SYMPATHETIC AROUSAL DURING APPROACH-AVOIDANCE DECISION-MAKING

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SYMPATHETIC AROUSAL DURING

APPROACH-AVOIDANCE DECISION-MAKING

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ABSTRACT

In response to emotional stimuli, individuals exhibit increased sympathetic nervous firings, which stimulate eccrine gland activation. This eccrine activity changes the electrical properties of the skin, or electrodermal activity (EDA). EDA has been used widely to assess autonomic arousal during various paradigms. Research has demonstrated how autonomic arousal (1) occurs during the processing or anticipation of emotional stimuli and (2) may inform the decision-making process. Our research focused on investigation of sympathetic arousal during decisions involving conflicting emotional outcomes, using an approach-avoidance processing paradigm. In these situations, individuals are faced with two emotionally valenced outcomes, typically one positive and one negative. However, if the negative outcome is chosen, the individual is given a reward; by this the individual experiences emotional conflict – they can approach the conflict, and receive a reward while experiencing a negative emotion, or they can avoid the conflict by choosing the positive outcome, which is not associated with a reward. Results suggest that sympathetic arousal during these decisions is influenced by potential reward, degree of choice certainty, and an individuals aversion to negative experiences. Sympathetic arousal increased with larger potential reward, and individuals who expressed more uncertainty in their desired outcome exhibited larger emotional responses when making decisions.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the College of Arts and Sciences have examined a thesis titled "Sympathetic Arousal During Approach-Avoidance Decision-Making," presented by Alex J. Francisco, candidate for the Master of Arts degree, and certify that in their opinion it is worthy of acceptance.

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LIST OF ABBREVIATIONS

Approach-Avoidance Conflict = AAC

Autonomic Nervous System = ANS

Electrodermal Activity = EDA

Canonical Response Function = CRF

Heart Rate = HR

Iowa Gambling Task = IGT

Respiration Rate = RR

Skin Conductance = SC

Skin Conductance Response = SCR

Skin Conductance Level = SCL

CHAPTER 1

INTRODUCTION

Changes in the electrical properties of the skin are due to differing amounts of eccrine (sweat gland) activity near the surface of the skin. Underlying autonomic nervous activation, specifically the sympathetic nervous system, drives eccrine activity. This process makes the measurement of electrodermal activity (EDA) a useful tool in assessing psychological processes that involve autonomic arousal, specifically emotionally provoking paradigms. In response to an emotionally provoking stimulus, individuals exhibit *skin conductance responses* (SCRs), which are short term, large increases in conductivity (Dawson, Schell, & Filion, 2007). Electrodermal activity and SCRs have been used in the past to assess autonomic arousal during a wide variety of emotion-related paradigms, including: emotional images and white noise (Bach, Flandin, Friston, & Dolan, 2010), emotional faces (Banks, Bellerose, Douglas, & Jones-Gotman, 2012), imminent electrical shock (Folkins, 1972), music (Baumgartner, Esslen, & Jäncke, 2006), and odor (Kiecolt-Glaser et al., 2008). Previous research has also examined EDA during decision-making paradigms, usually concerned with how SCRs may inform the decision-making process (Bechara, Damasio, Tranel, & Damasio, 1997; Damasio, 1994). Anxiety has been shown to affect EDA during these decision-making paradigms as well (Miua, Heilmana, & Houserb, 2008; Werner, Duschek, & Schandry, 2009). Previous research has generally been focused on anticipatiory SCRs, and how they affect immenent decisions. However, research has not yet directly examined EDA during specific types of decision-making phases, using outcomes that produce an emotional conflict in the participant. The current study will aim to examine how

EDA and SCRs change during a specified, time-constrained decision phase, and will investigate the role trait anxiety might have on EDA during these decsisons.

CHAPTER 2

REVIEW OF THE LITERATURE

Neurophysiological Production of Electrodermal Activity

Electrodermal activity (EDA), and skin conductance in particular, has long been considered as a physiological marker of many underlying emotional states (Boucsein, 2012; Dawson et al., 2007). Several terms have been used to describe the properties of the skin that allow for electrical conductance, and the resulting increases and decreases in conductivity associated with differing levels of autonomic activity. Most broadly, the term electrodermal activity applies to any electrical property that involves eccrine (sweat gland) activity, as well as the dermal layers. Because of the direct link between eccrine activity and sympathetic activation, which has been associated with experienced emotion (Boucsein, 2012; Dawson et al., 2007), electrodermal activity is often used as an index of emotion related sympathetic activity, and can be used as an unobtrusive and objective indicator of emotional state (Critchley, 2002).

The underlying electrical activity that generates the skin conductance response is driven by the autonomic nervous system (ANS). The ANS has two branches; the sympathetic and the parasympathetic nervous systems. Sympathetic activity is responsible for preparing the body for action: increasing heart rate and blood pressure, and decreasing non-necessary physiological functions; it is what drives our "fight-or-flight" response (Breedlove, Watson, & Rosenzweig, 2010). Activity in the parasympathetic branch is responsible for preparing the body for rest; decreasing heart rate and blood pressure, as well as increasing digestive

processes (Breedlove et al., 2010). The production of the underlying sudomotor (nerves that stimulate sweat glands) activity that drives EDA was once considered to be controlled by both sympathetic and parasympathetic branches of the autonomic nervous system (Dawson et al., 2007). However, bursts of activity in the sympathetic nervous system, which are associated with emotional arousal, have been shown to be highly correlated with skin conductance responses under normal thermoregulatory conditions (Wallin, 1981). The original confusion between which branch of the autonomic nervous system is truly responsible for sudomotor innervation may be due to the fact that the neurotransmitter acetylcholine, normally associated with parasympathetic activity, is actually the primary conduit for sudomotor activity (Dawson et al., 2007). There is some evidence to suggest that adrenergic fibers contribute to sudomotor activity as well (Shields, MacDowell, Fairchild, & Campbell, 1987), but its role is minor compared to that of the cholinergic innervation (Sato, 1977).

The cholinergic innervation of these fibers begins in the brain, elicited from regions that respond to a wide variety of external stimuli. In general, sympathetic activity is elicited by the hypothalamus (Boucsein, 2012), and the efferent pathway that controls our eccrine sweat glands is no different, beginning there and projecting down to preganglionic sympathetic neurons in the spinal cord (Hemingway & Price, 1968), and eventually to sudomotor fibers controlling our sweat activity. The initial neural response and subsequent EDA can be affected by many brain regions that all have varying responsibilities, including: insular activity, implicated in the representation of internal bodily states (Oppenheimer & Cechetto, 1990); the hippocampus, implicated in memory and fear conditioning and extinction; anterior cingulate, dorsolateral, and ventromedial prefrontal cortices, associated

with motivation, decision-making, and inhibition/regulation of responses (Kaada, 1951; Neafsey, 1990); the amygdala, representing emotional significance (Gelsema, Agarwal, & Calaresu, 1989; Kaada, 1951); and the motor cortex, active in the initiation and control of movement (Ángyán, 1994; D. J. Bradley, Ghelarducci, & Spyer, 1991; Kaada, 1951).

There are two descending pathways that influence EDA production of particular interest. A contralateral system expresses activity from descending influences in the lateral prefrontal cortex and basal ganglia, which is indicative of cognition, orienting, and locomotion (Boucsein, 2012). Ipsilateral descending influences from the limbic regions (e.g. amygdala, hippocampus, and cingulate) affect EDA production via the posterior hypothalamus. This ipsilateral pathway elicits sudomotor activity, and is thought to indicate emotional processing (Critchley, 2002; Mangina & Beuzeron-Mangina, 1996). From the hypothalamus, fibers relay through the tegementum and medullary nuclei before descending to the preganglionic sympathetic neurons of the spinal cord. After passing through the paravertebral sympathetic ganglion (cell bodies located adjacent to spinal cord) the signal is relayed to the unmyelinated postganglic axons that surround the individual eccrine sweat glands, which are found over nearly all of our skin but are most dense on the palmar and plantar regions (Critchley, 2002; Shields et al., 1987).

Increases in these sudomotor nerve firings result in increased sweat production in the ducts of the eccrine glands. The sweat rising in these glands forms a conductive path through the layers of the dermis and eventually the stratum corneum (outermost layer of the epidermis), which is normally resistant to conductivity (Dawson et al., 2007). This pathway, which starts with activity in the hypothalamus and ends with sweat production in the palm of the hand, is part of the thermoregulatory response. However, this specific path has also been

suggested to respond to stimuli that are psychologically significant. The sudomotor activity in the palmar regions is thought to be more than simply a representation of evaporative cooling, primarily because this ipsilateral control system is associated with influences from brain regions known to be involved in emotional processing (Boucsein, 2012; Critchley, 2002; Dawson et al., 2007; Mangina & Beuzeron-Mangina, 1996).

Measurement of Electrodermal Activity

Most commonly, measurement of EDA requires two or three electrodes placed on the surface of the skin. These electrodes are typically on the palmar surfaces of the hand, as these areas are dense in eccrine glands (Shields et al., 1987). However, other electrode placements (such as those on the forearm and foot) may be used if circumstances do not allow for hand placement. Skin conductance is not a direct measurement of the number of eccrine glands active at any given time, but is instead an indirect measurement that relies on passing an electrical current across the skin. As noted earlier, the sweat rises in the ducts of these glands, and creates a path of conductivity that is used by the electrodes placed on the surface of the skin to pass a small electrical current back and forth. This indirect measurement of conductance is highly correlated with sweat gland activity, meaning high levels of sweat gland activity are strongly associated with high conductance levels (Freedman et al., 1994; Peek, 1987).

