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Computational Structure of Evolved Forgiveness Systems.

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Computational structure of evolved forgiveness systems

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ABSTRACT

Researchers have recently suggested that humans possess dedicated cognitive systems for forgiveness, which evolved to repair valuable cooperative relationships with transgressors and stave off harmful revenge behaviors. These putative systems are computational in nature, utilizing information pertaining to the relationship value, exploitation risk, and genetic relatedness of a transgressor in determining whether or not to employ forgiveness. While a few studies have provided empirical support for this conjecture, surprisingly little empirical research has been conducted to determine if forgiveness systems actually have such a computational structure. The aim of this thesis was to fill this gap in the literature by testing hypotheses related to evolved systems for forgiveness. Using a sample of undergraduate participants, we tested hypotheses related to the computational structure of forgiveness, focusing on the role of internal regulatory variables (IRVs) including relationship value, exploitation risk, and genetic relatedness. Seven separate predictions were all empirically supported, providing verisimilitude to evolved accounts of forgiveness, and offering new insights into the form and function of forgiveness systems.

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This thesis is dedicated to my mother, Cynthia, my father, Dennis, and my grandparents, Joe and Joseph.

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Chapter 1: Theoretical Overview

Overview

Experiencing aggression, violence, or harm is a highly aversive experience for nearly all humans (Bloom, 2010). When these acts are committed by close relationship partners such as friends or family, the magnitude of the unpleasantness increases substantially, often inducing a crisis in the relationship. Such an experience is difficult to process, as it elicits confusing feelings of anger, resentment, and disbelief towards a person that the victim previously thought cared about them. Forgiving a transgressor and continuing the relationship can make the situation even more difficult. Forgiveness requires the victim to move past the unpleasant experience, dispel negative sentiment, and become vulnerable to future harm at the hands of a proven transgressor. Yet, humans across nearly all cultures frequently restore relationships with individuals who have transgressed against them, forgoing abandonment and revenge in favor of reparation and rectification (Worthington, 2005). Forgiveness, then, presents a puzzle: why do individuals display a strong proclivity to continue relationships with people who have hurt them, rather than seek out more benevolent relationship partners?

Recent evolutionary research provides a new perspective to this question, suggesting that forgiveness' pervasiveness across time and place is tied to its importance in maintaining valuable cooperative relationships (Aureli & de Waal, 2000; McCullough, 2008). Cooperation, wherein one organism benefits another (West et al., 2007), is key to human life, driving our evolutionary success across all spheres of social interaction, ranging from dyadic interaction to large-scale global coordination (Henrich, 2004). Cooperative relationships, however, are imperfect. Noisy environmental conditions (i.e., conditions that result in a choice different than the one that was intended; Wu & Axelrod, 1995), accidental offenses, and other aberrations in simpatico relationships are common occurrences that strain and threaten relationships. If these events warranted relationship termination, very few long-term reciprocal relationships would exist. Because forgiveness and cooperation are close bedfellows, humans likely developed evolved cognitive systems designed to achieve forgiveness in order to promote beneficial cooperative outcomes (Burnette, McCullough, Van Tongeren, & Davis, 2012; McCullough, Kurzban, & Tabak, 2013).

However, relatively little is known about the evolved structure of forgiveness. What informational cues do forgiveness mechanisms process, and what is the engineering design undergirding forgiveness' computational structure (Williams, 1966)? Evolved psychological mechanisms must be computational, as they function to process relevant environmental information in order to adaptively regulate behavior (Cosmides & Tooby, 2013). Evolved forgiveness mechanisms accomplish this by processing information pertaining to a transgressor's value as a relationship partner, and their likelihood of recidivism. Forgiveness mechanisms then integrate this information to determine if the relationship should be re-established or terminated (McCullough et al., 2013). While many researchers have offered theoretical arguments about the computational nature of evolved forgiveness mechanisms (McCullough 2008; McCullough et al., 2013; Petersen et al., 2011), surprisingly little research has empirically examined the hypotheses stemming from this theory. The purpose of this thesis is to fill this gap in the literature by testing hypotheses that correspond to an evolutionary account of forgiveness. We aim to 1) Determine the empirical validity of theory pertaining to evolved forgiveness mechanisms 2) Extend theory by examining the structural links between the informational components governing forgiveness mechanisms. The first section reviews social psychological research on forgiveness. This is followed by more recent evolutionary perspectives on forgiveness, which bears out the predictions that this thesis tests. We conclude with our results, which suggest that the theorized structure of evolved forgiveness systems reflects their extant structure.

Forgiveness

Forgiveness is the focus of much interdisciplinary research, spanning anthropology, philosophy, law, psychology, and biology. Forgiveness has garnered so much attention in part because of its association with a wealth of positive outcomes. Numerous benefits are conferred upon individuals who forgive, including increased psychological well-being (McCullough et al., 2001; Bono et al., 2008; Karremans, J. C., Van Lange, Ouwerkerk, & Kluwer, 2003), better health outcomes (Harris & Thoresen, 2005), reduced vengeful behavior (McCullough, Kurzban, & Tabak, 2013), and decreased negative affect (Enright & The Human Development Study Group, 1991). Forgiveness' permeation across diverse research efforts is reflected in its diffuse conceptualization, including forgiveness' construal as a cooperative response in the context of a social dilemma (Axelrod, 1980; Nowak & Sigmund, 1992), an attributional tendency (Balliet, Lin, & Joireman, 2011; Darby & Schlenker, 1982), and a personality trait (McCullough & Hoyt, 2002; Walker & Gorsuch, 2002). The definition of forgiveness varies as widely as its conceptualization. Prominent forgiveness researcher Everett Worthington suggests that forgiveness is the replacement of negative emotions towards a transgressor with positive emotions (e.g., Worthington & Wade, 1999). Similarly, Enright and Fitzgibbons (2000) define forgiveness as a process involving change in behavior, cognition, and emotion towards an offender. These and other definitions roughly converge onto the same underlying construct of forgiveness as a prosocial psychological and behavioral *change* towards an offender, emphasizing the temporal component of the forgiveness experience. Thus, for the purpose of this thesis, forgiveness will be defined as “the suite of prosocial changes in motivation, behavior, and emotion towards an interaction partner who has committed a perceived transgression” (e.g., Bono, McCullough, & Root, 2008; McCullough, Pargament, & Thoresen, 2000; Worthington, 2005). This definition incorporates the core feature of intertemporal prosocial change, while explicitly bridging forgiveness’ emotional, motivational, and cognitive aspects.

Forgiveness can be measured as both a state, capturing a particular response to a transgression, and as a trait, a stable individual difference in responses to transgressions (Berry, Worthington, Parrott, O’Connor, & Wade, 2001; Brown, 2003). This review will focus primarily on state forgiveness unless otherwise noted. Forgiveness covaries with a distinct profile of personality and situational characteristics. Individual differences in agreeableness, conscientiousness, and perspective taking positively correlate with forgiveness, while neuroticism, vengefulness, and rumination are negatively correlated with forgiveness (Balliet, 2010; Balliet, Li, & Joireman, 2011; McCullough, Bono, & Root, 2007; McCullough & Hoyt, 2002; McCullough et al., 1998; McCullough, Worthington, & Rachal, 1997; Mullet, Neto, & Riviere, 2005; Walker & Gorsuch, 2002). Despite its high correlation with prosocial personality traits, forgiveness appears to be about more than just being “nice”; individuals who are high on self-control and executive functioning exhibit greater situational forgiveness, especially when they are low on trait forgivingness (Balliet, Li, & Joireman, 2011; Finkel & Campbell, 2001). Demographically, there is evidence that people become more forgiving with age (Toussaint, Williams, Musick, & Everson, 2001), that women forgive more than men (Miller, Worthington, & McDaniel, 2008; however, see also Fehr, Gelfand, & Nag, 2010), and that the religiously-affiliated forgive more frequently than the unaffiliated (McCullough, Bono, & Root, 2005; Tsang, McCullough, & Hoyt, 2005). Cognitively, increased perceptions of a transgressor's blame, intentionality, and severity reduce forgiveness; emotionally, increased empathy directed towards a transgressor increases forgiveness (McCullough et al., 1998).

Empathy, the vicarious experience of another person's emotions (Davis et al., 2015; McCullough, 2001), is a particularly crucial component of forgiveness. Empathy is composed of a cognitive component, the ability to recognize emotional states in another person (Dziobek, Rogers, & Fleck, 2008), and an affective component, the emotional response to another person's inferred state (Blair, 2005). Empathy has been described as part of the natural process of forgiveness (Enright, Freedman, & Rique, 1998), as well as an ability that is necessary for forgiveness (McCullough, 2000). Using cross-sectional, longitudinal, and experimental research methods, McCullough and colleagues (McCullough, Worthington, & Rachal, 1997; McCullough et al., 1998) have found evidence that empathy for a transgressor is the driving force behind forgiveness: transgressors who apologize elicit empathy from victims, leading to forgiveness. Empathy is one of a constellation of variables that are highly correlated with forgiveness, along with closeness to a transgressor, relationship commitment (Finkel, Rusbult, Kumashiro, Hannon, 2002), and apology (McCullough et al., 1997), amongst other variables. Forgiveness' frequent covariance with these constructs suggests that forgiveness may causally hinge on the function of these psychological mechanisms (McCullough et al., 1998).

Evolved function of forgiveness

Forgiveness appears to be a universal psychological phenomenon. The Human Relation Area Probability Sample Files, a comprehensive ethnograph documenting the world's cultural strata, shows that 93% (56/60) of cultures demonstrate some form of forgiveness (McCullough, 2008; Naroll, 1967). While short of 100% universality, it has been argued that forgiveness' absence in four cultures is likely the result of anthropologists failing to notice and document forgiveness when it was actually occurring (i.e., a false negative; McCullough, 2008). Forgiveness is historically pervasive as well, featuring prominently in religious doctrines across the world dating back thousands of years (Griswold & Konstan, 2011). The ubiquity of forgiveness across time and place suggests that humans may have an innate propensity to forgive. Recent evolutionary research supports this conjecture, suggesting that humans possess dedicated cognitive systems for forgiveness (Burnette et al., 2012; de Waal, 2000; McCullough et al., 2013; Petersen, Sell, Tooby, & Cosmides, 2010).

Forgiveness systems would have evolved because of their positive effect on cooperation, a behavior designed to provide a benefit to another organism (West et al., 2007). Cooperation between unrelated individuals is one of the driving forces for human social evolution (Rand & Nowak, 2013). Cooperation is a first order adaptive problem that spans many species, posing a selection pressure to organisms at nearly all levels of biological organization (Nowak, 2006). Forgiveness is a second order adaptive problem, scaffolding cooperation by adaptively maintaining cooperative social relationships with valuable relationship partners who have committed transgressions (McCullough et al., 2013). Ancestral humans endowed with genes that mapped onto forgiveness-promoting thought and behavior would have mended relationships marred by aberrant transgressions, leading to increased gains from cooperation; those lacking forgiveness mechanisms would have been more likely to terminate otherwise valuable relationships on the basis of these outlier events. Further, these forgivers would have been vigilant for signals indicating remorse and a lack of future threat from transgressors, and would have had the ability to impose costs if necessary (i.e., they do not passively absorb costs). Forgivers would have reaped the gains of a continued cooperative relationship, and foregone the multiple costs of losing a cooperative partner, such as having to form a replacement relationship and engaging in revenge behaviors. Over epochal time scales these evolutionary forces would have caused forgiveness adaptations to propagate through the population.

Forgiveness' ability to increase fitness gains suggests that it may be an adaptation, a trait that uniquely solves a problem ancestral humans recurrently faced in the environment of evolutionary adaptedness (EEA; Williams, 1966). The EEA refers to the trait-relevant environmental characteristics that imposed selection pressures on a species, influencing fitness and shaping design features accordingly (Irons, 1998). Importantly, the EEA is not a time or place, but rather a statistical composite that aggregates the linear weight of selection pressures on an organism's' features (Tooby & Cosmides, 1990). Adaptations that solve problems presented by the EEA possess evidence of "special design", the non-random coordination between EEA features and the phenotypes organisms developed to solve those problems (Williams, 1996). The EEA and special design features fit together like a 'lock and key': the environment is the lock, and the special design features are the key fitted to it. In the case of forgiveness, the recurrent problem to be solved in the EEA was retaining cooperative relationships with valuable partners who committed inevitable transgressions; the special design features were the specific psychological and behavioral characteristics victims use to forgo revenge, implement forgiveness, and restore damaged relationships.

Support for the existence of evolved forgiveness systems comes from consilient research findings in anthropology (Narroll, 1967), human psychology (Burnette et al., 2012; McCullough et al., 2013; McCullough, Luna, Berry, Tabak, & Bono, 2010), computer simulations (Nowak & Sigmund, 1992), and mathematical modeling (Nowak, 2006). The most compelling interdisciplinary evidence, though, comes from ethological and primatological research on reconciliation, which provides an analogue to human forgiveness in a phylogenetically close species (de Waal, 2000; Ho & Fung, 2011; McCullough, 2008). As previously noted, reconciliation is distinct from the forgiveness, and corresponds to observable behavior rather than psychology. However, reconciliation can be understood as an outcome following forgiveness, and in the primate literature has been defined as "a behavioral mechanism that allows primates to repair social damage caused by hostilities" (de Waal & Porkny, 2005, pg. 17). Reconciliatory behaviors are extremely prevalent in primates: chimpanzees that are targeted for dyadic aggression frequently respond to aggressors with conciliatory tendencies 51% of the time, *exceeding* the friendly contact that occurs prior to the aggressive encounter (de Waal & Roosmalen, 1979). Other primates, such as bonobos, apes, and macaques (animals that are characterized as hyper-aggressive) also display greater post-aggression friendly contact compared to pre-aggression relationships (Aureli & de Waal, 2000).

In short, human ancestors that possessed forgiveness-promoting genes would have enjoyed the fitness gains conferred by retaining benefit-generating relationships with valuable partners, while simultaneously avoiding the costs incurred by a breakup, such as harmful revenge behavior and having to find a new interaction partner. This is the ultimate explanation for the evolution of forgiveness systems, as it addresses the problem-solving logic of forgiveness and provides a description of *why* forgiveness systems would have been evolutionarily favored (Tinbergen, 1963). However, it remains to be explained how forgiveness' logic actually manifests in humans carrying forgiveness-promoting genes. *How* do forgiveness adaptations lead to increased fitness? What kinds of thought and behavior are implemented by these genes to fitness-enhancing ends? These questions address the proximate explanation of evolutionary phenomena, which complements the ultimate, adaptive explanation (Scott-Phillips, Dickins, & West, 2011).

