Forgiving Minds: Unraveling the Role of Executive Functioning and Right Dorsolateral Prefrontal Cortex Activation

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ABSTRACT

The current study investigated the relationship among executive functioning, activation of the right dorsolateral prefrontal cortex (dlPFC), and forgiveness among students enrolled in Christian colleges in the United States. Guided by the regulatory model of forgiveness framework, employing a two-study methodology, our aim was to uncover the neurocognitive correlates of forgiveness. In the first study, 159 participants (67% women) completed neuropsychological tasks sensitive to PFC impairments alongside self-reported forgiveness measures. Results revealed a significant positive correlation between executive functioning and both state and dispositional forgiveness. In the second study, 36 participants (46% women) engaged in an ultimatum game followed by a dictator game, with changes in regional cerebral blood oxygenation (rCBO2) serving as an indicator of dlPFC activation. We found heightened right dlPFC activation during fair allocation of money to unfair opponents compared to unfair allocation within the same participants, suggesting a higher cognitive load in forgiving decision-making. Despite limitations associated with convenience sampling and a small sample size, these findings contribute to a deeper understanding of the cognitive and neural mechanisms underlying forgiveness, with potential implications for interventions aimed at fostering forgiveness and enhancing overall well-being.

KEYWORDS
executive functioning
prefrontal cortex
rCBO2
forgiveness

INTRODUCTION

Forgiveness is a multifaceted psychological phenomenon with profound implications for individual well-being and interpersonal relationships. It encompasses both state forgiveness, involving the release of negative emotions in specific situations, and dispositional forgiveness, reflecting a stable inclination to forgive across diverse contexts (Brose et al., 2005; Worthington, 2020; Worthington, Hook et al. 2007). Positive outcomes linked with forgiveness include reduced stress, anxiety, and depression, enhanced cardiovascular health, and improved interpersonal relationships (Gao et al., 2022; Hill et al., 2015; Skalski-Bednarz & Toussaint, 2024; Skalski-Bednarz et al., 2024; Toussaint, 2022; Toussaint & Webb, 2005; Toussaint & Worthington, 2023; Toussaint et al., 2015). However, the relationship between forgiveness and cognitive processes, particularly executive functioning, remains a topic of ongoing investigation in the field.

Understanding the predictors of forgiveness is pivotal for unraveling the dynamics of this psychological phenomenon. Considerable research has scrutinized the influence of personality traits (Abid et al., 2015; Walker & Gorsuch, 2002), morality (Lindsey, 2013), motivation (Strelan et al., 2017), and interpersonal factors, such as relationship quality (Fincham et al., 2002), on forgiveness. However, there remains a conspicuous gap concerning the impact of cognitive capacities, notably executive functioning, on forgiveness.

Executive functioning, located in the frontal lobe, encompasses a suite of processes vital for regulating behavior, thoughts, and emotions to attain specific objectives (Diamond, 2013; Schall et al., 2017; Suchy, 2009). These processes encompass diverse abilities, including working memory, attention, cognitive flexibility, and impulse control (Drigas & Karyotaki, 2017; Friedman & Robbins, 2022). Executive functioning plays a relevant role within the broader framework of cognitive control, governing the regulation and coordination of cognitive processes to effectively achieve goals (Friedman & Robbins, 2022).

The *regulatory model of forgiveness* (Ho et al., 2020) provides a useful theoretical framework and suggests that emotion regulation, particularly cognitive reappraisal, correlates with higher levels of forgiveness. Within this model, forgiveness functions as a cognitive

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reappraisal process that reduces feelings of anger, hostility, rumination, and their negative consequences, even in the face of emotional distress and the inclination for retaliation (Worthington, Witvliet et al. 2007). Earlier research indicated that damage to frontal brain regions associated with executive functioning correlates with impaired social skills, diminished empathy, and challenges in regulating social behavior (Shamay-Tsoory et al., 2003; Wood & Worthington, 2017).