Because the measurement of skin conductance requires a small, constant current between electrodes, a paste is applied to the skin that is used to increase the conductivity underneath the electrode. This paste should closely resemble the salinity of sweat in order to avoid confounds in conductivity (Boucsein et al., 2012; Dawson et al., 2007). The recorded electrodermal activity will show tonic as well as phasic components. Both components of

skin conductance are *ease of conductivity* measurements, meaning that high levels indicate that electrons passing from one electrode to another across the skin will encounter small amounts of resistance, while low levels mean electrons are not passing as easily from one electrode to the other. The unit used to express skin conductance is μS (microsiemens), and tonic levels typically fall in the range of 2-20 μS (Dawson et al., 2007). The tonic component of EDA, skin conductance level (SCL), is calculated as average conductivity over a specified amount of time. Again, at any given point an individual's EDA is determined by the resistance level of passing electrons, which is driven by the amount of eccrine sweat gland activity, which in turn, is driven by underlying sympathetic nervous system activation.

A system of physiological underpinnings that drive the phasic component of EDA, known as skin conductance responses (SCRs), was put forth by (Edelberg, 1993). Edelberg's model proposed a poral valve system in order to explain the sudden increases and subsequent decreases in EDA. Initially, the sweat duct is empty and the pore just beneath the skin is closed. According to (Edelberg, 1993), SCRs will occur when sweat rises in the ducts as a response to a stimulus, increasing skin conductance momentarily. Once the duct is filled to capacity, pressure will push the sweat through the pore, opening the poral valve, which yields maximum skin conductance. The loss of sweat to the skin surface eventually lowers intraductal pressure, which is necessary to keep the pore open. The poral valve then closes, causing a rapid decline in skin conductance, and thus ending the skin conductance response. However, skin conductance responses do not rely solely on secretion of sweat to the skin; a conductive path is still created through the corneum when sweat is filling the ducts (Dawson et al., 2007). When looking at evoked responses, such as those that occur in response to discrete stimuli, SCRs will resemble waves in the larger drifts seen in SCL (Lyyken &

Venables, 1971). Skin conductance responses are generally considered to have occurred, regardless of the presence of stimuli, when skin conductance amplitude rises by anywhere between 0.01-0.05 μS (Boucsein, 2012). The time between stimulus presentation and SCR onset, known as latency, is about 1-3 seconds (Dawson et al., 2007). In the absence of stimuli, individuals will still exhibit 1-3 SCRs per minute, denoted as non-specific SCRs (NS-SCRs). These can be used as a measure of tonic EDA, but must be differentiated from responses due to breathing or movement (Boucsein et al., 2012). Skin conductance responses, as well as changes in overall SCL, can be elicited by a wide variety of stimuli, including cognition, locomotion, and emotional processing (Boucsein, 2012).

Emotional Processing and Electrodermal Activity

General Emotional Processing

The measurement of electrodermal activity during emotional processing is an important tool for assessing autonomic arousal. With it, we can see how our sympathetic nervous system activates in many different situations, which allows for experimenters to differentiate between situations that elicit sympathetic activity, and those that do not. Electrodermal activity can also be used to differentiate between specific psychological traits between individuals; for example highly anxious individuals generally show higher resting EDA than non-anxious individuals (Lader, 1967). While changes in EDA can result from several varied sources, emotional processing and related paradigms specifically will induce fluctuations in sympathetic activity, which eventually results in differing amounts of skin conductance (Boucsein, 2012). At the most basic level, increases in EDA are highly correlated with the amount of arousal elicited by emotional images (Peter J. Lang, Bradley, & Cuthbert, 1998). Note that with EDA we are only able to estimate the level of emotional

arousal, and not necessarily the valence experienced (i.e. positive or negative) by a participant viewing an emotional image. Some work has been done to differentiate the emotions expressed via analysis of psychophysiological measures (Ax, 1953; Bos, Jentgens, Beckers, & Kindt, 2013; Stemmler, 1989), but evidence is mostly inconclusive when attempting to parse out separate emotions based on physiological measures alone. Because we cannot determine from EDA alone what emotion is being elicited in the subject, results are always contextualized based on the paradigm used. The use of subjective rating scales in order to assess emotions experienced can be beneficial for verifying the valence of the stimuli presented. Compared to a resting state or neutral stimuli, paradigms used to evoke responses in EDA have included emotional images and white noise (Bach et al., 2010), emotional faces (Banks et al., 2012), imminent electrical shock (Folkins, 1972), music (Baumgartner et al., 2006), as well as odor (Kiecolt-Glaser et al., 2008).

Emotional Learning

Electrical shock specifically has been used to evoke EDA responses in classical conditioning paradigms. Early investigations into the use of classical conditioning paradigms with EDA seemed to reveal that an unconditioned response (increased EDA in response to a unconditioned stimulus) could, through training, be paired with a conditioned stimulus (Boucsein, 2012). Electrodermal responses were mostly thought of as something learned through replacing one stimulus with another, so that what was once an unconditioned response (fear, for example) from some sort of aversive stimuli could be elicited by a conditioned stimulus. There is some evidence to suggest that increased EDA during the conditioned response will not occur until participants are consciously aware of the relationship between the unconditioned stimulus and the conditioned stimulus (Dawson &

Biferno, 1973) (Dawson, Catania, Schell, & Grings, 1979; Dawson et al., 2007). However, other learning paradigms suggest that conscious knowledge of the relationship between stimuli isn't necessary to elicit differing EDA responses, even suggesting that these unconscious EDA responses may have an effect upon our future decisions (Bechara et al., 1997; Bechara, Tranel, Damasio, & Damasio, 1996; Crone, Somsen, Beek, & Molen, 2004).

Trait Effects

While conditioned EDA responses can certainly be elicited in most healthy participants, not all individuals have identical EDA responses to emotional or non-emotional stimuli. Many researchers agree that evidence for trait personality differences in EDA is fragmented (Boucsein, 2012), but there are a few dimensions, as well as pathological states, that seems to consistently effect the manifestation of EDA. When looking at responses to emotional stimuli, electrodermal activity will vary with diagnoses of depression (Ward, Doerr, & Storrie, 1983), schizophrenia (Hempel et al., 2005), and anxiety (Lader & Wing, 1964), compared to healthy individuals. Even at rest, individuals who exhibit high levels of anxious states specifically will show elevated SCL compared to non-anxious individuals (Lader & Wing, 1964). In response to emotionally provoking stimuli, anxious individuals also tend to exhibit ever increasing EDA responses, even when healthy individuals do not (Lader, 1967; Lader & Wing, 1964). There is also evidence that altered EDA responses may be one mechanism through which trait-anxiety affects emotional decision-making (Miua, Heilmana, & Houserb, 2008; Werner, Duschek, & Schandry, 2009).

Electrodermal activity has been linked to an individual's behavioral inhibition system as well, with evidence showing that as behavioral inhibition increases, EDA will also rise (Fowles, 1980). Conversely, individuals with low behavioral inhibition, such as those high in

psychopathy, will show hyporeactivity to conditioned stimuli, resulting in slower learning, which may lead to poor future decision making (Boucsein, 2012). Physical damage to the prefrontal cortex can also delay learning, and impair an individual's ability to respond autonomically to stimuli, which in turn can influence their anticipation of future outcomes, affecting the decision-making process (Bechara, Damasio, Damasio, & Lee, 1999; Bechara et al., 1996). This evidence suggests that anxiety and behavioral inhibition may influence our autonomic nervous system (and EDA) via prefrontal-limbic mechanisms. By influencing the autonomic nervous system, and EDA in particular, this can disrupt our processing of anticipation and risk, and influence decision-making.

Decision-making and Electrodermal Activity

In addition to playing a role in emotional processing and learning, evidence suggests that our EDA responses can provide us with information about how we make decisions, and may even influence our decision-making process (Bechara et al., 1997; Damasio, 1994). Skin conductance is most often used in decision-making paradigms to measure affective processes and overall sympathetic arousal. A majority of the research involving decisions and electrodermal activity focuses on anticipatory SCRs, determining those SCRs that occur sometime before a decision is made. Most of this research has been conducted in concert with the Iowa Gambling Task (IGT). The IGT is a widely used decision-making paradigm developed by (Bechara et al., 1997). In this paradigm, there are two card decks that the participant chooses from. One set of decks represents high risk, and as such involves larger rewards, but even larger losses. These decks, if chosen consistently for the entire task, will yield an overall loss for the task. Choosing the other set of decks will result in moderate gains, with minimal losses, resulting in a net reward for the task. Using these two kinds of

possible outcomes, the IGT has produced a conflict within the subject, who must weigh each possible reward within the context of a potential loss. They can opt to choose the decks associated with larger gains and even larger losses, or conversely may see the benefit in choosing small, but consistent rewards and losses. This conflict elicits a state of indecisiveness within the subject, a state which (Bechara et al., 1997) suggests may be relieved by our autonomic nervous system, in that we use our level of autonomic arousal as a guide to inform us of the relative risk involved in each decision we make.

