# THE PERRUCHET EFFECT IN ELECTRODERMAL RESPONSES TO PICTURES

A Thesis
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**Abstract**

THE PERRUCHET EFFECT IN ELECTRODERMAL RESPONSES TO PICTURES

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This study sought to further our understanding of classical conditioning. Classical conditioning is the process by which two stimuli are paired and the first stimulus gains a response that is typically evoked by the second stimulus. Currently the two primary explanationsfor this phenomenon are an automatic (unconscious) link between the two stimuli or a propositional (conscious) understanding of the contingency. One design, known as the Perruchetdesign, unpredictably pairs stimuli to produce uncertainty. The Perruchet design uses probabilistic fallacies to then put conscious expectation of reinforcement in opposition with unconscious expectation of reinforcement, producing a difference in prediction between the two models. The Perruchet effect has almost exclusively been studied using sounds and air puffs as stimuli. The present study tested the generalizability of this design to other stimuli, by using visual stimuli tracked by electrodermal activity. The stimuli used in this experiment were a picture frame as the conditioned stimulus (CS) and aversive images set within the frame as unconditioned stimuli (UCS).

The setup of the Perruchet design entails pairing the CS and an the UCS on 50% of trialsin a pseudo-random order consisting of a number of runs. A run is a string of consecutive trials of the same type (paired or unpaired) and we included runs with a length of 1,2, and 3. On each trial we recorded a verbal report of (conscious) expectation

of the UCS, as well as (unconscious)skin-conductance responses to the CS. Based on previous findings on the Perruchet effect, we predicted that verbal expectations would increase with longer unpaired runs, and decrease with longer unpaired runs. In the opposite direction, we predicted that skin-conductance responses would be weaker during longer unpaired runs, and stronger during longer paired runs.

Due to data loss errors, we were able to analyze only paired runs. We observed the expected decrease in verbal expectation across paired runs, but we did not find a significant difference in skin conductance response strength between paired runs. This means that we were unable to replicate the Perruchet effect. Future studies should focus on the role of habituation in visual stimuli or investigate other types of stimuli to ensure that the Perruchet effect is not uniqueto eyeblink conditioning.

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## Dedication

Dedicated to my uncle Kim and my grandfather Norfleet, who showed me how to persevere, no matter what.

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# The Perruchet Effect in Electrodermal Responses to Pictures

The present study focused on classical conditioning. Classical conditioning is an effect that emerges when a neutral stimulus is repeatedly presented alongside a stimulus with a preexisting response. Over several presentations, the previously neutral stimulus develops a response similar to that of the paired stimulus (Pavlov, 1927). Classical conditioning has been known about since the days of Aristotle but have only come under the scrutiny of empiricalstudy within the 20th century. Within this century, the focus on predictions of conditioning and stimulus selection has given us a strong understanding of conditioning outcomes but left hidden the underlying processes that drive conditioning. In other words, many studies have addressed the questions of what happens when classical conditioning occurs but there is a deficit in research that asks the question of how classical conditioning occurs. Thus, our question deviates from the typical investigation of classical conditioning by studying the processes that drive conditioning, rather than focusing on outcomes. Specifically, we investigated whether contingency awareness is required to produce classical conditioning effects.

Presently, there is a debate on conditioning processes about whether conscious awareness is necessary for conditioning to occur (Mitchell et al., 2009). The present study contributes to this discussion by testing the robustness of the Perruchet effect, which has been shown to produce classical conditioning in the absence of contingency awareness (e.g., Clark, et al., 2001; Graves, 2017; Perruchet, 1985, 2015). The Perruchet design produces a unique conditioning effect that separates conscious and unconscious learning in humans. The current study applies this technique to classical conditioning using visual stimuli.

## Classical Conditioning

Classical conditioning is a process by which two previously unassociated stimuli or events form an association (Pavlov, 1927). This process is markedly seen by a conditioned stimulus (CS) acquiring the reactive properties of a biologically relevant unconditioned stimulus (UCS). The typical classical conditioning procedure consists of multiple, close temporal and spatially contiguous pairings between these two stimuli. After a number of trials, the subject begins to respond to the CS in a similar manner as it responds to the UCS. This new response to the conditioned stimulus is called a conditioned response (CR). The most famous example of this type of conditioning is Pavlov's (1927) salivation study. In his procedure, a tone (the CS) was presented shortly before a dog was given food (the UCS). This presentation of a tone shortly followed by food was repeated across several trials. Over time, the dog's innate response to salivate when given food (the UCR) began to occur at the sound of the tone, even before the food was presented (the CR).

Within this framework of association, two of the main factors that are thought to govern the strength of an association are contiguity and contingency. Pavlov (1927) was the first to systematically study the concept of contiguity. Contiguity is the closeness in time and space between the two stimuli. As described by Pavlov, the further that stimuli are across either of those dimensions, the slower the acquisition process becomes. Therefore, in the context of Pavlov's salivation study, conditioning would occur faster if the tone was presented immediately before the food than if the tone was presented 30 seconds before the food. Similarly, conditioning would occur faster if the tone was presented adjacent to the food, rather than if the tone was presented from the opposite side of the room. The other main factor that contributes to conditioning strength is contingency (Rescorla, 1968). Contingency is the ratio of pairings

between the CS and the UCS. A contingency of 1 would entail all CS and UCS presentations occurring together, neither occurring in the absence of the other. A 0.5 contingency could entail only half of the CS presentations being followed by a UCS presentation, with the other 50% of the UCS presentations in the absence of the CS. A contingency of 0.0 would mean that the CS and UCS are equally likely to occur in the presence or absence of the other. Unpaired stimuli can take the form of a CS presentation without the UCS or a UCS presentation without the CS. A higher contingency value produces faster and stronger conditioning. Using the salivation example again, the dog would learn fastest if the tone predicted every bit of food the dog received (1.0), slower if the tone precedes the food on most of the trials (0.75) and the dog would not develop the association at all if the tone was not presented in any way that systematically varied with food presentation (0.0).

**Explanations of the Classical Conditioning Effect**

Despite the acceptance of classical conditioning as a robust and replicable phenomenon, there is a disagreement about the mechanisms which drive the conditioning process (Lovibond & Shanks, 2002; Mitchell, et al., 2009). The disagreement about the mechanisms of classical conditioning centers around the role that propositional thought and conscious knowledge of the CS-UCS contingency play in developing a conditioned response. Two interpretations of conditioning exist that attribute classical conditioning to either higher or lower-order reasoning. One interpretation is that classical conditioning is driven by higher-order propositional thought, in which an understanding of the CS-UCS contingency is required to develop a conditioned response. The other interpretation is that classical conditioning is driven by lower-order associative processing that occurs automatically and independent of propositional reasoning. The

lower-order associative processing has been described as an associative link that forms a subconscious connection between the two stimuli (Sloman, 1996).

These theories of associative processing have conflicting explanations for the mechanisms of conditioning but maintain the same behavioral expectations. Take Pavlov's (1927) salivary conditioning study for example. After conditioning, propositional (higher-order) reasoning-based theorists would predict that the dog has become consciously aware that food follows the tone and thus the digestive system activates in preparation. In that interpretation, the tone functions as a reliable predictor of food and the deployment of the CR is expectation based. Conversely, associative link theorists would predict that after sufficient pairings, the tone evokes the same digestive response as the food. In this interpretation, the tone itself activates the digestive system as though hearing the tone was equivalent to receiving the food.

Although the two interpretations have different explanations about how conditioning occurs, they often share the same prediction for a behavioral outcome (i.e., salivating in response to the tone). Thus, attempts to support one theory over the other have varied widely in methodology. Toward addressing this, Mitchell, De Houwer, and Lovibond (2009) analyzed human conditioning studies over the past 50 years and describe their findings as overwhelming support for the propositional model of conditioning. One illustrative example of this type of support is a study on contingency reversal (McNally, 1981). In this study participants were given a differential conditioning procedure, in which they were shocked after viewing pictures of spiders, but not after viewing pictures of snakes. After 12 presentations of the pictures, participants were instructed that the contingency would reverse, and they would receive shocks only after pictures of snakes. Fear was tracked using electrodermal activity and researchers saw

an immediate reversal of CRs following the instructions. Namely, on the initial few trials after informing participants of the change in contingency participants displayed CRs to pictures of snakes and no CRs to pictures of spiders. Thus, it would appear as though propositional knowledge about contingency reversal was enough to change responding, even before a new contingency could have been learned through an automatic link.

