{SCR magnitude} + 1)$] and standardized into *Z*-scores [$(x$ of participant's response to CS - \bar{x} of participant's response to CS) / *SD* of participant's response to CS] to minimize violations of normality and inter-individual variance respectively (Braithwaite & Watson, 2015). *Z*-scores were advantageous as they provided unique response profiles for each individual, particularly since a non-response represented a different numerical value for each participant.

The difference between the maximum amplitude during presentation of the CS and the minimum amplitude 6 s prior to CS presentation represented the tonic SCR. This calculation was advantageous, as it discarded ambiguous EDA fluctuation embedded in a means analysis, and it guaranteed that SCR measurements represented only responses that were rises, not falls. In this analysis, the response peak of an SCR always followed the trough of the response. If the difference between maximum and minimum amplitudes solely during CS presentation represented the tonic SCR, it would be difficult to identify if the peak followed or preceded the trough. Performing a difference between two maximums or two minimums would not be suitable because that would ignore either troughs or peaks respectively.

A specific SCR to the CS occurred if the phasic waveform crossed from negative phase to positive phase at a minimum latency of 1 s after CS onset to a maximum latency of 7 s after CS onset. Two methods measured phasic SCR. The phasic waveform was first analyzed using parameters suggested by Kim et al. (2004), the 10% threshold SCR. The suggested parameters involved a global analysis of each individual experimental file. Within each file, the software identified the maximum SCR recorded across the entire file, and identified all SCRs by locating phasic changes that exceeded 10% of the amplitude of the maximum SCR. The threshold change in the phasic waveform was 0 μ S, as the 10% cutoff functioned as a filter against minute responses.

The phasic waveform was additionally analyzed utilizing a more powerful approach, one that retained as much data as possible. The 10% cutoff suggested by Kim et al. (2004) was not based on rigorous evidence. Thus, the 10% threshold SCR method was utilized, but was modified by grading the threshold with two additional steps involving increasing liberal

criteria, the 3-step threshold SCR. The software first identified responses at the 10% cutoff. At this stage, Z -scores of each individual $3 SD$ above the mean were discarded. This discarded hypo responders who generated no responses to the CS, as zero variance resulted in undefined Z -scores for every hypo responder's stimulus response. Performing this exclusion later would have included participants who generated no "meaningful" response to the stimulus in the data set, with Z -scores primarily consisting of minute electrical shifts across the phasic waveform.

Retaining all of the collected responses from the first stage, the software re-identified responses at the 5% cutoff. A stimulus assigned a non-response primarily from the 10% cutoff stage but assigned a response from the 5% cutoff stage was marked as a response at the magnitude output provided by the 5% cutoff. On average, this stage retained an additional three or four responses of substantial magnitude. The procedure repeated, and the final stage identified SCRs at the 0% cutoff. This stage retained primarily small responses, but did occasionally contribute responses of substantial magnitude. In total, this method included three-steps for specific SCR identification.

Expectancy. Participants provided expectancy judgments that an image would follow the next fixation cross. When primed with the question "Do you expect the next cross to be followed by a picture?" 1 s after trial termination, participants identified their confidence on a scale from 1 (*very unlikely*) to 9 (*very likely*) using the number pad. Pressing 1 indicated lowest level of expectancy, pressing 5 indicated chance level of expectancy, and pressing 9 indicated highest level of expectancy. Participants were encouraged to use the entire spectrum of options to delineate their true expectancy. E-prime measured expectancy on every trial, resulting in 28 measures of interest for each participant.

Perruchet Paradigm

CS+ trials and CS- trials were presented in a way that challenged participant's ability to predict whether a CS+ or CS- trial would occur next. The trials incorporated a 50% contingency, such that half the trials were CS-US pairs (CS+ trials) and half the trials were the CS alone (CS- trials). There was an attention check on all CS+ trials. The attention check was a simple question about the US, specifically whether or not the image included a human face, to ensure participants at least minimally processed and inspected the visual stimulus. Some of the images were unpleasant to view, thus participants may have been tempted to look away when an unpleasant image appeared. The question about the presence of a human face lessened this possibility. The differences between CS+ trials and CS- trials were neither the US nor the attention check were presented on CS- trials, as the attention check pertained specifically to the US. Figure 1 shows the sequence for a CS+ trial. In Figure 1, time proceeds from left to right. Upward movement of the lines indicates stimulus presentation while downward movement of the lines indicates stimulus termination. The US immediately followed the CS, and duration of both stimuli was 6 s. CS- trial sequence was identical, except there was no US and no attention check.

There were two runs of CS+3/-3, four runs of CS+2/-2, and eight runs of CS+1/-1, resulting in 44 trials. Out of the 44 trials, 28 of the trials were of theoretical interest. Twenty-eight of the trials commenced a run sequence. The first trial after termination of a run was the trial of interest when collecting data for the terminated run. For example, a CS-2 run may have terminated a CS+1 run. The response to the first CS of the CS-2 run represents the response towards the preceding CS+1 run. An additional trial at the end of the experiment terminated the final run in order to collect data on that final run. In the McAndrew et al.

(2012) study, participants were not instructed that a 50% contingency was employed.

Following Perruchet (1985), participants in the current study were instructed that a 50% contingency was employed. This lessened some of the ambiguity in the task. Whether or not this instruction is necessary for the Perruchet effect is not known.

Experimental Design

The experiment followed a 3 (run length: 1, 2, 3) x 2 (trial type: CS+, CS-) within subjects design, creating six distinct run values: [CS-3 (CS-, CS-, CS-), CS-2 (CS-, CS-), CS-1 (CS-), CS+1 (CS+), CS+2 (CS+, CS+), and CS+3 (CS+, CS+, CS+)].

Procedure

The experimenter welcomed participants into the laboratory. First, participants read and signed an informed consent form, located in Appendix C. Next, the experimenter asked participants to wash and dry their hands thoroughly and remove any jewelry from their non-dominant hand, to limit contamination of EDA recording. Ambient room temperature was maintained at approximately 73° F (23° C) to limit baseline EDA variability across participants (Boucsein et al., 2012). The experimenter attached the electrodes to the participant's index and middle fingers on their non-dominant hand. At least 5 min passed after electrode attachment before commencing EDA recording, to allow enough time for the skin to absorb the isotonic gel. The participant's dominant hand was electrode-free. Participants used their dominant hand for answering questions on the computer keyboard. The experimenter placed the keyboard directly in front of the participant's dominant hand so the task required minimal movement, because sudden or large movements obscure EDA readings. When the participant was relaxed, the experimenter instructed them to remain relaxed throughout the experiment. Before the experimental trials began, the participants

rested for 10 min as the EDA recording process began. This 10 min period allowed enough time for the EDA of the participant to return to a relaxed state, and allowed the experimenter to ensure that the EDA signal was good quality. The experimenter read to participants the following instructions:

You are about to participate in a study which involves visual stimuli. During this experiment, you will view a cross on every trial. On certain trials, pictures will follow the cross. Pictures will follow the cross 50% of the time, and the cross will be presented by itself 50% of the time. It is your job to predict if a picture will follow the cross on any given trial. Try to remember what has happened on previous trials throughout the experiment. On each trial, you will be asked to report your confidence of your prediction by selecting from the numbers 1 (very unlikely) to 9 (very likely), 1 indicating the strongest confidence that a picture will not appear after the cross, 5 indicating no confidence in either direction, and a 9 indicating the strongest confidence that a picture will appear after the cross. We encourage you to use the entire spectrum of options to specifically identify your prediction. If a picture does follow the cross, you will be asked if that picture included a human face. Pressing “y” indicates “yes” and pressing “n” indicates “no”. You will be reminded during the experiment how the keyboard corresponds to answers for both questions. You will read these instructions again on the computer screen. Do you have any questions?

