Forgiveness from the Heart: A Psychophysiological Study

DISSERTATION

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Abstract

Interpersonal forgiveness is a burgeoning area of research in psychology and has been linked to lower levels of depression and perseverative cognitive states such as rumination. As much of the extant research employs self-reported assessments of forgiveness, the aims of the present work are to test a novel operational definition of forgiveness using behavioral outcomes from economic games—specifically, the Ultimatum Game (UG) and Dictator Game (DG)—and to explore how such behavior corresponds with phasic heart rate (HR), heart rate variability (HRV), individual differences, and psychosocial variables. Participants \( n = 89; \) age \( M = 19 \) years; 46% female) were instrumented with continuous electrocardiogram and were seated for a 5-minute resting baseline, a pre-post adaptation of the DG and UG with digital opponents, randomization to forgiveness or rumination imagery, and a 5-minute recovery period. Participants reported affective ratings as a manipulation check as well as questionnaires on state and trait forgiveness, hostility, and rumination. Forgiving behavior was operationalized as more generous monetary offers to previously unfair, provoking opponents (positive value for post- minus pre-manipulation DG offer). As hypothesized, individuals who imagined forgiving previously unfair, provoking opponents showed more behavioral forgiveness in their return offers and reported less negative affect.
compared to those instructed to ruminate. The *Forgive* group also showed reduced HR reactivity and increased HRV during imagery and when instantiating forgiveness behavior compared to the *Ruminate* group. Behavioral forgiveness was positively correlated with trait forgiveness and benevolence motivation, and negatively correlated with hostility, revenge motivation, and avoidance motivation. No individual differences by gender or baseline HRV emerged in forgiving behaviors, and no gender differences emerged in physiological responding; however, rumination surprisingly predicted forgiving behavior among men only. The results support the behavioral paradigm, corroborate a model of neurovisceral integration with respect to phasic HRV changes, and suggest that forgiving may recruit executive functions in parallel with emotion regulation processes. Forgiveness may proffer cardioprotective benefits via reduced cardiovascular reactivity, while attention to gender differences in the link between forgiveness and rumination is encouraged in future research and intervention.
For Azalea Elizabeth Schrock and Eyatta Fischer.

Azalea, may you fly and soar to the vast lengths your mind, heart, and soul conceive.

Eyatta, Heaven took you weeks shy of your doctoral defense. This work is dedicated to you, your achievements, and your legacy.
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**Fields of Study**

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Chapter 1: Introduction

From instances of social injustice to news of genocide and war atrocities, the concepts of interpersonal forgiveness and retribution have been and continue to be socially and intrapersonally relevant. Forgiveness is a renowned construct with much devoted attention in theological, philosophical, political, legal, and psychological fields. Over the past two decades, researchers in psychology have begun to theorize and examine its antecedents, correlates, and outcomes in areas of social motivation, cognition, emotion, and health. Ensuing is a discussion of the conceptualizations of forgiveness as well as a summary of the research findings in psychology.

1.1 Defining Forgiveness

Interpersonal forgiveness has been examined and discussed across academic, professional, and lay circles, and not surprisingly there is no universal agreement on its definition even within bailiwicks. The Merriam-Webster Dictionary defines forgive as “to give up resentment of or claim to requital for” or “to cease to feel resentment against (an offender)” (“Forgive,” Merriam-Webster, 2014). It is derived from the Old English forgiefan, meaning “to give up” or “to give in marriage” with Germanic origins translated from the Latin perdonare, or “to give completely, without reservation” (Oxford English Dictionary, 2014). The verb has thus evolved historically, from 900 A.D. as a behavioral
giving something of oneself at a cost to oneself, to its modern conception as a psychological process of releasing emotion (“Forgive,” Oxford English Dictionary, 2014; Smith, 2008). Forgiveness is then the action of forgiving, or as denoted in the Stanford Encyclopedia of Philosophy, “a dyadic relation involving a wrongdoer and a wronged party … [to re-establish] a relationship ruptured by wrongdoing” (Hughes, 2010). Such a re-establishment requires a victim’s moral reassessment of the wrongdoer, which can be achieved by relinquishing negative emotion (e.g., resentment, anger) or a desire for retributive behavior (Hughes, 2010).

1.2 Forgiveness in Psychology

The empirical study of forgiveness in psychology has burgeoned in the past two decades. As noted, scholars in various fields disagree on its definition, and the field of psychology is no exception. Moral developmental psychologists Enright, Gassin, and Wu (1992) derive a definition of interpersonal forgiveness from North (1987) and note that forgiveness entails not only the relinquishment of negative emotion and desire for revenge, but also efforts to adopt positive affect and views (e.g., benevolence or compassion). That is, they note that certain elements are removed from affective (e.g., resentment), cognitive (e.g., planning revenge), and behavioral systems, while certain elements are also added to each system (e.g., compassion) in the process of forgiving (Enright et al., 1992). Most psychologists adopt this two component conceptualization.

Enright’s group and other psychologists additionally define forgiveness by what it is not: forgetting, pardoning, condoning, excusing, reconciling, indifference, or the simple reduction of negative emotion over time (Enright, Gassin, & Wu, 1992; Fincham,
That is, forgiveness is intentional, the offender is still held responsible, and the offense is not minimized, tolerated, or publicly exonerated. Psychologists have affirmed that forgiveness is unconditional and reconciliation is not necessary in the process of forgiveness, as in instances when an offender dies (Fincham, 2000; Witvliet, 2001). Worthington and Wade (1999) further distinguish between forgiveness and what they term unforgiveness: “a ‘cold’ emotion involving resentment, bitterness, and perhaps hatred, along with the motivated avoidance of or retaliation against a transgressor” (p.386). Unforgiveness is posited as a delayed response that is not engendered by immediate threat or frustration (Worthington & Scherer, 2004), but instead may be facilitated by rumination (McCullough, Bono, & Root, 2007)—a form of prolonged, repetitive, and often maladaptive thinking of one’s distress arising from actual versus desired states (Smith & Alloy, 2009). Forgiveness is contrasted as one of several avenues toward diminishing unforgiveness (Worthington & Wade, 1999).

State and trait forgiveness are also distinct concepts in psychological study. The majority of empirical literature on forgiveness involves state or current experiences of forgiveness, while a growing body of work has begun to address a forgiving personality. Berry and colleagues (2005) define forgivingness as the disposition to forgive transgressions over time and across situations. Trait forgivingness is negatively correlated with trait anger, hostility, neuroticism, and vengeful rumination, and positively correlated with trait empathy and physical health (Berry, Worthington, O’Connor, Parrott III, & Wade, 2005; Lawler et al., 2005; Lawler-Row, Karremans, Scott, Edlis-Matityahou,
Edwads, 2008; Whited, Wheat, & Larkin, 2010). Trait forgiveness has also been tied to depressive symptoms. For example, Brown (2003) demonstrated that individuals with low tendency to forgive but positive attitudes toward forgiving had more depressed symptoms compared to those who did not value forgiveness.

With respect to its application, much of the early literature on forgiveness has focused on applications in psychotherapy (e.g., DiBlasio & Proctor, 1993) and anger or marital conflict (e.g., Fitzgibbons, 1986; Worthington & DiBlasio, 1990). More recent work has called attention to its relation with depression and ruminative processes (e.g., Brown, 2003). Forgiveness has been frequently linked with lower levels of depression or depressive symptoms (Toussaint & Webb, 2005; Krause & Ellison, 2003). For example, in one epidemiological study of over 1,400 adults, forgiving others, forgiving oneself, and feeling forgiven by God all predicted lower odds of developing major depression among women, while forgiving oneself predicted lower odds of depression among men (Toussaint, Williams, Musick, & Everson-Rose, 2008). In another nationwide survey of over 1,300 adults, forgiveness of others and perceived forgiveness by God were negatively related to depressed affect (Krause & Ellison, 2003). Similar patterns have been reported in the intervention literature. For instance, in a process intervention on forgiveness among incest survivors, individuals in treatment showed reduced depressive symptoms compared to those in a wait-list control (Freedman & Enright, 1996). Researchers have demonstrated that the negative association between forgiveness and depression is mediated by rumination (Ysseldyk, Matheson, & Anisman, 2007). Rumination is a construct of interest in the present study and will be reviewed more in
depth in the section 1.23 Affect. Given the burden of depression and depressive symptoms in healthcare costs (Greenberg, Fournier, Sisitsky, Pike, & Kessler, 2015), loss of productivity (Greenberg et al., 2015), and reduced quality of life (Daly et al., 2010), a closer examination of forgiveness and its inverse relation with depression may not only inform treatment and intervention planning in clinical populations, but may also ameliorate costs at the level of prevention in non-clinical populations.

As is patent in the above conceptualizations, forgiveness is a dynamic, multifaceted construct involving social, motivational, behavioral, cognitive, affective, physiological, and health systems, and these bear implications for psychopathology intervention and treatment. Researchers have refined our understanding within each system, and attention is turned now to each in a brief review of the current literature.

1.21 Social Motivation and Behavior

McCullough and colleagues (1997) conceptualize forgiveness as a set of prosocial motivational changes that include less motivation to retaliate against or avoid an offender and increased motivation for goodwill and conciliatory behavior towards the offender. They note that forgiveness is not a motivation per se, but a set of complex motivational changes over time that are prompted by empathy. This hypothesis was supported in factor analytic and covariance structure exploration as well as direct intervention comparisons. Specifically, empathy was found to partially mediate the relation between apology and forgiving, while forgiving was directly associated with conciliatory and (negatively with) avoidance behavior among participants asked to imagine a personal transgression (McCullough, Worthington, & Rachal, 1997). Comparing interventions, the same authors
found that an empathy seminar promoted more self-reported forgiving than a comparison seminar and wait-list control. In a recent longitudinal study, perceived conciliatory gestures by an offender predicted increased self-reported forgiveness and reduced anger (McCullough, Pedersen, Tabak, & Carter, 2014).

Self-report measures of forgiving and conciliatory behavior are useful but limited as indirect assessments of behavior; however, direct behavioral assessments are scant in the literature (e.g., Huang & Enright, 2000). One study implemented the Prisoner’s Dilemma Game and conceptualized forgiving behavior as increased cooperation after a computerized opponent defected; the authors found that the presentation of an apology facilitated forgiveness by producing higher rates of subsequent cooperation (Tabak, McCullough, Luna, Bono, & Berry 2012). Another study manipulated in-group and out-group soccer and netball teams with assigned team captains and players; forgiving behavior was operationalized as group inclusion and amount of money participants chose to give or withhold from transgressing captains and team players (Abrams, Randsley de Moura, & Travaglino, 2013). Participants in this study were more forgiving toward in-group captains than team players (Abrams et al., 2013). Few studies have operationalized and experimentally tested forgiving behavior and the present work contributes to this gap in the experimental literature.

1.22 Cognition

Recently, McCullough, Kurzban, and Tabak (2013) have described a functional, adaptationist model positing that cognitive systems for revenge and forgiveness have evolved in order to deter recurrences of harm as well as to preserve beneficial
relationships. The model is described within a computational framework of calculating costs and benefits of forgiveness or retaliation in terms of Welfare Tradeoff Ratios (Tooby et al., 2008). The computational model has been criticized as unnecessarily complex (Aureli & Schaffner, 2013), though it has received some burgeoning support from its proponents. In one longitudinal study, higher perceived relationship value and lower perceived exploitation risk by a transgressor were found to mediate relations between conciliatory gestures and increased forgiveness (McCullough, Pedersen, Tabak, & Carter, 2014). While more research is needed, it is noted that a functional model of forgiveness allows for the exploration of biobehavioral antecedents (McCullough et al., 2013; Williams, 1996).

Other cognitive processes associated with forgiving include attribution, rumination, reappraisal, and broadly, executive control. Attributions about responsibility of the transgressor (Fincham, 2000), intentionality (Struthers, Eaton, Santelli, Uchiyama, & Shirvani, 2008), offense severity (Exline, Baumeister, Zell, Kraft, & Witvliet, 2008), and stability of a transgressor’s behavior (Davis & Gold, 2011) have been shown to influence forgiveness. In one study, attributions of behavioral stability (i.e., believing that an offense is unlikely to occur again), perceived remorse, and empathy explained a sizable variance in forgiveness ($R^2 = 0.518$); the authors also reported a significant multiple mediation effect whereby perceived remorse increased forgiveness only when taking into account stability attribution and empathy (Davis & Gold, 2011). Reappraisal and rumination have also been linked to forgiveness; however, given the overlap and
attention these processes have garnered in the emotion regulation literature, these will be elaborated further in the following section under Affect.

Importantly, forgiveness has been recently tied with executive control (Burnette et al., 2014; Wilkowski, Robinson, & Troop-Gordon, 2010). Executive control or executive functioning broadly refers to a set of cognitive processes that shape behavior in an adaptive, goal-directed manner (Borkowski & Burke, 1996; Posner & Petersen, 1990; Petersen & Posner, 2012). These commonly refer to one’s self-regulatory ability to direct attention toward relevant information and inhibit irrelevant information, processes, or impulses (Smith & Jonides, 1999). Van der Wal and co-authors (2014) propose that executive control facilitates forgiveness by inhibiting negative emotion and retaliatory behavior. Merging social motivational and cognitive concepts in forgiveness, they tested relations between executive control and perceived relationship value in promoting forgiveness. Across four studies in adults and children using behavioral and self-reported measures of forgiveness, the authors found higher forgiveness in individuals with perceived relationship value, but only among those with high executive control; in addition, forgiveness was associated with executive control, but only for relationships that were valued (Van der Wal, Karremans, & Cillessen, 2014). Wilkowski and colleagues (2010) investigated cognitive control and forgiveness in hostile situations using a hostility-primed cognitive control measure, a lab aggression task, and self-reported revenge motivation. They showed that individuals with higher cognitive control in hostile situations showed less aggressive behavior, and this relation was mediated by forgiveness (operationalized as reduced revenge motivation; Wilkowski et al., 2010). The
evidence that executive control mitigates aggression and retaliatory behavior suggests that regulatory mechanisms in forgiveness apply to cognition as well as emotion, to which attention is turned next.

