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Investigating Mechanisms of Mindfulness and Positive Fantasizing as intervention Techniques for Reducing Perseverative Cognition in Remitted Depressed Individuals

Bachelor's Project Thesis

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Abstract:
Background: Major Depressive Disorder (MDD) involves mood, cognitive, and psychomotor abnormalities, with a high recurrence rate–around 80% of remitted patients experience relapse. MDD patients often dwell in a cycle of persistent, negative, and uncontrollable thoughts, known as rumination (i.e. perseverative cognition [PC]). Positive fantasizing and mindfulness are effective interventions for reducing PC and preventing depressive relapse. While positive fantasizing counters dysfunctional attitudes through positive imagery, mindfulness enhances acute consciousness of the present. This study aims to explore how these interventions affect PC in remitted MDD (rMDD) and never-depressed (ND) individuals and whether these effects differ between the two groups.
Methods and Aims: This study involved rMDD and ND participants performing an app-based Sustained attention to response task (SART), a go/no-go task where participants respond to frequent go stimuli and inhibit response to occasional no-go stimuli, combining self-reported thoughts with task performance to measure PC. Research suggests that off-task patterns resembling PC are linked to poorer and more variable task performance. Using pseudo-randomized mindfulness and positive fantasizing interventions, we aimed to explore how these interventions affect PC in rMDD and ND individuals and whether the effects differ between the groups.
Results: Both interventions reduced response times. Mindfulness increased accuracy at go trials and decreased accuracy at no-go trials in both groups, while also increasing on-task thinking in ND controls and decreasing it in rMDD individuals. Positive fantasizing improved go trial accuracy and reduced no-go trial accuracy only in ND controls, but increased on-task thinking in both groups. ND controls exhibited a greater difference in response times between on-task and off-task conditions than rMDD individuals, with on-task thinking correlating with higher accuracy in ND controls and lower accuracy in rMDD individuals during go trials.
Conclusion: Overall, our findings indicate that while both mindfulness and fantasizing reduced PC, their effects varied between the groups. Mindfulness improved task performance in both groups, enhancing focus and on-task thinking in ND controls but reducing task focus in rMDD individuals due to increased sensitivity to intrusive thoughts. Positive fantasizing had a stronger impact on ND controls than on rMDD individuals in terms of task performance, with both interventions generally impairing inhibitory control.

1 Introduction

Major Depressive Disorder (MDD) is an enfeebling disease that is characterized by depressed mood, anhedonia, impaired cognitive function, and vegetative symptoms (Otte et al., 2016). The chance of MDD recurrence is high. Approximately 80% of remitted patients experience at least one recurrence

throughout their life (Vos et al., 2004).

Compared to healthy individuals, patients with MDD tend to have more spontaneous thoughts that are negative, related to the past, and self-focused (Hoffmann et al., 2016). MDD patients often find themselves dwelling in a cycle of persistent, negative thoughts that are repetitive, uncontrollable, and hard to break away from, collectively referred to as rumination (Ehring & Watkins, 2008). In addition to repetitive, lengthy, and recurrent negative thinking about one's self, feelings, personal concerns, and upsetting experiences (Watkins, 2008), rumination is characterized by associated worry which comprises a fundamental component in the onset and persistence of MDD. These characteristics are key contributors to a high risk of relapse (Brosschot et al., 2010; Nolen-Hoeksema et al., 2008).

Another characteristic of MDD is mind wandering (Ottaviani et al., 2015) which can be described as the generation of thoughts or mental imagery that is not connected to our external environment or current activity, often leading to a diversion of attention (Chaieb et al., 2022). Killingsworth & Gilbert (2010) asserted that "a wandering mind is an unhappy mind". Rumination can be considered as a special sub-type of mind wandering (e.g., Van Vugt et al., 2018) which is primarily defined by its repetitive and often intrusive quality, along with its focus on negative aspects.

Ottaviani (Ottaviani & Couyoumdjian, 2013) hypothesized that when mind wandering becomes inflexible and rigid, it ceases to be adaptive and instead poses a health risk. Despite the different content of ruminative and worrisome thoughts, their appraisals and strategies show no significant differences (Brosschot et al., 2010). Therefore, Ottaviani et al. (2015) grouped them together as a single category, referred to as perseverative cognition (PC). This term encompasses both ruminative and worrisome thoughts building upon their shared characteristics and highlighting their mutual potential to contribute to mental health issues when they become uncontrollable and repetitive. After recovering from a depressive episode, PC often persists and is a common residual symptom (e.g., Nolen-Hoeksema et al., 2008).