On CS+ trials, participants viewed the CS for 6 s and then viewed the US for 6 s. On CS- trials, participants viewed the CS for 6 s but did not view the US. E-prime sent digital inputs to *AcqKnowledge* via the computer’s parallel port at 125 Hz to identify CS onset and US onset. Soon after trial termination (1 s), participants read questions on the computer

screen. The first question read: “Was there a human being in the last image you viewed?” This question only occurred after CS+ trials, 22 trials per participant. If participants failed to answer this question above 50% accuracy, an indicator of insufficient attention, they were excluded from analysis. The second question read “Do you expect the next cross to be followed by an image?” This question occurred after every trial, 28 measures of interest per participant. For CS- trials, the participant only answered the expectancy question. The ITI averaged at 25 s. The ITI had to be sufficiently long to allow EDA to settle before beginning the next trial. The ITI varied slightly to mitigate temporal conditioning as a potential confounding variable (Boucsein et al., 2012). During the ITI, the screen read: “Please remain relaxed and still. Continue to pay attention to the computer screen.” Each participant received a unique trial sequence, using randomization with restriction, to prevent order effects of images and runs. After the 44 experimental trials, participants had completed the task. The whole procedure took roughly 1 h to complete.

Results

Based on highly accurate performance from all participants on the attention check ($M = 99\%$, $SD = 8.7\%$) no participants were excluded from failure to pay attention to the task. The magnitude of all SCRs recorded in μS throughout the whole experiment ($M = 0.77$, $SD = 0.36$) and the rise time in seconds from phasic onset to peak of all SCRs ($M = 4.99$, $SD = 3.85$) provided a general response profile of the collected sample. Appendix D includes the tables and Appendix E includes the figures. Table 1 shows general responsiveness in magnitude and frequency to the stimuli, which functioned as a simple manipulation check. Overall, magnitudes and frequencies were not very high to presentation of either stimulus.

The US was more effective than the CS at eliciting responses, both in magnitude and frequency. Table 2 shows descriptive statistics, notably the various measurements of central tendency that factored into the statistical analyses.

A one-way repeated measures MANOVA with run value as the within-subjects factor and expectancy, 3-step threshold SCR, 10% threshold SCR, and tonic SCR as the four dependent measures revealed a significant influence of run value on at least one of the dependent measures, $V = .26$, $F(20, 1340) = 4.59$, $p < .001$. Table 3 shows that all four dependent measures failed Mauchly's test for sphericity and Kolmogorov-Smirnov's test for normality, meaning the variances between run values were heterogeneous and the dependent measures did not meet parametric assumptions of normality, respectively. Skewness, kurtosis, and histograms also indicated non-normal distributions for the dependent measures, particularly for the SCR measures. Because the dependent measures violated sphericity and normality, both one-way repeated measures ANOVAs with Greenhouse-Geisser corrected degrees of freedom and non-parametric Friedman's ANOVAs were conducted to test for univariate effects of run value on the four dependent measures. The Greenhouse-Geisser correction helped control for Type I errors, or false rejection of the null hypothesis. The Friedman's ANOVA helped control for Type II errors, or failure to reject the null hypothesis. Both the parametric and non-parametric tests offered unique information and are included for comparison.

The predicted effect of run value on the four dependent measures was linear, thus a simple correlation between run value and the dependent measures offered an alternative method to examine the linear patterns within the data. This method was unique from the ANOVAs, as the correlational analyses did not compound the data into separate cells and

then search for differences among the separate cells, but rather estimated a simple regression line between run value and the dependent measures. Thus, each analysis included correlations for run value treated as a continuous predictor on the four dependent measures to supplement the ANOVA analyses.

A one-way repeated measures ANOVA with Greenhouse-Geisser corrected degrees of freedom revealed a significant effect of run value on expectancy, $F(2.06, 138.01) = 16.80$, $p < .001$, $\eta^2 = .20$. Table 4 includes significant post-hoc comparisons for this parametric analysis. Twelve comparisons were significant, and followed predictions of the hypothesis. Planned linear within-subjects contrast revealed a significant negative linear pattern between run value and expectancy, $F(1, 67) = 23.42$, $p < .001$, $\eta^2 = .26$. Figure 2 shows the expectancy means across the six levels of run value, showing visual trends that follow predictions of the hypothesis. As run value increased, expectancy decreased. Friedman's ANOVA revealed a significant effect of run value on expectancy, $\chi^2(5) = 72.65$, $p < .001$. Table 5 includes significant post-hoc comparisons for this non-parametric analysis. Nine comparisons were significant, and followed predictions of the hypothesis. When treated like a continuous predictor rather than a discrete experimental manipulation, run value negatively correlated with expectancy, $r(1850) = -.24$, $p < .001$. This follows predictions of the hypothesis.

A one-way repeated measures ANOVA with Greenhouse-Geisser corrected degrees of freedom did not reveal a significant effect of run value on 3-step threshold SCR, $F(3.82, 256.10) = 1.42$, $p = .228$, $\eta^2 = .02$, $1 - \beta = .43$. Planned linear within-subjects contrast, however, revealed a significant positive linear pattern between run value and 3-step threshold SCR, $F(1, 67) = 4.26$, $p = .043$, $\eta^2 = .06$. Figure 3 shows the 3-step threshold SCR means

across the six levels of run value. Z-scores for each individual came from their 3-step threshold CRs throughout the experiment. Although not detected through a main univariate effect, Figure 3 reveals visual evidence that follows predictions of the hypothesis. As run value increased, 3-step threshold SCR increased. Friedman's ANOVA revealed a significant effect of run value on 3-step threshold SCR, $\chi^2(5) = 36.21, p < .001$. Table 5 includes significant post-hoc comparisons for this non-parametric analysis. Five comparisons were significant and followed predictions of the hypothesis. When treated like a continuous predictor rather than a discrete experimental manipulation, run value positively correlated with 3-step threshold SCR, $r(1850) = .05, p = .041$. This follows predictions of the hypothesis