Results from the IGT tend to show that before participants can report conscious knowledge concerning the riskiness of the decks, SCRs can reveal unconscious processing of that risk level (Bechara et al., 1997; Bechara et al., 1996). These results suggest larger SCRs will occur before an individual makes a risky decision (i.e. choosing deck A or B) than a safe one (decks C or D). In this manner, we are led to determine that the decisions we make have specific "somatic markers", which may influence the decisions we make (Damasio, 1994). (Damasio, 1994) proposed the *somatic marker hypothesis*, suggesting that in these situations individuals use somatic signals as a way to increase the efficiency of our decision-making. He suggests that during the learning process, we develop somatic signals in the presence of emotionally salient stimuli that inform our decision-making process by alerting us about the possible negative outcomes related to our decisions (Damasio, 1994).

According to the somatic marker hypothesis, these SCRs are related to affective responses that develop during the association of risk with each deck. When the ventromedial prefrontal cortex, implicated in decision-making and cognition, is damaged we fail to generate these somatic markers and associated emotions. The ventromedial prefrontal cortex is known have downstream effects on the production of EDA (Neafsey, 1990), and evidence

supports that damage to this area will reduce the amplitude of SCRs informing participants of risky decisions (Bechara et al., 1999), giving evidence to support the SCRs role in informing the participant about a decision (Boucsein, 2012).

Even though several studies support the view that somatic markers are a driving force in decision-making for healthy individuals (Bechara et al., 1997; Bechara et al., 1996; Crone et al., 2004), the validity of these assumptions is a topic of debate. Many researchers have discussed how the IGT does not exclusively involved decision-making, but may also be reflective of classical conditioning (Dunn, Dalgleish, & Lawrence, 2006). In this case, it may be that the participants are simply conditioned to expect a punishment when they choose a deck with more risk rather than using this "somatic signal" to inform future decision-making. A review by (Dunn et al., 2006) summarizes some significant issues that are not directly addressed by the IGT, specifically in terms of interpreting the SCRs involved. First, the temporal precedence of the somatic marker is ambiguous. Because the hypothesis of somatic markers relies on the idea that our SCRs are informing an imminent decision, it is important to establish that the response occurs before the decision is made. However, it is unclear whether the SCR is driven by the beginning of the decision or the end of a decision (T. Davis, B. C. Love, & W. T. Maddox, 2009). This is compounded by the fact that the IGT involves both a learning component and a decision-making component, making it difficult to discern which process is influencing the observed autonomic responses (Dunn et al., 2006). The IGT is also proposed as an emotional decision-making paradigm, but it is based solely on monetary gains and losses, which represent more secondary reinforcement and punishment. This is in contradiction to the work examining EDA responses to emotional stimuli, which uses images, sounds, or videos that relate more closely to primary fears and

anxieties (Banks et al., 2012; Baumgartner et al., 2006; Bos et al., 2013; Boucsein, 2012; Hempel et al., 2005). This makes it difficult to generalize between the EDA research related to emotional processing and that related to "emotional" decision-making.

Approach-Avoidance Conflict

Approach-avoidance conflict is a construct that may be useful in further delineating the relationship between autonomic responsivity and decision-making. Most decisions we make (including those modeled by the IGT) involve some sort of emotional conflict, where we are forced to weigh the impact the outcomes of our decisions will have. Sometimes, the outcomes of our decisions may conflict with each other. For example, the same situation or behavior may be associated with both reward *and* punishment, and we must decide whether to approach or avoid this situation. These kinds of situations, deemed approach-avoidance conflicts, have been extensively studied in animal models. The basic model for animal conflict paradigms involves a single behavior being associated with both reward, like food or water, and punishment, such as a mild shock (Millan & Brocco, 2003). The ability of pharmacologic compounds to increase approach behavior during animal conflict seems to predict their effectiveness as anxiolytics for human. This supports the use of conflict paradigms to model anxiety. These paradigms also have face validity for their relevance to anxiety, as they assess the propensity to approach or avoid during emotional or risky situations (Mennin, Heimber, Turk, & Fresco, 2005).

Several attempts have been made to develop human paradigms assessing approach-avoidance conflict behavior (Aupperle, Sullivan, Melrose, Paulus, & Stein, 2011; Heuer, Rinck, & Becker, 2007; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009). Using these paradigms, the process of uncovering the neural substrates involved in approach-avoidance

conflict has begun, many of which overlap with regions that control the downstream manifestation of EDA. Activity in the anterior cingulate cortex and striatum has been shown to be a function of anticipating pain that is paired with a reward (Talmi et al., 2009). Regions showing greater activity during emotional conflict in approach-avoidance, compared to non-conflict trials, include insula, caudate, anterior cingulate, and dorsolateral prefrontal cortex (Aupperle, Melrose, Francisco, Paulus, & Stein, 2014). Research utilizing other paradigms that involve emotional conflict have also supported a role for anterior cingulate cortex in the implicit resolution of emotional conflict (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006). Skin conductance responses have also been shown to increase during conflict versus non-conflict trials, supporting the idea that these regions are having downstream effects on EDA (Talmi et al., 2009).

The approach-avoidance paradigm developed by Aupperle et al. (2011) significantly differs from previous attempts to quantify approach-avoidance behavior in humans. The paradigm used by Aupperle et al. (2011), called the approach-avoidance conflict (AAC) task, requires participants to make explicit decisions to approach or avoid conflicting situations. This is in contradiction to previous paradigms (Etkin et al., 2006; Heuer, Rinck, & Becker, 2007) that examine implicit processing by measuring reaction times either when faced with conflicting stimuli (e.g., negative emotional face with a positive emotional word) or when asked to perform a behavior inconsistent with a stimulus (e.g., push a joystick forward when faced with a negative emotional stimuli). The AAC involves conflict trials that have participants choosing between one of two outcomes, viewing a negative image and hearing a negative sound, or viewing a positive image and hearing a positive sound. On the conflict

trials specifically, the participants receive reward points for choosing the outcome associated with negative affective stimuli, thus creating an approach-avoidance conflict.

The AAC leaves out any learning component to the task, in order to examine explicit decision-making specifically. It also uses emotional punishment, by means of using negative pictures and images, as opposed to paradigms such as the IGT, which use monetary loss as punishment. By using affective reward and punishments, this paradigm may allow for an in-depth examination of approach-avoidance behavior specific to affective states. The current study will use the AAC to assess the relationship between EDA responses and emotional decision-making, thus furthering the knowledge gained from previous work that has focused heavily on the IGT and other learning based paradigms.

Study Aims

The focus of this study will be to determine the psychophysiological changes that take place during emotional decision-making in healthy undergraduate students. We will use the AAC to further elucidate how electrodermal activity may contribute to emotional decision-making. Benefits of using the AAC include (1) a focus on decision-making specifically, rather than the learning process, (2) the use of conflicting emotional and reward outcomes, thus allowing for greater generalization to the emotional processing paradigms used previously with EDA (Baumgartner et al., 2006; Bos et al., 2013; Hempel et al., 2005) and potentially more relevance to anxiety, and (3) including both conflict and non-conflict decision-phases, thus allowing for examining different EDA responses during conflict decision-making only.

Specifically, the aims of the current study are as follows.

1) Determine the changes in electrodermal activity when making decisions during emotional conflict. We hypothesize that decisions involving emotional conflict will induce larger amplitude SCRs during decision-making than those involving no conflict.

2) Determine how the changes in electrodermal activity relate to decision-making behavior during emotional conflict. We hypothesize that individuals who exhibit higher amplitude SCRs during conflict decision-making will display greater avoidance as evident in their choices during conflict situations. Additionally, we hypothesize that individuals who are uncertain in their decisions will exhibit greater SCRs during decision-making. Within conflict decisions, we expect increased potential reward to be associated with increased SCRs.

3) Investigate the role anxiety and behavioral inhibition/activation may play in influencing EDA during emotional decision-making. We hypothesize that individuals high in trait anxiety or behavioral inhibition will exhibit greater amplitude SCRs during conflict decisions (compared to no conflict).

CHAPTER 3

METHODS

Participants and Procedure

As part of a larger, ongoing study, participants will be recruited from students enrolled in psychology courses at the University of Missouri-Kansas City. Timeslots for participants will be placed in an online format (http://umkc.sona-systems.com) designed for participant recruitment. Participants must be over the age of 18, speak English as their first and primary language, and have normal or corrected to normal hearing and vision (to enable completion of neuropsychological assessments). In addition, participants who report any current psychiatric or neurological disorders will be excluded. The protocol will be completed in a single session. A research assistant will conduct the diagnostic and psychometric assessment according to a standardized protocol to assure a high degree of reliability and validity in using the standard clinical questionnaires. Prior to completing any of the described tasks or procedures, the research assistant will describe the purpose of the study and complete written informed consent. The full assessment session will be completed in approximately 2.5-3 hours. Participants will be given class credit for their participation.