Although there is a wealth of evidence supporting propositional knowledge playing a part in conditioning in intact humans, support for automatic link conditioning has come in the form of studies on patients with amnesia and animal studies. Mauk and Thompson (1987) attempted to show conditioning in animals that were unable to become aware. Mauk and Thompson removed all forebrain tissue from rabbits, which contains the brain regions associated with declarative memory and conscious thought (contingency knowledge) and exposed them to a classical conditioning procedure. The procedure consisted of a tone (CS) preceding an air puff blown toward the eye (UCS) and responses measured were eye blinks elicited during the tone (CR). The lesioned rabbits developed CRs at the same rate as the control sample of intact rabbits. This finding supported previous findings by Norman, Villablanca, Brown, Schwafel, and Buchwald's (1974) study, in which they removed the same brain regions from a sample of cats and compared their ability to form an association to that of intact cats. Norman and colleagues used the same conditioning procedure as Mauk and Thompson. They found that the lesioned cats developed associations at a similar rate as the intact cats. Both studies found clear displays of classical conditioning in subjects that lacked the capacity to become aware of the CS-UCS contingency. In a similar study, Gabrieli and colleagues (1995) exposed human participants with amnesia and a sample of education-matched controls to another tone-air puff conditioning procedure. Like in the results from the non-human animal studies, the patients with amnesia developed a CR at the

same rate as their intact counterparts. These studies provide strong support for the automatic link interpretation of classical conditioning. As a whole, research on the topic of awareness in conditioning is still very discordant and thus more investigation is necessary into the mechanisms of conditioning.

**The Perruchet Effect**

The Perruchet effect provides a unique opportunity for further investigation into processes that drive human learning by producing conditioning in intact humans without explicit propositional knowledge the CS-UCS relationship (Perruchet, 1985). Pierre Perruchet created a procedure in which a modified classical conditioning procedure used uncertainty to disrupt the formation of propositional knowledge about the CS-UCS relationship. His original study used eyeblink conditioning with human participants in which the CS was a tone, the UCS was a puff of air blown into the participant's eye, and the CR was blinking. Unlike typical classical conditioning procedures, Perruchet's procedure paired the CS and UCS on 50% of the trials. The participant was made aware of the contingency beforehand, introducing uncertainty about when the UCS would be presented. Trials in which the air puff was presented would be classified as CS+ trials and trials in which the air puff was not presented became known as CS- trials. Along the course of the experiment, participants' expectations of receiving the air puff were measured between trials. Before each new presentation of the tone, participants were asked the extent to which they expected an air puff on the next trial on a scale ranging from *1* to *7* (*1* indicating no expectation, *4* indicating uncertainty, and a *7* indicating the strongest expectation). Because the presentation of the air puff was randomized across trials there were occasions where participants experienced 1, 2, 3, or 4 consecutive CS+ or CS- trials. The number of consecutive trials of the same type became known as the run number. A CS+ run of 3 means that the participant

experienced 3 CS+ trials in a row. The same is true where a CS- run of 2 means that the participant received 2 CS- trials in a row. Thus, a CS+ run of 4 represented the strongest conditioning, and a CS- run of 4 represented the strongest extinction.

Perruchet (1985) predicted that participants, having been explicitly informed that the UCS had a 50% chance of occurring, would expect the UCS less after CS+ trials and expect the UCS more after CS- trials. This prediction came from the gambler's fallacy, in which people expect that past results on a probabilistic outcome have an effect on future occurrences and adjust their expectations accordingly (e.g., Burns & Corpus, 2004). Thus, on longer CS+ runs participants should expect the UCS to be less likely to occur and on longer CS- runs participants should expect the UCS more. By contrast, it was predicted that CRs would strengthen (i.e., more frequent blinking) after CS+ (reinforced) trials and would weaken (i.e., less frequent blinking) after CS- (extinction) trials. These predictions are very important because they place responding in direct opposition with expectation. In other words, the utility of this procedure is that it separates the predictions of the two conceptualizations of classical conditioning. The propositional knowledge model would predict that CRs follow the reported expectations, while the automatic link model would predict that CRs follow the contingency, regardless of expectation.

The results of Perruchet's (2015) study followed these predictions. Expectation followed the gambler's fallacy, whereas CRs followed typical classical conditioning and an inverse relationship emerged between the amount of expectation and the strength of the conditioned response. The dissociation between expectations and conditioned responding was further widened by longer runs. Thus, the least expectation and strongest CRs were found on CS+ runs of 4, while the most expectation and weakest CRs were found on CS- runs of 4. The significance

of Perruchet's procedure is that the opposition of expectation and conditioned responding is one of the rare cases where propositional and automatic link theorists would predict different behavioral results. Propositional reasoning would predict that conditioning follows conscious expectation and the participant demonstrates a stronger CR when they most expect the UCS to appear. Automatic link conditioning would predict that an increased CR would follow CS+ trials, regardless of how much participants expect the UCS. Thus, the results of the Perruchet effect ultimately provide support for automatic link processing. This effect has been replicated multiple times since Perruchet's original report of the phenomenon (Clark et al., 2001; McAndrew et al., 2012; Weidemann et al., 2012), with the majority of these studies also using eyeblink conditioning (Perruchet, 2015).

**Conditioning with Visual Stimuli**

Considering that many of the studies that have observed the Perruchet effect have retained the same conditioning medium (eyeblink conditioning) as the original study, generalizability is an important line of investigation. To this end, Graves (2017) conducted a generalization study on the Perruchet effect using visual stimuli. In this study, a small fixation cross in the center of a computer screen (the CS) was paired on 50% of trials with a set of arousing photographs (UCS). The photographs contained positively and negatively valanced content, including images of predatory animals, human wounds, attractive humans (of both sexes) and romantic couples, each controlled for level of arousal. CRs were recorded using electrodermal activity, which is a physiological measure that will be discussed later on. Expectancy was recorded on a scale from 1 (*least*) to 9 (*most*). The results showed that the expectation portion of the Perruchet effect was successfully observed, however CRs were only

weakly associated with run number. The current study was a close replication of the procedures of Graves's study, with a number of changes designed to strengthen the effect.

In our replication we, like Graves (2017), used arousing images from the International Affective Picture System (IAPS; Lang et al., 2008). The IAPS is a set of images rated normatively across valence and arousal. There were a couple of reasons for using these images as the UCS. Firstly, IAPS has been tested across a number of physiological measures (e.g., EDA, heart rate, EMG) and has been found to elicit arousal reliably (Bradley & Lang, 2007). Additionally, the normative nature of IAPS allows researchers to select several images with categorically different content at similar levels of arousal, which is an important counter to habituation when using classical conditioning. Thus, for investigating classical conditioning with visual stimuli, the IAPS presents a uniquely efficacious and predictably arousing set of visual UCS. Unlike Graves (2017) however, we restricted our selection to the negatively valanced categories: predatory animals and human wounds. The reason for this is that gender differences in image ratings show that while photos of attractive people are fairly arousing for men, they are less arousing for women (Lang et al., 2008). Given that Graves' study consisted of predominantly female participants, this may have been a strong factor affecting his results. Additionally, we changed the CS from a fixation cross to an image of a picture frame. This is so that the UCS would be presented alongside the CS (aversive picture appearing inside the picture frame) and allow both stimuli to co-terminate, which should produce stronger conditioning (Pavlov, 1927). Lastly, we adjusted the timing of stimulus presentations and inter-trial interval timings. The specifics of the time adjustment and rationale will be discussed in the procedures section.

**Measuring Responses with Electrodermal Activity**

Like Graves (2017), this study measured conditioned responding using electrodermal activity. Electrodermal activity (EDA) is a psychophysiological measure of sympathetic nervous system activation that detects sweat response by measuring the electrical conductance of the skin (Handler et al., 2010). EDA functions by applying a constant weak voltage to the skin through two electrodes placed on the fingers. When the sympathetic nervous system activates and sweat is produced, ions within the sweat increase conductivity and the change is measured. This change in conductivity is measured in microsiemens (μS). Changes in EDA are further broken down into two different categories of waveforms; tonic and phasic (Critchley, 2010). Phasic waveforms are rapid changes in EDA that raise conductivity to a crest and return to baseline within a matter of seconds. Phasic changes in EDA are thought to represent short intense responses to arousing stimuli, like a startle or an electric shock. Tonic waveforms are gradual changes in EDA that take place over an extended period of time (10 s to 10 min). Tonic changes in EDA are thought to represent lingering or subtle responses to emotional or arousing stimuli. Tonic EDA is affected by factors such as individual differences in skin conductivity, temperature, mood and hydration. These dynamic changes in EDA are referred to as skin conductance responses (SCR). It is important to note that EDA is also affected by bodily movements and if a participant is not still, these movements can appear as artifacts in the data. Despite this, SCR has been reliably used in a number of studies looking at classical conditioning (Lovibond & Shanks, 2002; Mitchell et al., 2009).