A one-way repeated measures ANOVA with Greenhouse-Geisser corrected degrees of freedom did not reveal a significant effect of run value on 10% threshold SCR, $F(3.92, 262.77) = 1.21, p = .306, \eta^2 = .02, 1 - \beta = .37$. Planned linear within-subjects contrast also did not reveal a significant positive linear pattern between run value and 10% threshold SCR, $F(1, 67) = 3.34, p = .072, \eta^2 = .05, 1 - \beta = .44$. Figure 4 shows the 10% threshold SCR means across the six levels of run value. Z-scores for each individual came from their 10% threshold CRs throughout the experiment. Although not detected through a main univariate effect nor a linear contrast, Figure 4 reveals visual evidence that follows predictions of the hypothesis. As run value increased, 10% threshold SCR increased. Friedman's ANOVA revealed a significant effect of run value on 10% threshold SCR, $\chi^2(5) = 34.45, p < .001$. Table 5 includes significant post-hoc comparisons for this non-parametric analysis. Three comparisons were significant but directly contrasted predictions of the hypothesis. When treated like a continuous predictor rather than a discrete experimental manipulation, run

value did not significantly correlate with 10% threshold SCR, $r(1850) = .05, p = .053$.

Overall, evidence solely from the 10% threshold SCR provides little evidence for the hypothesis.

A one-way repeated measures ANOVA with Greenhouse-Geisser corrected degrees of freedom did not reveal a significant effect of run value on tonic SCR, $F(3.44, 230.77) = 1.50, p = .210, \eta^2 = .02, 1 - \beta = .43$. Planned linear within-subjects contrast, however, revealed a significant positive linear pattern between run value and tonic SCR, $F(1, 67) = 5.21, p = .026, \eta^2 = .07$. Figure 5 shows the tonic SCR means across the six levels of run value. *Z*-scores for each individual came from their tonic CRs throughout the experiment. Although not detected through a main univariate effect, Figure 5 reveals visual evidence that follows predictions of the hypothesis. As run value increased, tonic SCR increased. Friedman's ANOVA revealed a significant effect of run value on tonic SCR, $\chi^2(5) = 19.33, p = .002$. Table 5 includes significant post-hoc comparisons for this non-parametric analysis. Three comparisons were significant and followed predictions of the hypothesis. When treated like a continuous predictor rather than a discrete experimental manipulation, run value positively correlated with tonic SCR, $r(1850) = .05, p = .047$. This follows predictions of the hypothesis.

Table 6 shows all the correlations between the dependent measures. None of the SCR measurements significantly correlated with expectancy in either direction. There was a highly positive correlation between 3-step threshold SCR and 10% threshold SCR. While both phasic measurements positively correlated with the tonic measurement, the value of the correlations were relatively low, given that the tonic and phasic both estimated measurements

of SCR. The correlations in Table 6 were not tests of the hypothesis, but were included to highlight similarities and differences among the dependent measures.

Discussion

Findings

The results generally supported the hypothesis that expectancy of a US and CR to a CS can be dissociated and manifest orthogonally as a function of run value (McAndrew et al., 2012). This conclusion, however, is more apparent in a visual analysis of the data than an inferential analysis of the data. The volatility of the larger absolute value run groups may have caused the parametric tests to produce seemingly contradictory results. That being said, there were detectable linear trends in the data that counter predictions of the single-process model (Mitchell et al., 2009). These results provide preliminary evidence supporting the dual-process model, as both theoretical processes manifested simultaneously in the current analysis. Under the assumption that the expectancy and SCR measurements adequately mapped onto conscious representation of predictions and conditioned autonomic responses respectively, the single-process model did not accurately predict the results of this experiment. The single-process model would predict that expectancy measurements and CR measurements would follow similar trends, rather than opposite trends (Mitchell et al., 2009). It seems that the Perruchet effect in the electrodermal paradigm is flexible and may be detectable in various experimental procedures (Perruchet, 2015).

Addressing Limitations

There were analytical limitations in this experiment. The 10% threshold approach reflected non-parametric patterns that were less similar to the actual measured means.

Specifically, the mean ranking of CS+3 using the 10% threshold approach revealed the lowest CR mean, while the actual mean of CS+3 using the 10% threshold approach revealed the highest CR mean. The mean rankings of the 3-step threshold analysis, although not identical, were more similar to the actual means.

While the 10% threshold may be generally representative of capturing “meaningful” SCR’s, the definition of a “meaningful” SCR is not easily defined nor is it explicitly defined in justification for the 10% cutoff (Kim et al., 2004). While useful, there are several problems with a 10% cutoff. Different experimental procedures yield different response magnitudes and frequencies, participants differ in lability, and aberrant SCRs can cause discarding useful data points. Because of the potential issues of the 10% threshold approach, both the 10% threshold approach and 3-step threshold approach were included in the data analysis for comparison. There was a highly positive correlation between 10% threshold SCR and 3-step threshold SCR. This makes sense, given that the majority of the influential data points within both of these dependent measures were identical. The strong correlation also justified the use of the 3-step threshold analysis, as the strong correlation showed both measurements were essentially measuring the same construct. The 3-step threshold approach did usefully add power to the data analysis, as reported in the results section, due to overall increased magnitude measurements and frequency, making it the more useful and interpretable analysis for this particular data set.

None of the SCR measurements significantly correlated with expectancy in either direction. While this did not necessitate retaining the null hypothesis, as SCR and expectancy follow different measurement scales, more research will be necessary to show that a negative correlation between expectancy and CR is possible. Detection of this correlation would

augment the empirical evidence for a dissociation between the two learning systems. While both phasic measurements positively correlated with the tonic measurement, the value of the correlations were relatively low, given that the tonic and phasic both measured SCR. This weak correlation suggests that tonic and phasic measurements possess unique qualities and measure different elements of EDA, and that both should be included in electrodermal event-related analyses.

There were procedural limitations in this experiment. When measuring EDA, repeated and extended presentation of a stimulus leads to habituation towards that stimulus. Although the US being unpredictable in terms of valence and content partially addressed habituation, future experiments could minimize habituation further. The US could be on the computer screen for less time. The presentation of the US could be truncated from 6 s to 3 s, to lessen extended exposure. Amplification of US intensity would also help buffer against habituation effects. The USs in this experiment were only mildly arousing. Future experiments could employ more intensely arousing visual stimuli. Increasing the intensity of the US would allow the flexibility to keep all the USs within the same content category. This would also lessen ambiguity of the CS. In this experiment, different valences in the images may have led to ambiguity regarding the CS and what exactly it signaled, potentially attenuating the CRs. Controlling for the image content would be advantageous in that the association between the CS and the US would be more unidimensional. For example, pornographic imagery would lead to positively arousing associations while mutilation imagery would lead to negatively arousing associations. Unidimensional learning would also allow analyses to detect possible interactions between image content and linear patterns for the Perruchet effect.