These impairments in social skills, forgiveness, empathy, and behavior regulation can also be explained by theory of mind (ToM), first introduced by Premack and Woodruff (1978). ToM is the cognitive ability to attribute mental states, such as beliefs, intentions, desires, and emotions, to oneself and others, enabling the understanding and prediction of behavior. It is increasingly recognized as a multidimensional construct, with a key distinction between cognitive and affective ToM. Affective ToM pertains to understanding and inferring emotions, while cognitive ToM involves understanding and inferring knowledge, intentions, and beliefs. Findings provide evidence for the functional independence of cognitive from affective ToM and highlight the role of the dorsolateral prefrontal cortex (dlPFC) in the neural networks mediating cognitive ToM (Kalbe et al., 2010).

Whitmer and Banich (2007) proposed that forgiveness requires the regulation and inhibition of negative responses, with executive functioning, specifically its ability to reduce rumination, playing a crucial role in facilitating the forgiveness process. Conversely, Toussaint et al. (2018) observed in a national sample of American adults that self-forgiveness has the potential to alleviate the adverse effects of hostile feelings on cognitive impairments. Pronk et al. (2010) found a positive correlation between executive functioning and dispositional forgiveness, implying that individuals with higher levels of cognitive functioning may be more predisposed to forgive. However, their exclusive focus on highly committed relationships raises questions about the generalizability of their findings across diverse contexts, underscoring the imperative for further exploration.

Tasks involving executive functions in neurotypical individuals often activate prefrontal brain regions, including the PFC, which also play a role in processing and regulating emotions. This overlap suggests that these brain structures may be involved in the affective and cognitive dysregulation associated with the state of unforgiveness. While the relationship between the PFC and cognition is well-established, less is known about the neural substrates underlying emotion regulation and prosocial behavior. For instance, studies by Feeser et al. (2014) demonstrated that applying anodal transcranial direct current stimulation (tDCS) to the right dlPFC significantly improved subjects' ability to engage in cognitive reappraisal, highlighting the distinct role of the dlPFC in cognitive emotion regulation. Pripfl and Lamm (2015) found that cortex activation in the right, but not the left dlPFC was associated with enhanced executive functioning during emotion regulation, particularly with negative emotional stimuli. Additionally, Allard (2012) showed that increased activation in the dlPFC correlated with reduced severity of distress and higher cognitive empathy, indicating improved performance in visuomotor processing speed and executive functioning. Regarding forgiveness, Maier et al. (2018) utilized continuous theta-burst stimulation (cTBS) to the right dlPFC, impairing inhibitory control, planning, and attention. This provoked unforgiveness and revenge-seeking behavior, thus supporting the assumption about the role of cognitive emotional processing in forgiveness.

Advances in neuropsychology have sparked inquiries into the neural mechanisms governing emotion regulation and prosocial behaviors, particularly focusing on cortical regions such as the dlPFC. Nevertheless, the specific contributions of these cortical areas to forgiveness have not been fully explored. To address these gaps, we conducted a two-part study aimed at elucidating the neurocognitive predictors of forgiveness. Building on previous research, we hypothesized a positive association between executive functioning and forgiveness, alongside increased right dlPFC activation during forgiveness decision-making, reflecting enhanced cognitive control over emotions. To test these hypotheses, we initially conducted a cross-sectional study where participants completed neuropsychological tasks sensitive to PFC impairments, correlating them with self-reported state and dispositional forgiveness. In a subsequent experimental study, we examined changes in regional cerebral blood oxygenation (rCBO2) as an indicator of cortical activation during forgiving and unforgiving conditions in a dictator game, following the ultimatum game. During the ultimatum game, participants encountered both fair and unfair opponents, and in the subsequent dictator game, roles were reversed, enabling them to seek revenge or extend forgiveness. Through these efforts, our aim was to deepen our understanding of the cognitive and neural foundations of forgiveness, ultimately refining interventions to promote forgiveness and enhance overall well-being.

METHOD

Participants

Both studies were conducted following approval from the respective ethical committees of the participating colleges. Convenience sampling was utilized to recruit participants from colleges located in Iowa and Florida. The first cross-sectional study involved 159 participants, with 67% being women, and an average age of 21 years (SD = 1.2). The ethnic composition of the sample comprised 62 European Americans, 15 Asian Americans, 48 Latinos/Latinas, 32 African Americans, and two Native Americans. In the second study, 36 students from a college in Florida took part, with 46% being women, and an average age of 20.7 years (SD = 0.9). The ethnic composition of this sample included 21 European Americans, two Asian Americans, 10 Latinos/Latinas, and three African Americans.