1.23 Affect

Worthington and Scherer (2004) distinguish between decisional and emotional forgiveness. The former, they propose, is a behavioral intention to restore relationships and release an offender from debt, though an individual may still harbor negative emotions and cognitions in the process. In contrast, emotional forgiveness is defined as “the emotional juxtaposition of positive other-oriented emotions against negative unforgiveness, which eventually results in neutralization or replacement of all or part of those negative emotions with positive emotions” (p.387). In line with this hypothesis, empathy is a robust positive correlate of forgiveness in the literature, while anger, rumination, and hostility are negatively associated with forgiveness (Berry, Worthington, O’Connor, Parrott III, & Wade, 2005; Riek & Mania, 2012); however, a clear causal direction has not been established. Forgiveness may result from or produce empathy in a process of cognitive and emotional change. Such conceptualizations find a parallel in the widely studied construct of emotion regulation. According to Gross (2002), emotion regulation refers to “the processes by which we influence which emotions we have, when we have them, and how we experience and express them” (p.282) dynamically over time. Gross’s (1998) process model of emotion regulation entails antecedent and response focused strategies that occur before or after emotions are activated, respectively. Two strategies that have been
examined in the forgiveness literature are reappraisal and expressive suppression. Gross (2002) defines reappraisal as “construing a potentially emotion-eliciting situation in nonemotional terms” (p.283) and suppression as inhibiting the behavioral expression of emotion. In one study, compassionate reappraisal was compared with expressive suppression and offense-focused rumination as coping responses after an offense (Witvliet, DeYoung, Hofelich, & DeYoung, 2011). Only compassionate reappraisal, (imagery of an offender’s humanity and benevolence) facilitated increased positive emotions and forgiveness, while both expressive suppression (imagery to suppress negative offense-related emotions) and compassionate reappraisal decreased negative emotion. In contrast, offense-focused rumination produced negative emotion and accelerated heart rate (Witvliet et al., 2011). Their results replicated similar earlier findings in which compassionate reappraisal facilitated greater empathy, forgiveness, and slower cardiac activity, while ruminating about the offense produced increased negative emotion, decreased positive emotion, and cardiac acceleration (Witvliet, Knoll, Hinman, & DeYoung, 2010). Similarly, Larsen and colleagues (2012) showed that individuals who engaged in angry ruminative imagery had greater increases in blood pressure compared to those engaging in forgiving imagery. In the context of emotion regulation, much of the forgiveness literature has contrasted forgiving with ruminative processes. These comparisons find support in the evidence that rumination is inversely related to executive function (Watkins & Brown, 2002; Whitmer & Banich, 2007) and that rumination mediates the link between executive control and forgiveness (Pronk, Karremans, Overbeek, Vermulst, & Wigboldus, 2010). That is, higher executive function predicts
forgiveness, in part through the down-regulation of negative emotions and ruminative processes (Pronk et al., 2010). Altogether, these findings suggest that forgiveness is consonant with emotion regulation strategies that recruit executive control in the interests of inhibiting negative affect and increasing positive affect. These in turn bear implications in physiological and psychological health.

1.24 Health

Interest in the psychological and physiological health outcomes of forgiveness is strong and growing. The impact of forgiveness on mental health outcomes has received considerable attention in the psychotherapy intervention literature. Wade et al. (2014) recently reviewed 54 studies in a meta-analysis of psychotherapeutic interventions and found that treatments that specifically promote forgiveness increase hope and forgiveness and decrease depression and anxiety better than no treatment or alternative treatments. Duration of treatment significantly moderated this effect, which was stronger for longer treatments (Wade, Hoyt, Kidwell, & Worthington, 2014). Similar findings have been discussed in a narrative review of the salutary effects of forgiving on mental health outcomes (Witvliet, 2001). As noted above, a number of non-intervention studies show that forgiveness is associated with increased positive affect, decreased negative affect, and decreased angry or vengeful rumination (e.g., Berry et al., 2005)—all potential protective and vulnerability factors, respectively, in the onset and course of psychopathology. Indeed, data from a large representative sample suggested that forgiveness among women was associated with decreased likelihood of 12-month prevalence of major depression (Toussaint, Williams, Musick, & Everson-Rose, 2008). In
a longitudinal study, forgiveness on a given day was associated with greater psychological well-being on a subsequent day, and this relation was stronger for individuals who reported feelings of closeness and commitment and who perceived an apology from a transgressor (Bono, McCullough, & Root, 2008). The reverse relation was found in which increases in well-being were also associated with subsequent forgiveness, though this was not mediated by social connectedness. The findings suggest that affective and social mechanisms may underlie the link between forgiveness and psychological health.

Psychologists have recently conceptualized forgiveness as an emotion-focused stress coping strategy with implications for somatic health (Worthington & Scherer, 2004; Worthington, Witvliet, Pietrini, & Miller, 2007). Namely, it is posited that unforgiveness is stressful and that forgiveness is one of several coping mechanisms to reduce the stress of unforgiveness (Worthington & Scherer, 2004). A growing body of literature has investigated the physiological outcomes of forgiving, as well as the deleterious effects of unforgiving. Acute and prolonged cardioacceleration and vascular reactivity have been shown to accompany unforgiving, angry, or ruminative states compared to forgiving states in a number of published findings (Larsen et al. 2012; Lawler et al., 2003; Lawler-Row, Karremans, Scott, Edlis-Matityahou, & Edwards, 2008; Witvliet et al., 2010, 2011). For example, Larsen and collaborators (2012) manipulated forgiving, ruminating, and distracting imagery conditions and found that increases in systolic and diastolic blood pressure were most pronounced among individuals who engaged in angry rumination. These replicated similar cardiovascular findings among
individuals with low state forgiveness during an interview about a personal transgression (Lawler et al., 2003); in the same study, the authors showed that self-reported illness was positively associated with hostility and stress, and negatively associated with forgiveness (Lawler et al., 2003).

Similar findings extend to investigations of trait forgiveness (Friedberg, Suchday, & Shelov, 2007; Lawler et al., 2003; Lawler-Row et al., 2008; Whited, Wheat, & Larkin, 2010). In one study, individuals high in trait forgiveness showed faster recovery of diastolic blood pressure (DBP) and mean arterial pressure in response to a live transgression (Whited et al., 2010). Friedberg and colleagues (2007) also found that trait forgiveness predicted faster recovery of DBP following an anger recall task. This finding was nuanced by sex in yet another study in which men with high trait forgiveness showed faster DBP recovery following an interview about a personal betrayal (Lawler et al., 2003).

Altogether, the evidence for state and trait forgiveness suggests a clear link to cardiovascular health. It has been posited that forgiving has beneficial health effects by buffering the deleterious effects of stress and hostility (Worthington et al., 2007). Hostility is by now widely known to have adverse health consequences, particularly in the onset of coronary heart disease (Myrtek, 2007). In a large representative sample of over 1,600 respondents, forgiveness moderated positive associations between aging, hostility, and poor health through its inverse relation with hostility (Silton, Flanelly, & Lutjen, 2013). Lawler and co-authors (2005) tested the mediating effects of spirituality, reduced negative affect, social skills, and stress reduction on the relation between state
and trait forgiveness and physical health (measured as physical symptoms). Reduced negative affect and stress fully mediated the link between state forgiveness and health, while reduced negative affect, stress, and increased conflict management mediated associations between trait forgiveness and health (Lawler et al., 2005). In a more recent study, health was assessed physiologically as well as through self-reported symptoms (Lawler-Row et al., 2008). Trait forgiveness accounted for significant variance in blood pressure and rate pressure product, and the same for state forgiveness and heart rate, even after controlling for gender and anger expression; their results suggest that forgiveness is related to physiological health beyond mechanisms of anger reduction (Lawler-Row et al., 2008). Overall, the literature suggests that forgiveness may confer physiological health benefits not only through reductions in negative affect, but also via stress reduction and social mechanisms.

1.3 Theoretical Underpinnings

How exactly forgiveness influences somatic health may be understood from models of perseverative cognition, allostatic load, and the integration of neurovisceral networks recruited in the interests of self-regulation and adaptive organism flexibility (Brosschot, Gerin, & Thayer, 2006; Thayer & Lane, 2007, 2009). Specifically, perseverative cognition—repetitive thinking in anticipation of (e.g., worry) or following a stressor (e.g., rumination)—has been posited and shown to exacerbate the effects of stress on somatic health through mechanisms of prolonged physiological arousal (Brosschot et al., 2006; Brosschot, Verkuil, & Thayer, 2010). That is, cognitive representations of threats long before and after the occurrence of stressful events contribute to allostatic
load, or physiological “wear and tear” over time (McEwen, 1998), which then contribute to poorer health across endocrine, immune, and cardiovascular parameters (Brosschot et al., 2006). The ruminative processes of unforgiveness, and conversely the affective and cognitive regulatory processes of forgiveness, may thus relate to somatic and particularly cardiovascular health through a process of prolonged physiological activation—specifically through neurovisceral instantiation (Thayer & Lane, 2009).

As reviewed in sections 1.23 Affect and 1.24 Health, the cardiovascular benefits of forgiveness are concomitant with stress reduction as well as a reduction in negative affect. While relations between stress and cardiovascular damage are relatively understood, a model of neurovisceral integration may explain how the emotion regulatory processes of forgiveness are related to cardiovascular health. Specifically, Thayer and colleagues (Thayer & Lane, 2009; Thayer & Siegle, 2002) have outlined a network of neural structures and bidirectional cortical-subcortical pathways that are implicated in affective and cardiac regulation. Such emotion and cardiac regulation is instantiated via top-down cortical inhibitory control and vagally mediated parasympathetic innervation (Thayer & Lane, 2009; Thayer, Åhs, Fredrikson, Sollers III, & Wager, 2012). Successful regulation of emotions is thus consonant with tonic inhibitory control of cardioacceleratory tendency (Uijtdehagge & Thayer, 2000), as well as increased neural activity in regions such as the medial prefrontal cortex (Lane et al., 2009; Thayer et al., 2012). The converse of such successful regulation—cortical disinhibition and attendant low vagal function—has been robustly shown to precede and predict cardiovascular disease and its risk factors (Thayer & Lane, 2007). Thus, angry, resentful, and other
negative emotions concomitant with unforgiving states may reflect processes of cortical disinhibition and decreased vagally-mediated cardiac function.

Such cortical activity and cardiac autonomic control are reliably indexed with heart rate variability (HRV; Thayer et al., 2012), which is the temporal variation between consecutive heartbeats in milliseconds obtained through non-invasive electrocardiogram (ECG) recording. HRV may be derived using spectral density estimation of power as a function of frequency (frequency domain measures), as well as through arithmetic manipulation of the interval between consecutive beats from continuous ECG recording (time domain measures; Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology [Task Force], 1996).

Given corroborating evidence in the literature (reviewed in 1.24 Health and 1.22 Cognition), it is assumed in the present work that unforgiving, ruminative states reflect cortical disinhibition, while forgiveness may recruit cognitive and affective regulatory processes (i.e., executive control) associated with cortical inhibition and cardiac autonomic control. In the present work, it is thus expected that time and frequency domain measures of HRV will be related to forgiveness as substantiated by models of perseverative cognition and neurovisceral integration.

1.4 Psychophysiology of Forgiveness and Perseverative Cognition

In recent years, authors have begun to explore the psychophysiological correlates of forgiveness and perseverative cognition. Witvliet, for example, has published several psychophysiological studies manipulating forgiveness, unforgiveness, and ruminative imagery (Witvliet, Ludwig, & Vander Laan, 2001; Witvliet et al., 2008; Witvliet, Knoll,
Hinman, & DeYoung, 2010; Witvliet, DeYoung, Hofelich, & DeYoung, 2011). In one study, participants each imagined two forgiving (cultivating empathy, granting forgiveness) and two unforgiving scenarios (rehearsing hurtful memories, harboring grudges) about a personal transgressor. Those who imagined unforgiving scenarios experienced more negative emotion and showed greater brow muscle tension, skin conductance, and increased heart rate and blood pressure compared to those who imagined forgiving scenarios (Witvliet et al., 2001). In another study, forgiveness imagery was associated with reduced anger, greater empathy, calmer heart rate (HR) and lower brow and eye muscle tension (Witvliet et al., 2008). More recent studies have shown that compassionate reappraisal is associated with better HRV and HR outcomes compared to offense-focused rumination (Witvliet et al., 2010, 2011). Similar results have been replicated in studies showing increased cardiovascular activity in the recovery period after ruminative imagery (Larsen et al., 2012) or a provocation (Whited et al., 2010). In one pilot study, HRV decreased in the recovery period among women who ruminated about a personal offense or who were distracted with laundry instructions, while only those women who imagined forgiving a transgressor showed increases in HRV (Hu, Patel, & Thayer, 2012, November). Altogether, the results support a hypothesis of perseverative cognition and the role of forgiveness in buffering the adverse cardiovascular effects of rumination.