Characteristics of PC, are closely linked to the cognitive impairments observed in MDD. Among the main cognitive impairments observed in depressed patients are deficits in the executive attention system and the existence of negative biases (De Raedt & Koster, 2010; Gotlib & Joormann, 2010). Deficiency in the executive attention system, responsible for the detection and selection of relevant information from an environment of distracting information, leads to difficulties in selective and sustained attention (Gotlib & Joormann, 2010). Depressed individuals exhibit a tendency to focus on negative information due to impaired inhibitory attentional control (Mathews & MacLeod, 2005; Mogg & Bradley, 2005). This pattern of skewed attention has been demonstrated in several studies, including selective (Bradley et al., 1997) and sustained (Koster et al., 2005) attention to negative words and sustained attention to angry faces (Leyman et al., 2007), suggesting that such biases may play a role in developing negative thought patterns, rumination, and negative mood (i.e. PC)(Verhoeven et al., 2014). Research has indicated that even after recovering from depressive episodes, individuals may continue to exhibit these cognitive shortcomings and tendencies towards negative information processing (Joormann & Gotlib, 2007). These patterns can resurface and intensify during periods of stress or when experiencing a depressed mood (Teasdale et al., 1995). Therefore, these patterns might be an accurate indication of an MDD recurrence development (Beevers, 2005).

Additionally, a bi-directional relationship has been hypothesized to exist between mind wandering and depression (Ottaviani et al., 2015), suggesting a disruptive role for the cognitive characteristics of depression in attentional control. For instance, Smallwood et al. (2009) manipulated mood and observed that negative relative to positive mood reduced attentional commitment to the task at hand, perhaps by giving more attention to task-irrelevant personal concerns (Ottaviani et al., 2015).

In line with these findings, interventions intended to decrease negative repetitive thoughts, such as mindfulness-based cognitive therapy (MBCT; Z. W. Segal & Williams, 2002) reduce the risk of relapses in depression (Williams & Kuyken, 2012). For instance, Piet & Hougaard (2011) indicated that MBCT decreases the likelihood of relapse among patients who have experienced three or more episodes of depression and is equally effective in preventing relapse when compared to maintenance therapy with antidepressants. In the

context of MBCT, mindfulness involves a technique that aims to shift away from dysfunctional attitudes and schemas by promoting acute consciousness of the present. This acute consciousness is achieved through practices where patients learn to increase their awareness of the "here and now", thereby becoming more cognizant of depressotypic information-processing patterns (Verhoeven et al., 2014). Participants in MBCT are instructed to repeatedly redirect their attention to a specific focus in the present moment, commonly their own breathing. This practice enhances the voluntary deployment of their attention (Z. W. Segal & Williams, 2002). It not only bolstered selective attention by training participants to attend only one focus but also improved sustained attention throughout the duration of these exercises (Teasdale et al., 1995). These mechanisms, which enhance both selective and sustained attention, are hypothesized to fortify attentional control, a critical component in the therapeutic process of MBCT. This enhanced attentional control facilitates the disengagement from dysfunctional cognitive patterns (Bishop et al., 2004; Phillipot & Segal, 2009; Verhoeven et al., 2014).

In addition to MBCT, preventive cognitive therapy (PCT), a form of cognitive behavioral therapy specifically developed for remitted recurrently depressed patients, has demonstrated efficacy in lowering the risk of relapse. It is administered sequentially and can be provided after the completion of acute treatment (De Jonge et al., 2019). Research indicates that PCT is effective in reducing relapses and recurrences among patients with multiple depressive episodes over a span of 2-10 years when compared to care as usual (C. L. Bockting et al., 2015). Among patients with five or more prior episodes, PCT decreased the risk of relapse from 72% to 46% over a 2-year period (C. L. Bockting et al., 2005). Combining PCT with antidepressant treatment led to a 41% relative risk reduction in relapse compared to using antidepressants alone. Additionally, the risk of relapse was not lower for remitted patients who continued taking antidepressant medication (ADM) compared to those who received PCT while gradually reducing their ADM (C. L. Bockting et al., 2018). Positive fantasizing is part of a PCT and hence, has shown to be effective in preventing depressive relapse and reducing depressive symptoms (C. L. Bockting et al., 2009). A brief 10-minute fantasizing exercise has been demonstrated to effectively reduce negative affect in a single session (Besten et al., 2023). Positive fantasizing focuses on countering dysfunctional attitudes (i.e. PC) and thought patterns. It employs the power of positive imagery to develop a sense of well-being and promote optimistic thoughts. This technique is used to reinforce positive affect and positive cognition (Besten et al., 2024). Both these interventional techniques have shown efficacy in single-session exercises. For instance, single-session mindfulness exercises were shown to be effective at reducing ruminative thinking and depressive symptoms (Burg & Michalak, 2011; Conley et al., 2018). Similarly Besten et al. (2023) showed that a brief period of positive fantasizing enhanced mood and shifted focus toward a more positive and future-oriented mindset, compared to after a stress-induction intervention. Therefore, positive fantasizing has a strong effect in diminishing PC by leveraging uplifting fantasies to enhance positive affect and positive cognitions. Mindfulness, with its emphasis on increasing the awareness of the present moment, is equally effective in mitigating PC. However, it remains important to understand how each intervention produces these effects and how they differ in their approach to reducing PC.