Circuit logic and welfare tradeoff ratios

Forgiveness mechanisms carry out their function by way of the innate psychological mechanisms that constitute cognitive circuit logic (Cosmides & Tooby, 2013). Circuit logic conceptualizes the human mind as a computational device, and explicitly frames brain functions in computational terms. According to circuit logic, the mind contains a collection of specialized psychological mechanisms adapted to solving unique problems that were prevalent in the EEA (Tooby & Cosmides, 2000). These adaptations function as 'programs' or 'subroutines' that evaluate and process information - including external and interoceptive stimuli, as well as unconscious and consciously accessible thought - in order to produce adaptive behavioral regulation (Tooby, Cosmides, Sell, Lieberman, & Sznycer, 2008). The specialized mechanisms that comprise the human mind's circuit logic utilize internal regulatory variables (IRVs) to function, just as computer-based algorithms utilize variable input to complete tasks (Tooby et al., 2008). IRVs serve as the interface between motivation, affect, and cognition, seamlessly translating information in the environment to relevant psychological processes and behavioral regulation. IRVs make decision-making processes feel effortless. This is frequently accomplished through felt experience, such as behavior-regulating emotional programs such as anger (Sell, 2009), gratitude (Forster, Pedersen, Smith, McCullough, & Lieberman, 2017), and shame (Sznycer et al., 2012).

The cognitive architecture of human kin-detection, an evolved program designed to avoid fitness-costly incestual behavior, exemplifies the connection between evolved programs, IRVs, affect, motivation, and behavior (Lieberman, Tooby, Cosmides, 2007; Tooby et al., 2008). Kin-detection mechanisms function by indexing cues pertaining to the genetic relatedness of a target individual, such as the maternal perinatal association (MPA; i.e., the amount of time that one's mother cares for another younger individual); in the case that the target is older and maternal care cannot be witnessed, co-residence duration is used as a genetic cue. Genetic relatedness is determined by the information from these indices, and is then registered as a sexual value IRV, where increased cues to genetic relatedness (i.e., higher MPA) negatively correlate with the sexual value of a target. Situations that suggest the prospect of sex with low sexual value targets (close family members) produces the felt emotional experience of disgust. Disgust then motivates the aversion of sex with these individuals, producing adaptive incest-avoidance behavior (Lieberman et al. 2007; Tybur, Lieberman, Kurzban, & DeScioli, 2013).

Although the mind contains an exhaustive number of specialized mechanisms that target specific adaptive problems, the IRVs underlying these mechanisms do not operate in isolation from one another. IRVs that index important information about an organism's physical state, the social world, or the surrounding environment can be fed into other IRV computations if such linkage is deemed adaptive by natural selection. For example, information about genetic relatedness feeds into IRVs that govern both sexual value and altruistic intention. One important IRV that feeds into many specialized social psychological processes is the welfare tradeoff ratio (WTR; Delton & Robertson, 2012, 2016; Sell, 2011; Tooby et al., 2008). WTRs are summary magnitude IRVs that estimate the value of a target individual relative to the value of oneself; or equivalently, the amount of a resource that one is willing to sacrifice to benefit another individual (Delton, 2010). WTRs are spontaneously formed cognitive representations, appearing effortlessly, intuitively, and unconsciously to the experiencer. These cognitive representations function as a summary variable that encodes features of a target associated with other IRVs, such as the target's genetic relatedness, relative formidability, expected length of the reciprocal relationship, and other evolutionarily important information (Delton & Robertson, 2012; Lieberman, Tooby, & Cosmides, 2007). WTRs also encode IRVs that index features of the situation, such as the cues to surveillance by others (Haley & Fessler, 2005), or the likelihood that a behavior will be punished by third party observers (Delton & Robertson, 2016). WTRs towards a target take two forms: intrinsic and monitored (Sell et al., 2009). Intrinsic WTRs correspond to how an individual acts towards a target regardless of whether or not the target is aware of their actions (i.e., representing an individual's "true feelings"), while monitored WTRs reflect how an individual acts towards a target when the target or the target's coalition can detect their actions (Tooby et al., 2008). The probability of detection often raises the monitored WTR an individual possesses towards a target, particularly when the target is capable of inflicting costs (e.g., they are extremely formidable, or have a large coalition at their behest). Monitored WTRs will never be lower than intrinsic WTRs, as intrinsic WTRs represent the floor of an agent's WTR towards a target (Petersen et al., 2010).

The logic of forgiveness

IRVs underpin the cognitive machinery governing forgiveness systems. Using the language of IRVs, one can outline the computational structure of forgiveness systems in terms of precise fitness gains and losses associated with particular behaviors and information. Transgressions arise when a valuable relationship partner engages in a behavior that demonstrates their WTR towards the victim is lower than what the victim anticipated. For example, individual A believes that B holds a WTR of 0.50 towards A (i.e., B is willing to forgo 5 units of a resource to benefit A with 10 units of the resource). However, B engages in a behavior showing that B's actual valuation of A is much lower than 0.50. The action that demonstrates this low valuation is abstract, and can take many forms: time, money, effort, or other finite resources that represent value. In this case, A desperately needs a ride to the hospital from B - who currently has no plans - and B refuses to give A a ride. B has thus demonstrated that their idle time is more valuable than A's dire health needs, expressing a WTR towards A that is much lower than 0.50. A becomes angry, shocked, and hurt by B's actions. A now perceives B as a transgressor who has committed a wrong.

Victims of transgressions can respond in three ways: First, if a victim is helpless, they can accept the affront and decline to respond, resulting in a downward revision of the WTR the transgressor holds towards them. This downward revision in WTR is accepted by both the victim and the transgressor, who proceed with the relationship under the newly established WTR. In the case of A and B, this might mean that B now holds a WTR of 0.05 towards A, which A accepts in future resource allocation events. Acceptance is a sub-optimal decision, though, as it always leads to a lower post-transgression WTR compared to the pre-transgression WTR. A second response option is to seek revenge. Revenge functions to prevent a transgressor's exploitation by deploying deterrence measures. The goal of revenge is to halt a transgressor's cost-imposing behavior, forcing them to upwardly revise their WTR to a pre-transgression level (McCullough et al., 2013). Deterrence behaviors activated by revenge are mediated by feelings of anger, the felt emotional output that another individual has provided unfair treatment (Sell, Tooby, & Cosmides, 2009; Sell, 2011). Vengeance can result in fitness gains by negating the net benefit that a transgressor receives from imposing costs on the victim, rendering future exploitative efforts fruitless. In the case of A and B, A might lash out at B by withholding future benefits ("I'm not going to help you move across town"; "you're not invited to my party"), or punishing B through physical or social aggression.

However, revenge carries major costs, including the expenditure required to retaliate (i.e., costly punishment; Henrich et al., 2006), and the consequence of counter-revenge by the transgressor. While costly punishment is highly variable across ecologies and situations (Guala, 2012), counter-revenge is nearly always a threat, as transgressors targeted by an avenger's wrath are also liable to possess revenge systems. The ensuing feedback loop of aggression can result in endless cycles of counter-revenge, such as the kind epitomized by the infamous Hatfield-McCoy feud (Nisbett & Cohen, 1996). Revenge also terminates valuable relationships by making it much less likely that a cooperative relationship will be restored. If the original transgression was unintentional, such as in a noisy environment (Wu & Axelrod, 1995), then a cooperative relationship is needlessly lost.

The third response option to a transgression is to forgive. The goal of forgiveness is to proactively upregulate the WTR of the transgressor by inhibiting revenge motivations using non-revenge methods (McCullough et al., 2013). Whereas revenge upregulates a transgressor's WTR using costly violence, forgiveness upregulates WTRs using low-cost prosociality. Revenge inhibition is a crucial component of forgiveness, as vengeful motivations are highest immediately following a transgression (McCullough, Fincham, & Tsang, 2003). High initial revenge motivations likely reflects the initial uncertainty of future exploitations ("Will this be a regular occurrence?") and relationship value ("Do they even really care about me?"). Following revenge inhibition, the victim signals to the transgressor that they wish to restore the relationship to pre-transgression levels of exchange. These signals indicate that: 1) The victim recognizes the cost that has been imposed upon them, using emotions such as anger to communicate that a lower-than-expected WTR has been expressed by another individual, and demanding that the transgressor increase their WTR towards the victim. This could also involve reminders that the victim has provided numerous benefits to the transgressor and is a beneficial relationship partner ("I've done so much for you, and this is how you repay me?"). 2) The victim is forgoing the reciprocation of cost-imposition on the transgressor, rather than passively accepting the costs. If they wished, the victim could respond with aggression, but they choose not to, because they value the exploiter. 3) The victim is ready to renew a cooperative relationship, given that the transgressor will not exploit them again. In the case of A and B, A might exile B for a period of time, expressing their displeasure, but resisting the urge to attack B. B may recognize the potential benefits lost, and apologize to A. A feels less angry over time, accepts B's apology, and moves forward with the shared understanding that B will value A in the future (i.e., B possesses an intrinsic WTR of 0.50 or higher towards A). By resolving conflicts without aggression, forgiveness systems are able to subvert the costs associated with revenge, often while achieving better fitness outcomes (McCullough et al., 2013).

For these reasons, forgiveness is often preferable to revenge. However, unconditional forgiveness is an infeasible decision rule, as it would permit exploiters to ceaselessly farm forgivers for benefits. To counter this possibility, forgiveness and revenge systems access shared information regarding the relationship value and exploitation risk of a transgressor, IRVs that index pertinent information about a transgressor (Petersen et al., 2010). The relationship value IRV registers the benefits that a transgressor is capable of providing, and is sensitive to cues of high future value. Relevant cues include a transgressor signalling their commitment to the relationship (McCullough et al., 1998) and their ability to deliver unique benefits (Tooby & Cosmides, 1996). The exploitation risk IRV registers the prospect of a transgressor's recidivism, and is sensitive to cues indicating remorse, including apologies (especially those that bear costs; Ohtsubo, & Watanabe, 2009), self-punishment (Watanabe & Ohtsubo, 2012), compensation (Ohtsubo et al., 2012), and expressions of shame (Konstam, Chernoff, & Deveney, 2001). However, the information provided by either relationship value or exploitation risk alone is insufficient to warrant forgiveness or revenge; ultimately, the information provided by these IRVs must be integrated together in order to function adaptively (Burnette et al., 2012). Well-engineered forgiveness systems must compute an intermediate IRV to weigh the relative merits of exploitation and relationship value. The integrated output of these IRVs is the perceived association value of a transgressor, a summary variable capturing the linear weight of the two sub-IRVs (Petersen et al., 2010). Transgressors that are perceived to have high association values are forgiven; those with low association values are met with revenge.

In sum, forgiveness systems can be modelled as a choice that emerges from two steps of collected computations. The first step calculates relationship value, exploitation risk, and association value in order to determine whether forgiveness or revenge strategies should be implemented. If these upstream computations determine that a transgressor possesses high association value, forgiveness is deemed preferable to revenge; if a low association value is yielded, revenge becomes the optimal decision. Once a strategy is selected, proximate mechanisms are employed to carry out the appropriate response. In the case of forgiveness systems, vengeful responses are inhibited and forgiving behavior is implemented, as the forgiver seeks to upwardly revise the transgressor's intrinsic WTR to pre-transgression levels and restore the relationship.

Genetic relatedness

While the association value of a transgressor is predicated on exploitation risk and relationship value IRVs, other target traits and environmental factors feed into forgiveness computations (Petersen et al., 2010). Many forgiveness-related cues are observer-dependent, as the value assigned to a given target (or a feature of the environment) is not an objective property of reality, but a subjective valuation dependent on the agent making the evaluation (Barrett & Bliss-Moreau, 2009). For example, the perceived physical formidability of a target is not an objective feature of that target; the formidability of another individual is dependent on the strength of the perceiver (Delton & Robertson, 2016). A target that is perceived as being very strong to one individual may be thought of as weak by another.

Many of the IRVs underlying forgiveness computations involve subjective valuations. One notable variable is the genetic relatedness of a target (Lieberman, Tooby, & Cosmides, 2007). Genetic relatedness' influence on cooperative behavior is a cornerstone of altruism theories in the biological and psychological sciences, dating back to William Hamilton's theory of kin selection (Hamilton, 1964). According to kin selection, an organism's altruistic behavior towards a target covaries with their shared genetic material, resulting in behavior that is costly for the organism but beneficial for the target. An organism's altruistic behavior towards kin ultimately promotes the transmission of their own genes, even if the behavior causes them to incur a direct cost (Hamilton, 1964). Kin selection is modeled using the elegant mathematical formula:

$$r_{\text{Target}} * B_{\text{Target}} > C_{\text{Individual}}$$

Where *r* is the proportion of genetic covariance with a target organism, *B* is the benefit that the target receives from the organism's' actions, and *C* is the cost to the individual. When the lefthand side of the equation is larger than the righthand side, the organism will incur a cost to benefit the target. As *r* increases, the cost that the organism is willing to incur increases. If an action carries a cost of 10 ($C_{\text{Individual}}$=10), the benefit to the target is 25 (B_{Target}=25), and the target is a sibling (r_{Target}=0.5), the organism will, on average, perform the costly behavior. Compared to unrelated individuals, targets such as siblings, parents, and cousins are more likely to be the beneficiaries of altruism, as their fitness gains increase the benefactor's inclusive fitness.

Kin selection relates directly to WTRs, as indices of genetic relatedness serve as input into the computations underlying WTRs (Sell, Tooby, & Cosmides, 2009). Research demonstrate that genetic relatedness influences resource provision towards kin in both laboratory experiments, wherein individuals provide greater help and valuation to kin compared to non-kin (Burnstein, Crandall, & Kitayama, 1994), and natural field studies, wherein migrant workers' ability to enhance their family's welfare is highly predictive of the money that workers send home (Bowles & Posel, 2005). The relationship between WTRs and the cost/benefit ratio that determines when altruistic behavior should be favored by natural selection even shares the same parsimonious algebraic structure as theories of kin selection:

$$WTR_{\text{Target}} * B_{\text{Target}} > C_{\text{Individual}}$$

As the WTR towards the target increases, the costs one is willing to incur to benefit the target increases proportionally (Delton & Robertson, 2016). Researchers have theorized that the degree of genetic relatedness (i.e., kin selection) influences forgiveness as a function of WTRs (McCullough et al., 2013; Tooby & Cosmides, 2013). Given that higher WTRs predict greater pre-transgression and post-transgression association value (Petersen et al., 2010), genetic relatedness likely influences forgiveness via WTR computations.

Chapter 2: Empirical Research on Evolved Structure of Forgiveness

While much research has suggested that relationship value, exploitation risk, WTRs, and genetic relatedness IRVs are utilized by forgiveness mechanisms, relatively little empirical research has been conducted to determine if this is actually the case. Important contributions by Petersen et al. (2010) and McCullough et al. (2013) have outlined the logic that undergirds forgiveness based on consilient evidence from psychology, biology, and related disciplines. However, aside from a few exceptions (e.g., Burnette et al., 2012; McCullough et al., 2010) this theory is based largely on logical conjecture, and has yet to be subjected to rigorous hypothesis testing.