1.5 Economic Games

The use of economic games is recent in the psychophysiological and forgiveness literature. Specifically, authors have implemented adaptations of the Ultimatum Game
(UG) and Dictator Game (DG; Kahneman, Knetsch, & Thaler, 1986; Thaler, 1988) to explore forgiving behavior and reciprocity (e.g., Ferguson, Maltby, Bibby, & Lawrence, 2014). The UG and DG are two-player games in which participants are allocated a provisional sum of money. In the DG, the participant (Allocator) is instructed to divide a portion of the money to another player (Recipient). The Recipient may choose to accept this proposal, in which case the divided money is awarded to both players, or to reject the proposal, in which neither player earns money. The UG is similar except that the participant is now the Recipient and must choose to accept or reject offers proposed by the Allocator, with the same consequences for acceptance or rejection (Kahneman et al., 1986; Thaler, 1988). Theoretically, participants should make near-zero offers and universally accept offers to maximize personal gain (Rubinstein, 1982); however, a wide body of experimental literature suggests that this is not the case and that players tend toward relatively fair allocations as well as rejection of unfair offers (e.g., Forsythe, Horowitz, Savin, & Sefton, 1994; Rand & Nowak, 2013; Thaler, 1988).

In one adaptation of the UG, Ferguson and co-authors (2014) varied the time delay for decisions to accept or reject one-shot, anonymous offers and found a “fast to forgive, slow to retaliate” effect; that is, individuals cooperated more when little time was given to reflect on mildly unfair (uncertain) offers, but rejected more with greater time to think. Their results suggest that prosocial cooperation with anonymous strangers is intuitive (fast) and may be more advantageous during uncertainty. However, cooperation with anonymous strangers is arguably distinct from forgiving a transgressor with whom the relationship is valued or with whom future interactions are expected. In the present
work, an adaptation of the UG will be implemented with named and pictured individuals rather than anonymous one-shot trials to more closely approximate a social context for interpersonal transgression and forgiveness.

Another adaptation of the UG has been recently tied to HRV and spontaneous baroreflex sensitivity in the context of anger coping (Vögele, Sorg, Studtmann, & Weber, 2010). Adolescents played one trial of the UG as proposer and a second trial as responder against a computerized opponent. The second trial was designed to provoke anger with an extremely unfair offer ($1) and a statement designed to increase angry feelings (“I know you would have liked more, but that’s the way it goes. Take it or leave it!”; Vögele et al., 2010, p.466). Adolescents who used cognitive reappraisal during the period after provocation showed higher high frequency HRV and spontaneous baroreflex sensitivity compared to those using anger rumination.

Neuroimaging results appear to corroborate findings of higher vagal activation. In one study, participants played an adaptation of the UG followed by the DG in which four opponents made equal amounts of fair and unfair offers. Participants who forgave, operationalized as resisting retaliation in the DG, showed greater activity in the right dorsolateral prefrontal cortex, an area associated with inhibition of prepotent emotional responses, while those who retaliated unfair offers showed greater activity in reward regions such as the ventral striatum (Brüne, Juckel, & Enzi, 2013).

Overall, the evidence suggests that economic games such as the DG and UG may be adapted to examine forgiving or retributive behavior, and that such behaviors show neural and cardiac autonomic correlates that are concomitant with a model of
neurovisceral integration in the context of adaptive emotion regulation. Thus, in the present study it is expected that forgiving behavior, as operationalized using adaptations of the DG and UG, will be associated with higher HRV.

1.6 Current Definitions, Aims, and Hypotheses

In line with concepts outlined by Worthington & Scherer (2004) and Gross (1998), interpersonal forgiveness in the present work is assumed to involve regulatory processes with implications for stress reduction and somatic health. Affective, cognitive, and behavioral components over time are implicated in emotion regulation (Gross, 2002) as well as in forgiveness (Fincham, 2000). As McCullough et al. (2013) and others have posited (e.g., Fincham, 2000), forgiveness entails not merely reduced negative affect or desire for retaliation, but also an intentional adoption of positive or prosocial motivation, affect, cognition, or behavior.

The present study aims to examine forgiveness and its cardiovascular and psychosocial correlates from a framework of perseverative cognition—that is, forgiveness in comparison to offense-focused rumination. Most authors implement self-reported measures of state forgiveness, while experimental manipulation and observation of forgiving behavior is infrequent in the literature (e.g., van der Wal et al., 2014). A behavioral definition of forgiveness and live provocation confers the benefit of relative control over the offense experience. Lawler and colleagues (2005) have suggested that lack of consistent associations between state forgiveness and cardiovascular measures in a community sample may have reflected variability in respondents’ transgression imagery of more serious personal events. Manipulated imagery of a live provocation may also
bypass the limitation of using past recollection of a personal transgression (e.g., Larsen et al., 2012), which may have already been the subject of a forgiveness process that would introduce noise in the experiment.

As reviewed above, hostility and rumination are frequently found to correlate negatively with forgiveness (e.g., Berry et al., 2005). Psychosocial correlates of forgiving behavior are of interest in the current study, particularly those that have support in the literature: ruminative responses, hostility, depressive symptoms, trait forgiveness, and state forgiveness motivations. A secondary aim of this work is to explore individual differences in forgiving behavior. Sex differences in forgiveness and health have been noted in the literature. For example, Toussaint and colleagues (2008) report decreased prevalence of depression among women with higher levels of forgiveness, but not among men. In addition, forgiveness was associated with lower systolic blood pressure among women who imagined a transgression, but not among men (Lawler et al., 2003). In addition, forgiveness has been linked with executive control (e.g., Wilkowski et al., 2010), which may be indexed with HRV (Thayer et al., 2012). To date, individual differences in HRV have not been examined with respect to forgiving behavior. Sex differences and individual differences in HRV are of interest in the present study. In summary, major aims are as follows:

1) to test the effects of a provocation and manipulation of forgiveness in real time on forgiving behavior in economic games,

2) to examine differences between forgiveness and rumination on cardiovascular physiology, and
3) to explore individual differences and psychosocial correlates in forgiving behavior.

Given the above aims and reviewed evidence, the following hypotheses are adopted in the present work.

**Hypothesis 1:** There will be a main effect of condition on behavioral outcomes.

Participants who imagine forgiving will show more forgiving behavior after a live provocation compared to those who ruminate.

**Hypothesis 2:** There will be a main effect of condition on physiology. Participants who imagine forgiving will show better profiles for HRV and HR throughout the study, particular during and after imagery manipulation, compared to those who ruminate.

**Hypothesis 3:** There will be individual differences. It is expected that women will show more forgiving behavior and better cardiovascular profiles than men. Individuals with higher baseline HRV are also expected to show more forgiveness.

**Hypothesis 4:** There will be psychosocial correlates. Forgiving behavior is expected to correlate positively with measures of trait and state forgiveness, and negatively with measures of brooding rumination, depressive rumination and hostility.
Chapter 2: Methods

2.1 Sample

Data were collected from a convenience sample of 89 college student volunteers from the Research Experience Program participant pool of General Introductory Psychology. Participants were healthy young men and women (46% female) between the ages of 18 and 35 (age $M = 19.0$ years; $SD = 1.79$). The sample was predominantly Caucasian (72%), with 17% reporting Asian ethnicity, 5% African American, 2% Latino, and 4% multi-ethnic. The sample size was estimated to provide 90% power to detect an effect at an alpha level of 0.05. Power analyses were conducted using estimates from a similar effect of reappraisal versus UG-provoked anger on HRV in a published study \( (HF(n.u.) \eta^2_p = .12; \text{Vögele et al., 2010}) \). Power analyses were performed using G*Power3 software (Faul, Erdfelder, Lang, & Buchner, 2007).

2.2 Design

A mixed factorial pre-post design was employed. In testing Hypothesis 1, mood and behavioral variables were contrasted between imagery groups. For Hypothesis 2, physiological variables were tested using repeated measures ANOVAs with the between-subjects factor of imagery condition (Forgive, Ruminate) and within-subjects factor of task (DG1, Manipulation, DG2, Recovery). Change scores for cardiovascular activity were subtracted from baseline across all tasks. Individual differences in Hypothesis 3
were examined using similar analyses as Hypothesis 1 and 2, except with between-subjects factors of sex (male, female) and a median-split of baseline HRV (high, low).

See section 2.7 Statistical Analyses for a summary of specific quantitative approaches.

2.3 Experimental Tasks

Participants played adaptations of the Dictator Game (DG) and Ultimatum Game (UG). The DG and UG are described in greater detail in section 1.5 Economic Games. Briefly, these are two-player games in which participants offer to split a sum of money to another player (DG) or are the recipients of a split offer from another player (UG). In each case, the recipient may elect to accept or reject the offer. If offers are accepted, both parties receive the agreed share. If offers are rejected, neither player receives money.

Contrary to expectations of rational economic behavior, a robust experimental literature shows that respondents tend to make relatively fair offers (e.g., Forsythe, Horowitz, Savin, & Sefton, 1994).

Currently, the DG was presented pre- and post-manipulation (DG1 and DG2, respectively) and was used to operationalize forgiving behavior. In the DG1, four computerized opponents with equal gender representation were introduced with names and face images. Adaptations of the UG and DG in the literature often use a high number of opponents or offers to establish effects (e.g., Brüne et al., 2012). In the present work, however, the same four opponents with names and faces were used to more closely simulate real-life interpersonal transgressions as opposed to a one-shot interaction with an anonymous stranger. Participants were instructed to split a sum of $10 to each opponent in whole dollar amounts. Each opponent was presented for 8 seconds followed
by an 8-second time delay with instructions for participants to think about their offer. Relatively fair offers were defined as splits of $5:5, $4:6, or $3:7, with unfair offers defined as $2:8 and $1:9, as reported previously (Brüne et al., 2013). Participants were not made aware of the predefined fair/unfair amount; they were only given instructions adapted from Kahneman et al. (1986), in which they were asked to split a sum of money that their opponents may accept or reject, and rejected offers would result in zero monetary gain while money from accepted offers would be retained.

Unbeknownst to participants, the computerized opponent in the DG1 was pre-programmed to accept all offers regardless of fairness in order to acquire a baseline amount. Thus, participants received only acceptance feedback and did not experience initial rejection from their opponents to preserve the effect of provocation in the subsequent UG (explained below). The post-manipulation game (DG2) was identical to the DG1 except that the computer program now rejected unfair offers ($2 or less). Forgiveness is defined as fairer offers in the DG2 compared to DG1. “Fairer offers” is explicitly defined as a positive value for DG2 minus DG1 amount. Because forgiveness is conceptualized to involve prosocial motivation and goodwill towards a transgressor, a mere zero sum at study’s end may not reflect this concept. Retaliatory behavior is defined as more unfair offers: a zero or negative value for DG2 minus DG1.

Between pre- and post-DG, an adaptation of the Ultimatum Game (UG) was used to simulate a live transgression in which participants received offers from the same opponents, half of which were fair ($5:5, $4:6) and half unfair ($2:8, $1:9). The same opponents as the DG were presented each for 8 seconds. Similar to a prior study (Vögele
et al., 2010), the computerized opponents issued statements at the time of offer. Opponents making fair offers issued cooperative or neutral statements such as “Let’s keep it even,” while those making unfair offers issued provoking statements such as, “That’s life. Take it or leave it!” to enhance feelings of offense. The provocations were presented for 8 seconds. Fair and unfair opponents were equally represented by gender. Participants were instructed to accept or reject offers made to them, and a time delay of 10 seconds was implemented for participants to think about their decision. To preserve violation of reciprocity, participants who made initially unfair offers in DG1 ($2 or less; \( n = 1 \)) were excluded from analyses, as similarly reported by Vögele and colleagues (2010). While it was not made explicit to participants, monetary awards were hypothetical as part of the game and no money was in fact awarded.

The pre-post format using a DG, then provocation with UG, followed by a subsequent DG is novel and designed to maximize the effect of retributive behavior and enhance the operationalization of forgiving behavior. In a meta-analysis of over one hundred dictator game experiments, meta-regression showed that participants give less when the game is repeated, but give more when the recipient is perceived to deserve it (Engel, 2011). Thus, a repetition of the DG as well as ostensible lack of deservingness from unfair opponents suggests that participants would be expected to give less at post-trial. As such, giving more money in a second round of DG would not only overcome this expectation but also would be more closely in line with a definition of forgiveness—something proactively and unconditionally given even when an offender has “abandoned the right” to it (Enright, Gassin, & Wu, 1992).
2.4 Procedure

Following informed consent, all participants were instrumented individually for continuous electrocardiogram (EKG) monitoring and completed the following sequence of procedures during one hour (see Figure 1).

**Baseline.** Participants sat quietly in a well-lit room for five minutes in front of a blank television screen with no presentation of stimuli. Participants were instructed to relax and to refrain from using any electronic devices or reading material. The room was kept in constant temperature with dim lighting. Participants were recruited between the hours of 10:00 a.m. and 3:00 p.m. and instructed to refrain from caffeine or tobacco use for at least two hours prior to the study.

**Mood Check.** Participants rated their current experience of unhappiness, anger, and frustration on a 5-point Likert scale. Unhappiness was rated along a dimension with happiness (1 = “Very Happy,” 5 = “Very Unhappy”), anger along a dimension with pleasantness (1 = “Pleasant,” 5 = “Very Angry”), and frustration along a dimension with calm (1 = “Relaxed,” 5 = “Very Frustrated”), with higher scores indicative of greater negative affect.

**Dictator Game 1 (DG1).** Participants played a round of the Dictator Game (DG1) as shown in Figure 2 and described in 2.3 Experimental Tasks.