Procedure

The procedure for Study 1 involved participants completing measures of forgiveness and engaging in cognitive tasks, with the entire session lasting approximately 20 minutes. Participants took part in the study in groups within a computer lab setting. For Study 2, participants individually engaged in a combined ultimatum and dictator game, with detailed instructions provided in the subsequent subsection. During this game, participants' rCBO2 levels were measured at the FP2 location based on the 10:20 electrode placement system. Both studies utilized materials presented on a 19 in. screen, with participants positioned approximately 27 in. away from the screen. The surveys and experiment presentation were developed and administered using the Qualtrics platform.

ULTIMATUM/DICTATOR GAME

The combined ultimatum and dictator game design was adapted from prior research by Maier et al. (2018). It consists of two sequential tasks: an ultimatum game followed by a dictator game, each comprising 30 trials lasting approximately 7 min. During the ultimatum game, participants were presented with a picture and the name of their opponent for 3 s, followed by a 2 s break featuring a jittered fixation cross. Subsequently, participants received an offer from the current opponent, with a total of $20 fictitiously divided among four opponents: two unfair (one male, one female) offering between $0 and $4, and two fair (one male, one female) offering between $6 and $10. After deciding to accept or reject the offer, participants viewed a feedback screen displaying the money allocations for 5 s; rejected offers resulted in $0 for the opponent. The images of the opponents were randomized and varied in terms of sex and ethnicity to reduce potential biases and preconceived beliefs towards them. The dictator game followed with identical timing to the ultimatum game. However, participants were tasked with redistributing the fictitious $20 among previous opponents, with no option for opponents to reject offers. The distribution of money was solely determined by participants' generosity rather than strategic considerations. Participants were instructed to envision playing for actual money with real individuals throughout the game.

Measures

STUDY 1

To assess state forgiveness, we utilized the Rye Forgiveness Scale (RFS; Rye et al., 2001), which consists of 15 statements measuring affective, cognitive, and behavioral forgiveness towards a specific wrongdoer. Participants rated their agreement with each statement on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). While the RFS assesses both the absence of negative and the presence of positive forgiveness responses to transgressions, our study focused exclusively on the overall forgiveness score (α = .87 in the validation study by Rye et al., 2001). RFS sample statements include "I can't stop thinking about how I was wronged by this person" and "I have compassion for the person who wronged me." Elevated scores on the RFS signify a stronger inclination towards positive state forgiveness. Validation studies revealed that the RFS score demonstrated significant positive correlations with other forgiveness measures, religiosity, hope, religious and existential well-being, and social desirability, while exhibiting a negative correlation with anger (Rye et al., 2001).

To measure dispositional forgiveness, the Trait Forgiveness Scale (TFS; Berry et al., 2005) was utilized, comprising 10 items designed to measure trait forgiveness, adapted from a longer scale employed in previous research (Berry et al., 2001). Participants rated each item on the TFS using a 5-point Likert-type scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). TFS example items include "I can usually forgive and forget an insult" and "There are some things for which I could never forgive even a loved one." Higher scores on the TFS indicate greater positive dispositional forgivingness, with the α reliability coefficient ranging from .74 to .80 among college-aged samples (Berry et al., 2005).

To evaluate executive functioning associated with divided attention abilities, we employed the multitasking test developed by Stoet et al. (2013). This test presents participants with a divided screen, requiring them to respond based on the stimulus location. The upper section entails identifying the shape of the figure (either a square or rhombus), while the lower section entails identifying the number of dots inside these figures (either two or three dots). The test comprises 48 trials, including 24 single-task trials (involving one stimulus feature: either figure shape or number of dots) and 24 multitask trials (involving two stimulus features: both figure shape and number of dots). In our study, we assessed the task-switch cost in milliseconds (ms), which represents the difference in mean response time between single and multitask conditions.