Self-Report Measures

State-Trait Anxiety Inventory – Trait (STAI-T)

The STAI (Spielberger, Gorsuch, & Lushene, 1970) is a widely used psychometric instrument designed to assess an individual's anxiety proneness. Specifically, the "trait" subscale (20 items) is meant to measure long-standing anxiety proneness. The STAI-T is a validated measure with internal consistencies for both subscales ranging from .83-.92

(Spielberger et al., 1970) and test-retest reliability of 0.97 for trait anxiety (Carver & White, 1994) (Metzger, 1976).

Behavioral Inhibition/Activation Scale (BIS/BAS)

The BAS/BIS (Carver & White, 1994) is a self-report measure including 24 items (based on a 4-point scale) meant to assess the dispositional appetitive and aversive (i.e. activation and inhibition) tendencies of individuals. The BIS measures an individual's tendency to inhibit behaviors that might lead to negative outcomes, and high BIS scores should reflect inhibition of movement towards goals (Carver & White, 1994). The BAS and its subscales measure sensitivity to engage in behaviors that move an individual towards goals, as well as responding to the rewards those goals may provide (Carver & White, 1994). The BIS/BAS subscales are: Behavioral Inhibition ($\alpha = .74$), Behavioral Activation – Reward Responsiveness ($\alpha = .73$), Behavioral Activation – Drive, ($\alpha = .76$) and Behavioral Activation – Fun Seeking ($\alpha = .66$).

After completion of the approach-avoidance conflict task (outlined in the next section), individuals completed a survey designed to assess various psychological constructs relevant to their behavior. Three such constructs were chosen to be of interest for subsequent analyses; one question regarding *difficulty making decisions*, another to assess *aversion to seeing negative images*, and a third to determine *reward point motivation.* These questions were assessed using a Likert scale ranging from 0 (not at all) to 7 (very much).

Approach-Avoidance Conflict Task

To assess emotional decision-making, a computer-based task known as the Approach-Avoidance Conflict (AAC) (Aupperle et al., 2011) task will be utilized. This task is designed to examine decision-making in the context of affective risk. The task itself can be split up

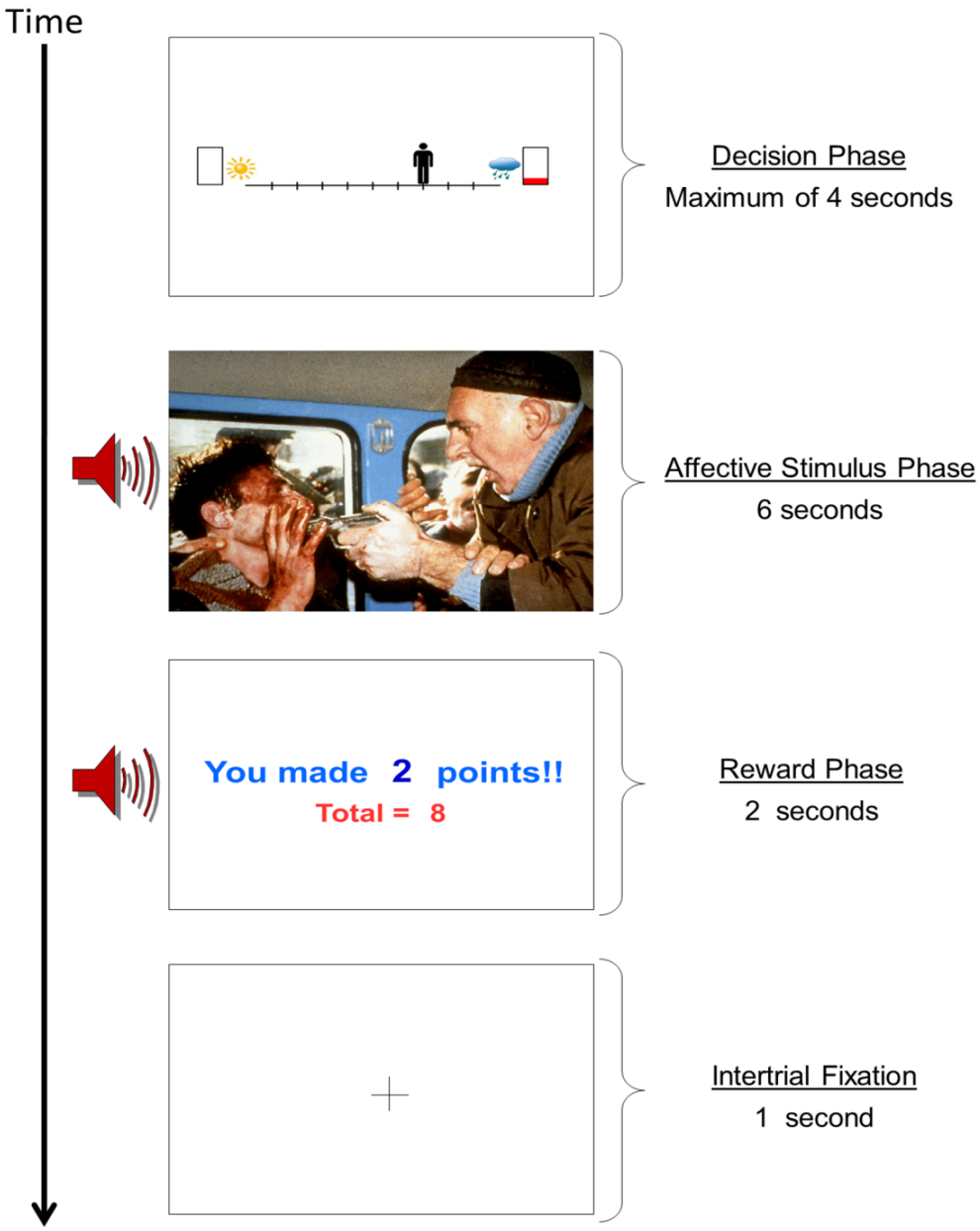

Figure 1. Sequence of Events During a Single-Trial of the Approach-Avoidance Task

Each phase of the AAC is shown here. At the start, participants see a runway, and are instructed to move the avatar to indicate how much they desire either of the two outcomes within a four second window. Following their decision, the outcome of their decision is displayed for six seconds, followed by a two second display of any reward gained. In between each trial a fixation cross is displayed for anywhere between one and eleven seconds.

into three phases: (1) a 4-second decision phase, followed by (2) a 6-second affective outcome followed by (3) a 2-second presentation of reward points. In between each decision phase there is an inter-stimulus interval jittered between one and eleven seconds (mean = 6 sec). See Figure 1 (page 19) for clarification of stimulus presentation and the corresponding stimulus times. As mentioned, during this task the participant is given a four second window, during which they must choose between two possible outcomes, one of which may or may not be associated with arbitrary reward points. At the beginning of each decision phase, the participant is shown a "runway"; a horizontal line on which an avatar, or figure, is placed. On either side of the runway are pictures that represent the outcome associated with that side of the runway. A sun or cloud is used to represent the type of affective image to be shown for that outcome. A sun is used to represent a positively valenced image, and a raincloud is used for a negatively valenced image. Next to the sun/cloud is a box in which the amount of red fill indicates the amount of reward associated with choosing that outcome. It should be noted that their decisions are graded; they make their choice by moving the figure towards one option or the other. The closer they are to one option, the more likely it is that they will receive that outcome. For example, if they move the figure completely towards one option, they have a 90% chance of obtaining that outcome; in comparison, there is a 10% chance that the opposite outcome will occur. If the figure is placed in the very middle of the two options, each outcome is equally likely to happen (50%).

There are five trial types that the participants are faced with. In the first trial type, one outcome is associated with positive affect – if the participant chooses (and receives) this outcome, they will be shown a positively valenced picture accompanied by a positive sound. If the participant chooses the other outcome, they would be shown a negatively valenced