**Manipulation.** Three components are involved in the manipulation: a provocation, imagery induction, and imagery manipulation.

**Ultimatum Game (UG) Provocation:** Participants were provoked with unfair offers using a round of UG with their DG1 opponents, who issued
statements such as, “That’s life. Take it or leave it!” to enhance feelings of offense (see Figure 3).

**Imagery Induction:** Participants were instructed to sit quietly for three minutes and to think about their opponents with the following script:

*Please think about your opponents for the next few minutes. Focus on how much money the unfair opponents offered you compared to how much you offered them. Focus on what they said and how offended, hurt, angry, or annoyed this made you feel.*

**Imagery Manipulation:** Participants were randomized to either Forgive or Ruminate imagery conditions, in which they were presented with a script adapted from similar imagery instructions by Larsen and colleagues (2012). The scripts for each group were as follows:

**Forgive**

*Picture yourself letting go of any negative feelings your opponents may have caused. You may also imagine reconciling with your opponents, seeing the good in them, saying a helpful response to them, or anything that you think is important in forgiving.*

**Ruminate**

*Picture yourself feeling the negative feelings your opponents may have caused, such as annoyance, hurt, anger, or resentment. You may also think about their disregard for you, why their responses were so wrong or hurtful, or the ways you’d like to get revenge.*
**Mood Check.** Participants were asked to rate the same mood items as they had prior to DG1 (anger, frustration, and unhappiness). These items serve as a manipulation check. A similar manipulation check was implemented in a previous study using a UG provocation (Vögele et al., 2012).

**Dictator Game 2 (DG2).** Participants played a second round of Dictator Game (DG2) identical to DG1 with the exception that unfair offers made by participants were now rejected by the computer, as described above in 2.3 *Experimental Tasks.*

**Recovery.** Participants sat quietly for five minutes and were given no specific instructions on thought content.

2.5 **Instruments and Stimuli**

Facial stimuli from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998) were used for the four opponents in the UG and DG. Four neutral faces, two female and two male, were chosen at random. A fair and unfair offer was made by each face gender.

Psychosocial variables were examined using scores from the following questionnaires:

1) The *Ruminative Responses Scale* measures the extent to which individuals ruminate along three sub-dimensions: reflective rumination, brooding, and depressive rumination in 22-items (Nolen-Hoeksema, 1991).

2) The *Anderson State Hostility Scale* assesses current mood associated with hostility or aggravation using 35 items (Anderson, Deuser, & DeNeve, 1995).
Subscales include feeling unsociable, feeling mean, lacking positive feelings, and aggravation (Anderson & Carnagey, 2009).

3) The Transgression Narrative Test of Forgiveness (TNTF) is a 5-item scenario-based scale that assesses trait forgiveness (Berry et al., 2001).

4) The Transgression-Related Interpersonal Motivations Inventory – 18 (TRIM-18) is an 18-item scale that assesses a respondent’s current thoughts and feelings about a transgressor (McCullough et al., 1998). Sub-factors include revenge motivation, avoidance motivation, and benevolence motivation.

2.6 HRV data extraction

Participants were seated for a 5-minute baseline and instrumented with the standard three-electrode setup for continuous electrocardiogram (ECG) recording. The ECG signal was passed through a Mindware Technologies BioNex 8-slot mainframe with a sampling rate of 1000Hz (Mindware Technologies LTD). The ECG time series was analyzed and manually inspected offline for ectopic beats and other artifacts with Biolab HRV 2.51 software (Mindware Technologies LTD). Five segments of inter-beat intervals (baseline, tasks, and recovery) were analyzed per subject and successive inter-beat intervals per segment were written to a single text file and analyzed with Kubios version 2.0 software (Tarvainen & Niskanen, 2008). Spectral estimates of HRV were derived using autoregressive techniques. High frequency HRV (HF; 0.15-0.4Hz) is of particular interest in the present study as it is posited to reflect vagally mediated parasympathetic activity associated with healthy cardiovascular functioning (Thayer & Lane, 2007; Task Force, 1996). Low frequency HRV (LF; 0.04-0.15Hz) was also derived and reflects
vagally mediated and sympathetic activity. The time domain measure of the root mean square of successive differences (RMSSD) also approximates parasympathetic activity, correlates positively with HF HRV, and is of interest in the present study.

2.7 Statistical analyses

For the manipulation check, repeated measures ANOVAs were implemented with the between subjects factor of condition (Forgive, Ruminate) and within subjects factor of time (pre- and post-imagery) on participant mood ratings for unhappiness, anger, and frustration. In addition, Student t tests were used to compare mood ratings by condition during baseline (pre-) and post-imagery.

For behavioral outcomes, identical tests were implemented as above (repeated measures ANOVAs and Student t tests) with the same between and within factors delineated above, except with monetary values from the economic games as the dependent variable. To examine individual differences in behavioral outcomes for Hypothesis 3, the between subjects factors of gender (Male, Female) and the median-slit of HRV (high, low) were examined.

For physiological outcomes by condition, repeated measures ANOVAs were implemented using condition (Forgive, Ruminate) as the between-subjects factor and task as the within-subjects factor. Two sets of analyses were conducted for physiology: one repeated measures ANOVA using change scores from baseline and one without change scores for clarification. Thus, the within-subjects factor of task had four levels for analyses with change scores (DG1, Manipulation, DG2, Recovery), and five levels for the analyses without change scores (Baseline, DG1, Manipulation, DG2, Recovery).
Physiological changes by gender were also examined. Identical analyses were completed as those for physiological changes by condition above, except with the between-subjects factor of gender (Male, Female). Repeated measures ANOVAs were examined with and without change scores as above.

Finally, Pearson correlations were examined across psychosocial variables, forgiving behavioral outcomes, and physiological parameters. Gender was tested as a moderator of the relation between psychosocial variables and forgiveness behavior using the PROCESS macro (Hayes, 2013), and multivariate regression was implemented to test predictive relations among significant correlates. All analyses were conducted using SPSS (version 20).
Chapter 3: Results

3.1 Missing Data

Data from two individuals were excluded from HRV analyses due to electrode malfunction of electrocardiogram (EKG) recording. These data are treated as missing completely at random. To preserve violation of reciprocity inherent in the mood induction, one additional subject’s data was excluded from behavioral and physiological analyses due to making initially unfair offers (less than $2) in DG1. A total of 86 individuals were included for analyses involving physiological data, while 88 individuals were retained for analyses on behavioral and mood variables. Questionnaire data from one participant was missing due to software malfunction and is treated as missing completely at random. Data from 87 individuals were retained for correlational analyses on psychosocial variables.

3.2 Manipulation Check

Self reported mood supported the effect of imagery manipulation. Repeated measures ANOVAs were implemented to test the effects of time (within subject; pre- and post-imagery) and condition (between subject; Forgive, Ruminate) on ratings for unhappiness, anger, and frustration; in addition, Student t tests were implemented to compare condition at pre- and post-imagery. There was a main effect of time as the unhappiness ratings from pre- to post-imagery were significantly different ($F(1, 86) =$
53.2, \( p < .001, \eta^2_p = .38 \) as was the condition x unhappiness interaction (\( F(1, 86) = 29.6, \ p < .001, \eta^2_p = .26 \)). Similarly, a main effect of time was significant for anger (\( F(1, 86) = 48.1, \ p < .001, \eta^2_p = .36 \)) as was the condition x anger interaction (\( F(1, 86) = 27.0, \ p < .001, \eta^2_p = .24 \)). Third, frustration ratings at pre- and post-imagery were significantly different (\( F(1, 86) = 48.1, \ p < .001, \eta^2_p = .35 \)), as was the condition x frustration interaction (\( F(1, 86) = 17.18, \ p < .001, \eta^2_p = .17 \)). That is, at baseline, no significant differences were found between those in Forgive (\( n = 44 \)) and Ruminate (\( n = 44 \)) conditions for unhappiness (Forgive \( M = 2.30, SD = .70 \); Ruminate \( M = 2.30, SD = .67 \); \( t(86) = 0.0, \ p = 1.0; d = 0.0 \)), anger (Forgive \( M = 1.84, SD = .71 \); Ruminate \( M = 1.95, SD = .86 \); \( t(86) = -0.67, \ p = .50, d = -.14 \)), and frustration (Forgive \( M = 1.68, SD = .74 \); Ruminate \( M = 1.66, SD = .78 \); \( t(86) = .14, \ p = .89, d = .03 \)). However, following imagery manipulation, individuals instructed to ruminate on unfair offers reported significantly greater negative affect compared to those instructed to forgive. Self-reported unhappiness (Forgive \( M = 2.45, SD = .73 \); Ruminate \( M = 3.39, SD = .72 \); \( t(86) = 6.02, \ p < .001, d = 1.30 \)), anger (Forgive \( M = 2.02, SD = .93 \); Ruminate \( M = 3.23, SD = .89 \); \( t(86) = 6.23, \ p < .001, d = 1.33 \)), and frustration (Forgive \( M = 2.02, SD = 1.04 \); Ruminate \( M = 3.05, SD = 1.22 \); \( t(86) = 4.23, \ p < .001, d = .91 \)) were all rated more highly among those who ruminated. See Table 1 for a summary of pre- and post-imagery descriptive statistics.

3.3 Hypothesis One: Behavioral Outcomes

Prior to imagery randomization, the groups were not statistically different in their percentage of offers rejected during the UG provocation (Forgive \( % M = 55.7, SD = 17.7 \);
Ruminate % $M = 47.2, SD = 26.5; \chi^2(4, N = 88) = 9.22, p = .06). In line with expectations, a main effect of time was not significant ($F(1, 86) = .90, p = .34, \eta_p^2 = .01$), while a condition x time interaction emerged ($F(1, 86) = 8.68, p = .004, \eta_p^2 = .09$).

Specifically, individuals in Forgive ($M = $4.33, $SD = .98$) and Ruminate ($M = $4.42, $SD = 1.04$) groups did not differ in their initial offers ($DG1; t(86) = -.45, p = .65; d = -.09$). However, participants who imagined forgiving made more generous subsequent ($DG2$) offers ($M = $4.58, $SD = 0.99$) compared to those who ruminated on unfair opponents ($M = $3.93, $SD = .97; t(86) = 3.07, p = .003, d = .66$). In support of a behavioral definition of forgiveness, the mean offer difference ($DG2$ minus $DG1$) was positive and significantly greater in the Forgive group ($M = $0.25, $SD = 1.23$) than in the Ruminate group, who made more unfair offers ($M = -$0.48, $SD = 1.14; t(86) = 2.90, p = .005, d = .61$). See Figures 4 and 5 and Table 2 for a summary of behavioral outcomes.

### 3.4 Hypothesis Two: Physiological Outcomes

Baseline RMSSD, absolute HF power, and absolute LF power were not normally distributed and were transformed with natural log. Change scores for each index were derived by subtracting baseline from task values. Repeated measures ANOVAs were used to test the effects of task by condition. For each physiological index, two separate analyses were conducted: one with change scores with four task levels ($DG1$, Manipulation, $DG2$, Recovery), and one without change scores with five task levels (Baseline, $DG1$, Manipulation, $DG2$, Recovery) for clarification. Three planned contrasts between Forgive and Ruminate were conducted among the analyses with and without change scores (during imagery Manipulation, $DG2$, Recovery) for each physiological
index and were computed with one-tailed Student $t$ tests using the effect specific error terms as recommended by Vasey and Thayer (1987), and the following equation from Rosenthal and Rosnow (2008), where $\lambda_i$ represents the $i$th contrast weight.

$$t_{contrast} = \frac{\sum (M_i \lambda_i)}{\sqrt{MS_{error} \left( \sum \frac{\lambda_i^2}{n_i} \right)}}$$

Forgive and Ruminate groups did not show significantly different heart rate (HR) at baseline; however, individuals randomized to Forgive had significantly higher HF power compared to those assigned to Ruminate ($F(1,86) = 4.10$, $p = .05$, $\eta^2_p = .05$), and they also trended with higher RMSSD at baseline ($F(1,86) = 3.75$, $p = .06$, $\eta^2_p = .04$). Refer to Table 3 for a summary of baseline physiology by condition.

3.41 Heart Rate

A repeated measures ANOVA was implemented with within-subjects factor of task change scores from baseline (DG1, Manipulation, DG2, Recovery), and between-subjects factor of condition (Forgive, Ruminate). Violation of sphericity was significant using Mauchly’s test ($\chi^2(5) = 31.7, p < .001$). There was a main effect of task on HR (Greenhouse-Geisser $\varepsilon = .80; F(3, 252) = 4.34, p = .01, \eta^2_p = .05$) and a significant quadratic polynomial trend ($F(1, 84) = 8.16, p = .005, \eta^2_p = .09$). As shown in Figure 6, HR (bpm) increased from baseline to DG1 for both groups, decreased relatively during manipulation, increased relatively to DG2, and leveled during Recovery. Individuals who imagined forgiving showed less HR increase from baseline to Manipulation ($M = 0.05$, $SE = 0.42$) compared to those ruminating ($M = 1.19$, $SE = .42; t(84) = -1.94, p = .03$),
though this effect was not significant at DG2 ($t(84) = -.13, p = .45$) or Recovery ($t(84) = -.22, p = .41$). See Figure 6 for phasic HR changes from baseline.