To assess executive functioning in processing speed, selective attention, automaticity, and parallel distributed processing, we employed a Stroop task. Participants were presented with single words representing color names and instructed to identify the font color (red, green, blue, and yellow) by pressing the corresponding button, while ignoring the word's meaning. Each trial lasted approximately 5 min and included 40 control tasks (where the font color matched the word's meaning) and 40 interference tasks (where the font color conflicted with the word's meaning), presented alternately. Our analysis focused on the task-switch cost, or Stroop effect, measured in ms, which indicates the difference in mean response time between interference and control tasks. The Stroop test is commonly used by researchers and practitioners to detect deficits in attention and potential degeneration in the PFC (Okruszek & Rutkowska, 2013; Skalski & Dobrakowski, 2020).

To assess executive functioning through an individual's ability to adapt to changes in reinforcement, we administered the Wisconsin Card Sorting Test (WCST). This neuropsychological assessment of set-shifting involves two sets of 64 cards each. Participants are instructed to match cards from one set to one of four reference cards using a mouse cursor. They must determine the sorting rule independently, receiving feedback after each response indicating its accuracy. Perseveration errors, defined as instances where participants persist in applying the previous rule, were documented in this study. The WCST has been utilized by neuropsychologists and clinical psychologists with individuals affected by acquired brain injury, neurodegenerative disorders, or psychiatric conditions such as schizophrenia (Chiu et al., 2018).

STUDY 2

For recording rCBO2, we employed a hemoencephalography (HEG) medical equipment system from MediTECH Electronic, based on near-infrared spectroscopy (NIRS) technology, capturing data at 32 samples per second, and worked with a 10-channel FlexComp Infiniti encoder from Thought Technology, featuring a resolution of 14 bits (1 part in 16,364). This method relies on the distinct optical properties of hemoglobin (Hb) and oxyhemoglobin (oxy-Hb). The HEG system comprises an emission optical probe (optode) with two electroluminescent diodes (LEDs) emitting red light at 660 nm and infrared (IR) light at 850 nm, along with a detection optode. Light beams disperse, refract, and reflect, with a portion returning to the surface, modified by absorption. Below wavelengths of 800–850 nm, Hb significantly absorbs light and poorly reflects it, while oxy-Hb reflects light strongly and absorbs it weakly. The optode detects reflected light to determine local Hb oxygen saturation, where red light indicates Hg oxygen saturation, and IR light serves as a reference. According to the modified Beer-Lambert law, light beam penetration depth depends on the distance between emission and detection optodes, reaching up to half that distance (Maikala, 2010). With a distance of 1.18 in. between optodes in the HEG system, light penetrates up to 0.59 in., reaching capillaries in the gray matter at the base of the cerebral cortex, thus registering cortex activation in the right dlPFC after placement at FP2 based on the 10:20 system. The HEG system is designed to prevent light permeation and external light influence. Peripheral blood pressure minimally affects capillary oxygenation, primarily controlled by tissue energy demand, making Hb oxygen saturation a convenient measure of local cerebral perfusion. The data were processed in Biograph Infiniti 6.2, including data filtering. rCBO2 was quantified by the HEG ratio: HEG red / HEG IR × 200, where HEG red and HEG IR represent reflected red and IR light values, respectively, based on mean recorded values. Previous studies have demonstrated the effectiveness of the HEG system in assessing cortical activation and its superior accuracy in rCBO2 measurements compared to other NIRS probes due to its higher sampling rate (Serra-Sala et al., 2012; Wolf & Greisen, 2009).

Statistical Analyses

The Kolmogorov-Smirnov test was employed to assess the normal distribution of the data, while Levene's test was used to evaluate homoscedasticity. Based on the obtained scores, parametric tests were deemed suitable for analysis. Specifically, a paired-samples t-test, Pearson correlation analyses, and structural equation modeling (SEM) were utilized to examine the hypotheses. Within the SEM framework, the cχ^2 statistic was employed to assess model fit, with an χ^2/df value below 2 considered acceptable (Byrne, 2016). Additionally, other recommended fit indices were considered (Kline, 2023): the comparative fit index (CFI) was used to evaluate model fit relative to a baseline model with uncorrelated variables, with values exceeding .95 indicating good fit and those above .9 indicating acceptable fit. The root mean square error of approximation (RMSEA) was also evaluated, with values ideally below .05 and those below .08 considered acceptable. Furthermore, the standardized root mean square residual (SRMR) was assessed, with values below .08 indicating proper fit. Statistical significance was set at $p < .05$, and effect size was determined based on R^2 or Cohen's d. Data analysis was conducted using Jamovi 2.4.7.