The use of EDA is especially prudent with our use of visual stimuli because, unlike a puff of air, arousal does not incur an obvious observable behavior across participants. EDA functions as an especially useful tool to this end because it observes changes in emotion and arousal, both

of which were manipulated by our image selection (Critchley, 2010; Lang et al., 2008). In order to capitalize on this effect, our images were selected from two IAPS categories (predatory animals and human wounds) that have been found to produce stronger SCRs than does other categories (Bradley et al., 2001).

**Current Study**

The aim of the current study was to replicate the procedures of Graves (2017) with a number of methodological changes designed to increase the probability of observing the Perruchet effect. We provide parametric insight into factors that may have weakened the findings of Graves' study, as well as additional support for the Perruchet effect using visual stimuli.

Instead of using images with both positive and negative valence, we used only negatively valanced images. This is because arousal ratings across negatively valanced images are more stable across gender than positively valanced images (Lang et al., 2008). We used an image of a picture frame as the CS instead of a fixation cross. This allowed us to partially overlap the CS and UCS to improve contiguity, which is one of the factors that affects associative strength (Pavlov, 1927). We also reduced the time between trials by an average of 33 s. This was based on observations during data collection of the Graves study that participants often became bored and disengaged toward the end of the experiment. Additionally, Graves used an average of around 60 seconds between CS presentations to ensure that responses did not compound over successive trials. After his experiment, he observed that the increase in SCR amplitudes caused by the UCSs returned to baseline much faster than anticipated, further supporting our more rapid stimulus presentation. We increased the sample size in order to achieve more statistical power. We ran a G*Power (Faul et al., 2007) power analysis based on our intended analyses. We ran thepower analysis expecting to run a Multivariate ANOVA, looking for a small effect (based on

Graves 2017), from a within-subjects design containing four presentations of six levels of the independent variable. Accepting an alpha of .05 and a beta of .05 the power analysis suggested that 204 participants should be sufficient to observe an effect if one is present [ANOVA: Repeated measures, within-factors, six groups, four repetitions (on average), *r* among repetitions = .10, ε = .78, effect size *f* = .14 (η 2 = .02), α = .05, β = .05]. Though we used this power analysis to determine the number of participants gathered, our analyses changed during the course of the experiment, and thus this number does not necessarily represent an accurate number of participants needed to ensure statistical power.

## Method

### Participants

We recruited 204 undergraduate students currently enrolled in a psychology course through the university's online recruitment pool. Eighty-five percent of participants identified as female, 15% identified as male, and no participants identified as another gender. Participants received course credit for their participation. Based on the power analysis was expected to be an appropriate number of participants to find an effect if there was one (Faul et al., 2007). All procedures were approved by Appalachian State University's institutional review board (Study #17-0214).

### Materials

#### *Conditioned Stimulus*

All visual stimuli were presented through E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The CS was a digital image of a wooden picture frame on a white background centered on the computer screen. The CS took up 72% of the widthof the computer screen and 90% of the height of the computer screen. Centered inside the frame was a blank white space that took up 52.3% of the width and 69.4% of the height of the screen.

The screen was 27 cm (Height) x 48 cm (Width). The CS appeared on every trial for a duration of 12 s.

### *Unconditioned Stimuli*

The UCSs were 22 negatively valanced images with high arousal as determined by the IAPS (Lang et al., 2008). These images were centered and stretchedproportionately to cover 52.3% of the width and 69.4% of the height of the computer screen, thusfilling the white space inside of the picture frame (CS). The UCSs appeared only on CS+ trials and were presented for 6 s overlapping with the second half of the CS presentation.

## Measures

### *Conditioned Response*

The conditioned response was measured by skin conductance response, using the BIOPAC MP36R and Acq*Knowledge* software (BIOPAC MP36R, 2008). Both tonic and phasic EDA were recorded throughout the experiment. Responses were marked innumber and strength by phasic SCRs. An SCR was considered a CR if it occurred after the CS onset and prior to the UCS onset. The strength of CR was determined by comparing pre-CS tonicEDA levels to post-CS phasic EDA levels, thus controlling for individual differences. Only SCRs with a magnitude of at least 10% of the largest SCR were considered. The others were ruled out in an attempt to control for artifacts in the data.

### *Expectancy*

Following each trial, participants were asked about their expectancy for theUCS on the next trial. Their expectancies were recorded on a scale anchored from 1 (*very unlikely*) to 9 (*very likely*). Their selection was recorded based on their press of a key on the number pad. They were instructed to use the entire scale to specifically identify their expectations.

### *Attention*

Our procedure included an attention check to ensure that participants remained focused throughout the experiment. On CS+ trials after the UCS and before the expectancy question, participants were asked: “Did the previous image include a human face?” We chose to ask about a face specifically in order to orient participants towards the content of the images. Data from participants who answered this question incorrectly more than 50% of thetime were excluded from analyses.

### *Experimental Design*

This experiment followed a 3 (run length: 1, 2, 3) x 2 (trial type: CS+, CS-) within-subjects design. There were 8 runs of 1, 4 runs of 2, and 2 runs of 3, in order to represent a binomial distribution. The difference in the effect between binomial distribution andequal distribution is not yet known, so we followed the precedent set by Perruchet (1985) and Graves (2017).

## Procedure

The experimenter invited the participant into the room and encouraged them to read the informed consent form. After the participant signed the informed consent, they were asked to wash their hands, in order to make it easier to obtain an EDA signal. Upon returning they were seated in front of the computer and had electrodes attached to the middle and index fingers of their non-dominant hand. The participant’s dominant hand was left free so that they could use it to answer questions using the computer keyboard. The keyboard was placed nearby to minimize required movement. After attaching the electrodes, the participant was wired to the computer and the researcher began recording EDA data. At least 10 minutes passed before beginning the experiment, in order to allow time for the electrode gel to penetrate the skin. After the 10-minute waiting period, the experimenter read a script instructing the participant that it was their job to

predict if a picture would appear on each trial, as well as how to answer the expectancy and attention questions. Participants were asked to move as little as possible in order to reduce artifacts in the data. Then, the researcher started the E-prime and begin stimulus presentation.

All trials started with a 5 s blank screen. On CS+ trials participants saw the picture frame alone for 6 s and then the picture appeared inside the picture frame and remained for 6 s. After stimulus presentation, participants viewed a blank screen for 2.5 s then received the attention check "Did the previous image include a human face?" After pressing the "y" key if the last UCS contained a face or the "n" key if the UCS did not contain a face, participants viewed a blank screen for another 2.5 s. On CS- trials participants saw the picture frame for 12 s and then it disappeared, and participants viewed a blank screen for 5 s. E-prime sent digital inputs to Acq*Knowledge* via the computer's parallel port at 125 Hz to mark the CS onset and UCS onset. We discovered later that 125 Hz was too short of a pulse for E-prime to detect the signals, resulting in data loss errors. On all trials, following the stimulus presentation and the blank screen, participants were asked "How much do you expect to see a picture on the next trial?". Responses were recorded on the keyboard using the keys 1-9. After the participant answered the expectation prompt, they viewed a blank screen for 2, 4, or 6 s, randomized to prevent temporal conditioning, followed by a 10 s inter-trial-interval. During this interval, the screen displayed the message "Please remain relaxed and still. Continue to pay attention to the computer screen". This interval was designed to allow phasic EDA to return to baseline. Sequences of runs were randomized between participants to prevent order effects. The procedure took approximately 40 minutes.

After all the trials had been completed (Approximately 30-40 minutes) the researcher saved the data, removed the electrodes and thanked the participant for participating. We predicted that participants would show a decrease in UCS expectancy as a function of

consecutive CS+ trials (run length), and show an increase in expectancy as a function of consecutive CS- trials (run length). We predicted that SCR responding would follow the opposite trend, in which CRs increase as a function of CS+ run length and decrease as a function of CS- run length. These findings would provide support for the generalization of the Perruchet effect and more generally provide support for the automatic link model of classical conditioning.

## Results

Due to communication difficulty between the E-prime and Acqnowledge software, stimulus presentation was not recorded for any of the CS- trials. We have been unable to retroactively identify stimulus timings and are therefore unable to include CS- trials in our analyses. Due to processing errors, some participants' data collection was terminated prematurely, leaving data points missing. Of the 204 participants, only 147 had sufficient data for analysis. Although, given that stimulus presentations were randomized, these missing data should have no systematic effect on results.

A mixed effects model was used to examine the effects of condition (CS+1, CS+2, and CS+3) on each dependent variable. The mixed effects model was used to account for multiple observation coming from many different participants. Much like ANOVAs, mixed effects models test for significant changes in multiple dependent variables across different levels of the independent variable. The advantage for the mixed effects model over multiple MANOVAS or repeated measures ANOVAs is in its handling of clustered samples. Because our analyses were made up of many samples of each condition clustered by participant, the mixed effects model was most appropriate to handle the stratification of the data.