For the repeated measures analysis of HR without change scores, violation of sphericity was significant ($\chi^2(9) = 46.8, p < .001$). A main effect of task was significant (Greenhouse-Geisser $\varepsilon = .79; F(4, 336) = 7.70, p < .001, \eta^2_p = .08$) as well as a cubic polynomial trend ($F(1, 84) = 11.86, p = .001, \eta^2_p = .12$). That is, HR increased from baseline to DG1, decreased during Manipulation, and steadily decreased thereafter. Individuals who imagined forgiving had lower HR compared to those who imagined ruminating, though the planned contrasts were not significant for any time point during Manipulation (Forgive: $M = 70.1, SE = 1.66$; Ruminate: $M = 73.4, SE = 1.66$; $t(84) = -1.37, p = .09$), DG2 (Forgive: $M = 71.2, SE = 1.68$; Ruminate: $M = 73.4, SE = 1.68$; $t(84) = -.92, p = .18$) or Recovery (Forgive: $M = 71.2, SE = 1.63$; Ruminate: $M = 73.5, SE = 1.63$; $t(84) = -.97, p = .17$). See Figure 7 for HR by condition across all tasks.

### 3.42 Heart Rate Variability

Time and frequency domain indices of HRV were also examined by condition. Repeated measures ANOVAs with the same within- and between-subjects factors as above were separately implemented to test effects of task and condition on natural log transformed RMSSD, absolute HF, and absolute LF. For each of these indices, analyses with and without change scores are described and depicted. Using change scores, Mauchly’s test of sphericity indicated that the assumption’s violation was not significant for RMSSD ($\chi^2(5) = 3.68, p = .60$). There was a main effect of task (Greenhouse-Geisser $\varepsilon = .97; F(3, 252) = 3.14, p = .04, \eta^2_p = .03$) and a significant cubic polynomial trend ($F(1,
Both groups showed decreased RMSSD from baseline to DG1, a relative increase at Manipulation, and a decrease at DG2 and Recovery (see Figure 8). Planned comparisons showed that although group differences were in the expected direction with higher HRV among those who forgave, these differences were not significant during Manipulation ($t(84) = .98, p = .16$), DG2 ($t(84) = 1.09, p = .14$), or Recovery ($t(84) = .68, p = .25$). See Figure 8 for a depiction of RMSSD changes from baseline.

For the analysis of RMSSD without change scores, violation of sphericity was significant ($\chi^2(9) = 53.7, p < .001$). A main effect of task emerged (Greenhouse-Geisser $\varepsilon = .71; \, F(4, 336) = 4.71, p = .004, \eta^2_p = .05$) and a significant quartic polynomial trend ($F(1, 84) = 8.30, p = .005, \eta^2_p = .09$). That is, RMSSD for individuals in both conditions decreased from baseline to DG1, increased during Manipulation, and again decreased steadily to Recovery. Planned contrasts were all significant and the Forgive group had higher RMSSD than the Ruminate group during Manipulation (Forgive: $M = 3.91, SE = .09$; Ruminate: $M = 3.62, SE = .09$; $t(84) = 2.42, p = .009$), DG2 (Forgive: $M = 3.87, SE = .08$; Ruminate: $M = 3.56, SE = .08$; $t(84) = 2.71, p = .004$), and Recovery (Forgive: $M = 3.87, SE = .08$; Ruminate: $M = 3.59, SE = .08$; $t(84) = 2.73, p = .004$). See Figure 9 for a display of RMSSD by condition across all tasks.

Violation of sphericity was significant for absolute HF power ($\chi^2(5) = 14.03, p = .015$) and a main effect of task was found (Greenhouse-Geisser $\varepsilon = .91; \, F(3, 252) = 2.77, p = .047, \eta^2_p = .03$) with a significant cubic polynomial trend ($F(1, 84) = 4.04, p = .048, \eta^2_p = .05$). Both groups showed a decrease in absolute HF power from baseline to DG1,
an increase to Manipulation, and relative decrease during DG2 and Recovery. These changes are displayed in Figure 10. Not unlike RMSSD, group differences are in expected directions such that HF power increased for the Forgive group during Manipulation and Recovery; however, the between-group contrasts were not significant at Manipulation ($t(84) = 1.21, p = .12$), DG2 ($t(84) = .09, p = .46$) or Recovery ($t(84) = .49, p = .31$).

For the analysis of absolute HF power without change scores, the test for violation of sphericity was significant ($\chi^2(9) = 42.5, p < .001$). There was a main effect of task (Greenhouse-Geisser $\epsilon = .80$; $F(4, 336) = 5.70, p = .001, \eta^2_p = .06$) and a significant quartic polynomial trend ($F(1, 84) = 5.66, p = .02, \eta^2_p = .06$). High frequency HRV decreased from baseline to DG1, increased during Manipulation, decreased again during DG2 and remained steady during Recovery. Planned contrasts showed that the Forgive group had significantly higher HF HRV compared to the Ruminate group at Manipulation (Forgive: $M = 6.93, SE = .18$; Ruminate: $M = 6.27, SE = .18$; $t(84) = 2.66, p = .005$), DG2 (Forgive: $M = 6.70, SE = .17$; Ruminate: $M = 6.20, SE = .17$; $t(84) = 2.08, p = .02$), and Recovery (Forgive: $M = 6.76, SE = .17$; Ruminate: $M = 6.20, SE = .18$; $t(84) = 2.39, p = .01$). Refer to Figure 11 for a display of absolute power by condition across all tasks.

Results for absolute LF power are depicted in Figure 9. Mauchly’s test of sphericity was significant ($\chi^2(5) = 12.22, p = .03$), and there was a main effect of task (Greenhouse-Geisser $\epsilon = .92$; $F(3, 352) = 15.15, p < .001, \eta^2_p = .15$) and a significant quadratic polynomial trend ($F(1, 84) = 24.73, p < .001, \eta^2_p = .23$). Both groups showed decreased LF HRV from baseline to DG2, an increase to Manipulation, and relative
decrease during DG2 and Recovery. Contrasts were not significant at any time point
(Manipulation: $t(84) = .92, p = .18$; DG2: $t(84) = .70, p = .24$; Recovery: $t(84) = .78, p = .22$). Refer to Figure 12 for a depiction of changes from baseline in LF power by group.

For the analysis of absolute LF without change scores, Mauchly’s test of
sphericity violation was significant ($\chi^2(9) = 50.8, p < .001$). A main effect of task was
observed (Greenhouse-Geisser $\varepsilon = .74$; $F(4, 336) = 10.33, p < .001, \eta^2_p = .11$) as well as a
significant quartic polynomial trend ($F(1, 84) = 29.3, p < .001, \eta^2_p = .26$). Low frequency
HRV for both groups decreased from baseline to DG1, increased during Manipulation,
decreased again during DG2, and steadily decreased during Recovery. The Forgive group
had significantly higher LF HRV compared to the Ruminate group at Manipulation
(Forgive: $M = 7.49, SE = .13$; Ruminate: $M = 7.13, SE = .13$; $t(84) = 2.08, p = .02$), DG2
(Forgive: $M = 7.27, SE = .14$; Ruminate: $M = 6.91, SE = .14$; $t(84) = 1.82, p = .04$), and
Recovery (Forgive: $M = 7.22, SE = .11$; Ruminate: $M = 6.87, SE = .11$; $t(84) = 2.26, p = .013$). Absolute LF power is displayed by condition across all tasks in Figure 13.

3.5 Hypothesis Three: Individual Differences

Individual differences by gender and by high and low HRV were tested on
behavioral outcomes using similar analyses (ANOVA and Student $t$ tests) as those for
Hypothesis One above. A median split of baseline RMSSD was used to define
individuals with high and low HRV. Prior to imagery, men ($n = 47$) and women ($n = 41$)
did not differ in their percentage of rejected offers during the UG (Men: $M = 53.7\%, SD$
$= 23.9$; Women: $M = 48.7\%, SD = 21.6$; $\chi^2(4, N = 88) = 2.79, p = .59$). Contrary to
expectations, individual differences did not emerge on any behavioral outcomes. That is,
there was no main effect of time \((F(1, 86) = 0.77, p = 0.39, \eta^2_p = 0.01)\) and the gender x time interaction was not significant \((F(1, 86) = 0.21, p = 0.65, \eta^2_p = 0.002)\). Specifically, women and men were not significantly different in forgiving behaviors defined by DG2 offer \((t(86) = 1.50, p = 0.14, d = 0.32)\) or by the mean offer difference (DG2 minus DG1; \(t(86) = 0.44, p = 0.67, d = 0.09)\). Similarly, no main effect of time \((F(1, 84) = 0.80, p = 0.38, \eta^2_p = 0.01)\) and no group x time interaction \((F(1, 84) = 0.07, p = 0.80, \eta^2_p = 0.001)\) emerged for individual differences in HRV. That is, individuals with high \((n = 44)\) and low HRV \((n = 42)\) were not different in forgiving behavior (DG2: \(t(84) = 0.15, p = 0.88, d = 0.03)\); DG2 minus DG1: \(t(84) = -2.21, p = 0.83, d = -0.05)\). See Table 4 for a descriptive summary of behavioral outcomes by gender and HRV.

Physiological changes by gender were tested using analyses similar to those of Hypothesis Two above. Namely, for each physiological index, two separate repeated measures ANOVA analyses were conducted: one with change scores with four task levels (DG1, Manipulation, DG2, Recovery), and one without change scores with five task levels (Baseline, DG1, Manipulation, DG2, Recovery). The between-subjects factor of gender (Men, Women) was tested for HR and log transformed HRV variables (RMSSD, absolute HF, and absolute LF power). Among analyses with change scores, planned contrasts were conducted at three time points similarly to those of Hypothesis 2 (Manipulation, DG2, Recovery).

For HR, Mauchly’s test for sphericity violation was significant \((\chi^2(5) = 31.37, p < 0.001)\), and there was a main effect of task (Greenhouse-Geisser \(\epsilon = 0.80; F(3, 252) = 4.45, p = 0.01, \eta^2_p = 0.05)\) and a significant quadratic polynomial trend \((F(1, 84) = 8.19, p = 0.005, \eta^2_p = 0.09)\).
Men and women showed increased HR from baseline to DG1, with subsequent decrease at Manipulation and relative and sustained increase at DG2 and Recovery (see Figure 14). There were no significant differences between men and women at Manipulation ($t(84) = -1.05, p = .15$), at DG2 ($t(84) = .33, p = .37$), or at Recovery ($t(84) = -.20, p = .42$).

For the analysis of HR by gender without change scores, a similar approach was used. Mauchly’s test of sphericity violation was significant ($\chi^2(9) = 45.4, p < .001$). A main effect of task was observed (Greenhouse-Geisser $\varepsilon = .80; F(4, 336) = 7.71, p < .001$, $\eta^2_p = .08$) as well as a significant quartic polynomial trend ($F(1, 84) = 10.15, p = .002, \eta^2_p = .11$). That is, men and women both showed increased HR from baseline to DG1, a decrease during Manipulation, and another increase to DG2 that remained steady during Recovery. Figure 15 depicts HR by gender across all tasks.

For RMSSD, violation of sphericity was not significant ($\chi^2(5) = 3.49, p = .62$). A main effect of task was found (Greenhouse-Geisser $\varepsilon = .97; F(3, 252) = 2.62, p = .05, \eta^2_p = .03$), with a significant cubic polynomial trend ($F(1, 84) = 4.49, p = .04, \eta^2_p = 0.05$). Men and women showed decreased RMSSD from baseline to DG1, with relative increase at Manipulation, and decrease at DG2 and Recovery (see Figure 11). Men and women did now significant differences at Manipulation ($t(84) = -1.17, p = .12$), DG2 ($t(84) = -0.45, p = .33$), or Recovery ($t(84) = -0.48, p = .32$). Refer to Figure 16 for a depiction of RMSSD changes from baseline by gender.

For the analysis of RMSSD without change scores, sphericity violation was significant ($\chi^2(9) = 54.6, p < .001$) with a significant main effect of task (Greenhouse-
Geisser ε = .71; $F(4, 336) = 4.67, p < .001, \eta^2_p = .05$ and a quartic polynomial trend ($F(1, 84) = 7.94, p = .006, \eta^2_p = .09$). Men and women had decreased RMSSD from baseline to DG1, an increase during Manipulation, subsequent decrease to DG2, and a steady increase to Recovery. RMSSD by gender across all tasks is depicted in Figure 17.

Results for absolute HF power by gender are depicted in Figure 18. Mauchly’s test of sphericity was significant ($\chi^2(5) = 15.41, p < .01$), and there was a significant main effect of task (Greenhouse-Geisser ε = .90; $F(3, 252) = 2.79, p = .05, \eta^2_p = .03$) and cubic polynomial trend ($F(1, 84) = 3.98, p = .05, \eta^2_p = .05$). Both groups showed a decrease in HF from baseline to DG1, an increase to Manipulation, a relative decrease to DG2, and leveling off at and Recovery. Men and women were not different at any time point (Manipulation: $t(84) = -0.35, p = .12$; DG2: $t(84) = -0.65, p = .46$; Recovery: $t(84) = 0.08, p = .31$).

For the analysis of absolute HF power without change scores by gender, the test for violation of sphericity was significant ($\chi^2(9) = 43.9, p < .001$). There was a main effect of task (Greenhouse-Geisser ε = .79; $F(4, 336) = 5.70, p = .001, \eta^2_p = .06$) and a significant quartic polynomial trend ($F(1, 84) = 5.42, p = .02, \eta^2_p = .06$). High frequency HRV decreased from baseline to DG1, increased during Manipulation, decreased again to DG2, and increased steadily to Recovery. Refer to Figure 19 for a display of absolute HF power by gender across all tasks.