RESULTS

Study 1

Table 1 presents the means and correlations among the study variables, which include state forgiveness, dispositional forgiveness, perseveration error count in the WCST, task-switch cost in multitasking (in ms), and the Stroop effect (in ms). A large correlation was observed between state forgiveness and dispositional forgiveness. Additionally, all other variables displayed moderate or small correlations with each other. Socio-demographic variables did not show a significant relationship with any variables.

SEM was employed using the maximum likelihood method to validate the proposed hypothesis (see Figure 1). The hypothetical model was verified, yielding satisfactory goodness-of-fit indices: $\chi^2(7) = 8.02$, $p = .331$, GFI = .998; AGFI = .990; RMSEA = .012 (.001, .111; 90% CI); SRMR = .02; TLI = .998; CFI = 1.00. According to the model, the latent exogenous variable comprising executive functioning indicators emerged as a significant predictor of both state forgiveness ($\beta = .21$, $p = .018$, $R^2 = .17$) and dispositional forgiveness ($\beta = .23$, $p = .011$, $R^2 = .19$) as endogenous variables.

Study 2

In Study 2, we investigated the neural mechanisms underlying forgiveness decision-making using a combined ultimatum and dictator game paradigm with a cohort of 36 students. Specifically, during the dictator game, we examined within-group differences in the average HEG ratio levels at the FP2 location between instances where participants unfairly allocated money to unfair opponents (unforgiving) versus when they fairly allocated money to unfair opponents (forgiving). Notably, across the entire combined game, participants accepted 71.4% of the fair offers and only 12.3% of the unfair offers. Furthermore, the participants consistently demonstrated a significant tendency to allocate fair monetary shares to both fair (89%) and unfair (61%) opponents.

TABLE 1.
Means and Correlations in Study of the Relationship Between Executive Functioning and Forgiveness ($N = 159$)

	M (*SD*)	1.	2.	3.	4.
1. State of Forgiveness (RFS)	50.6 (9.6)	—			
2. Dispositional Forgiveness (TFS)	50.4 (11.9)	.51***	—		
3. Task-Switch Cost [ms] (WCST)	217 (47.3)	−.16*	−.24**	—	
4. The Stroop Effect [ms] (Stroop Task)	157 (21)	−.21**	−.23**	.32***	—
5. Perseveration Error Count (Multitasking)	8.2 (3.4)	−.21**	−.26***	.31***	.32***

Note. *$p < .05$, **$p < .01$, ***$p < .001$

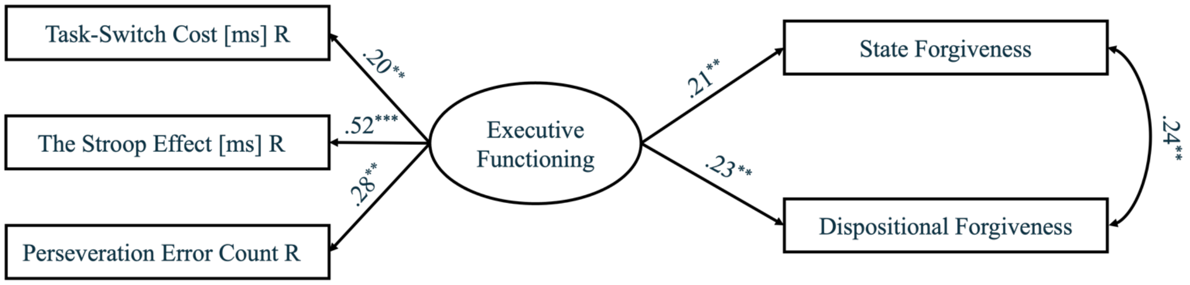

FIGURE 1.
Executive Functioning as a Predictor of State and Dispositional Forgiveness. **$p < .01$, ***$p < .001$, *R* = Reversed.