MBCT primarily focuses on improving both selective and sustained attention. Selective attention is enhanced by training individuals to concentrate on a single focus, while sustained attention is developed through long-duration exercises (Teasdale et al., 1995). Therefore, it can be hypothesized that mindfulness practices enhance attentional control and as a result mitigate PC (Phillipot & Segal, 2009). A number of studies have verified this relationship (Chiesa et al., 2011). So far, only a handful of studies have investigated the impact of attention effects in a depressed or remitted depressed sample. For instance, De Raedt et al. (2012) showed a broader attention span for all emotional information following MBCT, and Bostanov et al. (2012) reported an enhanced capacity to redirect attention to the present moment.

Until now, no research has been conducted that utilizes both positive fantasizing and mindfulness methodologies to evaluate the enduring impacts of these interventions on a sample having previously suffered from depression (rMDD) and healthy (ND)

individuals. As a result, there is a paucity of data regarding the influence of these interventions on attentional control and its correlation with PC and depression.

The study of mind wandering (and hence PC) poses challenges due to its subjective nature, which necessitates reliance on self-reporting. To validate these reports, researchers often compare them with less direct, objective measures, such as task performance (McVay & Kane, 2013). Task-unrelated thinking (a form of mind wandering; Turkelson & Mano, 2022), is measured indirectly using various methods, including response time variability (Van Vugt & Broers, 2016). This variability tends to increase when task performance is influenced by task-unrelated processes (Bastian & Sackur, 2013). To investigate task-unrelated thinking, scientists often use "thought probes". These probes are inserted during a task, and participants are asked questions such as "Were you just now on task, or thinking about something else?" (Van Vugt & Broers, 2016; Smallwood, Davies, et al., 2004). By analyzing responses just before participants report being off-task versus on-task, we can compare task performance (Van Vugt & Broers, 2016). Typically, off-task reports correlate with poorer performance, including longer response times, reduced accuracy, and increased response time variability (Bastian & Sackur, 2013). In line with these findings Van Vugt & Broers (2016) found that when off-tasking thinking resembled PC, task performance suffered and became more variable and inconsistent. The Sustained Attention to Response Task (SART) is a go/no-go task that incorporates questions about the frequency and content of participants' thoughts and integrates self-reported thinking processes with detailed performance measures (McVay & Kane, 2013). In SART, go trials require quick responses to frequent stimuli, with errors indicating lapses in attention, while no-go trials require inhibiting responses to infrequent stimuli, with errors reflecting issues with inhibitory control. The findings from the discussed studies indicate that the SART can serve as an objective behavioral measure of PC.

In this study, we aim to investigate whether positive fantasizing and mindfulness interventions are associated with subjective and objective changes in PC, in individuals with remitted MDD (rMDD), as well as in never-depressed (ND) individuals, and whether the effects of these interventions differ between the rMDD and ND individuals.

To this end, we will randomize remitted MDD (rMDD) individuals in a cross-over study to both mindfulness and positive fantasizing interventions, with the order of interventions randomized across participants and maintaining the same duration for each intervention. Additionally, ND participants will be matched to the rMDD participants and similarly randomized to undergo both mindfulness and positive fantasizing interventions. As previously discussed, the SART can be used as an objective behavioral measure of PC. For the aim of our study, participants will perform a short version of the SART adapted from McVay & Kane (2013), developed for use via a mobile application. The task includes four blocks with four thought probe questions (asking about the content, valence, temporal orientation, and stickiness of the current thought) per block. Both self-reported PC (extracted from thought probe questions) and task performance (i.e., response times and accuracy) will be extracted from the app-based SART. Notably, this study is the first to explore the effects of both mindfulness and positive fantasizing interventions on PC in both rMDD and ND individuals using an innovative app-based version of the SART task.

Based on prior studies, we hypothesize that these interventions will successfully reduce PC in rMDD individuals, as evidenced by research primarily focusing on clinical samples (e.g., C. L. Bockting et al., 2009). However, due to the scarcity of research examining the effects of mindfulness and positive fantasizing in ND individuals, we anticipate that the influences of these interventions on PC may vary in this group. In general, we hypothesize that the self-reported PC in the app-based SART will be reduced, and task performance will improve after interventions.

2 Methods

2.1 Design

In order to assess the different effects of mindfulness and positive fantasizing in rMDD and ND participants, we used the experimental design by Besten et al. (2024) in which participants receive both a mindfulness and a fantasizing intervention, in a randomized order. An initial screening is used

to determine study eligibility.