Figures 1 and 2 show a graph of phasic and tonic SCR respectively. The Y axis shows the average magnitude of the SCR, while the X axis shows the run number. These two figures show

both measures of SCR responding, neither of which change markedly over time. Tonic SCRs were in the expected direction, but with only very small changes across conditions. Figure 3

shows the differences in expectancy, with the 1 to 9 expectancy rating on the Y axis and CS+ run length on the X axis. Figure 3 shows a clear pattern of less expectation following more consecutive CS+ trials. Exploratory analyses investigated the average strength of CRs. This revealed that nearly all phasic SCRs had a magnitude of 0 (see figure 4). Tonic SCR's however, followed a more normal distribution (see figure 5) and thus are more relevant for analyses in this study. Additionally, we looked at tonic SCR changes across time. Baseline corrected averages of tonic SCRs to the CS did not show a pattern of increase or decrease across time (see figure 6). Baseline corrected averages of tonic SCRs to the UCS decreased over time, consistent with habituation (see figure 7). Detection of habituation to the UCS, while the CS response strength remained unchanged suggests that our measures were sensitive enough to detect meaningful change and thus supports the conclusion that the Perruchet effect did not occur undetected.

First, we used linear and quadratic mixed effects models to analyze phasic SCRs and tonic SCRs for CR strength. Phasic SCRs are rapid changes, while tonic SCRs are slower in duration and occur across several seconds. Tonic changes are more associated with emotional stimuli like the ones used in this study, and therefore we expected to get stronger results in tonic SCRs (Critchley, 2010). Though we expected linear changes across run length, we tested for both linear and logarithmic changes. Phasic SCR showed no significant change across conditions (Intercept $\beta = 0.1668$, SE $= 0.0120$, $t(164) = 13.918$, $p < 0.001$), (Linear $\beta = -0.0143$, SE $= 0.0156$, $t(657) = -0.915$, $p = 0.36$), (Quadratic $\beta = -0.0133$, SE $= 0.0134$, $t(384) = -0.997$, $p = 0.319$). Tonic SCR also showed no significant change across conditions (Intercept $\beta = -0.0994$, SE $= 0.0156$, $t(172) = -6.372$, $p < 0.001$), (Linear $\beta = 0.0122$, SE $= 0.0216$, $t(674) = 0.567$, $p = 0.571$), (Quadratic $\beta = 0.0055$, SE $= 0.0186$, $t(394) = 0.296$, $p = 0.768$). Finally, we used linearand quadratic mixed effects models to analyze changes in reported expectation across runs. Again, we expected to see a linear trend,

but we tested for both linear and quadratic trends to bemore comprehensive. Expectation showed significant linear and quadratic change across conditions (Intercept $\beta = 4.671$, SE $= 0.105$, $t(121) = 44.43$,$p < 0.001$), (Linear$\beta = -.943$, SE $= 0.124$, $t(326) = -7.59$, $p =< 0.001$), (Quadratic $\beta = 0.421$, SE $= 0.118$, $t(267) = 3.57$, $p < 0.001$).

## Discussion

Based on the results, we are unable to find support for either model of classical conditioning. The only observed effects pertained to expectation. Much like the gambler's fallacy, we found that expectancy significantly lowered as a function of longer runs of trials that contained the UCS. These ratings of UCS expectancy followed the pattern described in previous studies on the Perruchet effect (e.g., Graves, 2017, Perruchet, 1985). We were unable to find a significant pattern of SCR magnitude across trial types. A lack of SCR changes signifies a lack of CR development across levels of CS presentation. This finding is similar to those in Graves (2017), rather than the traditional eyeblink studies (Perruchet, 1985). As neither theoretical model describes a rationale for lack of CR differentiation, it seems as though this lack of CR development is a product of the procedure. This means that our study does not support the generalization of the Perruchet effect, nor does it support the opposing prediction of the propositional model. Our findings and methods should still be used to inform future replications.

### Limitations and Future Research

First and foremost, our findings are severely limited by the loss of CS- trials. This reduces our range from looking for an effect across six conditions, to looking for an effect across three. Even after the submission of this thesis, we will continue to try to recover the CS- data. Compounding this data loss were the processing errors that cost us several participants. We

would have liked to extend data collection to obtain 204 intact participant samples, however the COVID-19 outbreak prevented participant recruitment beyond the initial scope of the study. Fortunately, the processing error appeared to affect participants randomly, so no systematic effects appeared to be present in the data. Together, these data loss errors weaken the statistical power of these analyses, especially in the case of the three trial runs, of which there were few to begin with. Additionally, because we changed our analyses, our power analysis no longer provides an accurate estimation of a sufficient sample size.

Procedurally, there were a few limitations that should be discussed for the benefit of future research in this line. Firstly, while shortened inter-trial-intervals improved the duration of participant interest and engagement, relative to Graves (2017), it was still apparent that many participants grew bored or sleepy towards the end of the experiment. Secondly our analyses revealed a clear presence of habituation to the US across trials. This presents the continued challenge of developing procedures that consider both boredom and habituation. Our procedure shortened the inter-trial-interval in attempt to minimize boredom, while not confounding EDA between trials. A review of the characteristics of habituation suggest that this change may have inadvertently increased habituation due to an increase in frequency of stimulus presentations (Rankin et al., 2009). Thus, our efforts to reduce boredom are likely to have worsened habituation. Keeping in mind that participants still appeared bored despite this, future studies may benefit from fewer trials across more participants. Naturally, any decreases in duration must be carefully balanced with ensuring that enough data is collected from each participant to become representative despite individual differences in EDA. A second possible procedural alteration would be to divide trials into two blocks and provide participants with a break between blocks of trials. In addition to procedural considerations, our lack of findings may be due in part

to our selection of stimuli. The IAPS was first developed 20 years prior to this study (Lang et al., 2008). It is possible that photos rated to be significantly arousing at that time no longer hold the same effects. Future research may look to more modern photographs for arousing visual stimuli. Finally, different stimulus categories should be tested for resistance to habituation. It is possible that the aversive nature of our stimuli caused participants to develop avoidance strategies throughout our procedure. Neutral non-arousing stimuli may also be used as the CS- to increase stimulus variability. Regardless of the cause of habituation, it does necessarily reduce our ability to recreate patterns of learning in the laboratory setting.

Aside from habituation, it is possible that our method was not sufficient to invoke the pattern of learning. CR strength did not habituate like UR strength and responses were small across the entire duration of the session. Pairing one visual stimulus with another does not hold the same biological relevance as a sound predicting a puff of air being blown into the eye and thus may produce slower conditioning (Pavlov, 1927). Slower conditioning could then require more than 1-3 acquisition trials interspersed with extinction trials to produce a detectable conditioned response. If that is the case, then more powerful visual learning procedures must be identified before a form of the Perruchet effect could be observed in this medium. Alternately, a more sensitive measure of conditioned responding would need to be used to identify any learning occurring from these procedures.

Future investigations into this topic should also consider the possibility of a dual-process model of response acquisition. Research on eyeblink conditioning has suggested that when there is a gap in time between the CS and UCS the Perruchet effect no longer occurs and CRs follow expectations (Clark et al., 2001). While it seems unlikely, these two processes may work more

directly in opposition when occurring in conditioning procedures other than eyeblink conditioning, leading to no significant CR development.

Finally, should future studies on visual stimuli not be able to rectify the problems identified above, it remains important to test the Perruchet effect using methods outside of eyeblink conditioning. This investigation is necessary to ensure that there is nothing unique about the eyeblink response that interacts with propositional learning.

**Conclusions**

Our study did not replicate the findings of the Perruchet effect in electrodermal responses to pictures. The results indicated a lack of change in CR across differing run lengths. As such, our findings provide support for neither the automatic link, nor the propositional learning models of human learning. Future research should continue to investigate different adaptations of the Perruchet effect in order to more fully test its generalizability.