The detected SCR effects in this experiment were small. It is possible that the minuteness of the SCR effects were due to procedural limitations. The CS and its parameters were not ideal for powerful analyses. The presentation of the CS may have been too brief. The maximum latency of an SCR in reference to a specific stimulus is theoretically as long as 10 s (Braithwaite et al., 2013). Given the maximum latency due to the procedure was capped at 7 s in order to unambiguously assign responses to the CS, any response occurring between 7 s and 10 s that very well may have been due to CS presentation could not be measured. These responses would have added more data and thus more power to the analyses. Future experiments should extend CS duration to allow for a minimum latency of 1 s and maximum latency of 10 s when assigning a specific phasic SCR to the CS for both CS+ and CS- trials. Extended CS duration would also augment tonic analysis, as the average rise time to maximum amplitude for a phasic SCR was around 5 s. Extended CS presentation would allow enough time for more of the tonic shifts to reach their maximum amplitude during CS presentation.

The timing of the expectancy question and attention check may have been too close to the timing of stimulus presentation. On CS+ trials, the two questions appeared on screen 1 s after US termination. On CS- trials, the expectancy question appeared on screen 1 s after CS termination. The temporal proximity between stimuli and questions may have caused additional cognitive processes and subtle motor movement preparation to factor into CR measurement. This issue is easily controllable. Future experiments could have the questions occur in the middle of the ITI.

The CS as a fixation cross may have reduced the detected effect sizes. While a fixation cross in the middle of the screen in a laboratory setting was a novel experience for

participants, a fixation cross in reality is a simple plus sign. Plus signs are ubiquitous on computer keyboards and phone touch-screens. It is possible that latent inhibition attenuated responses to the fixation cross, in that its neutral and unexciting qualities were learned and thus less susceptible to change from experimental manipulations in the laboratory (Lubow & Moore, 1959). The cross itself was also relatively small on the computer screen, and may have not been a salient enough cue for participants. Stimulus intensity dynamism predicts that the associative strength of a CS is contingent upon the intensity of the CS itself (Hull, 1949). Whether or not participants actually viewed the fixation cross exactly at the time of stimulus onset is equivocal without any eye-tracking data or video recordings, yet not viewing the CS at the precise moment of onset would inadvertently cause the analysis to omit data. Presenting a more salient stimulus as the CS would help control for these issues.

A future experiment could employ a simple picture frame as the CS. The picture frame would be advantageous for two reasons. The picture frame would be less pre-exposed to the participant, and thus more sensitive to conditioning and partial reinforcement schedules. It would also allow for the CS and US to be truly contiguous, as the frame would surround the US image during US presentation. This would allow for a delay procedure where the CS and US temporally would overlap and terminate together. This was not possible using the fixation cross.

Theoretically, contiguity would strengthen the detection of a Perruchet effect. Past research suggests that expectancy and recent reinforcement may differentially drive conditioned responses under partial reinforcement schedules (Clark et al., 2001). When the researchers partially reinforced two stimuli and presented them contiguously, rather than temporally separating them briefly, learning effects resembled predictions of the Perruchet

paradigm. The study also showed the opposite data pattern emerge when the researchers utilized a trace procedure, an effect more in line with predictions of the single-process model (Clark et al., 2001). Thus, there is empirical evidence suggesting that contiguous presentation of the CS and US may be critical for Perruchet designs. The current experiment incorporated a delay procedure, but the CS and the US were not truly contiguous nor did the two stimuli terminate together. This method may have deflated the detected effect sizes. A future experiment could implement contiguous presentation and co-termination of the CS and US

There were statistical power limitations in this experiment. The laboratory and the associated issues that arose from its newness led to data loss. This data loss lowered the power of the experiment. While several analyses yielded significant effects, the observed power was low for the SCR measures. Despite the low power, the experiment was fruitful in providing data that generally supported the predicted dissociation of expectancy and CR. More data could be collected with this procedure, but other limitations in the procedure made designing an improved procedure for the next experiment a priority. Inserting empirical evidence from the weakest univariate effect, the 10% threshold SCR, a power analysis conducted using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) suggested a sample of 204 participants to detect an effect of run value on 10% threshold SCR [ANOVA: Repeated measures, within-factors, six groups, four repetitions (on average),- r among repetitions = .10, $\varepsilon = .78$, effect size $f = .14$ ($\eta^2 = .02$), $\alpha = .05$, $\beta = .05$]. The recommended n was triple the original n . As an improved procedure would likely amplify the effect, collecting data on 204 participants should be sufficient for a future experiment, even after discarding data from hypo responders. Specific attention would be devoted to accurate effect size calculations,

rather than significant results, of which a larger sample and improved procedure would facilitate.

Conclusions

While this study provided preliminary evidence for the Perruchet effect, there are clear ways to improve the procedure to better estimate the size of the effect. Further research is necessary to understand exactly how much each of the independent learning mechanisms contribute to the Perruchet effect. Our lab will conduct another experiment with the procedural changes outlined above. For now, this data provides preliminary evidence for two independent learning mechanisms in humans. Research examining whether or not this type of learning operates in other animals has not been published and would certainly be an interesting expansion of the phenomena.

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Appendix A

IAPS Image Statistics

	IAPS Image #	Arousal Rating (9-point scale)
<hr/>		
Predator		
	1052	6.52
	1321	6.64
	1726	6.23
	1650	6.23
	1930	6.42
<hr/>		
Wounds		
	3019	6.30
	3064	6.41
	3195	6.36
	3550.1	6.29
	9183	6.58
<hr/>		
Attractive Female (Male Ratings)		
	4006	6.59
	4150	6.41
	2300	6.23
	4325	6.75
<hr/>		
Attractive Male (Female Ratings)		
	4505	6.46
	4525	6.70
	4542	6.17
	4572	6.30
<hr/>		
Romantic Couples		
	4608	6.47
	4660	6.58
	4689	6.21
	4677	6.19
<hr/>		

Appendix B

IRB Approval

STUDY #: 17-0214

STUDY TITLE: Analyzing Electrodermal Responses to Pictures

Submission Type: Initial

Expedited Category: (4) Collection of Data through Noninvasive Procedures Routinely Employed in Clinical Practice, (7) Research on Group Characteristics or Behavior, or Surveys, Interviews, etc.

Approval Date: 3/04/2017

Expiration Date of Approval: 3/03/2018

Appendix C

Consent to Participate in Research

Information to Consider About this Research

Analyzing Electrodermal Responses to Pictures

Principal Investigator: Andrew Graves

Department: Psychology

Contact Information: Andrew Graves: 865-712-8818; gravesaj@appstate.edu

Faculty Advisor: Kenneth Steele: (828) 262-2272 ext. 436; steelekm@appstate.edu

You are being invited to take part in a research study examining changes in electrical activity beneath the skin. If you take part in this study, you will be one of 132 people to do so. We hope to learn how physiological arousal is affected by pictures.

The research procedures will be conducted at Appalachian State University in Smith-Wright 210.