In the first phase, participants undergo pre-intervention measurement 1 including the cognitive task performance two times per day for one week in total. In the second phase, participants undergo peri-intervention measurement 1 where they practice daily with an intervention and engage in the same measurements as in the pre-intervention measurement 1. Next, after a wash-out period of at least a month, the third phase which is the pre-intervention measurement 2 begins, which consists of two times cognitive performance tasks and lasts for one week in total. Finally, the fourth phase includes peri-intervention measurement 2, in which participants practice with the not-yet-performed intervention and undergo the same measurements as in the pre-intervention measurement 2.

2.2 Participants

Participants should be between 18 and 60 years old to be eligible for participation in this study. This age limit is set to reduce the potential impact of age-related deterioration in information processing (Salthouse, 2010). Participants are expected to exhibit average intelligence (with an IQ greater than 85, as evaluated by the Dutch Adult Reading Test (DART) (Schmand et al., 1991) and/or completion of at least a vocational level education) to ensure adequate understanding of the task. Remitted participants are required to have undergone a minimum of two depressive episodes, as per the criteria outlined in the Diagnostic Statistical Manual, version 5 (DSM-5), within the past decade. Additionally, participants in the rMDD group should score 21 or lower on the IDS-SR30 (Rush et al., 1996), indicating no clinically relevant depressive symptoms. These criteria should be fulfilled by the rMDD participants to ensure they are at high risk for a depressive relapse and currently exhibit no significant severity of depressive symptoms.

Participants are excluded from the study if they currently meet any DSM-5 diagnostic criteria as confirmed by the SCID-5 (First et al., 2016), use antidepressants, benzodiazepines, methylphenidate, beta-blockers, or other similar medications, have recently participated in PCT or engaged in mindfulness practices within the last two years, or are currently enrolled in another clinical intervention study, to ensure the purity of intervention effects and minimize confounding factors.

For the ND control group, (additional) exclusion criteria include having depression symptoms as indicated by an IDS-SR30 score greater than 13, ensuring the absence of clinically relevant depressive symptoms, and any lifetime psychopathology diagnosed by the SCID-5, to maintain a control group without psychiatric disorders (Besten et al., 2024).

The sample size for both the rMDD group and the ND group is set at 50 participants each. This sample size is determined to provide sufficient statistical power to detect reliable conclusions about the effects of mindfulness and positive fantasizing on PC and to allow for comparisons between the two groups.

ND control participants were matched with recruited rMDD participants based on their age, sex, and educational level.

2.3 Interventions

2.3.1 Mindfuleness

In MBCT, participants are trained to enhance their present-moment awareness, which enables them to recognize and modify maladaptive patterns of thought associated with depression. They are taught to consistently guide their attention back to a specific point of focus within the current moment, often centering on their breath. This practice serves to strengthen their ability to voluntarily manage their attention. MBCT is structured as an eight-week intervention, featuring eight training sessions, each lasting approximately two hours, complemented by daily home practice sessions of 30-40 minutes (Z. Segal et al., 2018). In this study, we specifically focus on the mindfulness component of MBCT and two crucial aspects of it: professional training and short daily exercises (Besten et al., 2024).

The professional training comprises a single training session lasting two hours conducted in groups of 2-8 people. This session is designed to acquaint participants with the intervention techniques, provide them with the fundamental knowledge required for the daily exercises, and address any questions they may have. The mindfulness training is conducted by a mindfulness professional and includes psycho-education, mindfulness instructions, and guided practice. The primary em-

phasis is on focusing attention on various stimuli, including breathing, external sounds, or bodily sensations, and enhancing awareness of the current focus of one's attention. Following the professional training, participants are guided to use a specially designed audio application on their smartphones, enabling them to practice brief exercises daily using the techniques they learned. Specifically, they are to perform a 10-minute exercise each day for a total of six days, further reinforcing the mindfulness skills acquired during the training.

2.3.2 Positive fantasizing

Positive Fantasizing is a component of PCT (C. Bockting, 2009), which has been demonstrated to be effective in both preventing depressive relapse and alleviating depressive symptoms (for e.g., Biesheuvel-Leliefeld et al., 2017). Positive fantasizing aims to challenge and counteract dysfunctional attitudes and thought patterns, such as PC, by encouraging constructive and optimistic thinking.