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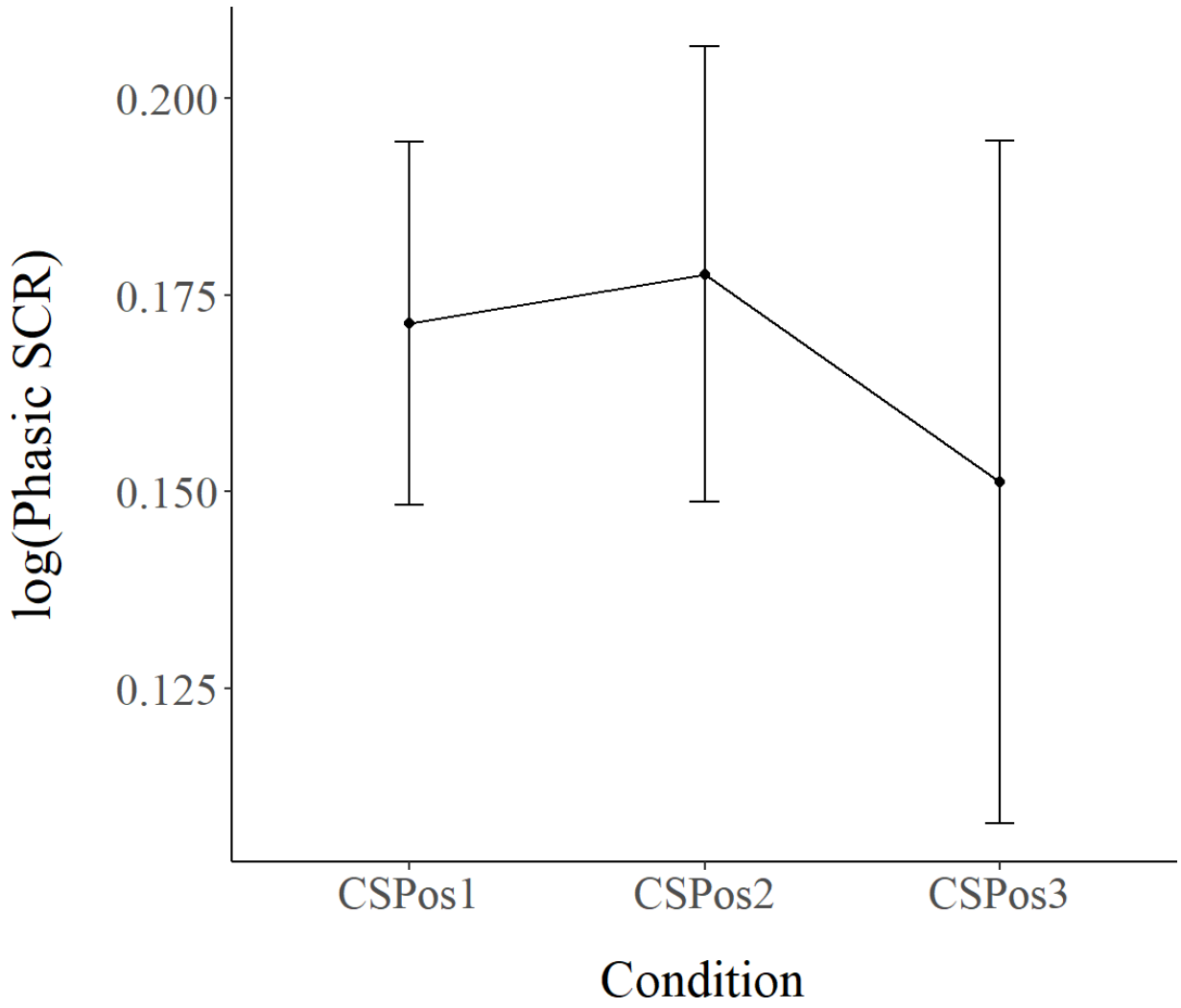
**Figure 1**

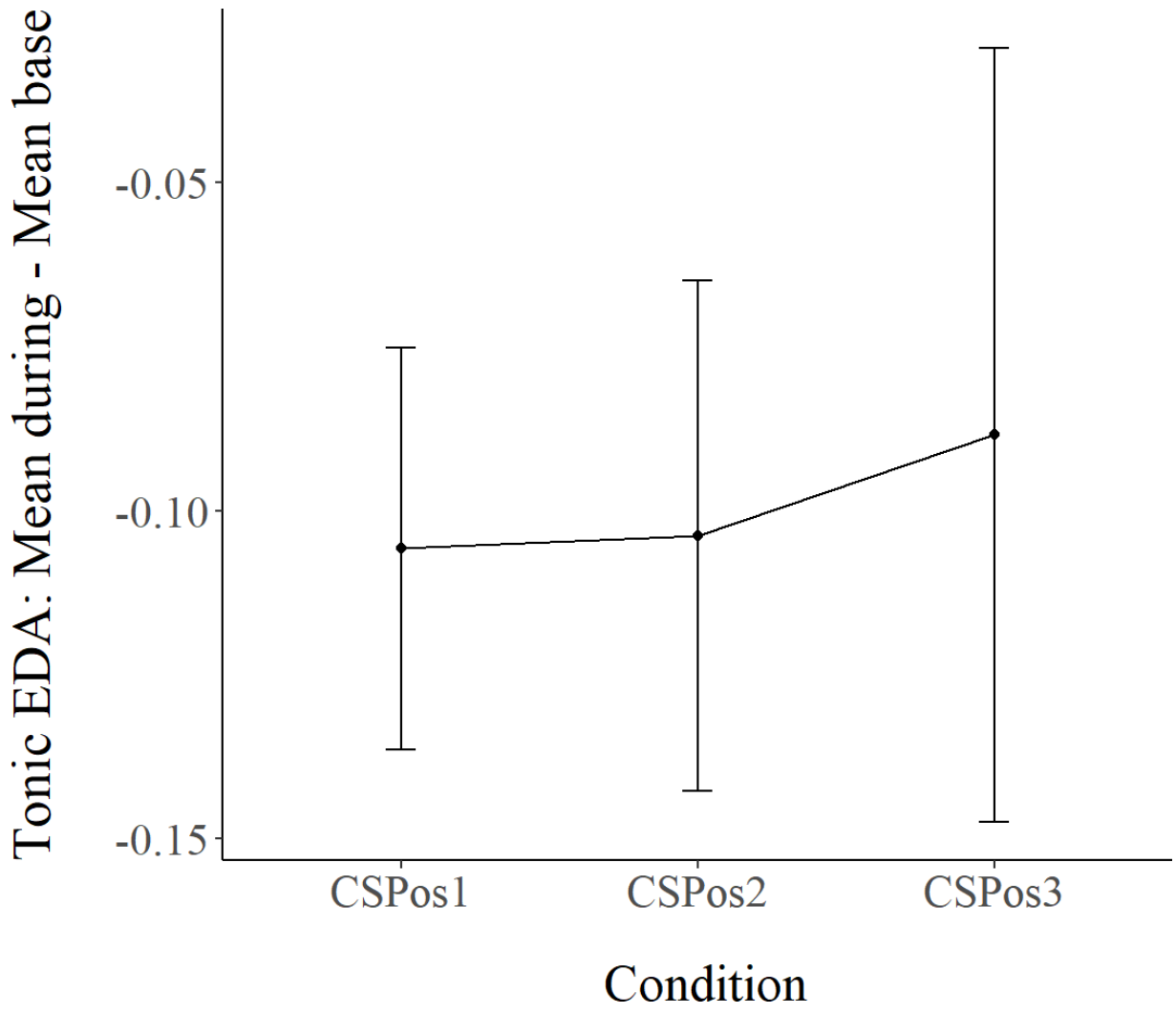
*Phasic SCR During CS Measured Across Conditions*




*Note*. The Y axis shows the magnitudeof the phasic SCR response (corrected for baseline EDA) and the X axis shows the run length, with the CSPos number indicating consecutive CS+ trials. There is significant standard error overlap between all three conditions and thus, despite the ups and downs the slope is effectively flat.