Changes in electricity underneath your skin will be measured. This measurement is non-invasive, painless, and innocuous. You will be asked to remain as still as possible throughout the experiment. You will be asked to view visual stimuli on the computer screen. You will be asked questions about the presented stimuli. The experiment will take roughly one hour to complete

You cannot volunteer for this study if you are under 18 years of age.

What are possible harms or discomforts that I might experience during the research?

Viewing the images may cause discomfort. The images belong to the following categories: predatory animals, human wounds, attractive humans, and romantic couples. If at any point you wish to leave, please let the experimenter know and they will terminate the procedure for you, and you will still receive your ELC credits. Additionally, the adhesive on the electrodes could cause a rash on your skin. During screening, please inform us if you are sensitive to adhesives. If the adhesive sticks very strongly, removing the electrodes could cause an abrasion. You could have an allergic reaction to the adhesive remover. The reaction could include rash, itching, fever, or breathing problems. If a bad reaction should occur, you should seek medical attention.

What are the possible benefits of this research?

There may be no personal benefit from your participation but the information gained will improve understanding of physiological responses to stimuli.

Will I be paid for taking part in the research?

You will not be paid for your participation in this study. However, you can earn up to 2 ELC credits for your participation. There are other research options and non-research options for obtaining extra

credit or ELC's. One non-research option to receive 1 ELC is to read an article and write a 1-2 page paper summarizing the article and your reaction to the article. More information about this option can be found at: psych.appstate.edu/research. You may also wish to consult your professor to see if other non-research options are available.

How will you keep my private information confidential?

This study is anonymous. The information you provide will not be attached to your name in any way. Data will be kept and stored until 1/2020.

Who can I contact if I have questions?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 865-712-8818. If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2692 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

Do I have to participate? What else should I know?

Your participation in this research is completely voluntary. If you choose not to volunteer, there will be no penalty and you will not lose any benefits or rights you would normally have. If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. There will be no penalty and no loss of benefits or rights if you decide at any time to stop participating in the study. If you decide to participate in this study, let the research personnel know. A copy of this consent form is yours to keep.

This research project has been approved by the Institutional Review Board (IRB) at Appalachian State University.

This study was approved on: March 4, 2017

This approval will expire on March 3, 2018 unless the IRB renews the approval of this research.

Participant's Name (PRINT)

Signature

Date

Appendix D

Tables

Table 1

Manipulation Check: Participant Responsiveness to Stimuli

Response	<i>M</i> (μ S)	<i>SD</i>	<i>Response Frequency</i>
<hr/>			
CS (10% threshold SCR)			
Magnitude	0.10	0.29	18%
Amplitude	0.63	0.75	
<hr/>			
CS (3-step threshold SCR)			
Magnitude	0.11	0.29	35%
Amplitude	0.32	0.41	
<hr/>			
US (10% threshold SCR)			
Magnitude	0.22	0.71	26%
Amplitude	0.83	1.19	
<hr/>			

Note. Magnitude estimates included responses and non-responses while amplitude estimates only included responses. Magnitude and frequency estimates may be deflated, as stimulus parameters were not ideal for capturing and retaining all specific SCRs. The 3-step threshold SCR was not computed for the US, as it was not necessary for testing hypotheses or informing future research decisions.

Table 2

Descriptive Statistics

Run Value	<i>M</i>	<i>M</i> 95% CI	<i>Mdn</i>	Mean Ranking	<i>SD</i>
Expectancy					
CS- 3	6.09	[5.57, 6.61]	6.48	4.43	2.15
CS- 2	6.07	[5.66, 6.48]	6.28	4.46	1.68
CS- 1	5.25	[4.96, 5.54]	5.19	3.47	1.19
CS+ 1	5.35	[5.06, 5.64]	5.27	3.62	1.18
CS+ 2	4.34	[3.94, 4.74]	4.14	2.59	1.65
CS+ 3	4.05	[3.58, 4.52]	4.02	2.44	1.94
3-step Threshold SCR					
CS- 3	-0.17	[-0.30, -0.04]	-0.34	2.46	0.55
CS- 2	-0.16	[-0.25, -0.07]	-0.23	3.21	0.36
CS- 1	-0.09	[-0.15, -0.03]	-0.10	3.96	0.24
CS+ 1	-0.06	[-0.14, 0.001]	-0.10	4.18	0.27
CS+ 2	-0.09	[-0.17, -0.01]	-0.20	3.62	0.34
CS+ 3	-0.01	[-0.14, 0.13]	-0.27	3.59	0.57
10% Threshold SCR					
CS- 3	-0.16	[-0.29, -0.05]	-0.31	3.96	0.48
CS- 2	-0.17	[-0.26, -0.09]	-0.27	3.12	0.35
CS- 1	-0.12	[-0.18, -0.06]	-0.17	3.43	0.24
CS+ 1	-0.07	[-0.13, -0.01]	-0.17	4.00	0.24
CS+ 2	-0.11	[-0.20, -0.03]	-0.25	3.97	0.36
CS+ 3	-0.03	[-0.17, 0.10]	-0.27	2.53	0.57
Tonic SCR					
CS- 3	-0.15	[-0.29, -0.01]	-0.35	2.78	0.60
CS- 2	-0.01	[-0.11, 0.11]	-0.06	3.54	0.47
CS- 1	-0.04	[-0.12, 0.03]	-0.09	3.74	0.30
CS+ 1	0.03	[-0.05, 0.11]	-0.01	3.99	0.32
CS+ 2	0.01	[-0.09, 0.12]	-0.13	3.78	0.45
CS+ 3	0.11	[-0.10, 0.32]	-0.19	3.18	0.87

Note. Friedman's ANOVA produced the mean rankings. The three reported measures of

central tendency did not necessarily follow identical patterns.

Table 3

Sphericity and Normality Tests

Test Statistics	Expectancy	3-step threshold SCR	10% threshold SCR	Tonic SCR
Mauchly				
χ^2	181.73	55.42	48.10	68.13
df	14	14	14	14
ε	0.41	0.76	0.78	0.69
p	< .001	< .001	< .001	< .001
K-S				
D	0.01	0.29	0.36	0.21
df	1850	1850	1850	1850
p	< .001	< .001	< .001	< .001

Note. The SCR data followed less of a normal distribution than the expectancy data.

Table 4

Expectancy One-Way Repeated Measures ANOVA Significant Comparisons

Run Value Comparisons	Mean Difference	95% CI	SE	<i>p</i>
CS- 3 > CS- 1	0.84	[0.35, 1.32]	0.24	.001
CS- 3 > CS+ 1	0.74	[0.09, 1.39]	0.33	.026
CS- 3 > CS+ 2	1.75	[0.93, 2.58]	0.41	< .001
CS- 3 > CS+ 3	2.04	[1.18, 2.90]	0.43	< .001
CS- 2 > CS- 1	0.82	[0.46, 1.18]	0.18	< .001
CS- 2 > CS+ 1	0.72	[0.18, 1.26]	0.27	.010
CS- 2 > CS+ 2	1.73	[1.02, 2.44]	0.36	< .001
CS- 2 > CS+ 3	2.02	[1.27, 2.77]	0.38	< .001
CS-1 > CS+ 2	0.91	[0.34, 1.48]	0.29	.002
CS- 1 > CS+ 3	1.20	[0.62, 1.78]	0.29	< .001
CS+ 1 > CS+ 2	1.01	[0.63, 1.39]	0.19	< .001
CS+ 1 > CS+ 3	1.30	[0.78, 1.83]	0.26	< .001

Note. All comparisons were Bonferroni corrected.