In this study, the positive fantasizing is segregated from PCT. During a two-hour session led by a professional trainer, participants are introduced to the positive fantasizing technique. They are provided with psycho-education material on the impact of dysfunctional beliefs and schemas. Originating from PCT, the positive fantasizing approach begins by identifying these dysfunctional beliefs and schemas, followed by engaging in fantasies centered around positive alternative beliefs. The fantasy belief employed in positive fantasizing could be analogous to the direct opposite of a dysfunctional belief. For instance, rather than adhering to the thought "I am worthless", participants are encouraged to embrace and explore the belief "I am wonderful". Under the guidance of the professional trainer, participants select a limiting belief and its contrasting, positive counterpart. They then explore this positive belief through the fantasizing technique, examining its implications and effects. With assistance from the professional, participants engage in imagery exercises to vividly imagine and experience the thoughts and feelings associated with their chosen belief, as though it were true in an ideal world. It is emphasized that the scenarios they envision do not need to adhere to realism, allowing for a broader exploration of positive outcomes. Following the use of imagery techniques, participants are encouraged by the professional to reflect on their experience with the fantasizing exercise. They are guided to consider how they might incorporate the essence of their fantasy belief into their everyday lives, transforming it into a more tangible and practical belief. This process aligns with the application of the positive fantasizing technique within PCT, aiming to foster more adaptive thinking patterns. Once participants grasp the fundamentals of the fantasizing technique, they collaborate with the professional trainer to document the specific belief they will focus on during their home practices. While they maintain the same core belief for daily fantasizing, they are given the flexibility to apply this central theme across various life scenarios, tailoring the exercise to different contexts and experiences.

Participants are instructed to engage in a daily 10-minute exercise using the fantasizing technique for a total of six days, facilitated through a mobile application on their smartphones. An audio guide within the app directs the exercise, posing prompts such as, "Describe and imagine what it would be like if you were to live according to your fantasy belief", to assist participants in navigating and immersing themselves in the fantasizing process.

For both the mindfulness and positive fantasizing interventions, the duration, instructions, and exercises are designed to be similar. The specifics of each exercise session, including the date and time, are recorded through the mobile app. This tracking enables the research team to accurately assess the extent of practice each participant undertakes.

2.4 Procedure

Once individuals express interest and receive full details about the study, they are requested to give written informed consent. Following this consent, their eligibility is determined through inclusion and exclusion criteria (see Participants section). Those who qualify are then invited to engage in the study, which unfolds across four phases including four sessions of pre- and peri-intervention measurements.

Participants are pseudo-randomized to undergo both interventions (mindfulness and positive fantasizing), with the sequence of interventions determined by alternating blocks of three-week sessions. This structured approach ensures a balanced distribution of interventions across participants (Besten

et al., 2024).

2.4.1 Pre- and peri-intervention measurement procedure

Participants are provided with instructions on how to carry out the measurements a few days prior to the commencement of the pre-and peri-intervention assessment periods. The main component of the pre-and peri-intervention measurements is the app-based version of SART (modified from McVay & Kane, 2013).

2.4.2 SART

The SART is a continuous performance task designed to measure attentional control. In this task, participants are typically asked to respond quickly to frequent non-target stimuli and to inhibit their response to infrequently occurring target stimuli. Robertson et al. (1997) suggested that "slips of action" occur due to short lapses in sustained attention, which they define as the mindful, conscious processing of stimuli, even when those stimuli possess repetitive and non-arousing characteristics. In this study, participants engage in a condensed version of the SART (app-based version), modified from McVay & Kane (2013), which combines self-report measures of PC with task performance, developed for use in a mobile application. In this study, the SART is conducted twice daily over a period of seven days, with each session lasting about five minutes. Each session consists of 25 go/no-go trials. Approximately once a minute, thought probes are presented. The thought probes inquire about the content, emotional valence, temporal orientation, and stickiness of the participant's current thoughts (see Appendix A).

Data on self-reported PC, based on participants' responses to probe questions regarding the content, emotional valence, temporal orientation, and stickiness of their current thoughts, along with measures of task performance, including response times and accuracy, are collected from the SART (app-based version) for subsequent analyses.

2.5 Study Aim

To assess whether the impacts of positive fantasizing and mindfulness interventions on PC exhibit differential outcomes between rMDD and ND individuals, this study investigates between-group variations in individuals' responses from before to after the interventions. The primary outcome variable includes the data collected from the app-based version of the SART task.

2.6 Sample Size

The study consisted of two parts. In the first part (pre-intervention measurement 1 and peri-intervention measurement 1), there were 25 ND controls and 20 rMDD individuals. In the second part (pre-intervention measurement 2 and peri-intervention measurement 2), due to participant dropouts, the number of ND controls decreased to 19, and the number of rMDD individuals decreased to 15.

2.7 Data Analysis

The primary objectives of this study were to investigate the impact of mindfulness and positive fantasizing on PC in individuals with rMDD and ND and to determine if these interventions have different effects on PC between the two groups. To this end, we compared response time, accuracy, and responses on the thought probes between the different task conditions (i.e. whether they were in the baseline or induction phase) and different groups (rMDD versus ND) using linear mixed-effects models (Luke, 2017). Linear mixed-effects (LME) models were employed for their robustness in handling missing or unbalanced data. For the analysis of accuracy, generalized linear mixed-effects (GLME) models were used to account for its binomial distribution. The effect of an experimental factor was tested using model comparisons with type III ANOVA (using the R package car) (Langsrud, 2003). A factor was considered significant when the model fit showed a substantial improvement based on the chi-square statistic. When a factor was found to be significant, the validity of individual contrasts was assessed by raw data visualization and reviewing the summary output of the model.