**Figure 2**

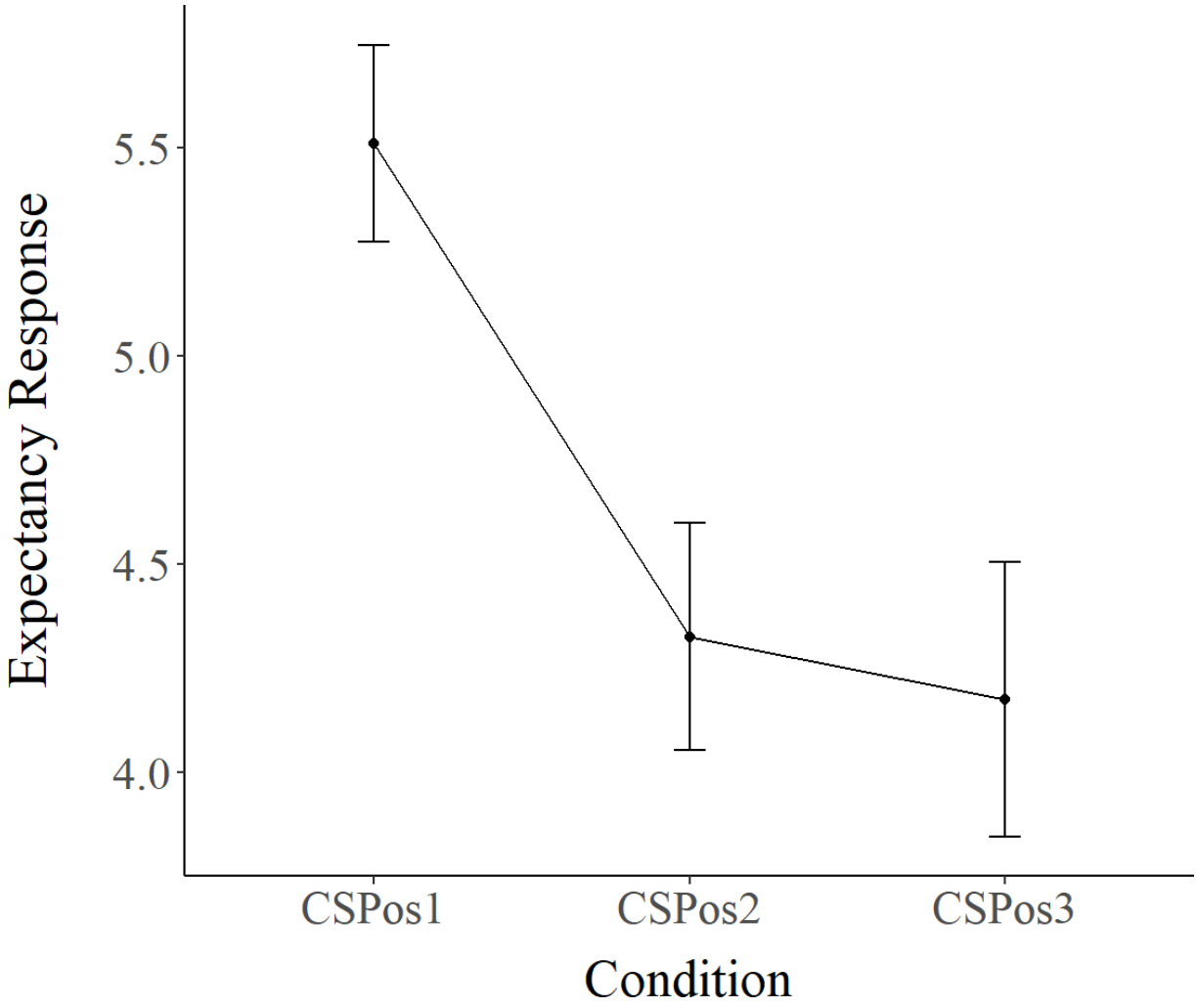
*Tonic SCR During CS Measured Across Conditions*




*Note*. The Y axis shows the magnitudeof the tonic SCR response (corrected for baseline EDA) and the X axis shows the run length, with the CSPos number indicating consecutive CS+ trials. There is significant standard error overlap between all three conditions and thus, despite the slight upturn the slope is effectivelyflat.

**Figure 3**

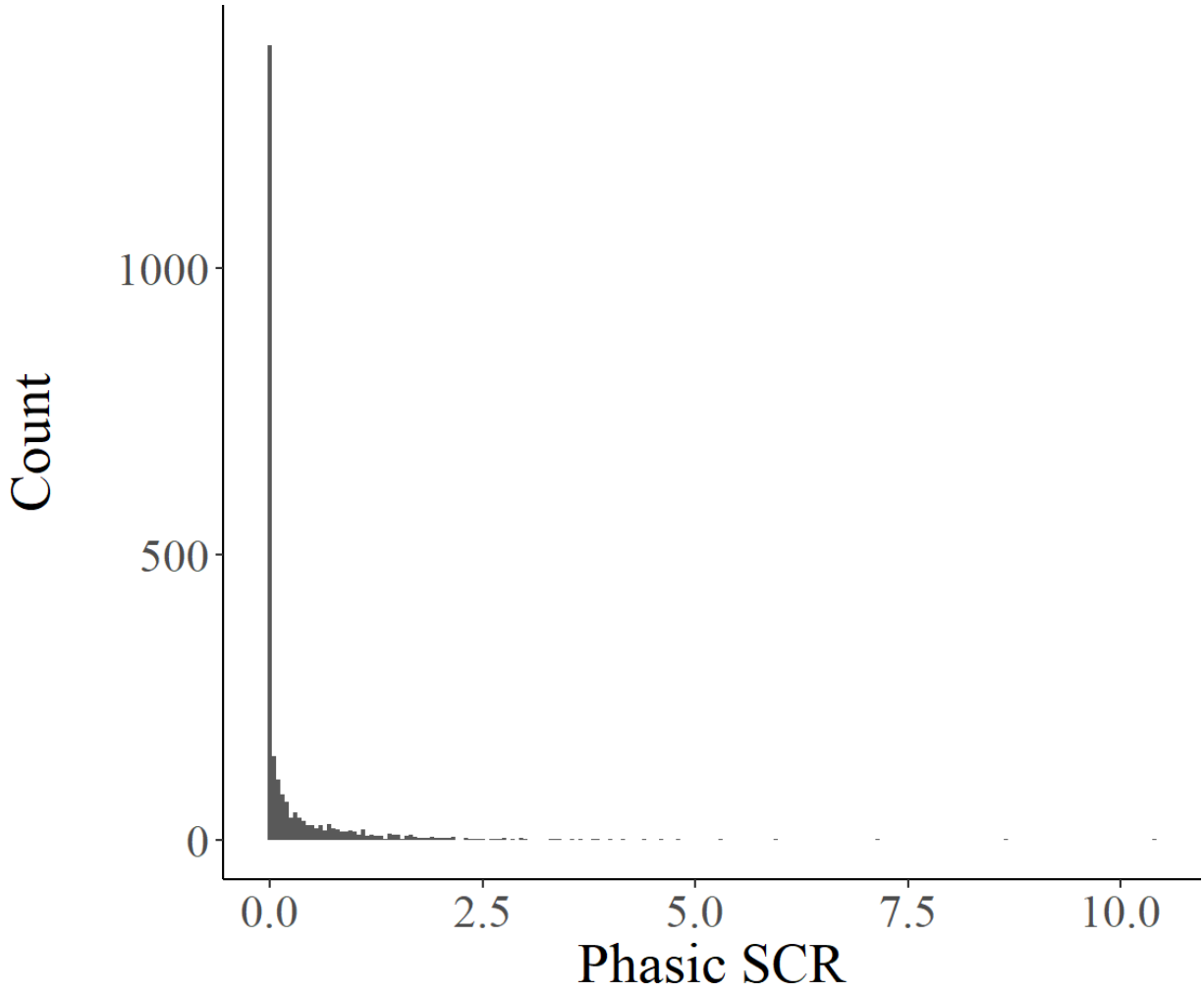
*Reported Expectancy Across Conditions*




*Note*. The steep slope across conditions displaysthe significant decrease in expectation observed with more CS+ trials in a row.