The goal of this thesis, then, is to investigate the putative circuit logic underlying evolved forgiveness mechanisms by empirically testing the theory laid out by other researchers, gaining insight into forgiveness' evolutionary design. We also seek to understand the computational structure of forgiveness' circuit logic by examining which IRVs function as predictors, mediators, and outcomes in the causal chain of forgiveness computations. We developed several testable predictions to fill this gap in the literature. Across seven predictions we examined the effect of two IRVs that have been posited to influence forgiveness: association value (Petersen et al., 2011) and kinship (Lieberman et al., 2007). These IRVs are indexed by cues of genetic relatedness, relationship value, exploitation risk, and the interaction between relationship value and exploitation risk. Figure 1 displays the proposed model that will be examined.

Three components of forgiveness were examined: transgression-related interpersonal motivations, decisional forgiveness, and emotional forgiveness. Transgression-related interpersonal motivations focus on the underlying motivations that lead to forgiveness, and include the dimensions of benevolence, avoidance, and revenge motivations (McCullough et al., 1998). Decisional forgiveness is the act of replacing negative behavior towards a transgressor with positive, prosocial behavior (Hook, Worthington, Utsey, David, & Burnette, 2012). This facet of forgiveness emphasizes the inter-individual and interdependent aspect of forgiveness. In contrast to the other-oriented nature of decisional forgiveness, emotional forgiveness focuses on the victim's attainment of inner peace, and the replacement of negative emotions with positive emotions (Hook et al., 2009). Emotional forgiveness emphasizes the intra-individual, self-oriented aspect of forgiveness rather than the victim's relationship with the transgressor. While decisional and emotional forgiveness are not necessarily mutually exclusive, individuals are more likely to allocate forgiveness efforts towards one or the other (Hook et al., 2012).

These measures of forgiveness were selected for two reasons. First, including multiple measures of forgiveness helps us gain a better understanding of how our predictors influence forgiveness. Emotional, decisional, and motivational forgiveness each capture unique dimensional space of forgiveness, providing us with a high resolution picture of forgiveness. Second, decisional and emotional forgiveness vary across different cultural contexts (Hook et al., 2009; Hook et al., 2012), while forgiveness motivations tend to be culturally invariant (Ohtsubo et al., 2015; Smith et al., 2016). The present thesis is part of a broader study that aims to determine how forgiveness functions across cultural contexts, making the inclusion of these culturally variant and invariant aspects of forgiveness essential to future research goals (see "Future directions" in the discussion section for more detail).

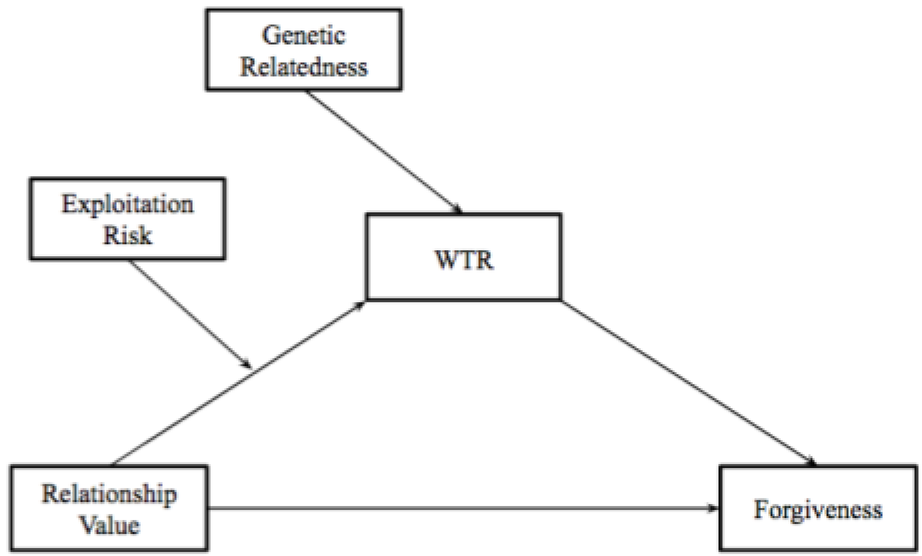

Figure 1. Proposed relationship between IRVs underlying forgiveness mechanisms.

Predictions

As previously mentioned, forgiveness systems integrate information pertaining to relationship value and exploitation risk to compute the association value of a target, which ultimately determines if forgiveness or some other strategy will be implemented (Burnette et al., 2012). We aim to replicate this finding, seeking to determine if the integration of this information (that is, their interaction effect) predicts each kind of forgiveness that was measured. We specifically focus on the interaction effect, as this captures the dependence of each kind of information in determining association value: high relationship value is worthless for a serial transgressor; likewise, a guarantee of future non-recidivism is worthless coming from a partner that offers no value (Burnette et al., 2012). As such, the interaction term between relationship value and exploitation risk will be treated synonymously with association value for the purposes of this thesis.

Prediction 1: Relationship value and exploitation risk will interact to predict forgiveness.

High association values should predict high WTRs, and both should predict forgiveness (Petersen et al., 2010). As such, the interaction effect of relationship value and exploitation risk IRVs should also be predictive of WTRs. No published research to date has determined if the interaction between relationship value and exploitation risk predict WTRs.

Prediction 2: Relationship value and exploitation risk will interact to predict WTRs.

Related to our second prediction, no published research has examined the relationship between WTRs and forgiveness. While past research indicates that WTRs likely positively predict forgiveness (e.g., Petersen et al., 2011), it is currently empirically unclear if this is actually the case.

Prediction 3: Higher WTRs will positively correlate with forgiveness.

Predictions 1-3 present a piecemeal account of the relationship between WTRs, relationship value, exploitation risk, and forgiveness. Integrating the previous three findings, we expect that the effect of relationship value on WTRs will be moderated by exploitation risk (i.e., the interaction will exert an effect on WTRs), and that the effect of WTR on forgiveness will depend on this interaction effect.

Prediction 4: The effect of the interaction between relationship value and exploitation risk on forgiveness will be mediated by WTR.

We expect that genetic relatedness will positively predict higher WTRs. Evolutionary research has demonstrated a positive relationship between genetic relatedness and altruism (Hamilton, 1964). The cumulative effect of these findings suggests a circuit logic such that IRVs indexing the degree of genetic relatedness towards a target feed into and upregulate the WTR towards the target. Lieberman et al. (2007) suggested such a connection, although the authors did not explicitly report a quantitative relationship between genetic relatedness and WTRs. We will examine if WTRs do indeed correlate with genetic relatedness.

Prediction 5: Genetic relatedness will be positively correlated with WTRs.

Genetically related transgressors are frequently targeted for forgiveness, as unforgiveness (or revenge) towards family members carries additional costs beyond the costs imposed on allies. First, familial transgressors possess shared genetic material with victims. By denying transgressors forgiveness, victims indirectly suffer by failing to increase their own inclusive fitness. Second, familial relationships offer valuable, long-term reciprocity opportunities (McCullough et al., 2013; Trivers, 1971). Individuals frequently develop familial relationships throughout their entire lifespan, making it likely that these relationships become the most enduring and valuable that individuals possess. Family size is also correlated with social interdependence, such that individuals with larger families tend to be more cooperative with family members for support (Van Lange, De Bruin, Otten, & Joireman, 1997). This simultaneously increases the likelihood that a family member will commit a transgression (as a larger number of familial relationships increases the chance of conflict), and the likelihood that victims will attempt to recover those relationships via forgiveness. Taken together, these findings suggest that genetic relatedness positively covaries with forgiveness.

Prediction 6: Genetic relatedness will be positively correlated with forgiveness.

Given that genetic relatedness is posited to be an antecedent of both WTRs and forgiveness, and that WTRs are posited to be an antecedent of forgiveness, we would expect that there is a mediating relationship between degree of genetic relatedness, WTRs, and forgiveness. Two separate lines of research provide preliminary support this prediction. Research on the relationship between families and forgiveness shows that families tend to have qualitatively different forgiveness dynamics than non-familial relationships (Hoyt, Fincham, McCullough, Maio, & Davila, 2005; Maio, Thomas, Fincham, & Carnelley, 2008). Family members are also long-term reciprocity partners (Trivers, 1971), making genetically related individuals excellent targets for forgiveness irrespective of genetic relatedness. Thus, integrating predictions 3, 5, and 6, we expect that increased genetic relatedness with a transgressor will positively influence WTRs towards that transgressors, and that WTRs will then positively influence forgiveness.

Prediction 7: Genetic relatedness' influence on forgiveness will be mediated by WTRs.

Methods

Pre-registration

In order to maximize the transparency of the study design, prevent post-hoc theorizing, and increase the reproducibility of materials and procedure (Nosek, Spies, & Motyl, 2012), all aspects of the study have been pre-registered on Open Science Framework at the following URL: https://osf.io/zkeks/. The description of this study is nested within a larger cross-cultural study that is described on the OSF page (see discussion section of this paper for more detail). The pre-registration for this project is currently under embargo until December 1st, 2017 in order to secure the intellectual content prior to submission of the manuscript for publication. However, all materials are available upon request from the author of this thesis.

Power analysis

Power analyses were conducted to determine the necessary sample size required to detect an effect for each of our predictions (table 1). We first determined the effect of each of our predictors on their respective dependent variables. Effect sizes from previous studies were used when possible; however, given the novel predictions made in this study we often used rule of thumb estimates or proxy effect sizes. In estimating forgiveness DVs, we were limited to estimating the effect of each predictor on TRIM to the exclusion of decisional and emotional forgiveness, as few other studies have examined these outcomes.

Power analyses were conducted in two parts. First, a priori analyses were used to determine the sample size required to achieve 80% power; this value represented our data collection goal. However, we were limited in terms of the number of participants we were actually able to collect (*n*=168). As such, we also calculated expected power based on our actual sample size if our analyses indicated that a test required more than 168 participants to detect an effect 80% of the time. Power calculations were conducted using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) unless otherwise noted.

Prediction 1: Association value's effect on forgiveness. Burnette et al.'s (2012) provided effect sizes for exploitation risk and relationship value's interactive effect on TRIM. Effect sizes were originally reported as η^2 and standardized regression coefficients, and were transformed to Cohen's d for the purposes of this power analysis. Four effect sizes were culled across two studies (n_1=304, n_2=328): *d*=0.46, *d*=0.47, *d*=0.28, *d*=0.23. The average of these effect sizes was *d*=0.36, a medium effect size. This is the value that we used for estimating the effect of association value on forgiveness in our power calculations. Power analyses indicated *n*=245 is required to achieve 80% power in detecting the effect of the interaction in a multiple regression model. Given that we were able to recruit 168 participants, the expected power for prediction 1 was 64%.

Prediction 2: Association value's effect on WTRs. No existing study has directly examined the effect of association value on WTRs. As such, we assumed an effect size of *d*=0.26, halfway between medium and small. The rationale for this effect size is based on our first prediction. Since association value exerts a medium effect size on forgiveness, and WTRs serve as input to forgiveness, our effect size designation reflects a conservative estimate of the actual effect size. Power analyses indicated *n*=395 is required to achieve 80% power in detecting the effect of the interaction in a multiple regression model. Given that we were able to recruit 168 participants, the expected power for prediction 2 was 44%.

Prediction 3. WTRs effect on forgiveness. The effect of WTRs on forgiveness was estimated. No previous research has directly examined this relationship. As such, we estimated a very conservative effect size of *d*=0.50. This was based on an previous literature linking forgiveness to high partner valuations (e.g., Burnette et al., 2010). Power analyses indicated *n*=131 is required to achieve 80% power in detecting this effect in a correlation. Given that we were able to recruit 168 participants, the expected power for prediction 3 was 88%.

Prediction 4: Association value's effect on forgiveness as mediated by WTRs. Using the estimates of effect size for the effect of association value on WTRs and forgiveness, and the effect of WTR on forgiveness (i.e., the power analyses for predictions 1, 2, and 3), we determined the sample size necessary to achieve 80% power in a moderated mediation analysis. Effect sizes are reported here as Cohen's *d* to remain consistent with previous reports, but power analyses were conducted using equivalent beta coefficients. Effect sizes are reported in terms of model path coefficients: pathway *a*=0.26 (effect of the interaction on WTR), pathway *b*=0.50 (the effect of WTR on forgiveness, controlling for the interaction effect), and pathway *c'*=0.10 (the effect of the interaction on forgiveness, controlling for WTR). According to the mediation power analysis guidelines provided by Fritz and Mackinnon (2007), *n*=461 participants were required to detect a mediation effect (Fritz & Mackinnon, 2007, table 3, p. 237). We also computed our expected power based on the above parameters using David Kenny's mediation power calculator (Kenny, 2016). Given that we were able to recruit 168 participants, the expected power for prediction 4 was 35%.

Predictions 5. Genetic relatedness' effect on WTRs. No existing study has directly examined the effect of genetic relatedness on WTRs. However, Lieberman et al. (2007) examined the effect of sibling cues to genetic relatedness on altruistic motivations. Given that altruistic motivations feed into and possess the same mathematical structure as Hamilton's model of kin selection, we have utilized these effect sizes to estimate genetic relatedness influence on WTR and forgiveness. Two effect sizes were culled across two studies reported by the authors (n_1=287, n_2=154): d=0.41, d=0.43. The weighted average of these effect sizes was d=0.42, a medium effect size. Power analyses indicated n=191 is required to achieve 80% power in detecting this effect in an independent samples t-test. Given that we were able to recruit 168 participants, the expected power for prediction 5 was 75%.

Prediction 6. Genetic relatedness effect on forgiveness. No research has directly examined the effect of genetic relatedness on forgiveness. However, research has demonstrated that prosocial behavior is highly correlated with genetic relatedness (e.g., Hamilton, 1964; Lieberman et al., 2007). As such, we estimated a medium effect size (d=0.50). Power analyses indicated n=131 is required to achieve 80% power in detecting this effect in a correlation. Given that we were able to recruit 168 participants, the expected power for prediction 6 was 88%.

Prediction 7. Genetic relatedness' effect on forgiveness as mediated by WTRs. Using the effect size estimates for predictions 3, 5, and 6, and the guidelines provided by Fritz and MacKinnon (2007), we determined the power to detect the effect of genetic relatedness on forgiveness as mediated by WTRs. As in prediction 4, effect sizes are reported as Cohen's d to remain consistent with previous reports, but analyses were conducted using equivalent beta coefficients. Pathway a=0.42 (effect of genetic relatedness on WTR), pathway b=0.50 (the effect of WTR on forgiveness, controlling for the interaction effect), and pathway c'=0.10 (the effect of the genetic relatedness on forgiveness, controlling for WTR). Analyses indicated that a sample size of n=204 is required to detect the effect with 80% power. We also computed our expected power based on the above parameters using David Kenny's mediational power calculator (Kenny, 2016). Given that we were able to recruit 168 participants, the expected power for prediction 7 was 69%.