A paired-samples *t*-test revealed significant differences (see Figure 2) in right dlPFC activation during forgiveness decision-making among participants: $t(35) = -2.07$, $p = .046$, Cohen's $d = -0.35$. Specifically, individuals showed lower HEG ratio levels during unforgiving decision-making ($M = 98.7$, $SD = 9.4$) compared to instances where the same individuals opted for forgiveness ($M = 101.8$, $SD = 11.3$), indicating a higher cognitive load in the forgiving condition.

DISCUSSION

When individuals confront transgressions, forgiving those who have wronged them, despite its well-documented positive effects on mental well-being (Rasmussen et al., 2019; Toussaint & Webb, 2005), often poses a challenge. Despite their moral convictions, worldview, and motivation to forgive, individuals may find themselves unable to do so. Guided by the regulatory model of forgiveness (Ho et al., 2020; Worthington, Hook et al. 2007), our research aimed to investigate the neurocognitive underpinnings that potentially influence forgiveness, specifically examining the relationship between executive functioning, dlPFC activation, state forgiveness, and dispositional forgiveness.

In Study 1, we identified a significant positive correlation between executive functioning and both state and dispositional forgiveness, indicating that individuals with higher levels of executive functioning may possess superior abilities to regulate negative emotions and engage in effective forgiveness, encompassing both specific incidents and general tendencies to forgive. This finding is consistent with previous research highlighting the critical role of executive functioning in emotion regulation and interpersonal behavior (Shamay-Tsoory et al., 2003; Whitmer & Banich, 2007; Wood & Worthington, 2017). Expanding on Pronk et al.'s (2010) findings, which suggested that individuals with higher cognitive functioning might be more inclined to forgive in intimate relationships by mitigating negative ruminations, our study extends this notion by proposing broader implications for forgiveness across various contexts. Thus, it seems that forgiving perceived wrongs entails redirecting focus away from oneself and reducing negative persistent thinking linked to the offense. This idea is supported not only by Pronk et al.'s (2010) report but also by Thompson et al.'s (2005) study indicating that reduced rumination is associated with forgiveness. Another significant contribution of our research, achieved through the integration of three distinct cognitive task paradigms, is the recognition that diverse cognitive abilities contributing to executive functioning, such as processing speed, selective attention, automaticity, parallel distributed processing, divided attention, and adaptation to changes in reinforcement, intricately participate in the forgiveness process. This finding aligns with contemporary literature indicating that various executive functions share fundamental processes of inhibition and attention, thereby underscoring the intricate nature of executive functioning in regulating affective and cognitive processes during forgiveness decision-making (Chung et al., 2014; Himi et al., 2021; Wu et al., 2011).

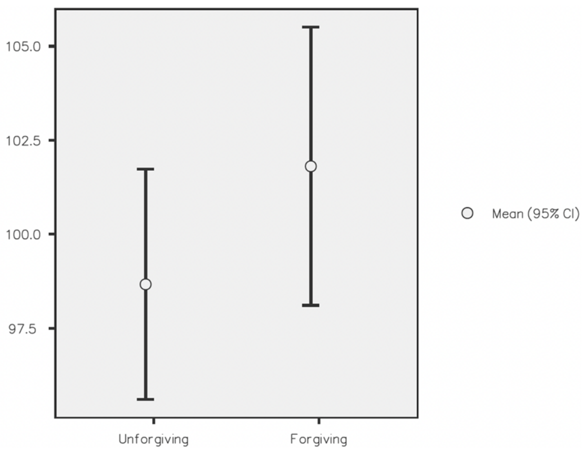

FIGURE 2.
Mean HEG Ratio in Fp2 During Forgiveness-Related Decisions in the Dictator Game