2.8 Data Preparation

For the analysis, we excluded SART responses with response times exceeding two seconds. Addi-

tionally, in rare instances, a possible bug in the mobile resulted in anomalous data where the response time was recorded as zero, the trial was a "go" trial, and the participant was marked as being correct. These anomalous cases were also removed from the analysis. In total, approximately 0.8% of the data was removed due to these criteria. For the analysis of response times, we calculated the response times exclusively for the correct trials, which comprised approximately 97.5% of the data. For thought probes' analysis, we computed the mean accuracy and mean response time for the series of SART responses associated with each thought probe, thereby summarizing the performance across these trial sequences. Moreover, we categorized each thought probe response as either on-task or off-task to distinguish between periods of focused attention and distraction.

3 Results

3.1 Response Time

In this study, we compared SART performances between ND and rMDD groups, and examined the effects of two interventions, mindfulness and positive fantasizing, on SART accuracy, response times, and thought probe responses between the two groups. Initially, we analyzed baseline differences in mean response times between ND and rMDD. Results indicated a higher response time for the rMDD group compared to the ND controls at baseline ($t(36652) = -18.609$, $p < 0.0001$).

To examine whether the interventions affected how fast participants performed the task, we compared response times between ND and rMDD participants assigned to each intervention. The LME model revealed a significant effect of interventions on response time ($\chi^2(3) = 148.8024$, $p < 0.0001$). Both mindfulness and fantasizing significantly reduced response times compared to baseline ($t(155505) = -8.415$, $p < 0.0001$ [Figure 3.1A], and $t(157905) = -10.314$, $p < 0.0001$ [Figure 3.1B], respectively).
To assess any potential differences in the effects of each particular intervention on the different groups (ND and rMDD), we evaluated the interaction effects of groups and interventions on response time. The LME model revealed no significant interaction effect of group and interventions (mindfulness and positive fantasizing) on response time ($\chi^2(3) = 6.3976$, $p = 0.09379$).

3.2 Accuracy

To examine participants' accuracy for the SART task, we distinguished between go and no-go trials. Go trials require participants to respond quickly to frequently presented stimuli, while no-go trials require participants to inhibit their response to infrequent stimuli. Go trials required a prompt and positive response from participants; thus errors in go trials were interpreted as a loss of attention. No-go trials required a conscious lack of response from the participants; thus errors in no-go trials were deemed as a problem with inhibition. Analysis of data from these tests was designed to reflect this distinction.

3.2.1 Go Trials

To compare accuracy between ND and rMDD, we first measured accuracy at baseline for each respective group at go trials. The GLME model revealed no significant difference between accuracy at baseline between the two groups at go trials ($\chi^2(1) = 2.9201$, $p = 0.08748$).

To examine whether the interventions affected task accuracy at go trials, we compared the accuracy between ND and rMDD participants for each intervention group at go trials. The GLME model revealed a significant effect of interventions on accuracy at go trials ($\chi^2(3) = 25.9779$, $p < 0.0001$). Specifically, mindfulness increased accuracy at go trials for both groups while fantasizing increased accuracy at go trials for ND controls ($z = -2.223$, $p = 0.0262$ [Figure 3.2A], and ($z = 4.346$, $p < 0.0001$ [Figure 3.2B], respectively).

3.2.2 No-go Trials

To compare accuracy between ND and rMDD, we first measured accuracy at baseline for each respective group at no-go trials. The GLME model revealed no significant difference between accuracy at baseline between the two groups at no-go trials ($\chi^2(1) = 0.0255$, $p = 0.8731$).