**Figure 4**

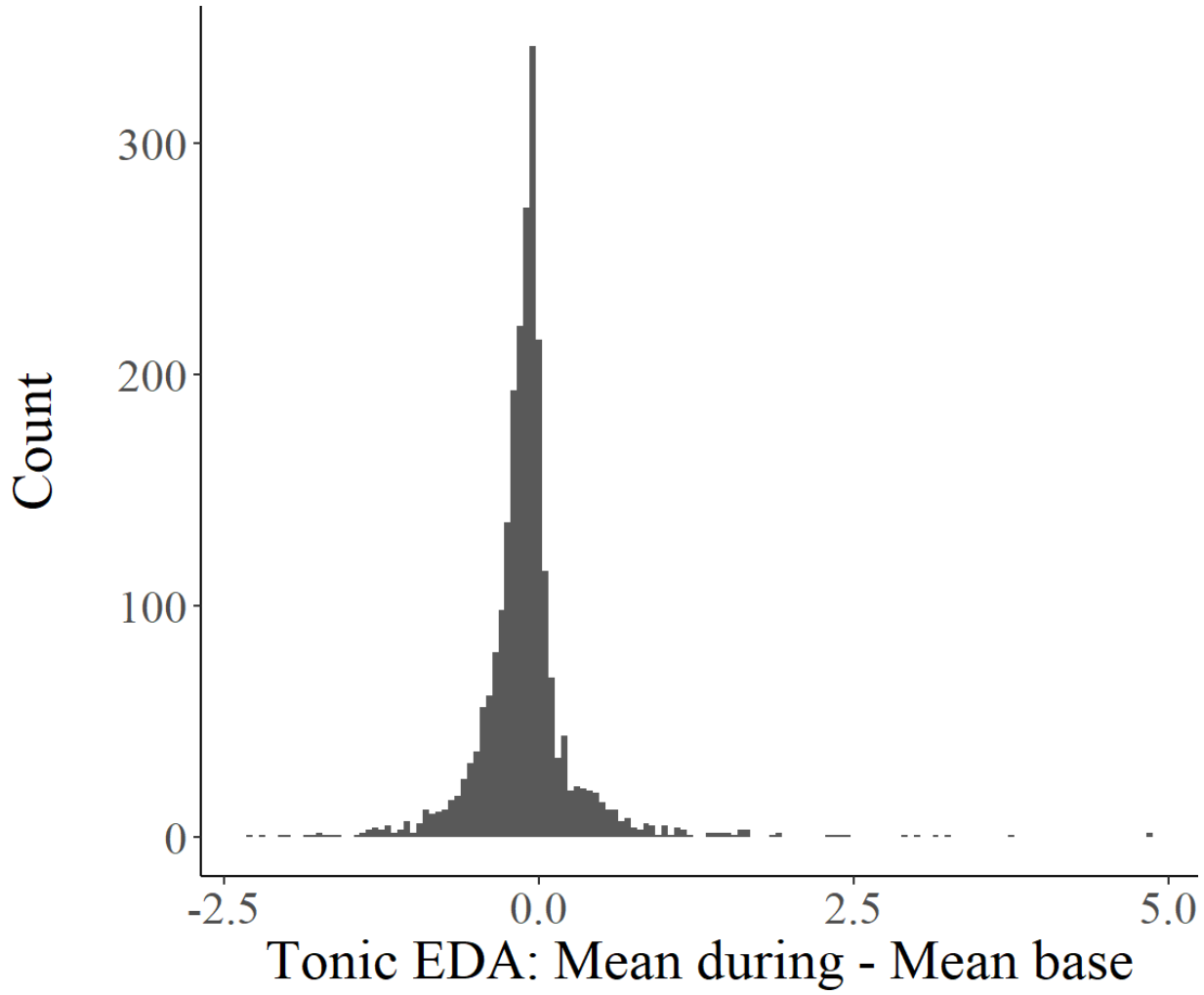
*Count of Phasic SCRs by Strength*




*Note*. The strongly skewed distribution shows that nearly all phasic SCRs had a strength of 0. In other words, there was nearly no phasic skin conductance change.

**Figure 5**

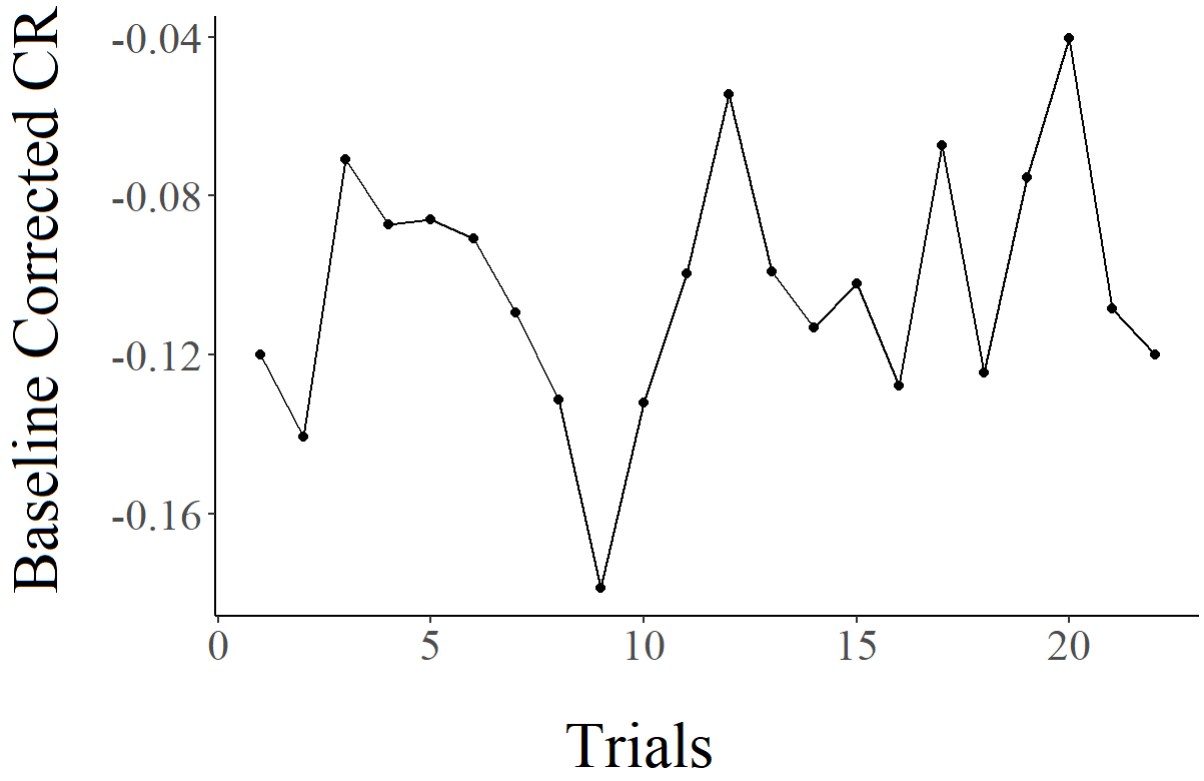
*Count of Tonic EDA by Strength*




*Note*. The distribution of tonic EDA demonstrates variability in strength of responding. In other words, there was a difference in strength of tonic responses across trials.

**Figure 6**

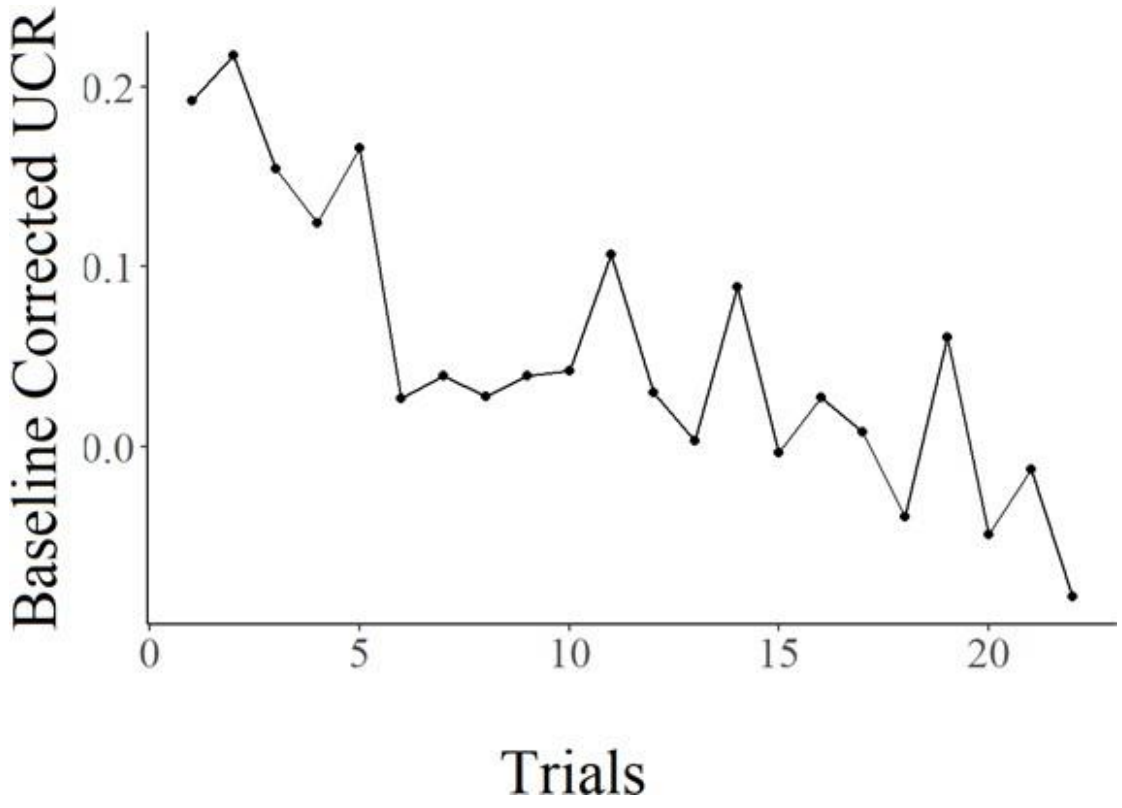
*Average Strength of CR Across Trials*




*Note*. No trend is apparent in average strength of CRs across the session.

**Figure 7**

*Average Strength of UCR Across Trials*




*Note*. The downward trend of UCR strengthrepresents habituation to the US across the duration of the experiment.