To recapitulate: We found that two of our seven predictions were adequately powered (≥80%), with the other five predictions underpowered (<80%) . Prediction 3 required the most participants to detect an effect (n=461), effectively setting n=461 as the required sample size to fully power all of the predictions in the present study. However, we have reason to believe that our a priori low power may be a minimal issue. In cases where the exact effect size was unknown, we used conservative estimates of expected effect size barring explicit reason otherwise. This resulted in several cases where our effect sizes estimates are likely much lower than in reality. For our mediation analyses - which suffered the largest power failures - we anticipated incomplete mediation of the direct effect, furthering hampering power estimates. In addition, these analyses all aim to achieve 80% power. In the cases where analyses failed to achieve 80% power, our power was still largely around 50%, the norm for most psychology studies (Cohen, 1992; Sedlmeier & Gigerenzer, 1989). Despite the low power estimates for a few predictions, it is likely that our study possesses more power than anticipated, and will produce results that are on par with the majority of studies.

Table 1.
Power analysis and expected power, based on n=168.

Prediction	Statistical test	Effect size *(d)*	Expected power (1-β)
1	Multiple regression	0.36	64%
2	Multiple regression	0.26	44%
3	Correlation	0.5	88%
4	Moderated mediation	path a=0.36 path b=0.50 path c'=0.10	35%
5	T-test	0.42	75%
6	Correlation	0.5	88%
7	Mediation	path a=0.42 path b=0.50 path c'=0.10	69%

Participants

168 undergraduates (100 females) in introductory psychology classes at the College of William & Mary participated for class credit. Students were recruited using SONA mass testing services. All students who filled out mass testing survey data were eligible for inclusion, except for international students who were from an East Asian country (in order not to confound the broader cross-national project design; see discussion section). In order to minimize the effect of self-selection bias, participants were randomly recruited using a vaguely worded email titled "Study of social interactions".

We were careful to avoid any description that alluded to the exact nature of the study, such as "forgiveness", "apology", or "transgression", as we did not want to bias our study towards participants who wished to gain catharsis (i.e., they are still angry over a past transgression and actively wish to share their experience). Such a group of participants may possess other characteristics that could confound our results with other factors, including increased likelihood of being targeted for transgressions; unrealistic expectations of the benefits a partner should provision (i.e., unreasonably high WTR expectations from others); and heightened anger responses, amongst other potential confounds. To further bolster security, participants were provided with a special passcode to enter the study. To ensure that students did not share their codes with unauthorized users, Qualtrics responses were checked against the list of participants solicited for participation. Any participants who were not recruited had their data removed prior to analysis.

Materials and measures

All data collection was conducted via Qualtrics surveys. Demographic variables, including sex, age, race, and ethnicity, were collected prior to survey administration via a mass testing questionnaire. Data collected from the survey included measures of relationship value and exploitation risk, welfare tradeoff ratios, decisional forgiveness, emotional forgiveness, and transgression-related interpersonal motivations. We also included measures of relational mobility (the degree to which individuals have the opportunity to form new relationships; Schug et al., 2009) and trait empathy (the emotional reaction to the observed experiences of another individual; Davis, 1980) as part of a separate, larger project. The following are the exact measures used, with a short description of their content. Items used for each scale can be found in appendix A. Cronbach's α is used to report reliabilities for scales and subscales.

Relationship value and exploitation risk were measured using the Relationship Value and Exploitation Risk scale (RVEX; Burnette et al., 2012). RVEX is a 10-item scale with 5 scale points for each item. RVEX consists of two factors (subscales): the relationship value of another individual (Relationship Value), and the perceived likelihood that they will commit a future offense (Exploitation Risk). Both the Relationship Value (α=.92) and Exploitation Risk (α=.77) subscales have high reliability (Burnette et al., 2012). Participants were instructed as follows: "Please answer the following questions about the person who committed the offense." Responses ranged from "Completely Disagree" to "Completely Agree".

Welfare tradeoff ratios (WTR) were measured using a modified version of the welfare tradeoff task (WTT; Delton, 2010; Forster, Pedersen, Smith, McCullough, & Lieberman, 2017). This version of the WTT is an 11-item scale with two options for each item, where participants choose between earning a resource for themselves, or sacrificing it for another individual. In this study, the other individual is the person they are writing about. Participants were instructed as follows: "Imagine that you are presented with the following choices, each of which produces a sum of money for either yourself, or the person that you have written about. Further imagine that your choices are anonymous: they would never know if you selected a sum for yourself, or for them. Please consider the choices as if they were real money, and select the ones that you prefer. Please make a selection for each of the following side-by-side choices."

Decisional forgiveness was measured using the Decision to Forgive Scale (DFS). The DFS is a 8-item scale with 5 scale points for each item. The DFS includes two subscales, the prosocial intention subscale and the harmful inhibition subscale. Hook, Worthington, Utsey, Davis, and Burnette (2012) conducted multiple studies to investigate the psychometric properties of the DFS scale, finding that the full DFS scale and its subscales possess high reliability (.78>αs>.86; Hook, Worthington, Utsey, Davis, & Burnette, 2012). Participants were instructed as follows: “Think of your current intentions toward the person who hurt you. Indicate the degree to which you agree or disagree with the following statements.” Responses ranged from “Strongly Disagree” to “Strongly Agree”.

Emotional forgiveness, an outcome, was measured using the Emotional Forgiveness Scale (EFS). The EFS is an 8-item scale with 5 scale points for each item, and includes the presence of positive emotion subscale, and the reduction of negative emotion subscale. Hook, Worthington, Utsey, Davis, and Burnette (2012) conducted multiple studies to investigate the psychometric properties of the EFS scale, finding that the EFS scale (.69>αs>.83), the presence of positive emotion subscale (.80>αs>.85), and the reduction of negative emotion subscale (.76>αs>.79) all possessed generally high reliability. Participants were instructed as follows: “Think of your current emotions toward the person who hurt you. Indicate the degree to which you agree or disagree with the following statements.” Responses ranged from “Strongly Disagree” to “Strongly Agree”.

Forgiveness motivations were measured using the Transgression-Related Interpersonal Motivation scale (TRIM). This project will utilize the 18-item version of the TRIM (as opposed to the 12 item version) with 5 scale points for each item. This version of the TRIM consists of three subscales: avoidance motivation, benevolence motivations, and revenge motivations. All three subscales possess high reliability (αs>.80; McCullough et al., 1997; McCullough, Fincham, & Tsang, 2003). However, it can be construed as a single unidimensional construct, and analyzed as such (McCullough, Luna, et al., 2010). Participants were instructed as follows: “For the following questions, please indicate your current thoughts and feelings about the person who hurt you; that is, we want to know how you feel about that person right now. Next to each item, circle the number that best describes your current thoughts and feelings." Responses ranged from "Strongly Disagree" to "Strongly Agree". Unlike the other measures of forgiveness used in this study, higher scores on the TRIM indicate *less* forgiveness. Composite TRIM scores were reversed scored in order to increase interpretability of results. As a result, higher TRIM scores in this study reflect more forgiveness.

Genetic relatedness was measured by asking participants to indicate the nature of the relationship between themselves and the person who committed the offense, before the offense occurred. Response options included: Close friend, romantic partner, parent, sibling, work colleague, and other. Participants who indicated that the transgressor was a parent or sibling were coded as genetically related; those who weren't were coded as genetically unrelated. If participants selected "other", they were asked to specify who committed the offense in written detail. If the person was determined to be a genetically related individual (cousin, grandparent, etc.), they were coded as genetically related. Participants were then asked to indicate the sex of the transgressor. Response options included "male" and "female".

Procedure

After signing the informed consent sheet, participants first filled out the relational mobility scale and the IRI to avoid carry-over arousal effects from questions pertaining to transgression recall. They were then asked to recall a past transgression by a close other individual using the following prompt:

> "Please think of a time that a close other person did something to upset you, hurt you, or otherwise commit an offense that caused a rift in your relationship. Please describe what happened, including the context and outcome of the event, using as much detail as possible. Keep in mind that your response here will be kept completely confidential. The person you are writing about will have no way to know that you have written about them, nor how you feel about them."

Participants then responded to measures that concerned the transgression they wrote about, including: the decision to forgive scale, the emotional forgive scale, the transgression-related interpersonal motivations scale, the relationship value and exploitation risk scale, and the welfare trade task. Participants then had the opportunity to provide free response feedback about the survey, and were thanked for their time. The median time to complete the study was 19.38 minutes.

Results

Preliminary analyses

Cronbach's alpha was used to determine the reliability of the TRIM scale (α=.94), the avoidance motivations subscales (α=.93), revenge motivations subscales (α=.81), and benevolence motivations subscales (α=.89). Reliabilities were also obtained for the DFS (α=.69), the prosocial intention subscale (α=.76), the harmful inhibition subscale (α=.56), the EFS (α=.86), the presence of positive emotion subscale (α=.86), the reduction of negative emotion subscale (α=.83), relationship value (α=.91), and exploitation risk (α=.83). All scales demonstrated high reliability (αs>.70), save for the DFS and the harmful inhibition subscale. Implications for the low reliability of the DFS and harmful inhibition subscales are addressed in the discussion section.

Independent samples t-tests were conducted on all dependent measures to determine if the participant's sex influenced results. All statistical tests for both preliminary and primary analyses were two-tailed unless otherwise noted. No sex differences were found on any measures (all *p*s>.05). As such, sex differences were excluded from primary analyses. Finally, zero-order correlations between all measures were calculated; all but one pair of variables were significantly correlated (see Table 2).

Table 2.
Means, standard deviations, and zero-order correlations amongst all variables in the present research.

Variable	*M*	*SD*	1	2	3	4	5	6
1. EFS	3.24	0.88						
2. DFS	4.13	0.61	.72** [.63, .78]					
3. TRIM	4.80	0.81	.84** [.79, .88]	.81** [.74, .85]				
4. Relationship value	3.38	1.13	.72** [.63, .78]	.61** [.50, .70]	.79** [.72, .84]			
5. Exploitation risk	1.96	0.86	-.45** [-.56, -.32]	-.47** [-.58, -.34]	-.51** [-.62, -.39]	-.33** [-.45, -.18]		
6. WTRs	0.45	0.44	.50** [.38, .61]	.51** [.38, .61]	.50** [.38, .61]	.45** [.31, .56]	-.28** [-.41, -.13]	
7. Genetic relatedness	1.14	0.34	.32** [.17, .45]	.25** [.10, .39]	.28** [.13, .41]	.32** [.18, .45]	-.04 [-.19, .11]	.22** [.07, .36]

Note. * Indicates $p < .05$; ** indicates $p < .01$. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation.

Prediction 1: Relationship value, exploitation risk, and forgiveness

Four regression analyses were conducted to examine the effect of relationship value (M=3.38, SD=1.13), exploitation risk (M=1.96, SD=0.86), and their interaction term on TRIM scores (M=4.80, SD=0.81), DFS scores (M=4.13, SD=0.61), and EFS scores (M=3.24, SD=0.88). Relationship value significantly predicted DFS scores (β=0.81, $p<10^{-8}$), EFS scores (β=0.90, $p<10^{-12}$), and TRIM scores (β=0.89, $p<10^{-15}$), while exploitation risk did not predict any measures of forgiveness (ps>.05). The interaction between relationship value and exploitation risk - our prediction of interest - significantly predicted DFS scores (β=-0.44, $p=10^{-8}$; figure 2,), EFS scores (β=-0.38, p=.01; figure 3), and TRIM scores (β=-0.29, p<.03; figure 4), such that a transgressor's increased exploitation risk reduced the effect of relationship value on all measures of forgiveness.

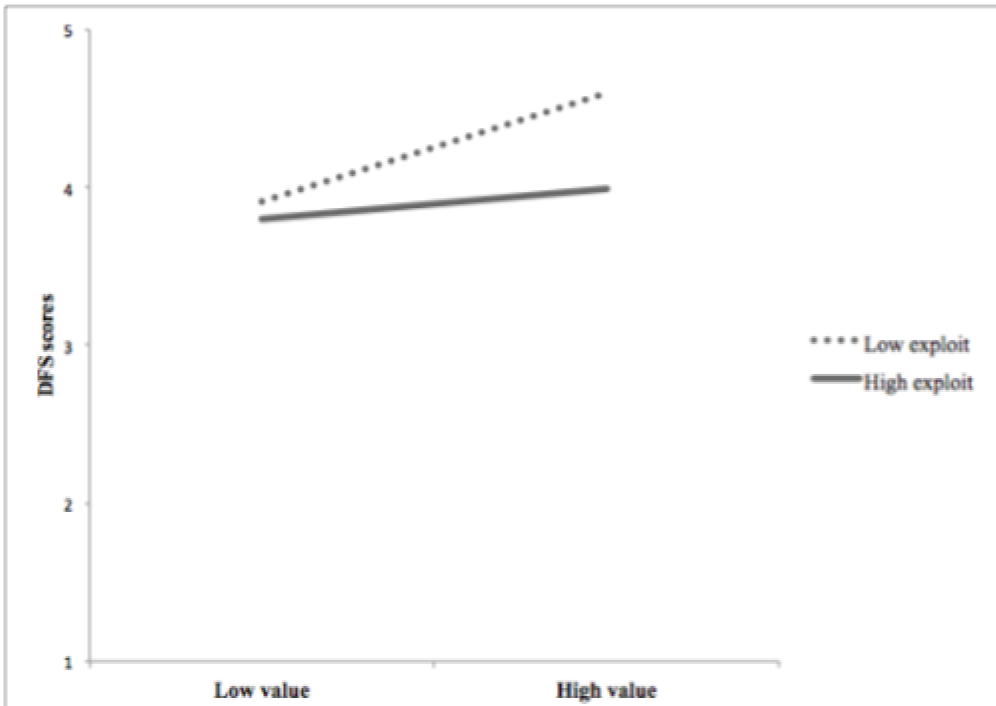

Figure 2. Interaction of relationship value and exploitation risk in predicting DFS scores following a transgression. Low and high values of exploitation risk/relationship value reflect -1/+1 SD scores.

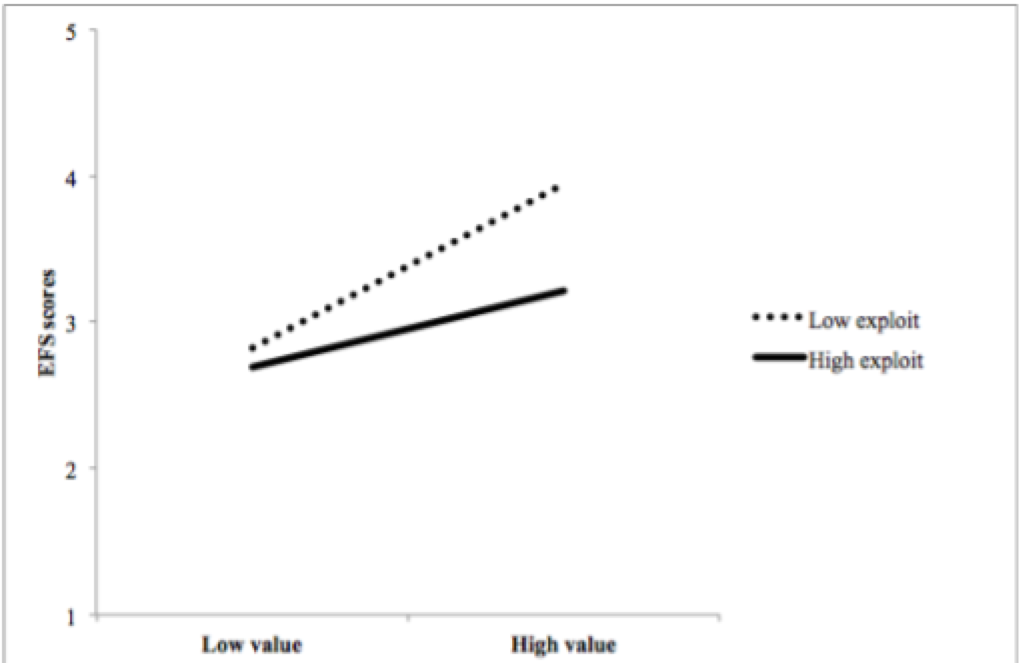

Figure 3. Interaction of relationship value and exploitation risk in predicting EFS scores following a transgression. Low and high values of exploitation risk/relationship value reflect -1/+1 SD scores.