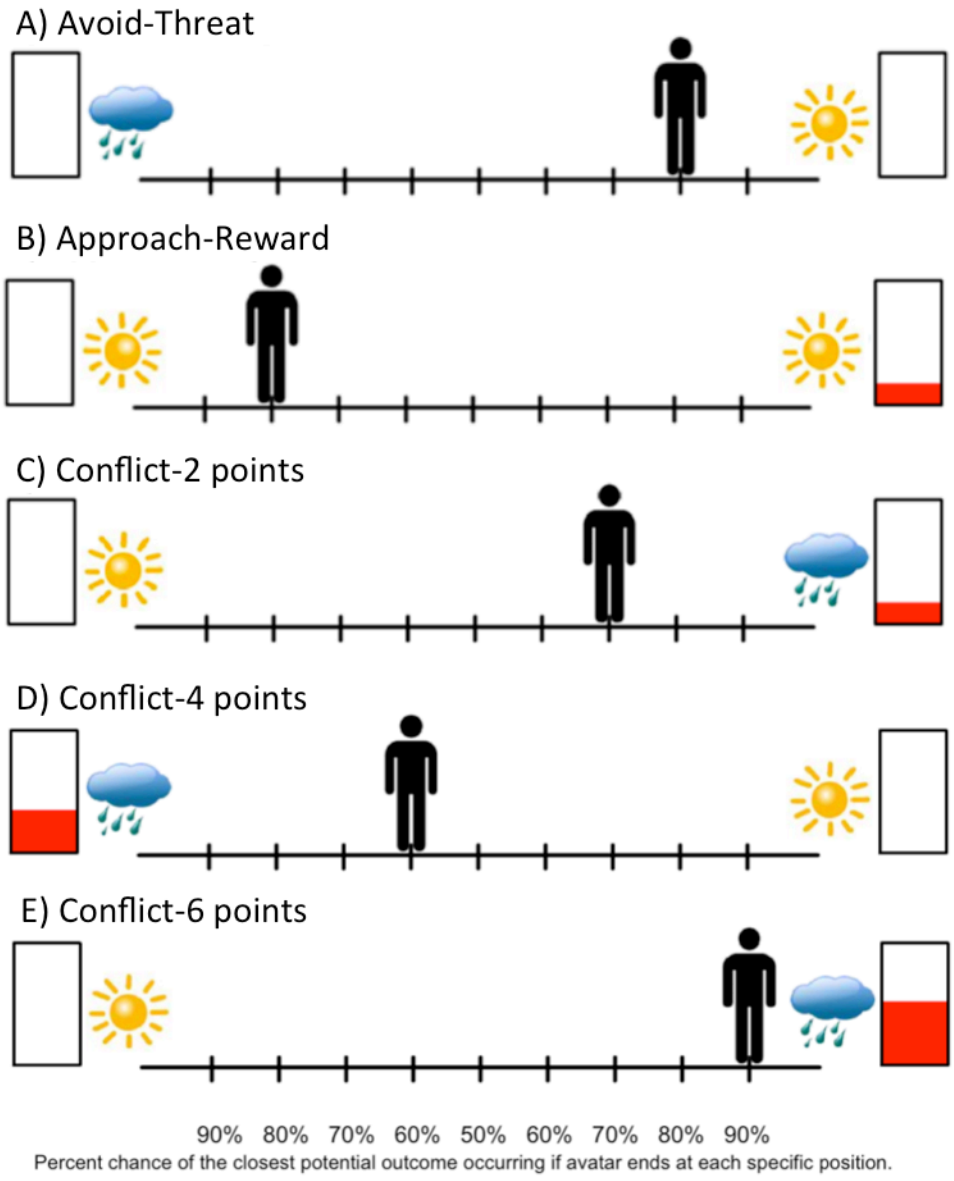

Figure 2. Decision Scenarios Used During the AAC
Each type of decision (denoted A, B, C, D, E) is shown here. The avatar, represented by a human figure, is moved by the participant to indicate the outcome of their preference, which is represented by the sun (positive outcome) and cloud (negative outcome) on either side of the runway. The likelihood of each outcome increases as the avatar is moved closer to one side. The bar located next to each outcome type is filled with varying amounts of red, indicating the level of reward associated with that particular outcome.

picture, paired with a negative sound. In this trial type, neither outcome is associated with a reward; the participant is simply choosing between the two options, with only the affect of the pictures driving their decisions. This kind of trial is thought of as an *avoid-threat* condition, because the incentives encourage the avoidance of the negative affective outcome, as neither outcome involves an external reward. In the second scenario, both outcomes are associated with positive affective outcomes, but one of the two is associated with reward points. In this case, the incentives encourage participants to approach the reward points; because of this, this scenario is deemed *approach-reward.* For clarification on runway, stimulus type, and trial types, see Figure 2 (page 21). The third scenario is of most interest, because it involves emotional conflict. In these situations, one outcome is associated with a positively valenced picture, but no reward points. The other outcome is associated with a negatively valenced picture, but will yield reward points if chosen by the participant. By choosing to subject themselves to the negative picture and sound, they can obtain the reward points. In this manner, the participants are subjected to *emotional conflict*; in one choice, they can avoid a negative stimulus, and receive a positively valenced outcome but receive no points, or, they can subject themselves to a negative experience and receive points. Some trials will have 2-points associated with the negative outcome, others 4 or 6. The number of points is not correlated in any way with the severity of the image, something that is made explicit during the instructions. In addition, it is made clear to the participant that the reward points are arbitrary, and that the number of points they accrue will not raise or lower the amount of credit they receive for participation. Both the positive pictures and the negative pictures are taken from the International Affective Picture System (IAPS), and the negative and positive sounds are taken from the International Affective Digitized Sounds (IADS) (M.

M. Bradley & Lang, 1999; P. J. Lang, Bradley, & Cuthbert, 2008) as well as other free online sources. The standardized IAPS and IADS stimulus sets, as well as stimulation stimuli have been used extensively in emotion research and are reliable elicitors of affective arousal. This measure is not copyrighted and was originally developed by Dr. Robin Aupperle (Aupperle et al., 2011) and is programmed in Adobe Flash.

Two behavioral outcome measures will be investigated using the AAC. First, *approach-avoidance behavior* will be measured as movement towards the outcome associated with conflict (i.e. a negative image which yields reward points). In this outcome, values range from four, where the is figure placed as close to the conflict outcome as possible, thereby approaching the conflict, to negative four, which would be placing the figure as far from the conflict outcome as possible. A second behavioral measure will be derived as well, which can be thought of as *behavioral certainty*. When making decisions during the AAC, the likelihood of receiving the outcome increases as the participant moves their figure closer to one outcome (or the other), starting at 50% at the center of the runway, and increasing by 10% with each movement, up to 90% at the maximum distance towards one outcome. *Behavioral certainty* is therefore regarded as an absolute value of distance from 50%. For example, a participant who places their figure directly in the center of the runway would receive a zero for that trial (50% likelihood of seeing either outcome and least amount of certainty); however, an individual who moved their figure entirely to one side (90% likelihood of that outcome and greatest amount of certainty) would receive a 4 for that trial – regardless of the direction of their choice (towards or away from the conflict outcome). To assess the effects of increasing point-values on behavior, a slope was calculated for behavioral uncertainty that ascertains the rate at which behavioral uncertainty changes as

points increase (from decisions with two points, to four, to six). As such, higher values indicate more certainty as points increase.

Physiological Measures

BioPac Systems, Inc. (www.biopac.com) hardware and software packages will be used to electrodermal activity during the AAC task. BioPac Systems provides both hardware for collection of these measures (BioPac MP150 system) and software (AcqKnowledge software for Mac-based systems) for analyzing these measures. Electrodes will be placed on the surface of the skin, on the first and second digits of the non-dominant hand. To avoid confounds from possible callouses electrodes will be placed on the second phalanges of each digit. The skin will be coated with isotonic gel (0.5% saline in a neutral base). Outcome measures for EDA will be SCR magnitude (as assessed by *SCRalyze*) for each of the five choice conditions. As with behavior, a slope will be calculated to highlight the rate at which SCR changed with increasing point levels.

EDA Analysis

Of primary interest will be the analysis of electrodermal activity during the 4-second decision phase of the AAC. As mentioned previously, the latency time for a skin conductance response to occur after stimulus presentation is between 1-3 seconds. During this paradigm, multiple stimuli occur within 6 seconds, which may cause overlap between the resulting SCRs. Peak scoring may be valid for assessing responses to the decision phase alone, but could be confounded by overlapping SCRs when assessing outcome and reward phases. A method of separating these SCRs has been put forth by Bach et al. (2010), who proposed using a deconvolution method to separate the peak amplitudes of two overlapping SCRs.

General Linear Model for Evoked SCRs

Several assumptions are made when deconvolving overlapping SCRs. This includes the assumption that a filtered SCR time series is the output of a finite Linear-Time Invariant (LTI) filter, when given a specified input function (i.e. the canonical skin conductance response). Within this assumption, it is also assumed that the response shape of an EDA response is constant; this should be the case within an individual as well as within an experimental condition. Second, it is assumed that overlapping responses are equal to the sum of the two separate responses. The final assumption infers that after an SCR, conductance levels will eventually decrease to a baseline, which is normally approximated via high pass filtering. This final assumption accounts for the slow-wave changes in SCL in order to assess phasic changes in EDA. It is not a requirement that the SCR time series strictly conforms to these assumptions; the method of analysis has been shown to be robust in the face of violations. In fact, violations of these assumptions lead to greater error terms and more conservative testing (Bach, Flandin, Friston, & Dolan, 2009).

The first step to the deconvolution of overlapped SCRs is to describe the impulse response function of the phasic EDA change. The method used by Bach et al. (2009) was to derive a *canonical* response function (CRF), or a mathematically defined set of parameters that can be used to describe the average shape of any SCR. The use of a CRF is preferable to other methods (such as deriving the shape from the sample data alone) because it lessens the chances of overfitting (Bach et al., 2009). The refined CRF developed by Bach et al., (2010) used 1278 SCRs, which were used to describe the CRF as an exponentially modified Gaussian function, the parameters of which were estimated using a least-square approach alongside a gradient search. But, because the parameters of an SCR are not going to be

precisely the same for each individual, time and dispersion derivatives can be added to the CRF in order to create an *informed basis set,* which allows for reduced residual variance. Once the informed basis set is defined, the impulse response function for the dataset can be modeled as a linear combination of the functions that comprise the set. The result is a defined SCR that is constructed from the convolution of the input functions with the informed basis set, which can then be analyzed using the general linear model (GLM). This method generates maximum likelihood estimators that correspond with ordinary least squares (OLS) estimates, which describe the, now deconvolved, average SCR amplitude per experimental condition. This entire process has been made into a program called *SCRalyze,* which provides a graphical user interface and allows for first and second level analyses. GLMs will be carried out on each third of the task to assess for habituation effects. If no significant habituation occurs from the second third of the task to the last third, the output of the two GLMs for each participant will be averaged.