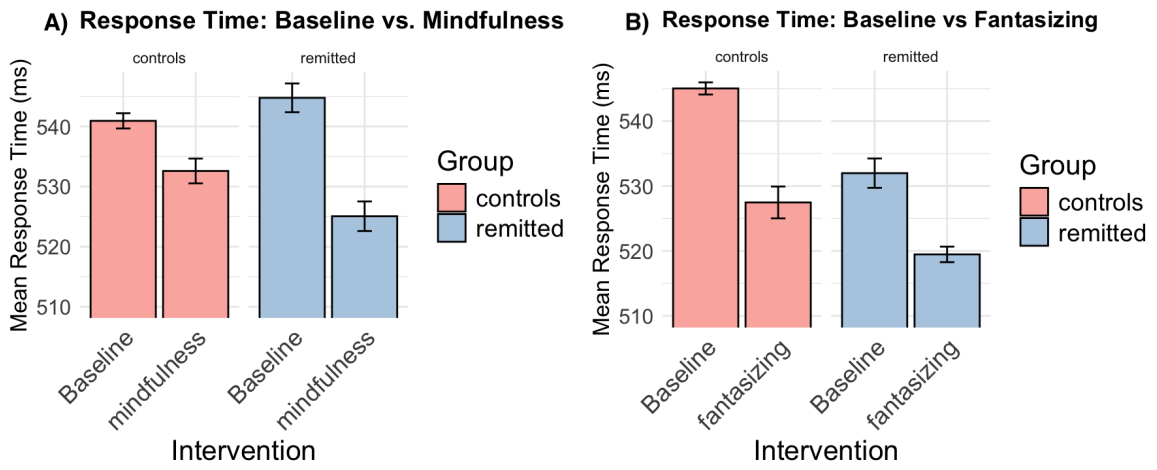

Figure 3.1: (A) Average Response time for mindfulness and its baseline by group. Mindfulness significantly reduced response times for both groups compared to their baseline response times. (B) Average Response time for positive fantasizing and its baseline by group. Fantasizing reduced response time compared to its baseline in both groups. Error bars reflect standard errors.

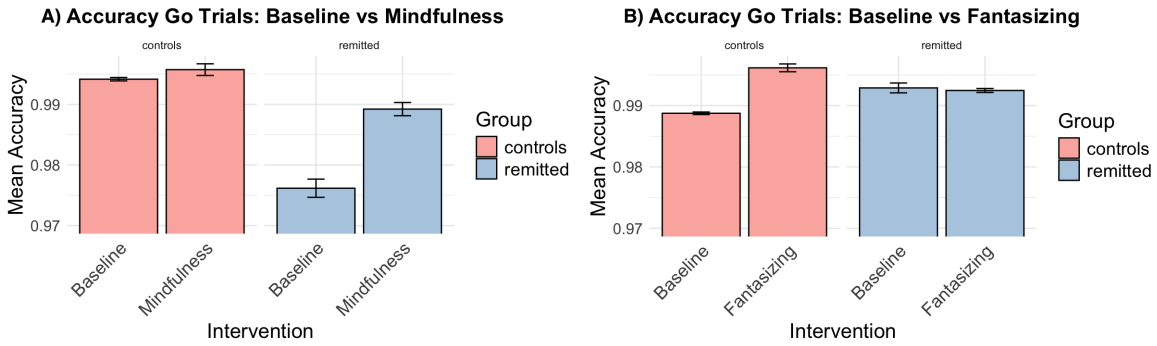

Figure 3.2: (A) Mean accuracy for mindfulness and its baseline by group at go trials. Mindfulness increased accuracy at go trials in both groups. (B) Mean accuracy for positive fantasizing and its baseline by group at go trials. Positive fantasizing increased accuracy at go trials in ND controls. Error bars reflect standard errors.

To examine whether the interventions affected task accuracy at no-go trials, we compared the accuracy between ND and rMDD participants for each intervention group at no-go trials. The GLME model revealed a significant effect of interventions on accuracy at no-go trials ($\chi^2(3) = 37.4733$, $p < 0.0001$). Specifically, mindfulness decreased accuracy in both groups compared to baseline while fantasizing decreased accuracy only in ND controls compared to baseline at no-go trials ($z = -4.880$, $p < 0.0001$ [Figure 3.3A], and $z = -4.095$, $p < 0.0001$ [Figure 3.3B], respectively).

3.3 Thought Probes: Response Time

At the end of each SART block, participants answered thought probe questions designed to evaluate their own perception of how they performed on the tasks and were designated as on-task if they were self-reportedly focused on the task and off-task if they were not.

To evaluate the relationship between participants' self-reported task status (i.e. on-task or off-task) and their actual task performance, we first compared the mean response times between on-task and off-task conditions for both groups. The LME model revealed a significant effect of task status on mean response time ($\chi^2(1) = 3084.9115$, $p < 0.0001$). Specifically, being on-task was linked to significantly lower response times compared to being off-task for both ND and rMDD groups ($t(37645.167) = -55.542$, $p < 0.0001$) [Figure 3.4]. Moreover, to examine whether the relationship between participants' responses to thought probes and their mean response times in the SART task differed between the ND and rMDD groups, we compared the response times between on-task and off-task conditions, considering the interaction between task status and group. The LME model revealed a significant interaction effect between task status and group ($\chi^2(1) = 1068.359$, $p < 0.0001$) on mean response time. This suggests that the difference in mean response times between on-task and off-task conditions varied depending on group membership. Specifically, the ND group had a significantly larger on-task versus off-task difference (mean response time difference) compared to the rMDD group ($t(37653.356) = 32.686$, $p < 0.0001$) [Figure 3.4].