# Appendix A
# Electrodermal Responses to Pictures Experimental Protocol

1) Have participant read and sign informed consent.
    a. The informed consent document and all other files for the experiment will be in the top drawer of the file cabinet
2) Have the participant go to a nearby bathroom to wash their hands with warm water (no soap) and dry their hands thoroughly.
3) Mark the participant on the sign-up sheet to assign them their subject number.
4) Turn on BIOPAC MP36 (power button is on back left).
5) When participant returns, grab two fresh electrodes from the white bag on the black counter in the back. Make sure the electrodes are not expired by checking the expiration date. They are considered fresh only for 30 days once the bag is opened, so mark the bag with the date when opening a new bag.
6) Ask the participant if they are right-handed or left-handed.
7) Ask the participant to remove any jewelry they may be wearing on their non-dominant hand.
8) Attach the electrodes to the participant's index finger and middle finger distal phalanges on their non-dominant hand. Ensure that the electrodes are attached securely.
    a. If the participant is left-handed, move the hand pad to the other side of the computer and pull the electrode wires behind it (the default set-up is for right-handed individuals).
9) Attach the red (positive) lead to the index finger electrode and the black (negative) lead to the middle finger electrode.
10) Instruct the participant to become comfortable in their seat. Politely ask them to relax and remain still for the remainder of the experiment. Heavy breathing, like sighs, or motor movement (including chewing gum, moving your finger the check your phone, or tapping your foot) will obscure data collection, so instruct participants to limit these behaviors in the experiment.
11) Wait at least a full 10 minutes before commencing experimental trials to allow the electrode gel to penetrate the skin, allow the skin to rehydrate itself, and allow participant's EDA level to settle to baseline
12) Open AcqKnowledge 4.4 Software
    a. Under "What would you like to do" select "Create/ Record a New Experiment"; Select "Use recent graph template:" and then select "Electrodermal Responses to Pictures"
    b. Click OK
    c. Hit "Start" in AcqKnowledge to begin the recording process. You must be recording for at least 10 minutes uninterrupted before beginning the experiment. Electrodes must be attached to participants for at least 10 minutes. This is extremely important for reliable measurement and establishing a participant's EDA baseline recording.
    d. Participant's baseline EDA level should be somewhere in between 6 and 12 micro siemens. If it is close to this range, that should be fine, but if it's drastically far away (say 2 micro siemens or 20 micro siemens), refer to the troubleshooting handout. The signal will not look right until the electrodes have been attached for several minutes. This is because the small amount of gel on the electrodes must penetrate the skin, and the skin must also rehydrate itself to normal levels after drying. Try not to mess with the electrodes until you are certain there is an issue with the measurement that is not caused by inadequate time.
    e. When the signal looks fairly normal, have participants take a deep breath in and a deep breath out. Several seconds after they do this you should see an increase in EDA of approximately 1 micro siemen or more. If you do not see an increase in EDA, have the participant stand up and sit down. Several seconds after they do this, you should see an increase in EDA similar to the deep breathing test. If you do not see evidence of EDA increase and sufficient time has passed from electrode application, refer to the troubleshooting handout.
13) Read script to participant
14) When 10 minutes has passed from the time electrodes were attached and you have good signal with a relaxed participant, open E-Run from the desktop and select "EXP 2 Electrodermal Responses to Pictures" to begin the experiment. For the subject number, enter the subject number assigned to the participant (see sign-up sheet). For the session number, enter 1.
    a. While the participant is doing the experimental procedure, remain seated in the corner and try to be as quiet as possible.
15) Once the participant is done, thank them and provide them their ELC, then save and label the AcqKnowledge File to the research project folder ("EXP 3 Electrodermal Responses to Pictures). You will name the file simply with the participant number.

## Appendix B
## Electrodermal Responses to Pictures Script

You are about to participate in a study which involves visual stimuli.
During this experiment, you will view a picture frame on every trial. On certain trials, pictures will appear in the picture frame. Pictures will appear in the picture frame 50% of the time, and the picture frame will be presented by itself 50% of the time. It is your job to predict if a picture will appear in the picture frame 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 in the picture frame, 5 indicating no confidence in either direction, and a 9 indicating the strongest confidence that a picture will appear in the picture frame. We encourage you to use the entire spectrum of options to specifically identify your prediction.
If a picture does appear in the picture frame, 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.
We will also be recording your physiological reactions during the session. Two electrodes will be connected to your fingers. There is no danger or pain involved with the recording process. However, we will ask that you not move your hand once the session begins because movements interfere with the recording process.
You will read these instructions again on the computer screen. Do you have any questions?

# Appendix C
# Acqknowledge EDA Preprocessing Steps

0. Preanalysis, do an eyeball test on the data to make sure it looks right
    - Set time scale on x-axis to 30 seconds (click on time value in x-axis to change)
    - Maybe change microsiemiens scale on the y-axis, zoom it in if it is too high (click on microsiemens value to change)
    - Observed tonic waveform should usually be in the 8 - 12 microsiemens range
1. In Resample Waveform
    - Make sure EDA signal (CH 1) is active channel (Click on CH 1 button above strip chart)
    - Top menu: Transform -> Resample waveform
    - Set new waveform sample rate to 62.5 Hz
    - Resampling will create CH 2
2. In Low Pass
    - CH 2 should be active channel
    - Top menu: Transform -> digital filter -> FIR -> low pass
    - Fix at: 1.00 Hz
    - CH 3 will be created
3. In Digital Inputs to Stim Events
    - (Menu immediately above strip chart)
    - Extract stimuli from: specific channels only
    - Trigger channels: Digital inputs, choose CH20, CH21, CH22, CH23
    - Latency 0
4. In Locate SCRs
    - Use Tonic EDA channel: CH 3 (the down sampled filtered data made in the previous steps)
    - Phasic EDA: Construct new (makes CH 4)
    - Might need to zoom out on time scale to inspect
5. In Event-related EDA Analysis
    - Set Rejection % setting in (top menu: Analysis -> EDA -> Preferences) to 10%.
    - Use Tonic = CH3, Phasic = CH4
    - Stimulus Event Type: Stimulus Delivery
    - Stimulus Event Location: Global Events Only
    - Maximum Separation Between Stimulus Event and SCR: 9 seconds
    - Sort tables by event label
    - Fixed width time epoch: 60 seconds
    - <checked> Output events for specific SCRS
    - Analyze entire graph
    - Display Results as: Excel Spreadsheet Only
    - In Phasic SCRS Spreadsheet o Delete first stimulus labeled 1 based on its earliest stim time and save as a new spreadsheet
        - Should be 28 rows of stim 1
    - Go to Top Menu to Analyze -> EDA -> Preferences menu. Change the rejection to 5% and repeat Step 5 again.
        - Only replace rows that the 10% threshold originally classified as 0. Keep all non-zero rows from original 10% threshold
    - Go to Top Menu and change the rejection to 0% and repeat step 5 again.
        - Only replace rows that the 10% threshold and the 5% threshold originally classified as 0. Keep all non-zero rows from original 10% threshold and 5% threshold.
6. In Stim-response Analysis
    - OK to extract Min, Mean, and Max for CH3
    - Start Measurement Intervals: At fixed intervals before or after stimulus
    - Display results as Excel Spreadsheet
    - Measurement width: 12 seconds
    - Set offset to -6 seconds for Baseline measurement
    - Set offset to 0 seconds for Stimulus analysis

# Appendix D
## Consent Form

### Consent to Participate in Research
*Information to Consider About this Research*

**Analyzing Electrodermal Responses to Pictures**

Principal Investigator: Kenneth M. Steele
Department: Psychology
Contact Information: 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 1 of 200 people to do so. We hope tolearn how physiological arousal is affected by pictures.

The research procedures will be conducted at Appalachian State University in Smith-Wright210.

We will be using an electrode to measure your sweat response while looking at pictures. This measurement is non-invasive and painless. You will be asked to remain as still as possible during the experiment because the measure also responds to bodily movement. You will viewthe pictures on a computer screen and be asked questions relating to the pictures seen. The experiment will take about 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. Some of the images are graphic, and often containwounds or physical injuries. If at any point you wish to leave, please let the experimenter knowand the experiment will end immediately. You will still receive your ELC credits if you decide toend the experiment. Additionally, the adhesive on the electrodes could cause a rash on your skin. During screening, please inform us if you are sensitive to adhesives.

**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?**

If you participate, you'll receive 2 ELCs. There are other research options and non-research options for obtaining extra credit or ELCs. 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. Youmay 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 anyway. Physiological data are stored in a special encrypted format.

Please note that while we have no intention of trying to match your data back to you, for a brieftime you will be listed in Sona as signed up for this research, in order for us to issue the ELC.

**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 steelekm@appstate.edu. 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, therewill 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 if you desire.

This research project has been approved by the Institutional Review Board (IRB) at AppalachianState University.
This study was approved on: March 4, 2017
This approval will expire on October 1, 2020 unless the IRB renews the approval of this research.

Participant's Name (PRINT) Signature Date

## Vita

Elijah Richardson was born in Raleigh, North Carolina, to Pamela and Randy Richardson. He received his Associate in Arts degree from Wake Technical Community college in 2016, and finished two Batchelor of Arts degrees, in Psychology and Spanish, at Appalachian State University in 2018. He continued his education at Appalachian State University, earning a Master of Arts in Experimental Psychology. Elijah aims to finish a doctoral degree in psychology with a concentration in applied behavior analysis at the University of North Carolina, Wilmington.