Table 5

Friedman's ANOVA Significant Comparisons for Dependent Measures

Run Value Comparisons	<i>T</i>	<i>p</i>
<u>Expectancy</u>		
CS- 3 > CS- 1	0.96	.043
CS- 3 > CS+ 2	1.84	< .001
CS- 3 > CS+ 3	1.99	< .001
CS- 2 > CS- 1	0.99	.032
CS- 2 > CS+ 2	1.87	< .001
CS- 2 > CS+ 3	2.02	< .001
CS- 1 > CS+ 3	1.02	.020
CS+ 1 > CS+ 2	1.03	.020
CS+ 1 > CS+ 3	1.18	.004
<u>3-step threshold SCR</u>		
CS- 1 > CS- 3	1.50	< .001
CS+ 1 > CS- 3	1.72	< .001
CS+ 1 > CS- 2	0.97	.037
CS+ 2 > CS- 3	1.16	.004
CS+ 3 > CS- 3	1.13	.006
<u>10% threshold SCR</u>		
CS- 3 > CS+ 3	1.43	< .001
CS+ 1 > CS+ 3	1.47	< .001
CS+ 2 > CS+ 3	1.44	< .001
<u>Tonic SCR</u>		
CS- 1 > CS- 3	0.96	.043
CS+ 1 > CS- 3	1.21	.003
CS+ 2 > CS- 3	1.00	.027

Note. All comparisons were Bonferroni corrected. The conflicting evidence from the 10% threshold comparisons may have been due to the volatility of the larger absolute value run groups, which had less data points and more variance.

Table 6

Correlations Between Dependent Measures

Correlations	<i>r</i>	<i>p</i>
Expectancy-3-step threshold SCR	.04	.089
Expectancy-10% threshold SCR	.04	.094
Expectancy-Tonic SCR	.00	.846
3-step threshold SCR-10% threshold SCR	.95*	< .001
3-step threshold SCR-Tonic SCR	.05*	.020
10% threshold SCR-Tonic SCR	.06*	.011

Note. Given the large sample size of the correlational analyses ($n = 1850$), a significant p value was not necessarily indicative of a strong relationship between the variables of interest.

* $p < .05$

Appendix E

Figures

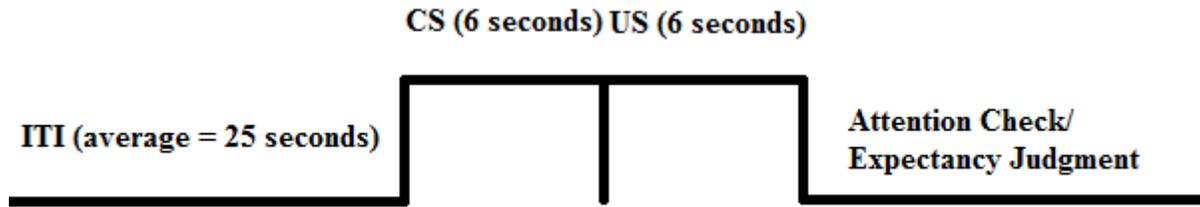


Figure 1. CS+ trial sequence. CS- trial sequence was identical, except there was no US and no attention check.

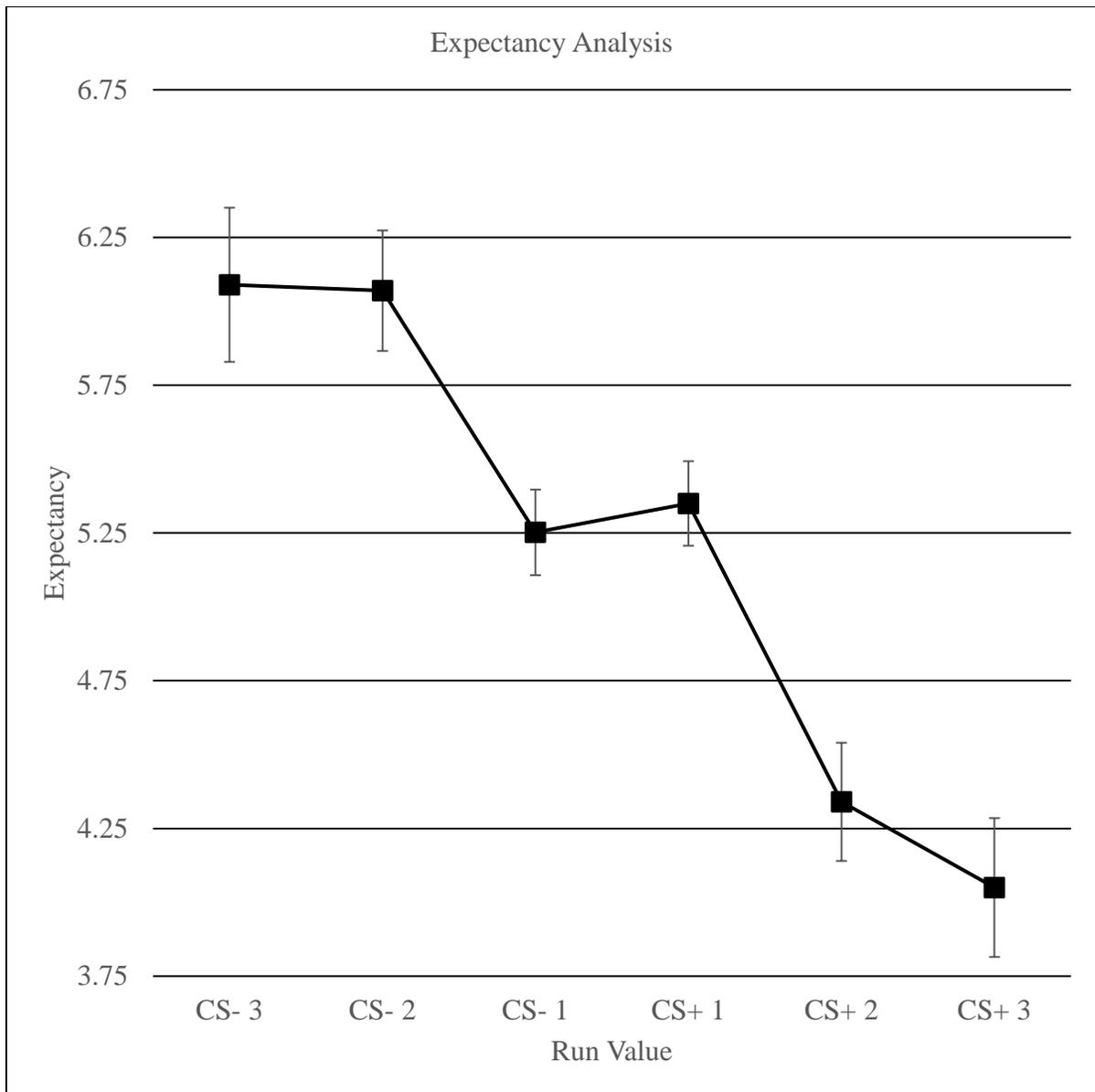


Figure 2. Expectancy as a function of run value. Errors bars represent standard error. As run value increased, expectancy decreased.