For absolute LF power, Mauchly’s test for sphericity violation was significant ($\chi^2(5) = 11.96, p = .035$) and a significant main effect of task was found (Greenhouse-Geisser ε = 0.92); $F(3, 252) = 14.7, p < .001, \eta^2_p = 0.15$), with a quadratic polynomial
trend \((F(1,84) = 24.10, p < .001, \eta^2_p = 0.22)\). Men and women both showed decreased LF power from baseline to DG1, a relative increase to Manipulation, and sustained decrease at DG2 and Recovery. Men and women did not differ at any time point (Manipulation: \(t(84) = -1.05, p = .18\); DG2: \(t(84) = .33, p = .24\); Recovery: \(t(84) = -.20, p = .22\)). Refer to Figure 20 for a depiction of LF power changes from baseline by gender.

For the analysis of absolute LF power without change scores, Mauchly’s test for violation of sphericity was significant \((\chi^2(9) = 51.8, p < .001)\). There was a main effect of task (Greenhouse-Geisser \(\varepsilon = .73\); \(F(4, 336) = 9.92, p < .001, \eta^2_p = .11\) and a significant quartic polynomial trend \((F(1, 84) = 29.1, p < .001, \eta^2_p = .26)\). Low frequency HRV decreased from baseline to DG1, increased to Manipulation, decreased to DG2, and remained steadily decreased to Recovery. Refer to Figure 21 for a display of absolute LF power by gender across all tasks.

3.6 Hypothesis Four: Psychosocial Correlates

Correlational analyses were examined across forgiving behaviors (DG2 offer, DG2 minus DG1) and psychosocial variables (hostility, ruminative responses, and state and trait forgiveness). Forgiving behavior (DG2 minus DG1) was associated with state forgiveness; specifically, correlations were positive for the TRIM-18 benevolence motivation factor \((r(87) = 0.25, p = .02)\), and negative for avoidance motivation \((r(87) = -.28, p = .008)\) and revenge motivation \((r(87) = -.17, p = .11)\), though the latter was not significant. Correlations (DG2 minus DG1) trended in the negative direction with total hostility \((r(87) = -.20, p = .06)\), and with hostility subscales feeling mean \((r(87) = -.21, p = .06)\) and lacking positive feelings \((r(87) = -.20, p = .06)\). Forgiving behavior was also
associated with TNTF trait forgiveness, though this effect was marginally significant (DG2 offer: $r(87) = .20, p = .07$). Lastly, forgiving behavior was associated with reflective rumination (DG2 offer: $r(87) = .22, p = .04$), as well as depressive rumination (DG2 offer: $r(87) = .22, p = .04$; DG2 minus DG1: $r(87) = .22, p = .004$); no association was found with brooding rumination (DG2 offer: $r(87) = .07, p = .52$; DG2 minus DG1: $r(87) = .11, p = .31$). Correlations are summarized in Table 5.

Physiological variables were associated in expected directions with self-reported forgiveness, but not with forgiving behaviors during and following imagery. During manipulation, heart rate correlated positively with avoidance motivation ($r(86) = .23, p = .04$) and revenge motivation ($r(86) = .25, p = .02$), and negatively with benevolence motivation (Manipulation: $r(86) = -.19, p = .04$). These associations for HR were marginally significant at DG2 (benevolence: $r(86) = .20, p = .07$; avoidance: $r(86) = .20, p = .07$; revenge: $r(86) = .20, p = .06$). Associations between RMSSD and benevolence motivation were found at DG2 ($r(86) = .24, p = .03$), though this was marginally significant during manipulation ($r(86) = .19, p = .09$). After imagery (DG2), RMSSD was negatively associated with avoidance motivation ($r(86) = -.22, p = .05$) and revenge motivation ($r(86) = -.14, p = .19$), though the latter was not statistically significant.

Predictive relations among significant psychosocial correlates were explored using multiple linear regression analyses on forgiving behavior. Two separate analyses were implemented for the response variables DG2 offer and mean offer difference (DG2 minus DG1). Reflective rumination and depressive rumination were significantly correlated with DG2 offer, while depressive rumination, avoidance motivation, and
benevolence motivation were significantly correlated with the mean offer difference (see Table 5). Predictors for DG2 offer were thus reflective and depressive rumination, and predictors for the mean offer difference were depressive rumination, avoidance motivation, and benevolence motivation. Because depressive and reflective rumination were highly correlated in the present sample ($r(87) = .66, p = .01$), two separate univariate regressions were implemented for predicting DG2 offer to avoid multicollinearity. In addition, avoidance and benevolence motivation were also highly correlated ($r(87) = -.79, p = .01$), and were also entered separately to avoid multicollinearity. Thus, altogether four separate regression analyses were conducted: two univariate analyses predicting DG2 offer, and two multivariate analyses predicting the mean offer difference. For the multivariate analyses, all variables were entered in one step.

The DG2 offer was significantly predicted by reflective rumination ($B = .10; SE = .04; \text{standardized } \beta = .26; \text{Adjusted } R^2 = 0.06; p = .014$) and depressive rumination ($B = .04; SE = .02; \text{standardized } \beta = .22; \text{Adjusted } R^2 = .04; p = .04$). For the mean offer difference, benevolence motivation ($B = .06; SE = .03; \text{standardized } \beta = .25; p = .02$), avoidance motivation ($B = -.06; SE = .02; \text{standardized } \beta = -.28; p = .007$), and depressive rumination ($B = .05; SE = .02; \text{standardized } \beta = .22; p = .03$) were all significant predictors. A summary of statistics for regression analyses is presented in Table 6 and Table 7.

Gender differences in rumination have been demonstrated in the literature (e.g., Butler & Nolen-Hoeksema, 1994). Gender was formally tested as a moderator of the
relation between depressive rumination predicting behavioral forgiveness (DG2 offer) using the PROCESS macro (Hayes, 2013) on SPSS (version 20). The model was significant \(R^2 = .12, F(3, 84) = 3.66, p = .02\), while the effect of gender as a moderator was marginally significant \(\Delta R^2 = .04, F(1, 84) = 3.53, p = .06\). The conditional effect of depressive rumination on forgiving behavior was significant among men \(b = .07, 95\% CI = (.02, .13)\), but not among women \(b = .01, 95\% CI = (-.04, .06)\). Figure 22 depicts the conditional effect of gender for depressive rumination on DG2 offer.

Testing gender as above with reflective rumination predicting DG2 offer, the model was significant \(R^2 = .09, F(3, 84) = 2.86, p = .04\), though gender was not a significant moderator \(\Delta R^2 = 0.0, F(1, 84) = .41, p = .52\). The conditional effect of reflective rumination on forgiving behavior was significant among men \(b = .12, 95\% CI = (.01, .22)\) but not among women \(b = .07, 95\% CI = (-.04, .18)\).

Regression analyses were conducted using sex as a selection variable similar to the regression models above (that is, DG2 offer was regressed against depressive and reflective rumination, and the mean offer difference was regressed against depressive rumination, and benevolence and avoidance motivation). Depressive rumination was a significant predictor of DG2 offer among men \(n = 46; B = .07; SE = .02; \text{standardized } \beta = .43; p = .003\), but not among women \(n = 41; B = .008; SE = .03; \text{standardized } \beta = .05; p = .76\). Similarly, reflective rumination predicted DG2 offer among men \(n = 46; B = .12; SE = .05; \text{standardized } \beta = .34; p = .02\), but not among women \(n = 41; B = .07; SE = .06; \text{standardized } \beta = .18; p = .26\). This pattern of results was also found for depressive rumination predicting the mean offer difference among men \(n = 46; B = .10; SE = .03; \text{standardized } \beta = .22; p = .03\).
standardized $\beta = .46; p = .001$) but not among women ($n = 41; B = -.002; SE = .03$; standardized $\beta = -.01; p = .95$). Benevolence and avoidance motivation did not show these patterns by gender. Refer to Table 6 and Table 7 for a summary of regression statistics by gender.
Chapter 4: Discussion

4.1 Paradigm Implications

The study of forgiveness, its antecedents, correlates, and more recently, its physiological outcomes is gaining ground in psychology. Nevertheless, much of the extant research employs self-reported assessments that may be unduly influenced by social desirability, personal history, and memory biases. Aims of the present study were to test a novel paradigm of behavioral forgiveness using economic games, as well as to explore the psychological and cardiovascular concomitants as well as individual differences in such behavior. A unique design was implemented with provocation using an adaptation of the Ultimatum Game (UG), randomization to forgiving or ruminative imagery, and pre- and post-trials of the Dictator Game (DG1, DG2, respectively). As demonstrated by affective ratings, the provocation and imagery were successful in eliciting anger, frustration, and feelings of unhappiness. Broadly, these results support the use of economic games to induce negative affect and provide an ecologically valid alternative to passive picture or film viewing (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Christie & Friedman, 2004).

Importantly, participants who imagined forgiving unfair opponents subsequently showed more behavioral forgiveness, and conversely those who were instructed to ruminate showed more retaliatory behavior. The findings indicate that the present design and adaptation with four computerized opponents is sufficient to elicit target forgiveness.
or revenge behaviors. Similar adaptations of the UG implementing one (Voegele et al., 2010) to four opponents (Bruene et al., 2010) have shown comparable success in eliciting affective behavior. The feasibility of this paradigm supports the use of complementary self-report and behavioral modalities in forgiveness and, importantly, facilitates replication.

4.2 Physiological Implications

Group differences emerged in cardiovascular reactivity indexed with heart rate (HR). While everyone showed increased HR from baseline to the first DG, those who engaged in rumination showed stronger increases from baseline during imagery compared to those imagining forgiveness, whose HR returned to near baseline levels. These differences in reactivity corroborate one of the first psychophysiological studies of forgiveness in which participants who imagined hurtful or begrudging scenarios showed stronger increases in HR from baseline compared to those imagining forgiving scenarios (Witvliet et al., 2001). A handful of studies have replicated similar effects of forgiving over ruminative processes with heart rate (Witvliet, DeYoung, Hofelich, & DeYoung, 2011; Witvliet, Knoll, Hinman, & DeYoung, 2010) and blood pressure (Larsen et al., 2012; Lawler et al., 2003).

In the present study, HR differences were not sustained during recovery. It is possible that forgiving imagery may not necessarily proffer cardioprotective benefits in the moments after provocation. However, this conclusion is less attractive as it runs contrary to the evidence from several studies showing prolonged benefits of forgiving during post-imagery or post-task recovery (Larsen et al., 2012; Whited, Wheat, & Larkin,
Alternatively, the lack of effect on HR recovery may suggest that the lab-induced provocation was insufficient to sustain arousal in the longer term. Affective ratings were collected at baseline and immediately following imagery, but not during recovery. Replication is encouraged with additional ratings to determine if negative affect is sustained throughout the study paradigm.

The study of forgiveness in relation to heart rate variability (HRV) is scant in the literature. Reappraisal strategies leading to forgiveness have been shown to attenuate decreases in HRV from baseline compared to rumination about hurtful offenses (Witvliet, Knoll, et al., 2010; Witvliet, DeYoung, et al., 2011). In the present study, although the results did not reach statistical significance, those who forgave showed changes from baseline in expected directions compared to those who ruminated: that is, the Forgive group showed attenuated decreases from baseline and higher HRV during imagery, while making subsequent dictator game offers (DG2), and during recovery for both time and frequency domain indices. This pattern of responding is in line with the model of neurovisceral integration outlined by Thayer and colleagues (Thayer & Lane, 2009; Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012) and described in 1.3 Theoretical Underpinnings. Specifically, HRV is a marker of flexible, dynamic autonomic responding, it is associated structurally with a reciprocal inhibitory cortico-subcortical neural network, and it corresponds with context-appropriate and successful regulation of emotions (Thayer et al., 2012). For example, at the state or phasic level, HRV has been shown to increase during reappraisal as well as suppression of emotion among women who conversed about an upsetting film (Butler, Wilhelm, & Gross, 2006). The current
results among those who engaged in forgiving trend in support of this evidence. Moreover, the results bear implications for the conceptualization of forgiveness, particularly at the moment of behavioral instantiation. That is, it may be consonant with successful emotion regulation and attendant cortical control and vagal innervation of the heart. Overall, forgiving imagery and behavior appear to proffer cardioprotective benefits via attenuated heart rate reactivity. Though outcomes in HRV were in the expected direction, the estimates of effect size were relatively small and larger sample sizes may be more fruitful for replication and other future investigations of forgiveness and HRV.

4.3 Individual Differences

At the trait level of analysis, individual differences in HRV have been examined frequently in the literature and, in line with the model of neurovisceral integration (Thayer et al., 2012), are associated with differences in affective and cognitive regulation (Ruiz-Padial, Sollers, Vila, & Thayer, 2003; Thayer & Brosschot, 2005), neural integrity (Thayer et al., 2012), and cardiovascular health (Thayer & Lane, 2007). In contrast, individuals with high and low HRV in the present sample did not differ in their forgiving behaviors, and HRV was correlated with self-reported but not behavioral forgiveness. While this result may seem to counter the assumptions of the model, it is important to consider its emphasis on context-dependent, adaptive, and goal-directed responding. Namely, the context of relationships and offense severity were likely not captured in lab-induced provocations by digital opponents. For example, relationship closeness (Karremans & Aarts, 2007) and interpersonal commitment (Karremans, van Lange, Ouwerkerk, & Kluwer, 2003) have been shown to influence forgiveness. Additionally,
Van der Wal and co-authors (2014) have found that executive control is associated with self-reported and behavioral forgiveness, but only in relationships that are highly valued. The authors affirm that executive control facilitates inhibition of negative emotional and retaliatory responses, and is recruited only if individuals value their relationships with the offender (Van der Wal et al., 2014). In addition, Pronk and colleagues (2010) found correlational and predictive links between executive control and forgiveness, and these were moderated by offense severity. Greater executive control is required for severe offenses in order to inhibit increased ruminative thoughts, while mild offenses are less likely to recruit such control in the process of forgiving (Pronk et al., 2010). Offense severity and relationship-specific variables were not varied in the present study; individuals likely had low perceived relationship value to computerized opponents, whose offenses may have been relatively mild. Altogether, the evidence suggests that in the absence of the context of relationships and offense severity, it may be less adaptive to recruit executive functions in the interests of forgiving, and this is consistent with theoretical assumptions and the lack of results for HRV at the trait level. Future directions include directly testing such relationship-specific and offense variables in the link between behavioral forgiveness and HRV, as well as implementing direct measures that test executive functioning.