Consistent with previous research (T. Davis, B. C. Love, & T. Maddox, 2009) the first several trials of each type of decision will be excluded to rule out possibility of task novelty confounding SCR magnitude. Specifically, the first third of the task (approx. 6 trials per decision type) will be excluded from all analyses. SCR magnitudes calculated using the GLM function in *SCRalyze* will be derived for each of the five decision types. If the output for an individual from the GLM was greater than zero, that individual's overall SCR for that decision type was considered to be non-existent, and subsequently recoded as zero to preserve the metric of SCR magnitude. However, if the individuals GLM output was >0, we assumed that individual indeed exhibited a response during that decision, and their output was not recoded. Our results are restricted to magnitude because the GLM function of

SCRalyze does not output individual trial estimates of SCR amplitude, but rather a summed linear combination of estimated responses.

Statistical Analyses

Using *SCRalyze*, regressors will be derived from the informed basis set including time and dispersion derivatives, to estimate average SCR amplitudes for each condition (approach-reward, avoid-threat, conflict-2, 4, 6pts). The amplitudes for each condition will be analyzed using a within-subjects one-way ANOVA, followed-up with post-hoc within-subjects t-tests to identify specific differences between conditions. Separate linear regressions for each of the five decision types will be run to determine whether the SCR amplitude during decision-making is correlated with approach-avoidance behavior during each respective condition. Additional regressions will also be carried out to determine the relationship that self-reports of anxiety and behavioral inhibition/activation may have with EDA during each of the decision types. Research with the AAC task has previously shown gender effects upon behavior (Aupperle et al., 2011), so gender will be investigated as a possible covariate. Correlations with SCRs and self-report will be exploratory in nature, and will be considered significant at $p < .05$. Previous studies using the AAC have reported non-normal data in regards to observed approach behavior (Aupperle et al., 2011). The normality of our data will be examined using skewness and kurtosis; if values fall outside +/-2, we will use Spearman's correlations to account for non-normality.

Previous research involving SCRs and emotional stimuli has reported medium effect sizes ($d = .53$) (Bach et al., 2009) and research investigating correlations of anxiety and SCRs during decision show small to medium effect sizes ($r = -.25$) (Stankovic, Fairchild, Aitken, &

Clark, 2013), and investigations into the interaction between emotional decision-making, anxiety, and SCRs have shown small effect sizes (d = .22) (Stankovic et al., 2013).With the enrolled sample size of N = 28 we estimate having 80% power to detect small to medium effect sizes (f = .16) for within-group repeated measures contrasts, small to medium effect sizes for our correlation analyses ($f2$ = .48). Thus, we should be sufficiently powered for Aim 1-3.

CHAPTER 4

RESULTS

Demographics and Self-Report

Table 1 contains demographic information and average self-report data for the sample. Our sample was predominantly female (73%), but results did not differ when split between the genders. Two participants failed to correctly respond to our demographics survey, and were excluded from age and gender summaries.

Table 1

Summary of Demographics and Self-Report Data

Demographics (n = 26)		
Age	M = 27.04	SD = 9.49
Gender	19 Female	7 Male

Self-Report (n = 28)	Mean	SD
ASI	37.25	10.81
BIS	19.25	3.97
BAS – Reward Responsiveness	17.07	1.82
BAS – Drive	11.61	2.56
BAS – Fun Seeking	11.18	2.52
AAC Post-Task Questionnaire		
Difficulty Making Decisions	2.64	1.54
Aversion to Negative Images	3.96	2.22
Reward Point Motivation	3.25	1.96

Behavioral Outcomes

Approach-Avoidance Behavioral Choices

Repeated-measures ANOVA using the original metric of approach vs. avoidance behavior revealed significant differences between the five decision types [$F(4, 108) = 30.90$, $p < .001$]. Additionally, approach-avoidance behavior differed on the three conflict

conditions [$F(2, 54), = 7.79, p = .001$] . As indicated in Table 2, post-hoc t-tests revealed that these findings were driven by participants exhibiting less approach behavior during avoid-threat trials compared to all other trials, more approach behavior during approach-reward trials compared to all other trials, and within the conflict conditions, less approach behavior during Conflict 2 as compared to both Conflict 4 and Conflict 6 and during Conflict 4 as compared to Conflict 6.

Table 2

Post-hoc t-tests Comparing Approach-Avoidance Behavior (n = 28)

Comparison	*t*	*p*
Approach > Avoid	10.37	<.001
Approach > Conflict 2	6.26	<.001
Approach > Conflict 4	4.77	<.001
Approach > Conflict 6	4.248	<.001
Avoid < Conflict 2	-3.279	.003
Avoid < Conflict 4	-4.518	<.001
Avoid < Conflict 6	-4.717	<.001
Conflict 2 < Conflict 4	-2.796	.009
Conflict 2 < Conflict 6	-2.850	.008
Conflict 4 < Conflict 6	-2.137	.042

Behavioral Certainty

A second set of behavioral analyses was conducted using the concept of behavioral certainty. To correct for issues of non-sphericity (Mauchly ≤ .05), results were Greenhouse-Geisser corrected. Behavioral certainty differed across the 5 choice conditions ($F(2.66, 71.89), = 4.001, p = .014$], but did not significantly differ during conflict decisions ($F(1.41, 38.10), = .323, p = .650$]. This suggests that although the reward points differed during these choices, individuals did not change in their level of certainty regarding which outcome they preferred. An individual who was certain of their choice when two points were offered was also certain when four or six points were offered; likewise an individual who was uncertain

in their preferred outcome with two possible reward points was still uncertain when four and six points were offered.

Electrodermal Activity

Analysis of Variance

Results were analyzed using log-transformed SCR magnitude (Boucsein et al., 2013), taking the log of the SCR+1 to account for individuals who were coded as zero-responses. Repeated-measures ANOVA using log-transformed SCR magnitude during all 5 choice conditions was significant [$f(2.61, 70.40), = 3.86, p = .017$]; Greenhouse-Geisser corrected]. ANOVA of SCR focusing on the three conflict decision types was found to be significant as well $f(1.49, 40.14), = 5.915, p = .01$; Greenhouse-Geisser corrected]. Post-hoc t-tests revealed that Approach-reward decisions elicited significantly greater SCR magnitudes than Conflict 2 point decisions [$t(27) = 2.317, p = .028$)]. SCR magnitude during the Avoid-threat decision was also larger than Conflict 2 [$t(27) = 2.268, p = .032$)]. For differences between the conflict conditions, see Table 3. Figure 3 highlights the major differences in SCR magnitude, along with the corresponding choice conditions as seen by the participants.

Table 3

SCR Magnitude* During Conflict Decisions with Differing Reward Points (n = 28)

Comparison	*t*	*p*	r^2
Conflict 2 < Conflict 4	-3.33	.003	.29
Conflict 2 < Conflict 6	-2.21	.036	.15
Conflict 4 = Conflict 6	.56	.579	.01

*SCR values log-transformed [log(SCR+1)]

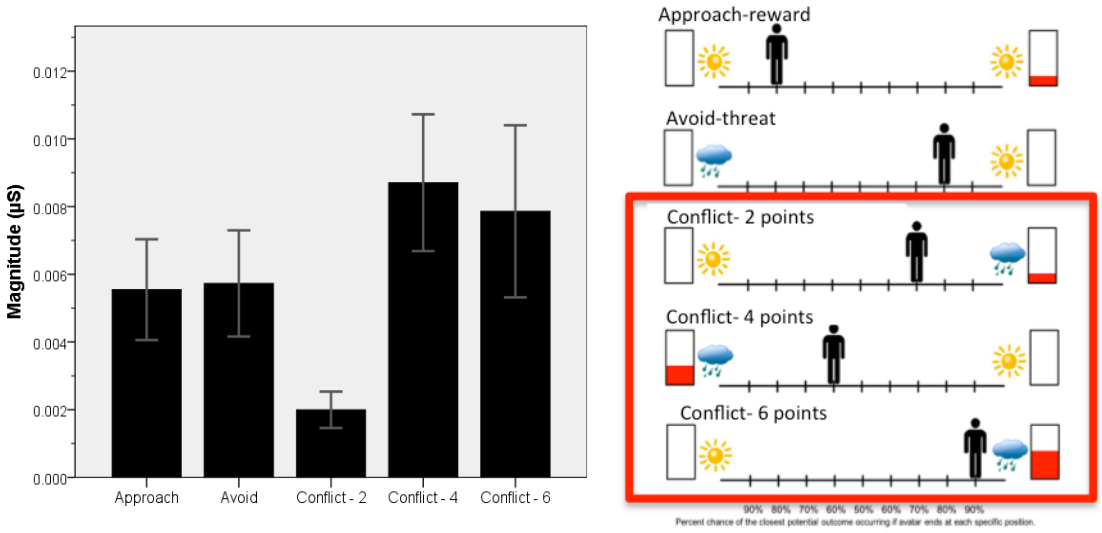

Figure 3. Average SCR Magnitudes Per Decision Type

Correlational Analyses

Behavior and Self-Report

The ASI, BIS, and BAS-subscales, along with our measures of *difficulty making decisions, aversion to negative images,* and *reward point motivation* were investigated in relation to observed measures of approach behavior and *behavioral certainty* during all five of the decision types.