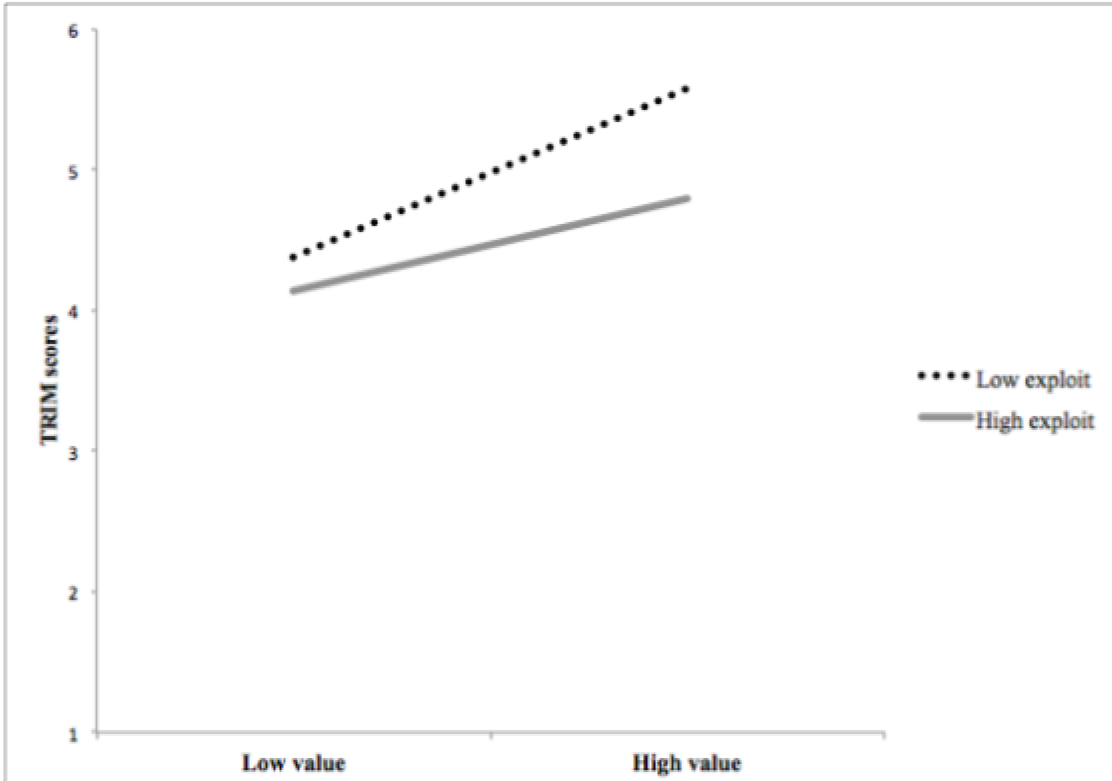

Figure 4. Interaction of relationship value and exploitation risk in predicting TRIM scores following a transgression. Low and high values of exploitation risk/relationship value reflect -1/+1 SD scores.

Prediction 2: Relationship value, exploitation risk, and WTRs

Zero-order correlations revealed that WTRs (*M*=0.45, *SD*=0.44) were significantly correlated with relationship value ($r(166) = 0.45$, $p < 10^{-8}$) and exploitation risk ($r(166) = -0.28$, $p < .001$). WTRs were regressed on relationship value, exploitation risk, and their interaction term. Relationship value significantly predicted WTRs ($\beta = 0.73$, $p < .10^{-5}$), while exploitation risk did not ($p = .15$). The interaction between relationship value and exploitation risk significantly predicted WTRs ($\beta = -0.48$, $p < .05$), such that increased exploitation risk reduced the effect of relationship value on WTRs.

Prediction 3: WTRs and forgiveness

Significant zero-order correlations were found between WTRs and DFS scores ($r(166)=0.51$, $p<10^{-12}$), EFS scores ($r(166)=0.50$, $p<10^{-12}$), and TRIM scores ($r(166)=0.51$, $p<10^{-12}$) (see figure 5).

Figure 5. Zero-order correlations between WTRs and forgiveness decision, emotions, and motivations.

Prediction 4: Mediating effect of WTRs on forgiveness

Three separate mediation analyses were conducted to integrate the findings from predictions 1-3. Mediation analyses were carried out using Andrew Hayes PROCESS macros in SPSS (Hayes, 2013). We utilized PROCESS model 7, which provides a test of the indirect effect of X on Y through M, with first-stage moderation by W. Relationship value was modeled as the antecedent (X), exploitation risk was modeled as the moderator (W), WTRs were modeled as the mediator (M), and each of the three measures of forgiveness were modeled as the outcome (Y). A bias-corrected confidence interval of the indirect effect for each model was generated using 10,000 bootstrapped samples (Rucker, Preacher, Tormala, & Petty, 2011).

The first analysis examined TRIM scores as the primary outcome.The analysis yielded a significant indirect effect of relationship value on TRIM scores, such that relationship value positively exerted an effect on WTRs, which then significantly decreased forgiveness motivations at low levels of exploitation risk, (*b*=0.07, 95% CI=[0.03, 0.12]), but not high levels (*b*=-0.03, 95% CI=[-0.07, 0.01]; *Index of moderated mediation*=-0.03, 95% CI=[-0.06, -0.01]) (See figure 6).

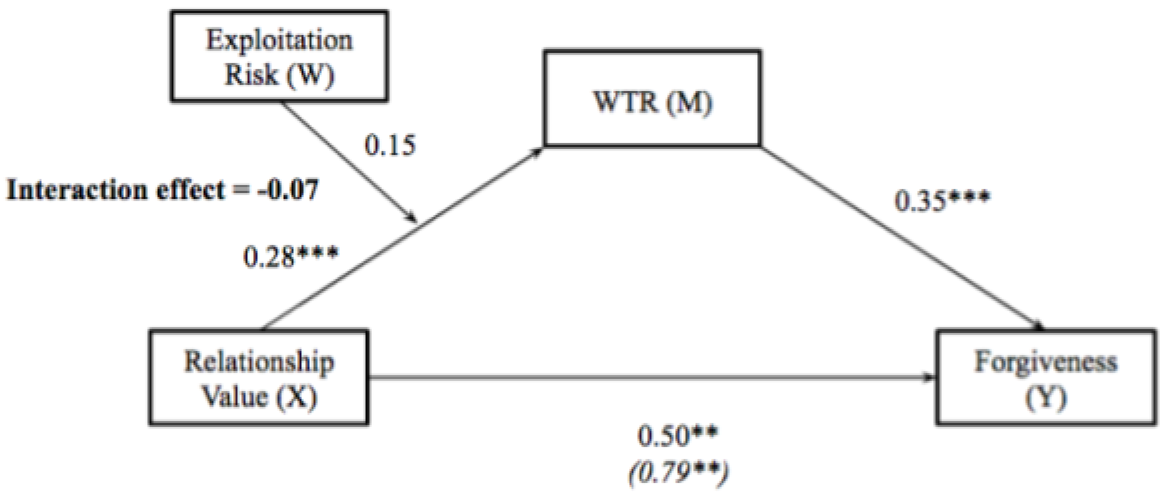

Figure 6. Coefficients for the moderated mediation model examining TRIM scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

The second analysis examined DFS scores as the primary outcome. The analysis yielded a significant indirect effect of relationship value on DFS scores, such that relationship value positively exerted an effect on WTRs, which then significantly increased decisional forgiveness at low levels of exploitation risk (*b*=0.08, 95% CI=[0.04, 0.13]), but not high levels (*b*=-0.03, 95% CI=[-0.01, 0.07]; *Index*=-0.03, 95% CI=[-0.07, -0.01]) (see figure

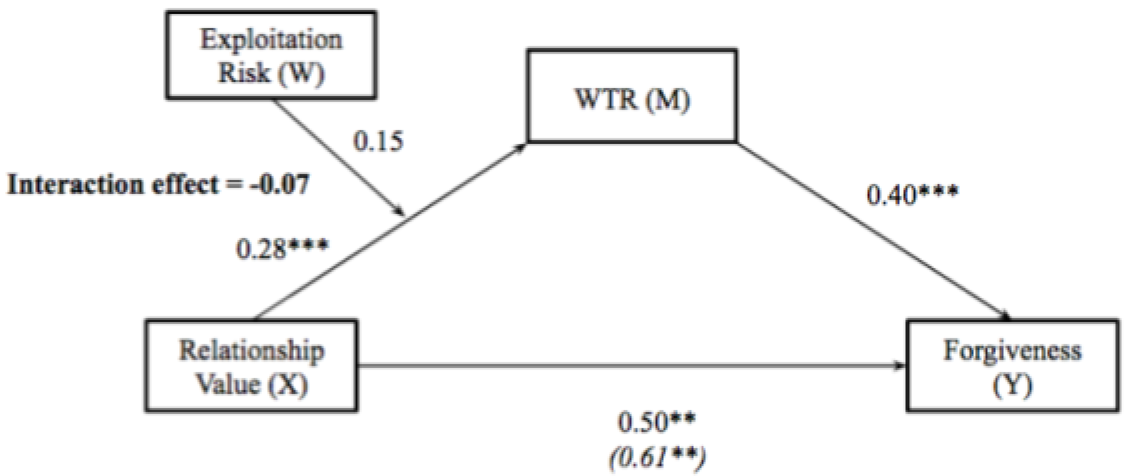

Figure 7. Coefficients for the moderated mediation model examining DFS scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

The third analysis examined EFS scores as the primary outcome. The analysis yielded a significant indirect effect of relationship value on EFS scores, such that relationship value positively exerted an effect on WTRs, which then significantly increased emotional forgiveness at low levels of exploitation risk (b=0.09, 95% CI=[0.04, 0.15]), but not high levels (b=0.03, 95% CI=[-0.01, 0.08]; *Index*=-0.03, 95% CI=[-0.08, -0.01]) (see figure 8).

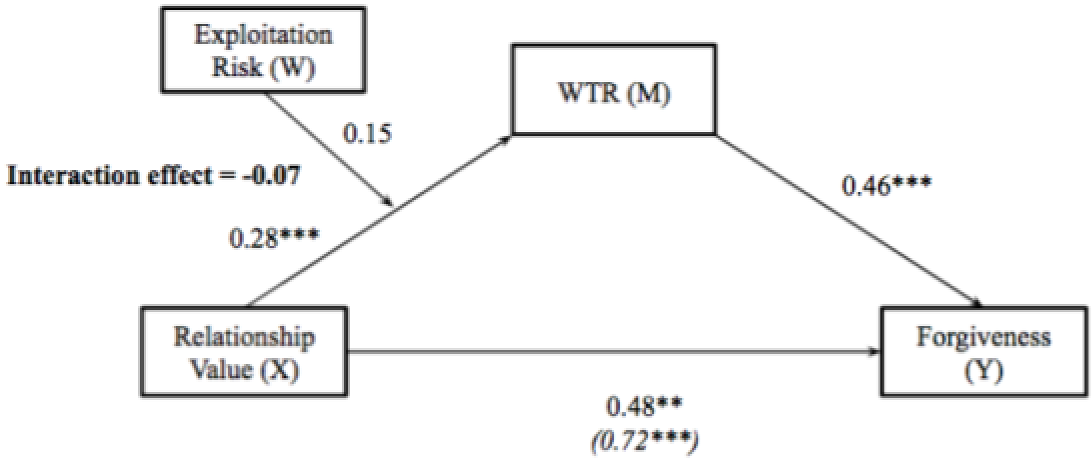

Figure 8. Coefficients for the moderated mediation model examining EFS scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

Prediction 5: Genetic relatedness and WTRs

The relationship between genetic relatedness (dummy codes: 1=unrelated, $n_{unrelated}$=145; 2=related, $n_{related}$=23) and WTRs was examined. Despite the low number of participants who identified genetically related individuals as transgressors (which severely hampered power), the analysis indicated that genetically related transgressors were the targets of higher WTRs, such that participants indicated higher WTRs towards related individuals (M=0.69, SD=0.42) than unrelated individuals (M=0.41, SD=0.43; $t(166)$ =2.89, p<.01) (see figure 4).

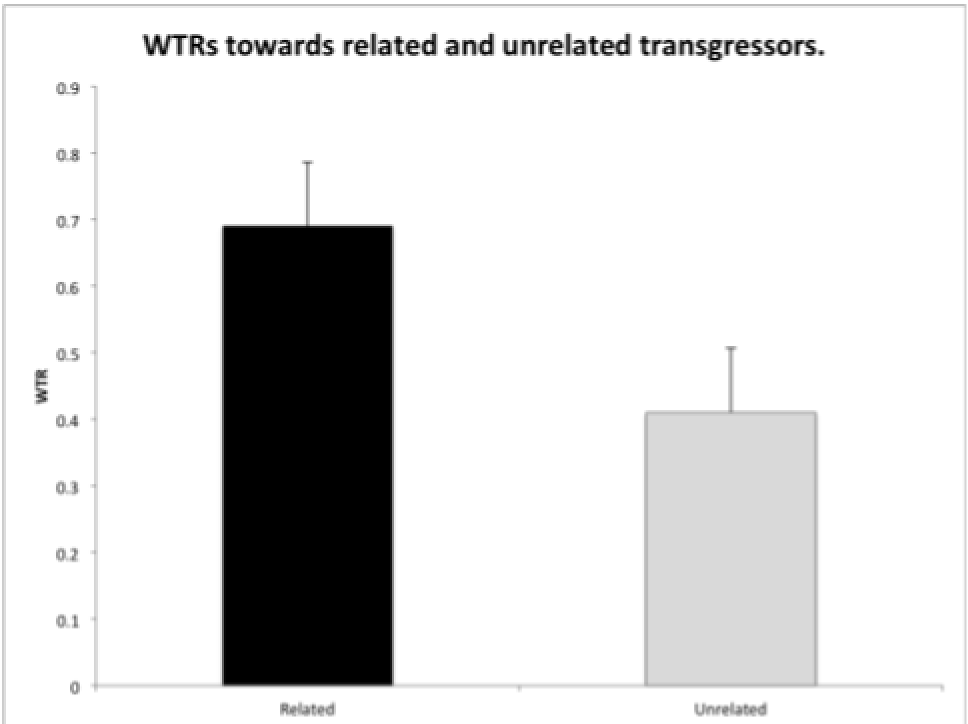

Figure 9. Participants' post-transgression WTRs towards genetically related and unrelated transgressors.