Individual differences by gender were also not significant in the present sample. Men and women showed similar levels of forgiving behavior and physiological changes. In contrast, meta-analytic and epidemiological evidence suggests that women report higher levels of forgiveness compared to men (Miller, Worthington, & McDaniel, 2008;
Forgiveness is predominantly assessed through self-reported questionnaires or surveys in the literature (Miller et al., 2008), and behavioral observations are rarely implemented (e.g., Van der Wal et al., 2014). It is possible that the discrepancy between the current results and prior research arises from differences between self-reported and behavioral evidence. Perhaps due to social desirability or socialized interdependent self-construals (Toussaint et al., 2008), women may be more likely to report forgiveness while demonstrating similar forgiving behaviors compared to men.

4.4 Psychosocial Correlates

Forgiving behaviors were negatively associated with hostility, revenge motivation, and avoidance motivation, and positively associated with trait forgiveness and benevolence motivation. This finding is unsurprising and dovetails with the extant literature on the correlates of self-reported trait and state forgiveness (Berry, Worthington, O’Connor, Parrott, & Wade, 2005; Lawler et al., 2003; Silton, Flannelly, & Lutjen, 2013). In addition, the state motivation to avoid transgressors as well as that of benevolence toward transgressors significantly predicted forgiving behaviors in the present study.

Contrary to expectations, behavioral forgiveness was positively correlated with both reflective and depressive rumination. State and trait forgiveness, however, is negatively associated with rumination in much of the literature, as reported in one meta-analysis across 11 studies (Riek & Mania, 2012). Rumination in response styles theory is conceptualized as self-reflective, perseverative thinking about one’s distressing
symptoms and feelings (Nolen-Hoeksema, 1991). The construct is not homogenous and subtypes have been found that are hypothesized to vary in their adaptive qualities (Trapnell & Campbell, 1999; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Reflective or pondering rumination, for example, has been characterized as a purposeful self-reflection to engage in cognitive problem solving and has been linked with less depression over time (Treynor et al., 2003). That reflective rumination is associated with forgiving behavior is thus less surprising and suggests it may have a more adaptive function.

On the other hand, depressive rumination has been linked with poorer problem solving, stronger negativity biases, inability to inhibit negative information, and the onset of depression (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Moreover, rumination has been found to mediate gender differences in depression (Butler & Nolen-Hoeksema, 1994; Nolen-Hoeksema, Larson, & Grayson, 1999). Specifically, women have been shown to ruminate more compared to men (Butler & Hoeksema, 1994), and rumination among women has been linked to reduced HRV (Woody, Burkhouse, Birk, & Gibb, 2015). Given these associations, exploratory predictive models of forgiving behavior were tested in the entire present sample, as well as separately by gender. Gender was tested as a moderator for depressive rumination on forgiving behavior and was trending towards significance. Contrary to the expectation that women might show a stronger effect of depressive rumination, the effect of depressive rumination on forgiving was significant among men only, and the effect sizes nearly doubled among men compared to the full sample, while they were diminished or nearly nonexistent among women. That is,
depressive rumination was a predictor of forgiving behavior, and this effect was found among men only.

Beyond facile methodological characteristics, disposition and style of emotion regulation may account for this unexpected finding. For example, trait vengefulness and rumination are positively correlated in the forgiveness literature (McCullough, Bellah, Kilpatrick, & Johnson, 2001). In a meta-analysis of gender differences in forgiveness, vengeance was the only significant moderator (Miller, Worthington, & McDaniel, 2008), and men have been found to score higher in vengeance than women (Brown, 2003, 2004). It is possible that the men in this sample had higher trait vengefulness, though this trait was not assessed as it was beyond the scope of the present study. Future research may profit from the exploration of vengeance, especially in the context of gender differences in forgiveness.

In addition, research has shown positive correlations between rumination and suppression of emotion (Wenzlaff & Luxton, 2003). Along Gross’s (1998, 2002) process model of emotion regulation, both reappraisal and suppression strategies are associated with higher HRV (Butler, Wilhelm, & Gross, 2006; Witvliet et al., 2011) and reduced HR reactivity (Witvliet, Hofelich Mohr, Hinman, & Knoll, 2015). Because no gender differences emerged in physiological responses or forgiving behavior, it is possible that the results reflect different strategies implemented in the instantiation of forgiveness between men and women. For example, emotional suppression may underlie the link between forgiveness and rumination among men but not women. Toussaint and colleagues (2008) found that forgiving others reduced the odds of a major depressive
episode in women, but not among men; it is possible that this may be partly explained by
gender differences in the specific regulatory processes typically adopted when forgiving
others. The present study is the first to highlight gender differences in depressive
rumination predicting forgiving behavior. These relations otherwise lack an empirical
basis for explanation and present an area for further research.

4.5 Clinical Implications

A number of implications can be drawn from the current findings. With respect to
methodology, the implementation of a measure of behavioral forgiveness is feasible,
cost-effective, and encourages replication in varied populations. Interventions may
benefit from the use of multiple measurement modalities as a complement to self-report
assessments, particularly when considering discrepancies between reported versus actual
behavior. With respect to physiological health, the results affirm that forgiving offers
cardioprotective benefits through mechanisms of attenuated cardiovascular reactivity and
enhanced parasympathetic activity. This is especially relevant in the context of comorbid
disorders and diseases, for example in populations with comorbid heart disease and
depression where forgiveness interventions to improve depressive symptoms may confer
attendant cardiovascular benefits. With respect to psychological health, the current
findings dovetail with emotion regulation strategies (e.g., Butler et al., 2006; Witvliet et
al., 2010). It is possible that forgiving may recruit executive control in the inhibition of
negative affect and retaliatory behavior and in the facilitation of positive affect. To this
extent, incorporating forgiveness practices may be fruitful among both clinical and
subclinical populations, as individuals grapple with interpersonal conflicts and the
emotions that arise from transgressions ranging from the quotidian, as in forgetting to unload the dishwasher, to the traumatic, as in coping with the murder of a loved one. Moreover, Gross (2002) has noted that emotion regulation is not inherently good or bad; instead, its adaptive quality is context dependent. Similarly, forgiveness per se may not be adaptive if the costly recruitment of executive resources does not occur within a context of personally meaningful relationships or transgressions. From a clinical standpoint, this highlights the importance of identifying the context in which forgiveness occurs, as it may or may not be fruitful in addressing interpersonal problems. Finally, results with respect to gender differences in the predictors of forgiveness suggest that men and women may recruit distinct cognitive processes when forgiving others. This intriguing finding is in need of replication and exposes a new area of forgiveness research. Furthermore, it encourages attention to gender differences in the study of forgiveness and in its clinical application.

4.6 Strengths, Limitations, and Future Directions

Notable strengths of the study include a novel behavioral definition of forgiveness that corresponds with self-reported measures. Experimental rigor and feasibility of the paradigm importantly encourage replication and cost-effective implementation in intervention research. A few limitations of the study warrant mentioning. Namely, the strength of experimental rigor also presents a limited ability to reproduce the context of personally meaningful relationships and transgressions inherent in many forgiving processes. Future directions include varying relationship- and offense-specific factors using more personally relevant stimuli, for instance by allowing participants to enter the
names of a personal transgressor as opposed to digital, unfamiliar opponents. Moreover, while the patterns in HRV changes suggest that forgiveness may recruit executive control, executive functions were not formally assessed in the present study. An examination of these relationships with inhibition, task switching, or updating tasks is encouraged and will add to the body of literature implicating forgiveness and executive control. In addition, a control imagery condition was not used wherein participants might imagine a neutral or pleasant scenario unrelated to forgiveness. The lack of a control condition imposes limitations on interpretations of forgiveness and its construct validity. For instance, individuals making more generous offers may be doing so as a result of the general positive valence of forgiveness imagery as opposed to specific facets of forgiveness itself; alternatively, the negative effects of rumination may be driving the observed differences. Fincham (2000) briefly discussed a similar limitation and noted that forgiveness behavior does not have a unique topography. That is, the negative dimensions of forgiveness, such as revenge behaviors, may be more easy to identify than the positive dimensions. He notes, “It is the respectful, interpersonal behavior expected in everyday life that, in the context of injury, assumes the mantle of forgiveness” (Fincham, 2000, p.9). Finally, the instantiation of forgiveness was cross-sectional in the present study. In practice, however, environmental cues such as places and objects related to transgressions may revive hurtful memories and emotions that return the victim to an unforgiving state. A longitudinal exploration of forgiveness is encouraged in future research, whereby the effects of forgiving repeatedly over time may be more closely examined.
4.7 Conclusion

A behavioral operationalization of forgiveness was tested using computerized adaptations of the Ultimatum Game and Dictator Game in a novel pre-post design. The paradigm elicited successful target forgiving behaviors and corresponded with affective and physiological changes in expected directions. That is, individuals who imagined forgiving unfair opponents made more generous return offers, showed reduced heart rate reactivity and higher heart rate variability, and reported less negative emotion compared to those who ruminated. Behavioral forgiving was also related negatively with avoidance motivation and positively with benevolence motivation. Surprisingly, depressive and reflective rumination predicted forgiving behaviors, and when examined separately by gender, these links were pronounced among men and virtually nonexistent among women. The results suggest that forgiveness proffers cardiovascular and psychological benefits, and may involve distinct cognitive processes between men and women. Future research and interventions might benefit from a cost-effective, complementary behavioral measure, while attention to gender differences in the process of forgiving is encouraged.
References


the literature (pp.159-183). Washington, DC: American Psychological Association.


Appendix A: Tables and Figures

Table 1. Manipulation check: pre- and post-imagery mood ratings (M (SD))

<table>
<thead>
<tr>
<th></th>
<th>Forgive (n = 44)</th>
<th>Ruminate (n = 44)</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Unhappiness</td>
<td>2.30 (.70)</td>
<td>2.30 (0.67)</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Anger</td>
<td>1.84 (0.71)</td>
<td>1.95 (0.86)</td>
<td>-0.67</td>
<td>0.50</td>
<td>-0.14</td>
</tr>
<tr>
<td>Frustration</td>
<td>1.68 (0.74)</td>
<td>1.66 (0.78)</td>
<td>0.14</td>
<td>0.89</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Post-Imagery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unhappiness</td>
<td>2.45 (0.73)</td>
<td>3.89 (0.72)</td>
<td>6.02</td>
<td>&lt;0.001</td>
<td>1.30</td>
</tr>
<tr>
<td>Anger</td>
<td>2.02 (0.93)</td>
<td>3.23 (0.89)</td>
<td>6.23</td>
<td>&lt;0.001</td>
<td>1.33</td>
</tr>
<tr>
<td>Frustration</td>
<td>2.02 (1.04)</td>
<td>3.05 (1.22)</td>
<td>4.23</td>
<td>&lt;0.001</td>
<td>0.91</td>
</tr>
</tbody>
</table>

*Note: Higher scores indicate greater negative mood on a 5-point Likert scale.*
Table 2. Behavioral outcomes by condition (M (SD))

<table>
<thead>
<tr>
<th></th>
<th>Forgive (n = 44)</th>
<th>Ruminante (n = 44)</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1 Offer ($)</td>
<td>4.33 (0.98)</td>
<td>4.42 (1.04)</td>
<td>-0.45</td>
<td>0.65</td>
<td>-0.09</td>
</tr>
<tr>
<td>DG2 Offer ($)</td>
<td>4.58 (0.99)</td>
<td>3.94 (0.97)</td>
<td>3.07</td>
<td>0.003</td>
<td>0.66</td>
</tr>
<tr>
<td>Offer Difference ($)</td>
<td>0.25 (1.23)</td>
<td>-0.48 (1.14)</td>
<td>2.90</td>
<td>0.005</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Note: UG = Ultimatum Game; DG1 = Dictator Game 1 (pre); DG2 = Dictator Game 2 (post).
Table 3. Baseline cardiovascular activity by condition and gender (M (SD))