Approach behavior specifically was unrelated to *aversion to negative images*. However, *aversion to negative images* was negatively correlated with the rate of change in *behavioral certainty* as points increased (r_s = -.561, p = .002), but unrelated to behavior on any one condition alone (all p > .05). This suggests that as reward points increased, individuals more averse to seeing negative images were less likely to exhibit behavioral choice certainty.

Approach behavior was positively associated with *difficulty making decisions* during avoid-threat decisions (r_s = .406, p = .032), as well as during Conflict 4 point decisions (r_s =

.412, p = .029), and Conflict 6 point decisions (r_s = .386, p = .043). These correlations are most likely a result of the negative average approach behavior on avoid-threat and conflict decisions; more participants showed avoidance behavior (movement away from the conflict outcome) as opposed to approach behavior. Hence, this positive correlation actually reflects movement towards the middle of the decision runway, representative of equal likelihood to receive each outcome. To corroborate this, *difficulty making decisions* was associated with *decreased behavioral certainty* during all three conflict decision types (all $p \leq .001$), and decisions during the avoid-threat condition (r_s = -.406, p = .032), but not during approach-reward decisions (r_s = -.263, p = .177). *Reward point motivation* was positively correlated with approach behavior during all three conflict decisions (all $p \leq .001$), but unrelated to *behavioral certainty* during conflict decisions (all $p > .05$).

Scores on the ASI were associated with reduced approach behavior during Conflict 2 point decisions (r_s = -.480, p = .01) and Conflict 4 point decisions (r_s = -.385, p = .045), but not during other decisions. ASI scores were also uncorrelated with *behavioral certainty* on any of the 5 decision types (all $p > .05$). BIS scores were not correlated with approach behavior or *behavioral certainty*, and of the three BAS subscales, only one (BAS – Fun Seeking) was positively correlated with *behavioral certainty* during Conflict 4 and Conflict 6 decisions (p = .016, p = .014, respectively; all others $p > .05$). A full correlation table is included on the next page (page 34).

Behavior and Decision SCR Magnitude

Separate correlations were carried out to specifically examine the possible behavioral influence on SCR responses during the three conflict decisions. There was not a direct relation between approach-avoidance behavior and SCR magnitude on any of the decisions

Table 4. Full Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	Approach-Reward SCR	-																								
2	Avoid-Threat SCR	.550**	-																							
3	Conflict-2 Points SCR	0.176	0.067	-																						
4	Conflict-4 Points SCR	.564**	.518**	0.271	-																					
5	Conflict-6 Points SCR	.501**	.477*	0.116	.509**	-																				
6	Point-Slope SCR	0.335	0.198	-.489**	0.287	.690**	-																			
7	Approach-Reward Uncertainty	-0.26	0.055	0.156	-0.187	-0.115	-0.106	-																		
8	Avoid-Threat Uncertainty	-0.017	0.147	-0.002	-0.271	0.05	-0.017	0.268	-																	
9	Conflict-2 Points Uncertainty	0.002	0.065	-0.063	-.433*	-0.118	-0.115	0.222	.568**	-																
10	Conflict-4 Points Uncertainty	0.014	0.107	-.392*	-.401*	-0.154	0.128	0.079	.558**	.727**	-															
11	Conflict-6 Points Uncertainty	-0.063	0.062	-0.244	-.437*	-0.093	0.006	0.079	.620**	.768**	.901**	-														
12	Point-Slope Uncertainty	-0.29	-0.157	-0.117	-0.167	-0.292	-0.184	-0.052	-0.113	-0.319	0.171	0.263	-													
13	Approach-Reward Behavior	-0.121	0.114	0.057	-0.05	-0.034	0.079	.914**	0.123	0.058	-0.028	-0.029	-0.036	-												
14	Avoid-Threat Behavior	0.017	-0.147	0.002	0.271	-0.05	0.017	-0.268	-1.00**	-.568**	-.558**	-.620**	0.113	-0.123	-											
15	Conflict-2 Points Behavior	-0.273	-.408*	-0.145	-0.022	-0.096	0.165	0.168	-.412*	-.448*	-0.211	-0.208	0.357	0.307	.412*	-										
16	Conflict-4 Points Behavior	-0.22	-0.31	-0.007	-0.035	-0.041	0.029	0.081	-0.368	-0.357	-0.262	-0.163	0.289	0.224	0.368	.894**	-									
17	Conflict-6 Points Behavior	-0.136	-0.23	0.039	-0.034	-0.053	-0.035	0.122	-0.345	-0.248	-0.252	-0.167	0.146	0.244	0.345	.806**	.961**	-								
18	Anxiety Sensitivity Index	0.252	0.29	0.056	0.175	0.139	-0.044	-0.197	0.288	-0.032	-0.018	-0.047	-0.185	-0.251	-0.288	-.480**	-.385*	-0.328	-							
19	State-Trait Anxiety Index	0.185	0.301	-0.155	0.094	0.066	0.068	-0.028	0.063	-0.191	0.06	-0.039	0.106	-0.031	-0.063	-0.097	-0.217	-0.174	.655**	-						
20	BIS	0.016	0.057	0.048	0.022	-0.221	-0.14	0.165	0.235	-0.124	-0.049	-0.183	-0.095	0.128	-0.235	-0.086	-0.229	-0.203	.553**	.664**	-					
21	BAS-Reward	-0.213	-.456*	0.045	-0.097	-0.112	0.045	0.305	0.024	0.028	-0.101	-0.049	-0.034	0.337	-0.024	0.192	0.195	0.146	-0.037	-0.285	0.066	-				
22	BAS-Drive	-0.042	-0.166	-0.088	-0.086	0.099	0.142	0.028	0.057	0.049	0.143	0.175	0.216	0.027	-0.057	0.072	0.174	0.17	0.162	-0.133	-0.201	.595**	-			
23	BAS-Fun	-0.097	-0.266	-0.227	-0.29	0.16	0.365	0.188	0.372	0.3	.450*	.459*	0.023	0.162	-0.372	0.191	0.063	0.032	-0.02	0.194	-0.043	0.204	0.275	-		
24	Difficulty Making Decisions	-0.038	-0.191	-0.063	0.27	0.041	0.109	-0.263	-.406*	-.591**	-.636**	-.692**	-0.265	-0.1	.406*	0.371	.412*	.386*	0.159	0.038	0.145	0.155	-0.063	-0.151	-	
25	Aversion to Negative Images	0.297	-0.039	-0.215	0.143	0.22	.422*	-0.196	0.108	-0.068	-0.163	-0.308	-.561**	-0.039	-0.108	-0.169	-0.18	-0.154	0.343	0.174	.384*	0.243	-0.037	0.019	.432*	-

** Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

types. However, *behavioral certainty* was exclusively correlated with SCR magnitude during conflict decisions involving 4 reward points (r_s = -.401, p = .034). Specifically, individuals who exhibited uncertainty in the outcome they desired (low *behavioral certainty*) had greater sympathetic arousal (higher SCR magnitude) when making conflict decisions that involved four reward points (but not those involving two or six points). Point-slope changes in SCR were unrelated to point-slope changes in behavior using either metric.

Self-Report and Decision SCR Magnitude

Self-report measures were then correlated with the various SCR magnitudes to see if there were individual level associations with sympathetic activity while making decisions. *Point-slope SCR* was significantly correlated with aversion to negative images (r_s = .422, p = .025), suggesting that the more averse an individual finds the possible negative images from each decision, the faster their SCR increases with increased reward. There was also a positive trend level correlation between the BAS – Fun Seeking subscale and *point-slope SCR* (r_s = .365, p = .056). The other subscales, along with the BIS and the ASI, were unrelated to any of the measures of SCR magnitude during conflict decisions, nor were any correlations significant with SCR during Approach-reward decisions (all p > .05). However, SCR magnitude during Avoid-threat decisions, which involved no possible reward, was negatively correlated with both BAS – Reward Responsiveness (r_s = -.456, p = .015), and self-reported *reward point motivation* (r_s = .502, p = .006). In this scenario, increased responsiveness to reward was associated with decreased sympathetic activity when making decisions that involved no potential reward points.

CHAPTER 5

DISCUSSION

This study used an approach-avoidance conflict paradigm to examine sympathetic arousal during decision-making, using explicit risks and rewards. By making risk and reward values explicit, we were able to examine sympathetic arousal during decision-making independent of a learning component (thus adding to the IGT literature). By varying the level of reward and the existence of conflicting outcomes, our results help elucidate how sympathetic arousal during decision-making is modulated by potential outcomes. By investigating the relationship between sympathetic arousal and specific decision-making behaviors and self-report measures, we were also able to identify possible reasons for the varying levels of arousal. First, we established that skin conductance differs across types of approach-avoidance decisions. Most specifically, skin conductance responses increase as potential reward increases during conflict decisions (See Table 3/Figure 3.) Second, we identified a relationship between the level of *behavioral certainty* and the level of sympathetic arousal observed during conflict decisions. Finally, by including self-report measures, we were able to examine whether a person's subjective experiences on the task or specific behavioral traits influence sympathetic arousal during conflict decisions.