Prediction 6: Genetic relatedness and forgiveness

Zero-order correlations between genetic relatedness and each type of forgiveness were generated. Genetic relatedness was positively related to TRIM scores ($r(166) = 0.28$, $p < .0001$), such that participants indicated higher forgiveness motivations towards related individuals (M=5.37, SD=0.77) than unrelated individuals (M=4.71, SD=0.79). Genetic relatedness was also positively related to DFS scores ($r(166) = 0.50$, $p < .0001$), with participants indicating greater decisional forgiveness towards related individuals (M=4.51, SD=0.55) than unrelated individuals (M=4.07, SD=0.59). Similar patterns were found for EFS scores ($r(166) = 0.32$, $p < .0001$), with participants expressing more emotional forgiveness towards related individuals (M=3.94, SD=0.87) than unrelated individuals (M=3.13, SD=0.83; see table 3).

Table 3.
Correlations between genetic relatedness and forgiveness measures.

Variable	*M*	*SD*	1	2	3
1. Genetic relatedness	1.14	0.34			
2. EFS	3.24	0.88	.32** [.17, .45]		
3. DFS	4.13	0.61	.25** [.10, .39]	.72** [.63, .78]	
4. TRIM	3.80	0.81	.28** [.13, .41]	.84** [.79, .88]	.81** [.74, .85]

Note. * indicates $p < .05$; ** indicates $p < .01$. Genetic relatedness coded such that 1=genetically unrelated, 2=genetically related. EFS=Emotional Forgiveness Scale. DFS=Decisional Forgiveness Scale. TRIM=Transgression-Related Interpersonal Inventory.

Prediction 7: Genetic relatedness, forgiveness, and WTRs.

Three separate mediation analyses were conducted to integrate the findings from predictions 3, 5 and 6. Mediation analyses were carried out using PROCESS model 4 from Andrew Hayes PROCESS macros, a simple mediation model. Genetic relatedness was modeled as the antecedent (X), WTRs were modeled as the mediator (M), and each of the three measures of forgiveness were modeled as the outcome (Y). A bias-corrected confidence interval of the indirect effect for each model was generated using 10,000 bootstrapped samples (Rucker, Preacher, Tormala, & Petty, 2011).

A significant indirect effect was found, such that the effect of genetic relatedness was carried by WTRs in influencing TRIM scores (b=0.24, 95% CI=[0.08, 0.44]; figure 10), DFS scores (b=0.18, 95% CI=[0.06, 0.34]; figure 11), and EFS scores (b=0.25, 95% CI=[0.09, 0.46]; figure 12).

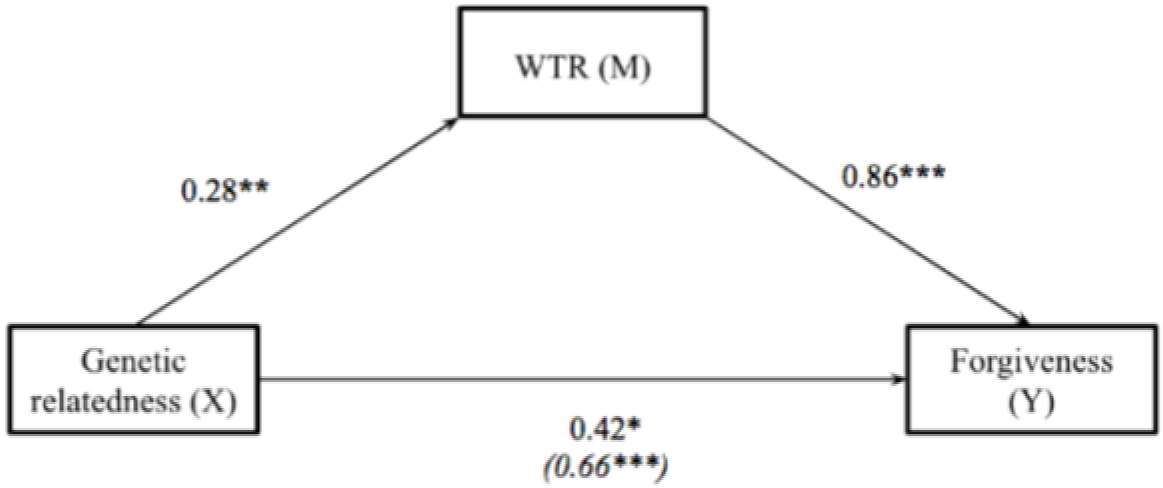

Figure 10. Coefficients for the mediation model examining TRIM scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. *Note*: * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

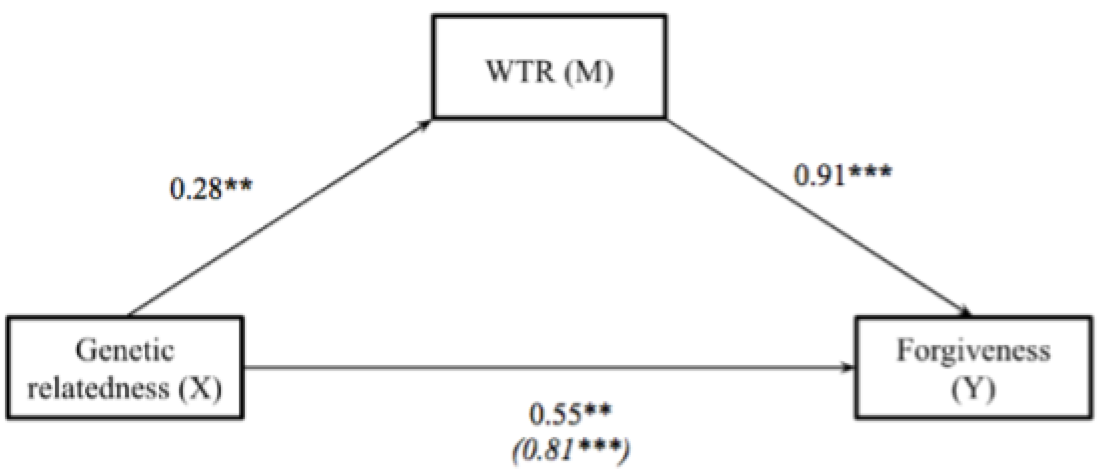

Figure 11. Coefficients for the mediation model examining EFS scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. *Note*: * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

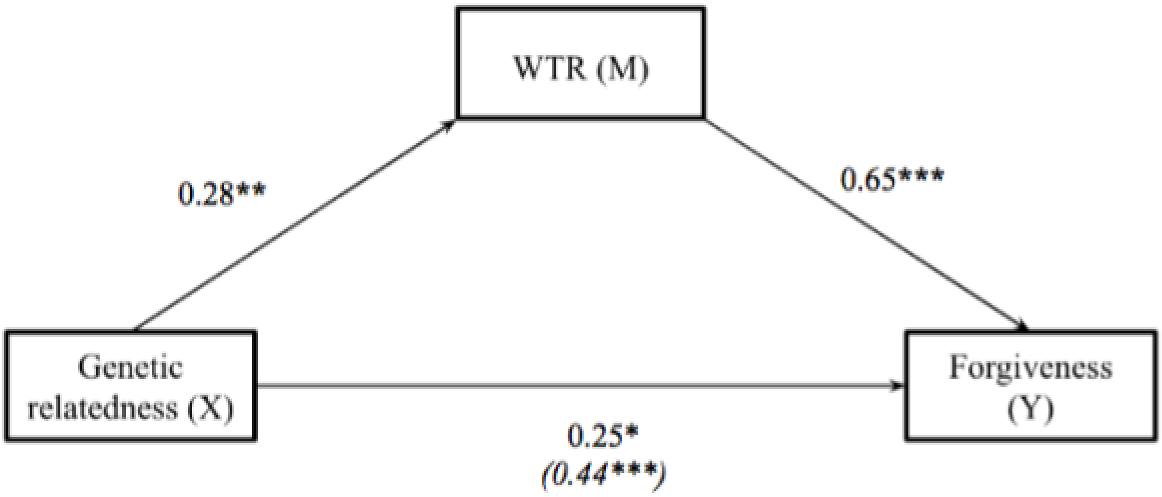

Figure 12. Coefficients for the mediation model examining DFS scores as the outcome. Coefficients in parentheses indicate the unmediated direct effect of X on Y before controlling for M. *Note*: * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

Chapter 3: Discussion and Conclusions

Discussion

Cooperative social relationships are extremely important to human life, conferring numerous fitness benefits and allowing humans to thrive in even the harshest conditions. Maintaining relationships was one of the most important selection pressures that ancestral humans encountered, heavily shaping the trajectory of our cognitive evolution (Henrich, 2016). However, even the strongest relationships come under duress at some point, as partners inevitably transgress against one another in the course of long-term dyads. Rather than abandoning these relationships, victims of transgressions frequently respond by forgiving and restoring the relationship. Forgiveness' crucial role in maintaining valuable cooperative relationships suggests that humans possess evolved, highly-specialized psychological mechanisms designed specifically for forgiveness. Across evolutionary timescales, individuals who forgave valuable relationship partners had higher fitness than individuals who failed to forgive. Successful forgivers did not forgive unconditionally, though; forgiveness was predicated on a complex circuit logic that integrated information pertaining to fitness-relevant criteria, including a transgressor’s perceived relationship value, likelihood of recidivism, and degree of genetic relatedness.

Despite supporting evidence culled from primatology, psychology, and biology, surprisingly little research has empirically investigated the predictions borne out from this theory. The purpose of this study was to fill this research gap. Using real-life instances of transgressions and forgiveness, we tested the hypothesis that evolved forgiveness systems utilize information regarding a transgressor’s degree of genetic relatedness, exploitation risk, and relationship value to estimates a target’s summary value (their WTR). WTRs in turn compute forgiveness outcomes. We first tested four hypotheses pertaining to relationship value, exploitation risk, WTRs, and forgiveness. We tested claims that 1) The interaction between a victim’s perceived relationship value and exploitation risk of a transgressor predicts their WTR towards that transgressor, 2) The interaction predicts forgiveness outcomes independent of WTRs, 3) WTRs predict forgiveness, and 4) The interaction’s effect on forgiveness is mediated by WTRs. Our results supported all four hypotheses. We then proceeded to test hypotheses pertaining to the genetic relatedness, WTRs, and forgiveness, including claims that 5) Degree of genetic relatedness positively predicts WTRs, 6) Degree of genetic relatedness positively predicts forgiveness, and 7) Genetic relatedness’ effect on forgiveness is mediated by WTRs. Our results supported these hypotheses as well.

We believe that our study possesses high ecological validity beyond the laboratory setting. Participants were asked to provide a detailed description of their offense, with many participants providing detailed emotional accounts of the offense. At the end of the survey, participants were asked to provide any additional information they wished, with many indicating that recalling the offense elicited strong emotional feelings, including anger and compassion. Given that emotional reactions are a crucial component of forgiveness' computational architecture, the next logical step is to examine the function of computational mechanisms while including measurements of emotional response.

Implications

These findings contribute to research on the evolved structure of forgiveness in several important ways. We replicated previous findings that forgiveness is computed in part by integrating information pertaining to a transgressor's relationship value and exploitation risk. We believe this is particularly important given the lack of, and concern for, reproducibility in psychological research (Open Science Collaboration, 2015). We also extended previous research on evolved forgiveness systems by examining how the proposed IRVs underlying forgiveness influence multiple distinct forgiveness outcomes. While past research has demonstrated that the interaction between relationship value and exploitation risk predicts forgiveness motivations (Burnette et al., 2012), no research has examined decisional and emotional forgiveness outcomes. Forgiveness decisions, emotions, and motivations were all significantly influenced by the IRVs we examined. Given that decisional and emotional forgiveness map onto facets of forgiveness distinct from forgiveness motivations (Davis et al., 2015), our research provides a clearer picture of the circuit logic governing inter- and intra-personal aspects of forgiveness, and the scope of forgiveness' computational network.

Our findings hone in on the functional logic of forgiveness using a cost-benefit analysis, producing novel insights that can only fall out from an evolutionary perspective. While other research has identified important causal components for forgiveness such as relationship commitment (Finkel et al., 2002) and closeness (Karremans et al., 2011), few studies have explored *why* this is the case. How is this information computationally processed to determine forgiveness? We have begun to address that question in this study. Just as Kirkpatrick and Ellis (2006) usefully reconceptualized self-esteem as a sociometer designed to measure social success or failure, we believe that future forgiveness research will benefit from understanding forgiveness as a functional response to maintaining valuable social relationships, obviating costly revenge, and reaping cooperative fitness gains.

While the findings presented here contribute directly to forgiveness research, they also add to broader evolutionary theory suggesting that the mind is composed of a network of specialized psychological mechanisms in two distinct ways (Cosmides & Tooby, 2013). First, our findings add to the literature on IRVs and WTRs, offering new insight into the shared architecture of modular cognition. An accumulating body of evidence suggests that WTRs underlie many key socio-emotional processes, feeding not only into forgiveness computations, but also altruism towards kin (Lieberman et al., 2007), anger towards foes (Sell et al., 2009), partner selection (Delton & Robertson, 2012; Tooby & Cosmides, 1996), and non-kin reciprocity (Lim, 2012). Given the usefulness of WTRs in explaining a wide array of social phenomena, they may be a strong candidate for understanding the computational structure of other complex cognitive processes. For example, dual-processing theories of cognition (Evans & Stanovich, 2013) may benefit from modeling explicitly WTRs, as they lie at the interface between automatic and effortful cognition (Tooby et al., 2008).

WTRs' role as a computational node shared by specialized psychological mechanisms is emblematic of evolutionary psychology's broader perspective of the human mind. Within an evolutionary framework, psychological mechanisms are viewed as integrated parts of a whole, wherein each psychological mechanism performs a specific duty, with shared information distributed across mechanisms to produce optimal engineering designs, given constraints (Barrett & Kurzban, 2006). Social behavior, then, is connected by the shared language of costs and benefits, adaptive value, and problem-solving; divisions between cognition, emotion, motivation, and behavior are eliminated. The end result of this efforts is the identification and integration of myriad cognitive tributaries that lead back to domain-specific fitness gains and losses. This perspective connects otherwise seemingly disparate phenomena such as incest disgust (Tybur et al., 2013), friendship formation (Tooby & Cosmides, 1996), romantic attachment (Kirkpatrick, 1998), commitment to extremist organizations (Fessler & Quintelier, 2013), and retributional sentiment (Petersen et al., 2009), amongst other mechanisms. We believe that forgiveness can be added to this list as well, allowing us to organize our findings within a broader research context.