In Study 2, we examined the neural mechanisms involved in forgiveness decision-making using a combined ultimatum and dictator game paradigm. Our results indicated heightened activation of the right dlPFC during forgiving decisions compared to unforgiving choices within the same participants, suggesting that forgiving unfair behavior may require increased cognitive effort, consistent with prior research linking the dlPFC to emotion regulation and moral decision-making (Feeser et al., 2014; Pripfl & Lamm, 2015). Additionally, findings from Zhao et al. (2021) support the role of the dlPFC in downregulating affective responses and facilitating voluntary emotion regulation through distraction and reappraisal strategies, highlighting its potential significance in social contexts. Similarly, Maier (2018) found that inhibitory cTBS of the dlPFC led to revenge-seeking behavior, further implicating this brain region in decision-making processes. Moreover, in line with the relational model of spirituality and forgiveness (Sandage & Williamson, 2010; Skalski-Bednarz & Toussaint, 2024), our findings align with previous research indicating the involvement of the PFC in religious and spiritual processes (Aftanas & Golocheikine, 2001; Johnstone et al., 2012). In essence, our study's neurocorrelational findings provide additional support for the concept introduced in Study 1, emphasizing the crucial role of executive functioning in both affective and cognitive processes underlying forgiveness. Furthermore, these findings underscore the intricate neurological mechanisms associated with forgiveness, particularly evident in the activation of the right dlPFC.

Our studies had several limitations. First, both relied on convenience samples of college students. Consequently, the findings may lack generalizability to the broader population, warranting replication in more diverse samples for broader applicability. Also, the cultural context of the participants could influence their attitudes and behaviors toward forgiveness, potentially confounding the findings. Future research should aim to replicate these findings with more diverse and representative samples to ensure the robustness and applicability of the results across different populations. Moreover, the cross-sectional design of Study 1 hinders the establishment of causality: We were unable to discern whether better executive functioning predisposes individuals to forgive or if forgiveness leads to improved executive functioning. However, given supportive literature and the findings of our experimental Study 2, it is highly plausible that executive functioning plays a predisposing role in forgiveness. Nonetheless, additional experimental and longitudinal studies could clarify reverse causality in this relationship and provide a clearer understanding of potential reciprocal causation. Additionally, in Study 2, the utilization of a combined ultimatum and dictator game paradigm to investigate forgiveness decision-making may not have fully captured the complexity and nuances of real-life forgiveness scenarios. The artificial nature of the game setting could limit the generalizability of the findings to real-world interpersonal forgiveness situations. Furthermore, incorporating actual financial compensation tied to subjects' responses could be a compelling enhancement to the current experiment, potentially heightening personal investment. Moreover, while the study identified heightened activation in the right dlPFC during forgiveness decisions, it did not explore other brain regions involved in forgiveness processes or potential individual and contextual factors that could influence forgiveness processes. These limitations could be overcome in future studies of forgiveness.

Overall, our findings provide valuable insights into the intricate neurocognitive mechanisms underlying forgiveness decision-making, particularly highlighting the significance of the right dlPFC in executive functioning processes. These insights hold direct implications for interventions aimed at promoting forgiveness and effectively addressing interpersonal conflict. Future interventions could explore innovative approaches, such as integrating mixed REACH Forgiveness therapy (Worthington, 2020) with HEG biofeedback (Skalski et al., 2021) or tDCS (Pripfl & Lamm, 2015) techniques to modulate right dlPFC activity. The structured REACH Forgiveness intervention offers a promising framework for guiding individuals through forgiveness processes and facilitating emotional healing. Augmenting this method with neurotherapeutic techniques could enhance executive functioning mechanisms involved in forgiveness, thereby aiding conflict resolution. By synergizing these psychological and neurophysiological approaches, future interventions have the potential to significantly improve forgiveness processes, leading to more effective resolutions of interpersonal conflicts and ultimately enhancing overall well-being.

By highlighting the importance of executive functioning and right dlPFC activation in forgiveness processes, this study suggests a neurological basis for forgiveness. Our findings indicate that both executive functioning and increased right dlPFC activity may independently play significant roles in forgiveness. Enhanced cognitive abilities, based on prior research, can ameliorate negative rumination about transgressions, thereby facilitating forgiveness. Additionally, dlPFC activation enhances overall cognitive functioning. These insights are pertinent for theoretical frameworks of forgiveness and practical interventions aimed at promoting forgiveness and enhancing well-being. Interventions targeting improved right dlPFC function may offer benefits for both cognitive and affective symptoms associated with forgiveness. However, acknowledging limitations, particularly regarding small convenience samples, underscores the need for future longitudinal and experimental studies.

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the Ethics Committee of the University of Economics and Human Sciences in Warsaw.

Informed consent was obtained from all individual participants included in the study.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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