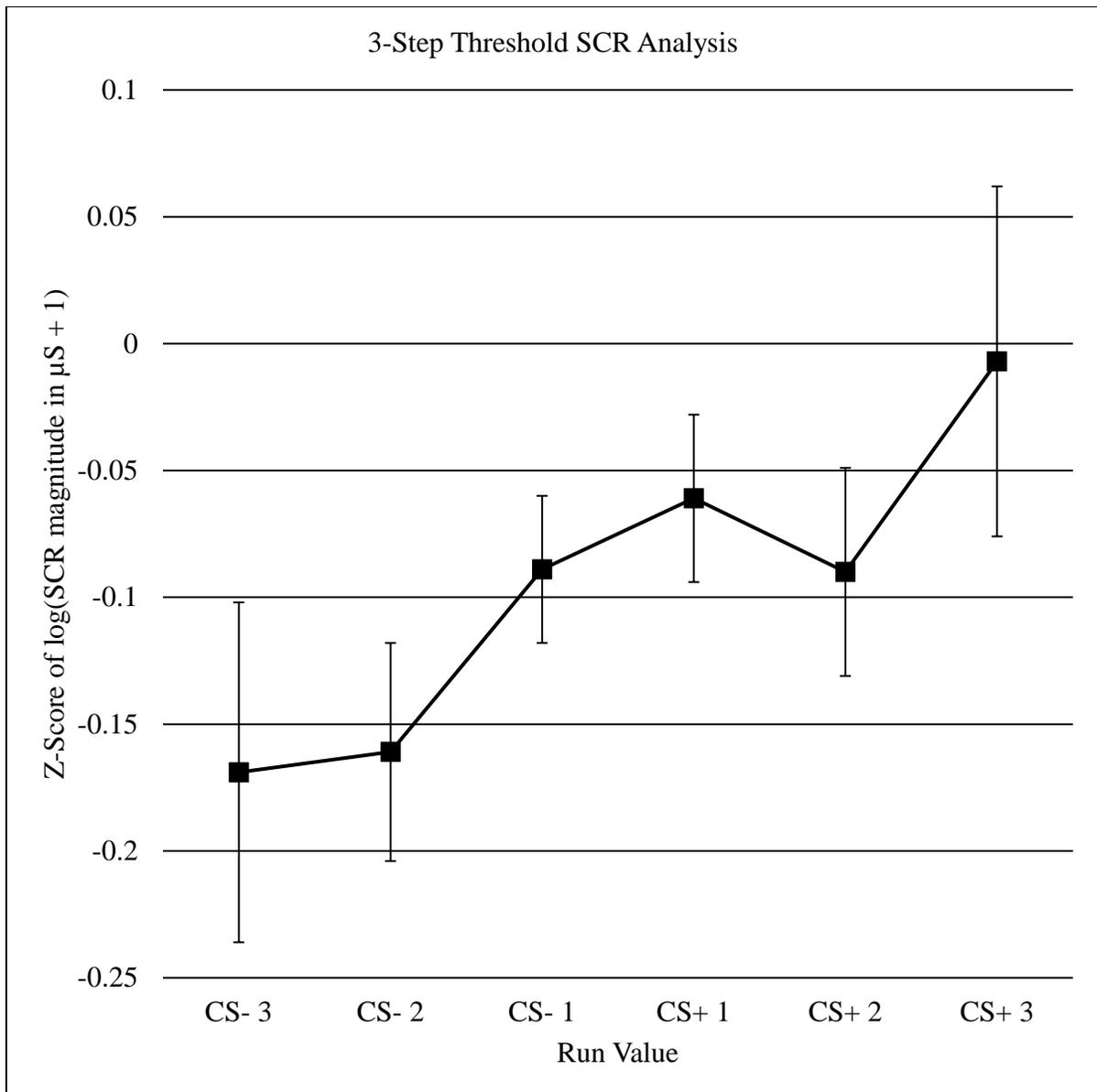


Figure 3. 3-step threshold SCR as a function of run value. Errors bars represent standard error. Generally, as run value increased, 3-step threshold SCR increased. This effect was larger than the 10% threshold SCR analyses for both parametric and non-parametric statistical tests.