Second, evolutionary psychology recasts the mind as an explicitly computational device. Social relationships are understood in terms of quantifiable WTRs (Delton, 2010); emotions are superordinate programs that coordinate memory, perception, motivation, and other neuro-psycho-physiological processes to produce adaptive responses (Cosmides & Tooby, 2013); and cognitive biases are ecologically rational strategies implemented with respect to contingent environmental costs and benefits (Haselton & Buss, 2000). Evolutionary psychology provides coheres these otherwise unrelated research topics, emphasizing causal reasoning (i.e., functional logic) and unpacking exciting new questions. We view the current findings on forgiveness as an important incremental contribution to this literature, helping to move the field towards a precise mapping of the human mind.

Limitations and future directions

While this thesis addressed outstanding questions surrounding evolved forgiveness systems, it also raises new questions to be explored in future studies. One important question is the role of emotion in forgiveness. At the end of the survey participants were invited to provide any other thoughts, questions, or concerns they had about the study. Many participants described strong emotional reactions in recounting their victim experience, often reporting feelings of renewed anger and compassion. This leads us to believe that our manipulation was very strong, and produced results with high ecological validity. However, we neglected to quantitatively capture emotional responses. Future research should include psychological and physiological measures of relevant emotional patterns, such as anger, empathy. This seems particularly important given that emotional responses are posited as the causal pathway through which forgiveness cognition takes place (McCullough et al., 1998; Smith et al., 2016).

We encountered two statistical issues in our study. First, the DFS scale possessed low reliability, and the version used here may be psychometrically inferior to more recent versions of the scale (Davis et al., 2015). As such, the variance accounted for by the DFS scale may largely represent random measurement error rather than a true effect. While this seems unlikely given that measures of emotional forgiveness and forgiveness motivations produced similar results, it remains a possibility. Second, a significant effect was found for genetic relatedness, despite the low number of participants who indicated that a family member had transgressed against them. While this may indicate that we had a large effect driving our study, small sample sizes are particularly vulnerable to false positives (Simmons, Nelson, & Simonsohn, 2011). Future studies should attempt to replicate our findings while employing a large number of individuals with transgressing family members.

Our study linked together forgiveness computations in a mediating fashion, supporting theory that suggests causality. However, the cross-sectional research design we utilized ultimately limits the strength of this conclusion. Future research should employ longitudinal research designs to ameliorate this uncertainty. Longitudinal research designs model change over time, which is particularly important in the case of forgiveness. Previous research shows that forgiveness is an inherently temporal phenomenon, wherein forgivers reliably decrease revenge and avoidance motivations over time (McCullough, Fincham, & Tsang, 2003), and that rates of change in relationship value and exploitation risk IRVs correlate with the temporal component of forgiveness (McCullough et al., 2010). In addition to longitudinal designs, experimental research designs may also bolster our findings. We chose to focus on real life transgression in this study, believing that real transgressions would elicit the full phenomenological experience of forgiveness. While this appeared to be a success, the tight control of experimental designs can hone in on specific mechanistic pathways, varying a hypothetical target's relationship value, exploitation risk, and WTR valuation.

A further improvement on the current design would be the employment of different statistical analysis. Our study relied on path modeling techniques in examining the causal flow of forgiveness computations. While path models allow us to address nuanced research questions, they (along with multiple regression models) make restrictive assumptions that may not hold in practice (Pedhazur, 1982), and fail to capture the complex relationships amongst all the variables we have investigated. An alternative solution would to be analyze these relationships using a structural equation model. While the present thesis modeled sets of interrelations between IRVs and forgiveness, we were unable to integrate all of our results into a single SEM model for two reasons. First, it was unclear if the proposed relationships between IRVs and forgiveness existed in the first place, as many of the effects we examined were novel. Second, our study was underpowered, lacking the required sample size necessary to detect an effect. We were also hampered by uncertainty regarding certain effect sizes, some of which had never been explored. We consider the study here to be a necessary first step before undertaking an SEM analysis. Given that some of these issues have been ameliorated by the findings from this study, and that the evolved structure of forgiveness is composed of highly dependent interrelated IRVs (see figure 1), an SEM model should be implemented to provide a more nuanced understanding of forgiveness systems.

Finally, the circuit logic governing forgiveness systems is almost certainly more complex than the IRVs investigated in this thesis. A complex network of computations involving formidability, group membership, institutional punishment, social norms, and other relevant variables likely figure into forgiveness. These computations likely interact with individual differences, which renders different costs and benefits for forgiveness based on the individual’s ability to successfully implement forgiveness. For example, physically attractive women are much more prone to anger than relatively less attractive women (Sell et al., 2009), which may make them less likely to forgive. Relevant individual differences that may influence forgiveness include additive genetic effects (Eaves et al., 2008), whether a victim is male or female (Bettencourt & Miller, 1996), and a victim's upper body strength relative to the transgressor (Fessler, Holbrook, & Gervais, 2014). To gain a full picture of forgiveness' evolved structure, future research should investigate how personality differences, environmental factors, and their interaction cumulatively influence forgiveness mechanisms. In fact, our current research program has already begun to examine some of these contributory factors, which is detailed next.

Broader project design

The studies described in this thesis are part of a broader project that aims to examine forgiveness mechanisms not only in the United States, but across diverse cultural environments. Our initial goal - and the one that was supported by the results in this thesis - was to determine if evolved forgiveness mechanisms function in accordance with the theoretical literature. Having established that this is the case, our next step is to determine how forgiveness mechanisms function in different cultures, focusing on variance in cultural dimensions that are likely to impact forgiveness. We believe that a cross-cultural investigation is important for three reasons.

First, as previously mentioned, a comprehensive understanding of how forgiveness mechanisms function necessitates understanding the full suite of endogenous and exogenous factors that influence forgiveness. Situational and ecological characteristics are among the most poorly understood factors influencing the evolved function of forgiveness (McCullough et al., 2013), making them good candidates for investigation.

Second, while the evidence for evolved forgiveness mechanisms is compelling, most of the supporting research has been limited to populations from the United States and Europe to the exclusion of non-Western cultures, a trend that is not unique to the study of forgiveness (Henrich, Heine, & Norenzayen, 2010). Gaining a cross-cultural perspective on forgiveness mechanisms is crucial, as understanding a putative adaptation in diverse cultural settings provides better resolution of its species-wide functionality (Barkow, Cosmides, & Tooby, 1995). Cognitive mechanisms cannot function absent cultural input, and rarely produce isomorphic output across variant cultural landscapes (Apicella & Barrett, 2016; Gangestad, Haselton, & Buss, 2006; Tooby & Cosmides, 1992). These mechanisms are frequently facultative by *design*, displaying dynamic expression across variant environments to yield plastic responses (Gangestad & Buss, 1993).

Finally, social psychological research has shown that patterns of forgiveness are highly variant across different cultural environments (Hook et al., 2009; Hook et al., 2012; Karremans et al., 2011; Ohtsubo et al., 2012; Sandage, Hill, & Vang, 2003). Cultural differences underlying forgiveness have primarily been described in terms of differences in individualism and collectivism (Triandis, 1995). Individualistic cultures are those that endorse independent self-construals where individuals are self-oriented, separated from their social context, functioning as unique, distinctive entities that autonomously navigate cultural milieu absent a social reference point. In contrast, collectivistic cultures endorse interdependent self-construals, where individuals are other-oriented, more connected to, and less differentiated from, others in their social group, with a self that is non-distinct from other members of their social group (Markus & Kitayama, 1991). Individualism and collectivism load onto cultural differences in forgiveness. Individualists tend to view relationships as contracts, value self-forgiveness highly, aim for personal well-being in forgiving, and make a well-defined distinction between reconciliation and forgiveness; collectivists tend to view relationships as covenants, possess low value for self-forgiveness, aim for social well-being in forgiving, and consider reconciliation to be closely related to forgiveness (Sandage & Wiens, 2001). These numerous cross-cultural differences arise as a function of the different goals and norms imbued by individualist and collectivist worldviews, such that collectivists forgive for the sake of maintaining social harmony, while individualists forgive in order to achieve inner peace (Karremans et al., 2011; Sandage & Williamson, 2005). Differences in individualist and collectivist forgiveness tendencies map onto emotional and decisional forgiveness, with collectivists resolving transgressional with decisional forgiveness, but not emotional forgiveness, and individualists displaying the opposite pattern (Hook et al., 2009; Hook, Worthington, Utsey, David, & Burnette, 2012; Huang & Enright, 2000).

It is currently unclear how relationship value, exploitation risk, and genetic relatedness map onto differences in emotional and decisional forgiveness tendencies in countries outside of the United States. For example, it may be that the patterns of IRVs and forgiveness observed in this thesis are inconsistent with those found in East Asian countries. Evidence suggests this may be the case, as important predictors of forgiveness in Western societies, such as relationship closeness, are significantly less predictive of forgiveness in Eastern societies (Karremans et al., 2011).

Socio-ecological roots of forgiveness

Previous research indicates robust cross-cultural differences in forgiveness, such that Eastern societies emphasize inter-individual decisional forgiveness and Western societies emphasize intra individual emotional forgiveness (Davis et al., 2015; Hook et al., 2009, 2012; Karremans et al., 2011). However, little research has determined *why* this is the case. Why do individuals from Western societies emphasize intra-individual emotional forgiveness, and why do individuals from East Asian societies emphasize inter-individual decisional forgiveness?

Just as a goal of this thesis was to identify why individuals display the forgiveness patterns that they do using an evolutionary perspective, our goal in pursuing a cross-cultural project is to determine why cross-cultural differences emerge by taking a *socio-ecological* perspective. Social ecologies are the objective social and physical features that constitute people's habitats, comprised of macrostructures such as political, economic, religious and societal systems, as well as geography, climate, and widespread architectural characteristics (Oishi & Graham, 2010). The socio-ecological perspective addresses how differences in psychology and behavior arise as adaptive strategies that individuals adopt to maximize self-benefits in a particular context (Kesebir, Oishi, & Spellman, 2010; Yamagishi, Hashimoto, & Schug, 2008). One benefit of the socio-ecological approach is that it removes the ambiguity of cultural syndromes, allowing researchers to identify objective antecedents of culture rather than focusing on causally agnostic cultural descriptions. By adopting the socio-ecological perspective, researchers can begin to address the question, "What causal factors give rise to and sustain cultural phenomena?"

Socio-ecological psychology feeds into the evolutionary framework by specifying the discrete, quantifiable information available in an environment, and how that information serves as input into evolved psychological mechanisms. In the case of the individualism-collectivism dimension, for example, it is unclear precisely how individualism and collectivism serve as input into the IRVs governing evolved forgiveness mechanisms. While there are clearly underlying attributes of individualism-collectivism that influence evolved mechanisms, descriptive concepts such as 'prioritizing social harmony' and 'emphasis on independent self-construal' do not non-trivially serve as input on their own. The socio-ecological approach also shares conceptual affinity with evolutionary psychology. Both model phenotypic plasticity at different levels of analysis; the evolutionary approach focuses on biological adaptations that are crafted phylogenetically across epochal timescales, while the socio-ecological approach focuses on cultural adaptations that emerge ontogenetically across individual lifespans. Both are interested in causal explanations of phenomena; the evolutionary approach focuses on ultimate explanations of how organisms have attained their features as a function of selection pressures imposed by the EEA, while the socio-ecological approach focuses on why cultural beliefs emerge as a function of the incentive structures imposed by objective ecological features. Most notably, both generate predictions based on the game theoretic premise that organisms respond to incentive structures, wherein decision-making is guided by cost-minimization.

Socio-ecological differences are relevant for a proposed forgiveness adaptation. Ecological conditions can shape the value of relationship partners compared to one's current partners (Tooby & Cosmides, 1996), the and the kinds of familial relationships individuals form in those conditions (Van Lange et al., 1997). For example, ecological conditions that engender low probabilities of re-encountering relationship partners (Krasnow, Delton, Tooby, & Cosmides, 2013) may reduce the likelihood that individuals forgive, and the kinds of forgiveness strategies (i.e., emotional, decisional) that are employed. It is plausible that a low probability of re-meeting a partner may lower the relative value of that partner. Similarly, ecological conditions, such as those characterized by cultures of honor (Cohen, Nisbett, Bowdle, & Schwarz, 1996), may lead to relatively less forgiveness as a function of heightened perceptions of violence and the exploitation risk posed by transgressors. Indeed, cultures that permit the widespread propagation of violence endure significantly more revenge behaviors, indicating that forgiveness is likely much lower (Gelfand et al., 2012). These are just a few examples of the ways in which ecological conditions may influence forgiveness mechanisms.

The broader project utilizes a cross-cultural survey design that examines patterns of forgiveness in participants from Japan and the United States. Japan and the United States are the ideal countries to study forgiveness, as they foster societies that are maximally different in terms of relational mobility, the degree to which individuals in a given context have the opportunity to form new relationships and leave existing ones (e.g., Schug, Yuki, & Maddux, 2010). It is extremely difficult to form new social relationships in Japanese society, while the United States offers a society that affords many opportunities to form new relationships. The present study constitutes the United States portion of the project, and the Japanese portion of this study will take place during the summer of 2017.

Conclusion

Researchers have suggested that the human mind contains evolved psychological mechanisms engineered for forgiveness, mechanisms that are designed to process fitness-relevant information in order to produce cooperation promoting and revenge reducing outcomes. The results of our study support this hypothesis, honing in on the computational role of relationship partner value, exploitation risk, and familial status in computing whether to forgive or not. They also point to the existence of interoceptive psychological mechanisms (i.e., IRVs) that fuel these evolved systems, and likely undergird many other social phenomena. We hope to build on this research in the future by examining how forgiveness systems function across variant cultural environments, identifying other IRVs that provide intermediate computations, and connecting theory on forgiveness systems to other psychological mechanisms underlying cooperation. Ultimately, we seek to gain a better understanding of the causal roots of forgiveness, with the hope that this knowledge may serve as an anodyne to the violence and aggression prevalent the world over.

Appendix

Description of the offense

Please think of a time that a close other person did something to upset you, hurt you, or otherwise commit an offense that caused a rift in your relationship. Please describe what happened, including the context and outcome of the event, using as much detail as possible.

Keep in mind that your response here will be kept completely confidential. The person you are writing about will have no way to know that you have written about them, nor how you feel about them.

Nature of the pre-transgression relationship with the offender

Please indicate the nature of the relationship between yourself and the person who committed the offense, before the offense occurred.

- ○ Close friend
- ○ Romantic partner
- ○ Parent
- ○ Sibling
- ○ Work colleague
- ○ Other (please specify)

EFS

Think of your current emotions toward the person who hurt you. Indicate the degree to which you agree or disagree with the following statements.

	Strongly Disagree (SD)	Disagree (D)	Neutral (N)	Agree (A)	Strongly Agree (SA)
1. I care about him or her.	SD	D	N	A	SA
2. I no longer feel upset when I think of him or her.	SD	D	N	A	SA
3. I'm bitter about what he or she did to me.	SD	D	N	A	SA
4. I feel sympathy toward him or her.	SD	D	N	A	SA
5. I'm mad about what happened.	SD	D	N	A	SA
6. I like him or her.	SD	D	N	A	SA
7. I resent what he or she did to me.	SD	D	N	A	SA
8. I feel love toward him or her.	SD	D	N	A	SA

Reverse code: 3, 5, 7
Presence of Positive Emotion subscale items: 1, 4, 6, 8
Reduction of Negative Emotion subscale items: 2, 3, 5, 7

DFS

Think of your current intentions toward the person who hurt you. Indicate the degree to which you agree or disagree with the following statements.