<table>
<thead>
<tr>
<th></th>
<th>Forgive</th>
<th>Ruminate</th>
<th>F</th>
<th>p</th>
<th>(\eta^2_p)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>43 (n = 19 female)</td>
<td>43 (n = 21 female)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HR (bpm)</strong></td>
<td>70.1 (12.4)</td>
<td>72.2 (10.4)</td>
<td>0.47</td>
<td>0.50</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>ln RMSSD</strong></td>
<td>3.92 (0.48)</td>
<td>3.68 (0.66)</td>
<td>3.75</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>ln Absolute HF</strong></td>
<td>6.96 (0.90)</td>
<td>6.47 (1.34)</td>
<td>4.10</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>ln Absolute LF</strong></td>
<td>7.35 (0.70)</td>
<td>7.14 (1.15)</td>
<td>0.97</td>
<td>0.33</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Women</th>
<th>Men</th>
<th></th>
<th>Gender</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>40 (n = 19 Forgive)</td>
<td>46 (n = 24 Forgive)</td>
<td></td>
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</tr>
<tr>
<td><strong>HR (bpm)</strong></td>
<td>73.9 (10.3)</td>
<td>68.7 (12.0)</td>
<td>4.51</td>
<td>0.04</td>
<td>0.05</td>
<td></td>
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</tr>
<tr>
<td><strong>ln RMSSD</strong></td>
<td>3.85 (0.09)</td>
<td>3.76 (0.09)</td>
<td>0.46</td>
<td>0.50</td>
<td>0.006</td>
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</tr>
<tr>
<td><strong>ln Absolute HF</strong></td>
<td>6.88 (0.18)</td>
<td>6.57 (0.17)</td>
<td>1.51</td>
<td>0.22</td>
<td>0.02</td>
<td></td>
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</tr>
<tr>
<td><strong>ln Absolute LF</strong></td>
<td>7.10 (0.15)</td>
<td>7.37 (0.14)</td>
<td>1.74</td>
<td>0.19</td>
<td>0.02</td>
<td></td>
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</tr>
</tbody>
</table>

**Condition x Gender**

|       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|
| **HR (bpm)** |       |       |       |       |       |       |       |
| **ln RMSSD**  |       |       |       |       |       |       |       |
| **ln Absolute HF** |       |       |       |       |       |       |       |
| **ln Absolute LF** |       |       |       |       |       |       |       |

**Note:** Men and women showed significantly different heart rate at baseline, while Forgive and Ruminate groups showed marginally significant RMSSD and HF power. Log transformed HRV variables are reported. **HR** = heart rate; **RMSSD** = root mean square of successive RR differences; **HF** = high frequency power heart rate variability; **LF** = low frequency power heart rate variability.
Table 4. Behavioral Outcomes by gender and HRV (M (SD))

<table>
<thead>
<tr>
<th>n</th>
<th>Women</th>
<th>Men</th>
<th>t</th>
<th>p</th>
<th>Low HRV</th>
<th>High HRV</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 (19 high HRV)</td>
<td>46 (25 high HRV)</td>
<td></td>
<td></td>
<td>42 (21 female)</td>
<td>44 (19 female)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DG1 Offer ($)</td>
<td>4.49 (1.01)</td>
<td>4.28 (0.99)</td>
<td>0.96</td>
<td>0.34</td>
<td>54.7 (24.5)</td>
<td>55.0 (22.0)</td>
<td>0.48</td>
<td>0.64</td>
</tr>
<tr>
<td>DG2 Offer ($)</td>
<td>4.43 (1.08)</td>
<td>4.10 (0.96)</td>
<td>1.50</td>
<td>0.13</td>
<td>3.98 (0.91)</td>
<td>4.21 (1.02)</td>
<td>0.16</td>
<td>0.88</td>
</tr>
<tr>
<td>Offer Difference ($)</td>
<td>-0.05 (1.25)</td>
<td>-0.17 (1.23)</td>
<td>0.43</td>
<td>0.67</td>
<td>-0.18 (1.23)</td>
<td>-0.15 (1.29)</td>
<td>-0.21</td>
<td>0.83</td>
</tr>
</tbody>
</table>

*Note: No individual differences were found by gender or baseline HRV in forgiving behavior, characterized by the DG2 offer and mean offer difference*
Table 5. Bivariate correlations among psychosocial variables and forgiving behaviors (n = 87)

<table>
<thead>
<tr>
<th></th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
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<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
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</thead>
<tbody>
<tr>
<td>DG2 Offer</td>
<td></td>
<td></td>
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<tr>
<td>Mean Offer Difference</td>
<td>.61†</td>
<td></td>
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<td></td>
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<tr>
<td>Hostility – mean</td>
<td>-.16</td>
<td>-.21</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hostility – lack positive</td>
<td>-.08</td>
<td>-.20</td>
<td>.52†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hostility – Total</td>
<td>-.11</td>
<td>-.20</td>
<td>.93†</td>
<td>.74†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressive Rumination</td>
<td>.22*</td>
<td>.22*</td>
<td>.28†</td>
<td>.23*</td>
<td>.37†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflective Rumination</td>
<td>.26*</td>
<td>.20</td>
<td>.02</td>
<td>-.03</td>
<td>.09</td>
<td>.66†</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Brooding Rumination</td>
<td>.07</td>
<td>.11</td>
<td>.24*</td>
<td>.16</td>
<td>.29†</td>
<td>.77†</td>
<td>.57†</td>
<td></td>
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</tr>
<tr>
<td>Trait Forgiveness</td>
<td>.20</td>
<td>.01</td>
<td>-.35†</td>
<td>-.46†</td>
<td>-.43†</td>
<td>-.28†</td>
<td>-.005</td>
<td>-.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIM Avoidance</td>
<td>-.15</td>
<td>-.28†</td>
<td>.27*</td>
<td>.34†</td>
<td>.34†</td>
<td>-.003</td>
<td>-.20</td>
<td>-.03</td>
<td>-.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIM Revenge</td>
<td>-.18</td>
<td>-.17</td>
<td>.34†</td>
<td>.39†</td>
<td>.39†</td>
<td>.10</td>
<td>-.03</td>
<td>.09</td>
<td>-.31†</td>
<td>.54†</td>
<td></td>
</tr>
<tr>
<td>TRIM Benevolence</td>
<td>.19</td>
<td>.25*</td>
<td>-.26†</td>
<td>-.42†</td>
<td>-.35†</td>
<td>-.03</td>
<td>.21*</td>
<td>.002</td>
<td>.30†</td>
<td>-.79†</td>
<td>-.58†</td>
</tr>
</tbody>
</table>

*p < 0.05; † p < .01
Table 6. Linear regression of psychosocial correlates on the DG2 offer

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>95% CI</th>
<th>β</th>
<th>Adjusted $R^2$</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(n = 87)</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflective rumination</td>
<td>0.10</td>
<td>0.04</td>
<td>(0.02, 0.17)</td>
<td>0.26</td>
<td>0.06</td>
<td>6.33</td>
<td>0.01</td>
</tr>
<tr>
<td>Depressive rumination</td>
<td>0.04</td>
<td>0.02</td>
<td>(0.002, 0.07)</td>
<td>0.22</td>
<td>0.04</td>
<td>4.36</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Men only (n = 46)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reflective rumination</td>
<td>0.12</td>
<td>0.05</td>
<td>(0.02, 0.21)</td>
<td>0.34</td>
<td>0.10</td>
<td>5.74</td>
<td>0.02</td>
</tr>
<tr>
<td>Depressive rumination</td>
<td>0.07</td>
<td>0.02</td>
<td>(0.03, 0.12)</td>
<td>0.43</td>
<td>0.16</td>
<td>9.86</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Women only (n = 41)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflective rumination</td>
<td>0.07</td>
<td>0.06</td>
<td>(-0.05, 0.18)</td>
<td>0.18</td>
<td>0.007</td>
<td>1.28</td>
<td>0.26</td>
</tr>
<tr>
<td>Depressive rumination</td>
<td>0.008</td>
<td>0.03</td>
<td>(-0.05, 0.06)</td>
<td>0.05</td>
<td>-0.02</td>
<td>0.09</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*Note: Reflective and depressive rumination (entered in separate univariate analyses) were significant predictors of forgiving behavior, and these effects were stronger among men and not significant among women.*
<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>95% CI</th>
<th>β</th>
<th>Partial r</th>
<th>Adjusted R^2</th>
<th>F</th>
<th>Model p</th>
</tr>
</thead>
<tbody>
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<td>(n = 87)</td>
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<tr>
<td>Depressive rumination</td>
<td>0.05</td>
<td>0.02</td>
<td>(0.004, 0.09)</td>
<td>0.22</td>
<td>0.23</td>
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<tr>
<td>Avoidance motivation</td>
<td>-0.06</td>
<td>0.02</td>
<td>(-0.02, -0.28)</td>
<td>-0.28</td>
<td>-0.29</td>
<td>0.11</td>
<td>6.16</td>
<td>0.003</td>
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<tr>
<td>Depressive rumination</td>
<td>0.05</td>
<td>0.02</td>
<td>(0.005, 0.09)</td>
<td>0.23</td>
<td>0.24</td>
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<tr>
<td>Benevolence motivation</td>
<td>0.06</td>
<td>0.03</td>
<td>(0.01, 0.12)</td>
<td>0.25</td>
<td>0.26</td>
<td>0.09</td>
<td>7.36</td>
<td>0.007</td>
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<tr>
<td>Men only (n = 46)</td>
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<tr>
<td>Depressive rumination</td>
<td>0.10</td>
<td>0.03</td>
<td>(0.04, 0.16)</td>
<td>0.46</td>
<td>0.47</td>
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<tr>
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<td>0.03</td>
<td>(-0.12, 0.003)</td>
<td>-0.25</td>
<td>-0.28</td>
<td>0.24</td>
<td>9.46</td>
<td>0.001</td>
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<tr>
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<td>0.03</td>
<td>(0.04, 0.15)</td>
<td>0.44</td>
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<tr>
<td>Benevolence motivation</td>
<td>0.04</td>
<td>0.04</td>
<td>(-0.04, 0.12)</td>
<td>0.14</td>
<td>0.16</td>
<td>0.20</td>
<td>6.60</td>
<td>0.003</td>
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Table 7. Linear regression of psychosocial correlates on the mean offer difference
Table 7 Continued.

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<td></td>
<td>B</td>
<td>SE B</td>
<td>95% CI</td>
<td>β</td>
<td>Partial r</td>
<td>Adjusted R²</td>
<td>F</td>
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<tr>
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<td>0.03</td>
<td>(-0.06, 0.06)</td>
<td>-0.01</td>
<td>-0.01</td>
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<tr>
<td>Avoidance motivation</td>
<td>-0.06</td>
<td>0.03</td>
<td>(-0.13, 0.001)</td>
<td>-0.31</td>
<td>-0.31</td>
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<td>1.97</td>
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<td>(-0.06, 0.07)</td>
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<tr>
<td>Benevolence motivation</td>
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<td>0.04</td>
<td>(-0.01, 0.14)</td>
<td>0.27</td>
<td>0.27</td>
<td>0.02</td>
<td>1.45</td>
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</table>
Figure 1. Experimental paradigm
Meet opponent Aaron

Think for a moment how much you wish to keep and how much you think Aaron should have

Please select how much you think Aaron should have

You chose the following:

Figure 2. Dictator Game task
Aaron has chosen the following:

You keep: $1
Aaron keeps: $9

Aaron says: “That's life. Take it or leave it!”

*Figure 3.* Ultimatum Game sample provocation
Figure 4. Forgiving and retaliatory behaviors in economic games. Individuals who imagined forgiving returned more fair offers to computerized opponents compared to those who ruminated on unfair offers; DG = dictator game. * $p < 0.005$
Forgiveness imagery resulted in successful forgiving behavior, operationalized as positive mean return offers to computerized opponents. Individuals who ruminated on unfair offers subsequently made more unfair offers. * $p = 0.005$

*Figure 5. Mean offer difference in Forgive and Ruminate groups.*
Figure 6. Heart rate (HR) changes from baseline during DG1, Manipulation, DG2, and Recovery.

Those who forgave unfair opponents showed attenuated increases in HR from baseline during imagery manipulation compared to those who ruminated on provoking offenses. *

$p < 0.05$
Figure 7. Heart rate (HR) by condition across all tasks
Individuals who forgave unfair computerized opponents showed attenuated decreases in RMSSD from baseline during Manipulation imagery, post-trial dictator game (DG2), and Recovery compared to those who ruminated, though these differences were not statistically significant. Natural log transformed RMSSD is reported. RMSSD = root mean square of successive RR differences.

Figure 8. RMSSD changes from baseline by condition.
Figure 9. RMSSD by condition across all tasks
The Forgive group showed attenuated decreases in HF power from baseline during Manipulation imagery and Recovery compared to the Ruminate group, though these differences were not statistically significant. Natural log transformed absolute HF power is reported.
Figure 11. Absolute high frequency (HF) power by condition across all tasks
Figure 12. Absolute low frequency power (LF) changes from baseline.

Differences between Forgive and Ruminate groups in absolute LF power did not emerge at any time point. Natural log transformed absolute LF power is reported.
Figure 13. Absolute low frequency (LF) power by condition across all tasks
Figure 14. Gender differences in heart rate (HR) changes from baseline.

Men and women did not show differences in HR change from baseline for any task.
Figure 15. Heart rate (HR) by gender across all tasks.
Men and women did not show differences in RMSSD change from baseline across all tasks. Natural log transformed RMSSD is reported. RMSSD = root mean square of successive RR differences.
Figure 17. RMSSD by gender across all tasks
Figure 18. Gender differences in absolute high frequency (HF) power changes from baseline.

Men and women did not show differences in HF power change from baseline across all tasks. Natural log transformed absolute HF power is reported.
Figure 19. Absolute high frequency (HF) power by gender across all tasks
Figure 20. Gender differences in absolute low frequency (LF) power changes from baseline.

Men and women did not show differences in LF power change from baseline across all tasks. Natural log transformed absolute LF power is reported.
Figure 21. Absolute low frequency (LF) power by gender across all tasks
Figure 22. Conditional effect of gender on the relation between depressive rumination and behavioral forgiveness.

Men made more generous return offers with increasing levels of depressive rumination, while this effect was not observed among women. Low and high levels of depressive rumination represent one standard deviation above and below the sample mean.