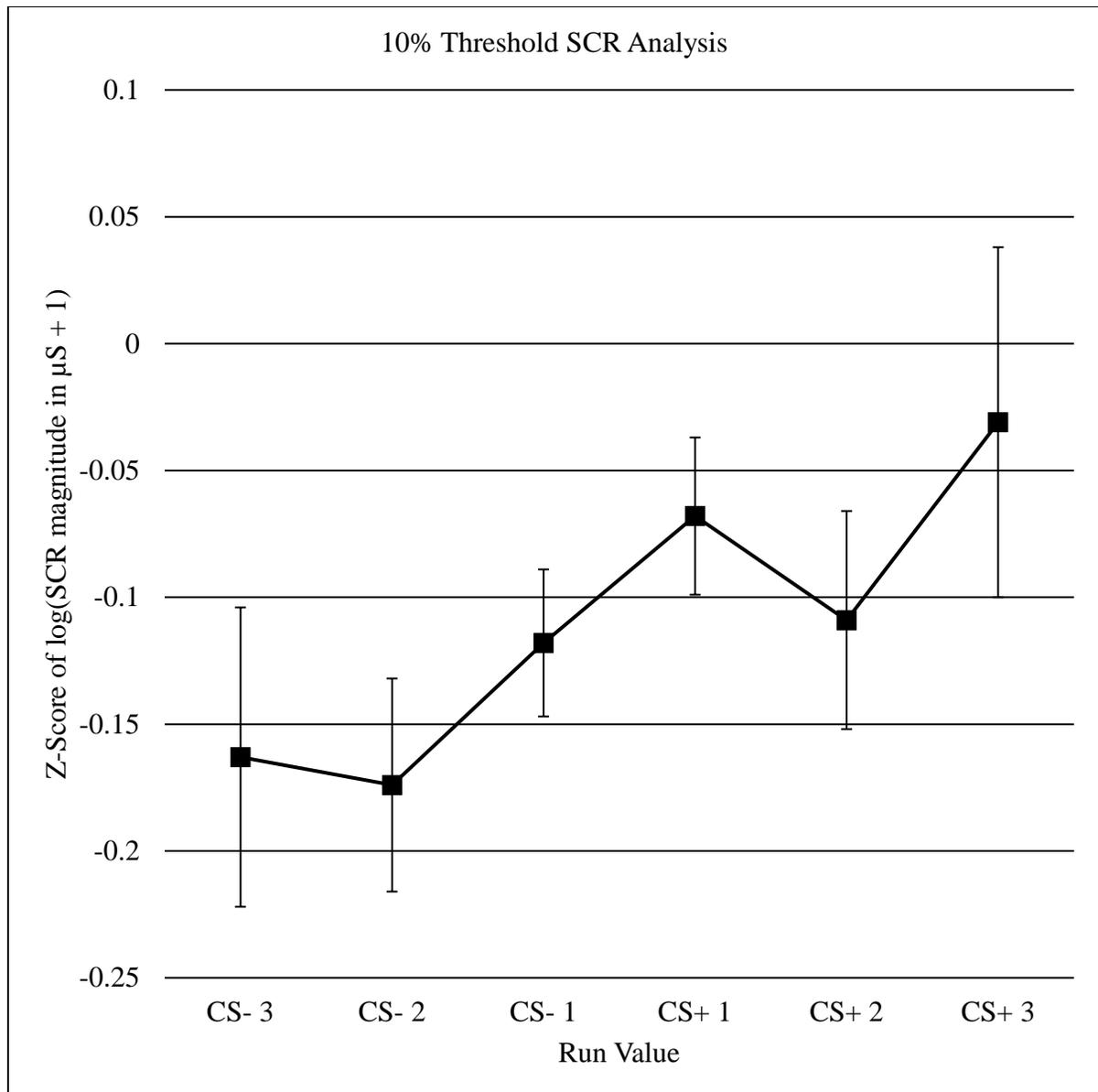


Figure 4. 10% threshold SCR as a function of run value. Errors bars represent standard error.

Generally, as run value increased, 10% threshold SCR increased. This effect was smaller than the 3-step threshold SCR analyses for both parametric and non-parametric statistical tests.

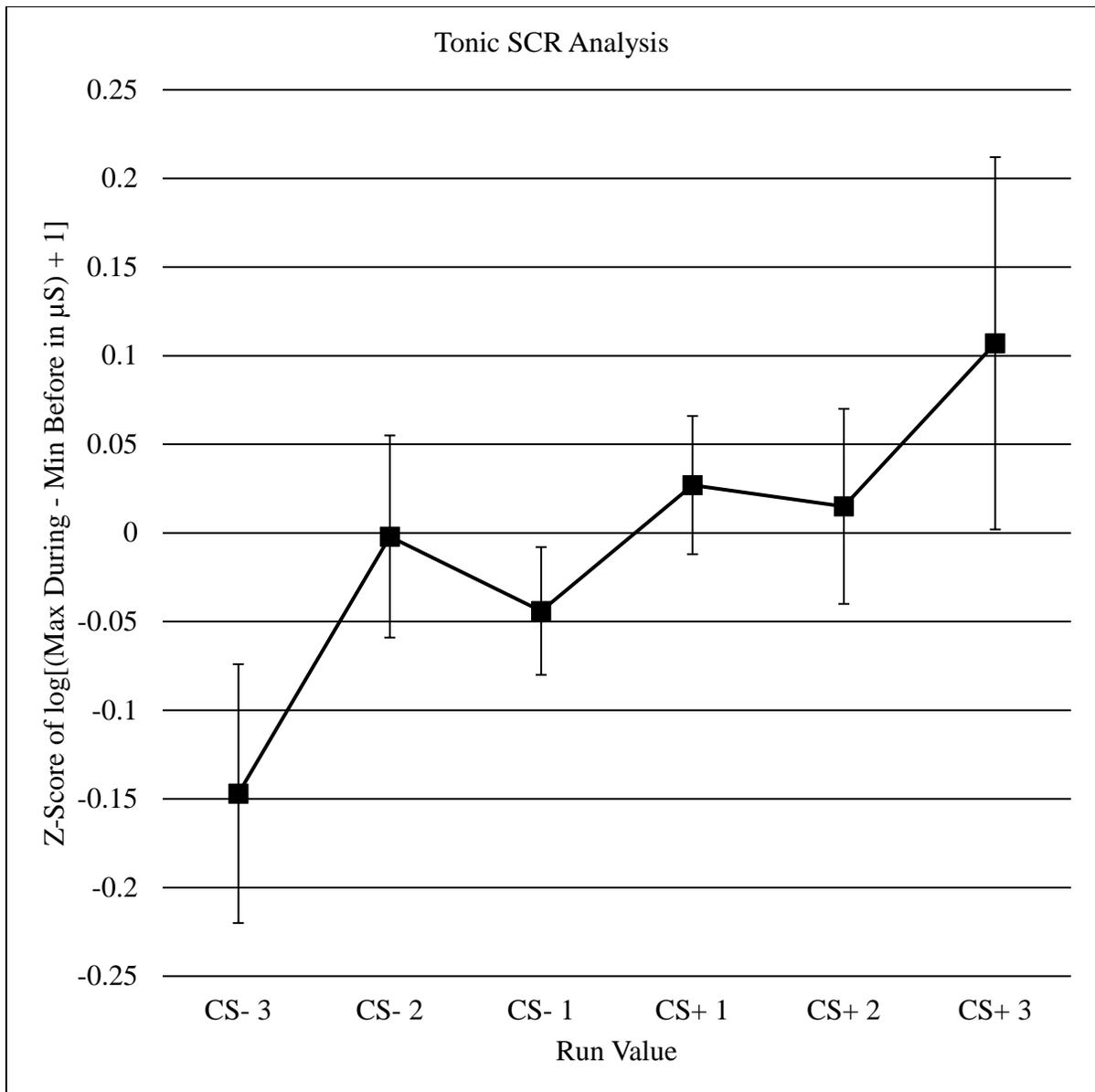


Figure 5. Tonic SCR as a function of run value. Errors bars represent standard error.

Generally, as run value increased, tonic SCR increased.

Vita

Andrew Joseph Graves was born in Knoxville, TN, to Joe and Virginia Graves. He graduated from the Christian Academy of Knoxville in May, 2011. The following autumn, he entered Appalachian State University to study psychology, and in May, 2015, he was awarded the Bachelor of Arts and the Bachelor of Science degrees in Psychology. In the fall of 2015, he accepted matriculation into the Experimental Psychology program at Appalachian State University and began study toward a Master of Arts degree. The Master of Arts in Psychology was awarded in August, 2017. In August, 2017, Mr. Graves commenced work toward a Ph.D. in Psychology at the University of Virginia, specializing in Cognitive Neuroscience.