	Strongly Disagree (SD)	Disagree (D)	Neutral (N)	Agree (A)	Strongly Agree (SA)
1. I intend to try to hurt him or her in the same way he or she hurt me.	SD	D	N	A	SA
2. I will not try to help him or her if he or she needs something.	SD	D	N	A	SA
3. If I see him or her, I will act friendly.	SD	D	N	A	SA
4. I will try to get back at him or her.	SD	D	N	A	SA
5. I will try to act toward him or her in the same way I did before he or she hurt me.	SD	D	N	A	SA
6. If there is an opportunity to get back at him or her, I will take it.	SD	D	N	A	SA
7. I will not talk with him or her.	SD	D	N	A	SA
8. I will not seek revenge upon him or her.	SD	D	N	A	SA

Reverse code: 1, 2, 4, 6, 7
Prosocial Intention subscale items: 2, 3, 5, 7
Inhibition of Harmful Intention subscale items: 1, 4, 6, 8

Trim-18
(McCullough, Root, & Cohen, 2006)

For the following questions, please indicate your current thoughts and feelings about the person who hurt you; that is, we want to know how you feel about that person **right now**. Next to each item, circle the number that best describes your current thoughts and feelings.

1. I'll make him/her pay.	1	2	3	4	5
2. I am trying to keep as much distance between us as possible.	1	2	3	4	5
3. Even though his/her actions hurt me, I have goodwill for him/her.	1	2	3	4	5
4. I wish that something bad would happen to him/her.	1	2	3	4	5
5. I am living as if he/she doesn't exist, isn't around.	1	2	3	4	5
6. I want us to bury the hatchet and move forward with our relationship.	1	2	3	4	5
7. I don't trust him/her.	1	2	3	4	5
8. Despite what he/she did, I want us to have a positive relationship again.	1	2	3	4	5
9. I want him/her to get what he/she deserves.	1	2	3	4	5
10. I am finding it difficult to act warmly toward him/her.	1	2	3	4	5
11. I am avoiding him/her.	1	2	3	4	5
12. Although he/she hurt me, I am putting the hurts aside so we can resume our relationship.	1	2	3	4	5
13. I'm going to get even.	1	2	3	4	5
14. I have given up my hurt and resentment.	1	2	3	4	5
15. I cut off the relationship with him/her.	1	2	3	4	5
16. I have released my anger so I can work on restoring our relationship to health.	1	2	3	4	5
17. I want to see him/her hurt and miserable.	1	2	3	4	5
18. I withdraw from him/her.	1	2	3	4	5

Scoring Instructions

Avoidance Motivations:
Add up the scores for items 2, 5, 7, 10, 11, 15, and 18

Revenge Motivations:
Add up the scores for items 1, 4, 9, 13, and 17

Benevolence Motivations
Add up the scores for items 3, 6, 8, 12, 14, and 16

Welfare Tradeoff Task

In the following questions please imagine the following scenario: you are given a choice between two monetary options. Your choice determines how much money either you, or the person that you have written about today, would receive. If you choose one of the options, a sum of money will be given to you and no money will be given to the other person. If you choose another option, a sum of money will be given to the other person and no money will be given to you.

There are no right or wrong choices, only those that you prefer. All choices are anonymous: the other person would never know if you selected a sum for yourself, or for them. Please treat the choices as if they were real money, and select the ones that you prefer.

Page Break

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$85 for you $0 for the other	$0 for you $75 for the other
○	○

Condition: $85 for you $0 for the other Is Selected. **Skip To:** Imagine that you are presented with t.... Options

Page Break

Just to confirm, you prefer to provide $75 to the other person, rather than receive $85 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm
○

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$0 for you $75 for the other	$75 for you $0 for the other
○	○

Condition: $75 for you $0 for the other Is Selected. Skip To: Imagine that you are presented with t....

Page Break

Just to confirm, you prefer to provide $75 to the other person, rather than receive $75 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm
○

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$0 for you $75 for the other	$55 for you $0 for the other
○	○

Condition: $55 for you $0 for the other Is Selected. Skip To: Imagine that you are presented with t....

Page Break

Just to confirm, you prefer to provide $75 to the other person, rather than receive $55 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm
○

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$45 for you $0 for the other	$0 for you $75 for the other
○	○

Condition: **$45 for you $0 for the other Is Selected**. Skip To: **Imagine that you are presented with t....**

Page Break

Just to confirm, you prefer to provide $75 to the other person, rather than receive $45 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm

○

Just to confirm, you prefer to provide $75 to the other person, rather than receive $35 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm

○

Condition: **Confirm Is Selected**. Skip To: **End of Block**.

- - - - - - - - - - Page Break - - - - - - - - - -

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$25 for you $0 for the other	$0 for you $75 for the other
○	○

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$0 for you $75 for the other	$15 for you $0 for the other
○	○

Condition: $15 for you $0 for the other Is Selected. Skip To: Imagine that you are presented with t....

- - - - - - - - - - Page Break - - - - - - - - - -

Just to confirm, you prefer to provide $75 to the other person, rather than receive $15 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm

○

Just to confirm, you prefer to provide $75 to the other person, rather than receive $5 for yourself?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm

○

Condition: **Confirm Is Selected**. Skip To: **End of Block**.

- - - - - - - - - - - - - - - - Page Break - - - - - - - - - - - - - - - -

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$0 for you $75 for the other ○	$0 for you $0 for the other ○

Imagine that you are presented with the following choice, each of which produces either a sum of money for you or or the person you have written about today. Please select one of the choices.

$ -5 for you $0 for the other	$0 for you $75 for the other
○	○

Condition: **$ -5 for you $0 for the other Is Selected.** Skip To: **End of Block.**

Page Break

Just to confirm, you prefer to provide $75 to the other person, rather than pay $5?

If yes, click "confirm". Otherwise, use the "<<" button at the bottom left corner of the page to go back.

Confirm

○

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Smith, A., Yagi, A., Yamaura, K., Shimizu, H., Ohtsubo, Y. (2016). *Why we forgive our valuable partners: Rational calculation, emotional adaptation, or a mixture of both?* Poster presented at the 28th annual meeting of the Human Behavior and Evolution Society in Vancouver, Canada.

Sznycer, D., Takemura, K., Delton, A. W., Sato, K., Robertson, T., Cosmides, L., & Tooby, J. (2012). Cross-Cultural Differences and Similarities in Proneness to Shame: An Adaptationist and Ecological Approach. *Evolutionary Psychology*, *10*(2).

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Wu, J., & Axelrod, R. (1995). How to cope with noise in the iterated prisoner's dilemma. *Journal of Conflict resolution*, *39*(1), 183-189.

Yamagishi, T., Hashimoto, H., & Schug, J. (2008). Preferences versus strategies as explanations for culture-specific behavior. *Psychological Science*, *19*(6), 579-584.

Curriculum Vitae (updated June 23rd, 2017)

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PERSONAL INFORMATION

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EDUCATION

University of Miami, Miami, FL
PhD, Psychology, 2022 (expected)
Major areas: Evolution and Human Behavior
Advisor: Dr. Michael McCullough

College of William & Mary, Williamsburg, VA
MA, Experimental Psychology, 2017
Major Areas: Social Psychology and Evolutionary Psychology
Advisor: Dr. Joanna Schug
Masters Thesis: Computational structure of evolved forgiveness systems.

University of Delaware, Newark, DE
BS, Psychology, 2014
Major Areas: Social Psychology and Clinical Psychology
Advisors: Dr. D. Michael Kuhlman and Dr. Adele Hayes
Senior Thesis: Self-reported neuroticism, judgments of neuroticism by others, and the facial width-to-height ratio.

HONORS AND AWARDS

2017 *Funding*, National Science Foundation research fellowship (~$15,000) - East Asia and Pacific Summer Institute Fellowship, Kobe University, Japan, awarded for summer 2017

2016 *Funding*, presentation travel award ($100) – 28th annual Human Behavior and Evolution Society student travel award

2016 *Funding*, student research grant ($300) – Arts & Sciences Graduate Research Grant, College of William & Mary, awarded for fall 2016

2016 *Nomination*, Japanese Ministry of Affairs Friendship Ties Competitive Study Abroad program, College of William & Mary

2015 *Funding*, presentation travel award ($300) – Arts & Sciences Graduate Student Association Conference Funds, College of William & Mary

RESEARCH

Accepted manuscripts

2016 Hayes, A. M., Yasinski, C., Grasso, D., Ready, C. B., Alpert, E., **McCauley, T. G.**, Webb, C., & Deblinger, E. Constructive and unproductive processing of traumatic experiences in trauma-focused cognitive-behavioral therapy for youth. *Behavior Therapy*.

2016 Yasinski, C., Hayes, A.M., Ready, C.B., Cummings, J., Berman, I., **McCauley, T.G.**, Webb, C., Deblinger, E. In-session caregiver behavior predicts symptom change in youth receiving trauma-focused cognitive behavioral therapy. *Journal of Consulting and Clinical Psychology*.

PRESENTATIONS

2017 **McCauley, T.G., Ohtsubo, Y., and** Schug, J. *A cross-cultural study of the relationship between social ecology and evolved cognitive systems for forgiveness*. Poster presented at the 2017 Japan Society for Promotion of Science summer experience in Sokendai, Japan.

2016 **McCauley, T.G.** *Social ecology and the evolved function of forgiveness*. Talk given at the College of William & Mary's Department of Psychology colloquium series.

2016 **McCauley, T.G.,** Schug, J., Yokotoa, K. *Social ecology moderates the extent to which synchrony enhances group cooperation*. Poster presented at the 28th annual meeting of the Human Behavior and Evolution Society.

2016 Lamba, A., Schug, J., and **McCauley, T. G**. *Simulating cooperative dynamics on static networks with stochastic modeling*. Poster presented at the 28th annual meeting of the Human Behavior and Evolution Society.

2016 Lamba, A., Schug, J., **McCauley, T.G**. *Allelic variation in the oxytocin transporter gene relates to social but not non-social risk taking*. Poster presented at the 10th annual meeting of the Northeastern Evolutionary Psychology Society.

2016 **McCauley, T.G.** *Synchrony, cooperation, and trust*. Talk given at the 15th annual William & Mary Graduate Research Symposium.

2015 **McCauley, T.G.**, Schug, J., Wiltermuth, S.S., Yokotoa, K., & Ensign, A. *A cross-cultural comparison of the effects of synchrony and relational mobility on in-group cooperation*. Talk given at the 37th annual meeting of the Society of Southeastern Social Psychologists.

2015 **McCauley, T.G**., Gemino, H., Furey, W., Heidt, R., Stivers, A., & Kuhlman, D. *Facial width-to-height ratio and aggression*. Poster presented at the 86th annual meeting of the Eastern Psychological Association.

2014 **McCauley, T. G.** *Self-reported neuroticism, judgment of neuroticism by others, and the facial width-to-height ratio*. Poster presented at the University of Delaware Psychological and Brain Sciences research symposium.

2013 Prokop, T., Gemino, H., **McCauley, T. G.,** Furey, W., Francisco, D., Heidt, R., Piazza, P., Riggelman, J. *Physical attractiveness and the facial width-to-height ratio in cooperators, competitors, and individualists*. Poster presented at the University of Delaware Psychological and Brain Sciences research symposium.

RESEARCH EXPERIENCE

Evolution and Human Behavior Lab, August 2017 (expected start date)
Principal Investigator: Dr. Michael McCullough
Role: Graduate Research Assistant

Evolutionary Social Psychology Lab, June 2017-August 2017
Principal Investigator: Dr. Yohsuke Ohtsubo
Role: Visiting Research Fellow

Mind and Society Lab, June 2015-June 2017
Principal Investigator: Dr. Joanna Schug
Role: Graduate Research Assistant

Depression and Trauma Cognitive-Behavioral Therapy Lab, April 2012-July 2015
Principal Investigator: Dr. Adele Hayes
Role: Research Assistant

Social Value Orientation Lab, September 2012-May 2015
Principal Investigator: Dr. D. Michael Kuhlman
Role: Research Assistant

Child Well-Being Initiative, April 2012-December 2013
Principal Investigators: Dr. Adele Hayes and Dr. Charles Webb
Role: Intern

Electrophysiology Lab, September 2012-December 2012
Principal Investigator: Dr. Robert Simons and Andrea Druga
Role: Research Assistant

PROFESSIONAL MEMBERSHIPS

Association for Psychological Science, 2014-present
Eastern Psychological Association, 2014-2015
Human Behavior and Evolution Society, 2016
Northeastern Evolutionary Psychology Society, 2016
Society for the Teaching of Psychology, 2014-present

TEACHING EXPERIENCE

Elementary Statistics (PSYC301), Dr. Cheryl Dickter, College of William & Mary
Lab Instructor, Fall 2015 (40 students)
Lab Instructor, Spring 2016 (40 students)

Research in Social Psychology (PSYC414), Dr. Cheryl Dickter, College of William & Mary
Lab Instructor, Fall 2016 (15 students)

Graduate Research Methods (PSYC631), Dr. Catherine Forestell, College of William & Mary
Invited Lecturer, topics in mediation and moderation analysis, Fall 2016 (7 students)

Research in Social Psychology (PSYC414), Dr. Joanna Schug, College of William & Mary
Lab Instructor, Spring 2017 (15 students)

SERVICE

Representative, Graduate Student Association, Department of Psychology, Spring 2016

Session proctor, William & Mary 15th annual Graduate Research Symposium, Spring 2016

Treasurer (elected), Graduate Student Association, 2016-2017

PROFESSIONAL DEVELOPMENT

Selected Coursework

2014 ANOVA (PSYC860) – Dr. Michael Kuhlman (*University of Delaware)*
2015 Multiple Regression (PSYC861) – Dr. Jean-Phillipe Laurenceau *(University of Delaware)*
2015 Research Methods (PSYC631) – Dr. Catherine Forestell *(College of William & Mary)*
2015 Proseminar in Personality (PSYC662) – Dr. Todd Thrash *(College of William & Mary)*
2015 Advanced Statistics I (PSYC632) – Dr. Lee Kirkpatrick *(College of William & Mary)*
2016 Advanced Statistics II (PSYC633) – Dr. Matthew Hillimire *(College of William & Mary)*
2016 Computer Applications in Psychology (PSYC672) – Dr. Paul Kieffaber *(College of William & Mary)*
2016 Networks in Systems Biology (APSC791) – Dr. Greg Smith *(College of William & Mary)*
2017 Statistical Modeling (PSYC663) – Dr. Todd Thrash *(College of William & Mary)*

PROGRAMMING SKILLS

SPSS
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Qualtrics
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References

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