Sympathetic Arousal and Conflict Decisions

We observed a significant decrease in SCR from situations involving no reward (Avoid-threat) conditions, to Conflict 2 point decisions, possibly due to increased cognitive load under the conflict decision. This is perhaps consistent with recent research reporting that increased use of cognitive strategies for regulating expectations of reward result in

attenuation of SCR responses as well as striatal responses to reward (Delgado, Gillis, & Phelps, 2008).

The three conflict decisions (2, 4, 6 points) of the AAC have the greatest potential for investigating how the magnitude of skin conductance response changes with potential reward. The only visual difference in these three decisions is the small amount of red (representing reward points) associated with choosing the conflict outcome (see Figure 1). Regarding the stimuli, reward points were the only thing that varied between the three situations; because of this we can reasonably conclude that potential reward had some influence on the increased SCR from decisions involving two points, to those involving four. Because SCR was not directly related to approach behavior, we cannot say that the probability of reward receipt, or loss, was driving the increase in SCR from two reward points, to four or six. Our results suggest that the simple possibility of larger reward during conflict decisions can increase sympathetic arousal experienced during the decision process. These findings are consistent with previous research reporting increased heart rate with increasing levels of potential reward during monetary incentive tasks (Brenner, Beauchaine, & Sylvers, 2005). Findings of increased SCR when choosing "risky" decks during the IGT has been taken as evidence that these somatic signals are indicating the level of risk involved in that decision and aiding in the learning process (Bechara et al., 1999; Bechara et al., 1997; Bechara et al., 1996). Our findings, however, would suggest that the "somatic signal" of SCR response occurs even when the outcomes are known (and thus, no learning is explicitly involved) and regardless of whether the individual is choosing to approach that risk or not.

Examining decisions involving *no possible reward* (avoid-threat decisions), we found SCR magnitude to be negatively correlated with BAS-Reward Responsiveness and self-

reported *reward point motivation*. This indicates that individuals more motivated by rewards experience less sympathetic arousal during emotional situations or decisions that do not involve any potential reward. This association further suggests that potential reward points played a role in sympathetic arousal, especially in those motivated to seek them. These results are consistent with previous studies (Brenner et al., 2005; Monat, Averill, & Lazarus, 1972), in which the only relationship between self-reported inhibition/activation drives and psychophysiological arousal was that between BAS Reward Responsiveness and greater parasympathetic arousal (measured by respiratory sinus arrhythmia) during reward extinction (i.e., when reward is not going to be given). Thus, these previous findings combined with our current finding would suggest that the trait of reward responsiveness relates to greater parasympathetic and reduced sympathetic arousal during situations involving no reward.

We additionally found that the rate at which SCR increased from decisions involving two, to four, to six points was associated specifically with self-reported *aversion to negative images*, but increases in approach behavior across the same three conditions was unrelated to SCR and *aversion to negative images.* This suggests that what is driving the larger response associated with increased reward may be interplay between the two constructs: experiences of negative affect and potential reward. That is, people highly averse to negative images had greater SCRs during decisions when points increased due to the compound effect of increased potential reward and the associated increase in risk of seeing a negative image necessary to receive those points.

Certainty of Outcome

In our study, we examined SCRs constrained to those responses recorded *during the decision*. A four second window was defined to examine SCRs, and the observed signal was

run through a convolution process to further define the SCR associated with that four second window only. Results from our study show that greater uncertainty in choice, defined behaviorally as moving the avatar closer to the middle of the runway (where there was 50% likelihood of either outcome), was associated with increased SCR during conflict decisions involving four reward points. This behavioral measure of choice uncertainty was highly correlated with self-reported *difficulty making* decisions, further suggesting that these individuals were exhibiting higher levels of internal conflict about which outcome they desired. However, with the current paradigm, we are unable to determine whether the increased SCR was due to the uncertainty in choice of the individual or in the greater uncertainty of outcomes (50% chance of either outcome as opposed to 90% chance of one outcome occurring). While SCR was unrelated to behavioral certainty during conflict decisions involving two or six reward points, the 4 point condition may have represented the "sweet spot" of our three scenarios, where potential reward and desire to avoid seeing a negative image were equally influencing SCR. Previous research has reported inconsistent findings in regards to whether uncertainty is associated with greater sympathetic arousal (Bankart & Elliott, 1974; Epstein & Roupenian, 1970; Monat et al., 1972). However, most of these studies manipulate the level of uncertainty in outcome, rather than letting the participants have control over determining the probability of outcomes. It is consequently possible that uncertainty in one's choice regarding potential outcomes is more arousing than is uncertainty in outcomes not under one's control.

Limitations and Future Directions

Some limitations of this study are inherent in the measure of SCR itself. It is a non-valenced measure of sympathetic arousal, meaning that we cannot say that these individuals

experienced higher levels of discomfort, or happiness, or any specific affect, during their decisions (Boucsein, 2012). However, previous research examining the neural underpinnings of decision-making during the AAC suggests the involvement of conflict monitoring and cognitive control regions such as the anterior cingulate and lateral PFC, as well as more visceral regions such the insula and caudate (Aupperle et al., 2014). These regions have downstream effects on EDA (Critchley, 2002), and here we support past findings with the AAC and extend them by showing that similar results are found in observed sympathetic arousal during conflict decision-making. Specifically, the lateral PFC, a region involved with "cold" cognitive control, is activated most during Conflict 2 decisions (Aupperle et al., 2014). It may be that activation of these cognitive control regions is what is leading to the reduced sympathetic arousal observed for this condition (compared to conflict decisions involving 4 or 6 points) in the current study.

Another limitation is our constraint to SCRs occurring *during* the four-second decision window. While effective in highlighting the SCR that occurs during the decision-making process, we cannot say whether the SCR occurred in response to the decision, or preceded the decision. However, we can say that it was not simply anticipatory in nature; there was no anticipatory period between the onset of the decision runway and the decision process. Also, the participants were explicitly told of the four-second time constraint on their decisions, so they knew in every scenario that after four seconds, they would be shown the result of their decisions. Due to the paradigm not including intervals between the decision phase and the outcome phases, we were also unable to investigate SCRs during receipt of reward or presentation of negative affective outcomes. Future research using modified versions of the AAC could be useful in understanding how sympathetic arousal during

emotional decision-making relates to sympathetic arousal during receipt of decisional outcomes.

While our study adds to the growing literature on psychophysiological profiles of decision-making, many questions remain. Future research should investigate more carefully the effect of reward on sympathetic arousal. Specifically, more research is needed to clarify how anticipation versus receipt of reward and anticipation versus receipt of reward-loss (which would relate to loss-aversion) relate to sympathetic arousal. Our paradigm was able to demonstrate a clear difference between conditions involving two and four points, but no clear difference was seen from four to six points. Additionally, our "reward points" were arbitrary, and did not have "real-world" consequences. As seen in our results, and supported by previous studies (Peters et al., 2011; Peters & Buchel, 2010), monetary and non-monetary rewards can elicit similar results. However, even larger differences in magnitude may be seen with decisions that involve real-world implications, and may aid in delineation of the effects of increasing rewards.

Because of the non-valenced nature of the SCR (Boucsein, 2012) it is difficult to determine exactly how the specific variables of the decision may have differentially affected the observed sympathetic response. Previous research demonstrated that potential reward (i.e. bet size) during a specific bet selection period is significantly correlated with increased SCR (Studer & Clark, 2011). We expanded on that work by establishing this relationship with an experimentally manipulated reward size. Other results have shown larger increases in SCR specific to decisions involving monetary gain, versus those with reward values of zero or loss (Talmi et al., 2009). In our scenario, individuals also have control over their likelihood of receiving that reward (up to 90%). Studies investigating neural activation and likelihood of

reward show that activity peaks at 50% likelihood, and decreases as rewards become more or less likely (Platt & Huettel, 2008) and our results of sympathetic arousal during 4 point conflict decisions replicate this idea using EDA.

Taken together, the observed sympathetic arousal experienced in our paradigm involving conflict decisions may be a *compound* effect of a possible negative image associated with potential reward points, and likelihood of receiving the desired outcome. Interestingly, conflict decisions with low reward (Conflict 2 points) had significantly lower sympathetic activity than those with no reward (Avoid-threat). Implications from this suggest that the introduction of a very small reward into a decision could have the effect of *lessening* the emotional burden experienced by an individual. Again, because EDA is non-valenced we are unable to say that the participant was experiencing a specific emotion during Avoid-threat decisions, but we can say confidently that emotional arousal, as a whole, was lower when making Conflict 2 decisions comparatively. However, a further increase in reward expands the sympathetic arousal during decision-making. Depending on the situation, this could be detrimental (if the goal is to decrease sympathetic arousal, for example during relaxation) or beneficial (if the goal is to override somatic signals related to potential negative events, such as during exposure-based therapies for anxiety). This could be a fruitful area for future clinical research.

In conclusion, we supported the idea that sympathetic arousal *during* a decision is influenced by the potential outcome variables, independent of a learning component. We demonstrated how various levels of behavioral certainty can influence experienced emotional arousal, and that increased potential reward significantly intensifies emotional arousal during a decision.

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