3.4 Thought Probes: Accuracy

3.4.1 Go Trials

To examine whether participants' responses to thought probes accurately reflected their accuracy in the SART task at go trials, we compared the mean accuracy between on-task and off-task conditions for both ND and rMDD groups at go trials. The GLME model revealed a significant effect of task status on mean accuracy ($\chi^2(1) = 0.03491$, $p = 4.4494$) at go trials. Specifically, being on-task was linked to higher mean accuracy compared to being off-task for ND controls however, being on-task was linked to lower mean accuracy compared to being off-task for rMDD individuals at go trials ($z = 2.109$, $p = 0.0349$) [Figure 3.5].

3.4.2 No-go Trials

To examine whether participants' responses to thought probes accurately reflected their accuracy in the SART task at no-go trials, we compared the mean accuracy between on-task and off-task conditions for both ND and rMDD groups at no-go trials. The GLME model revealed no significant effect of task status on mean accuracy ($\chi^2(1) = 1.7165$, $p = 0.1901$) at no-go trials.

3.5 Frequency of Being On-Task

To assess whether the likelihood of being on-task was affected by interventions (compared to their baseline), we compared the proportion of on-task responses across different phases (baseline and/or interventions) and groups. The GLME model revealed a significant effect of interventions on task status ($\chi^2(3) = 14.226$, $p = 0.002612$). Specifically, fantasizing ($z = 3.342$, $p = 0.000833$) significantly increased the odds of being on-task compared to baseline for both rMDD and ND groups [Figure 3.6A]. Moreover, mindfulness ($z = 2.493$, $p = 0.012676$) increased the odds of being on-task compared to baseline for ND controls while it decreased the likelihood of being on-task for rMDD individuals [Figure 3.6B]. Additionally, the GLME model revealed a significant interaction effect of interventions and groups on task status ($\chi^2(3) = 13.6854$, $p = 0.003366$). Specifically, the impact of fantasizing ($z = 3.294$, $p = 0.000987$) on increasing

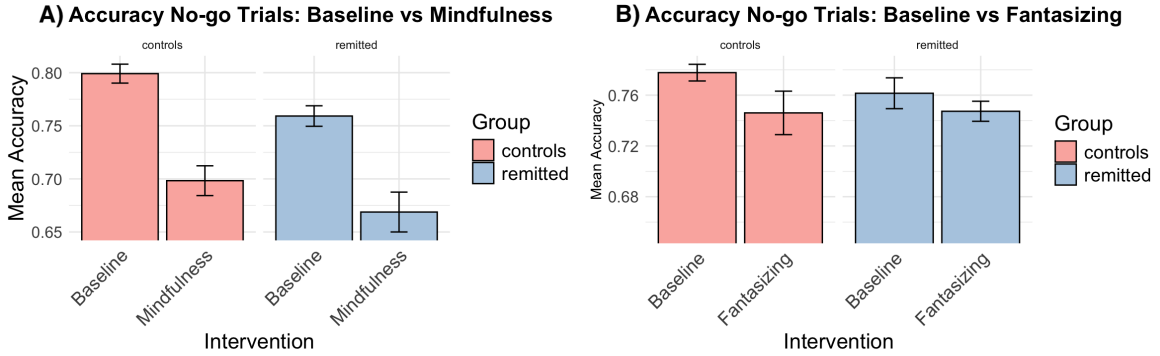

Figure 3.3: (A) Mean accuracy for mindfulness and its baseline by group at no-go trials. Mindfulness decreased accuracy at no-go trials in both groups. (B) Mean accuracy for positive fantasizing and its baseline by group at no-go trials. Positive fantasizing decreased accuracy at no-go trials in ND controls. Error bars reflect standard errors.

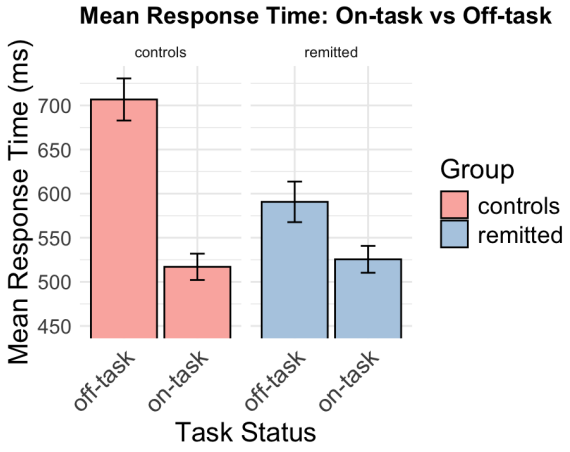

Figure 3.4: Mean response time by task status. Reporting on-task was linked to significantly lower response times compared to reporting off-task for both ND and rMDD groups. Error bars reflect standard errors.

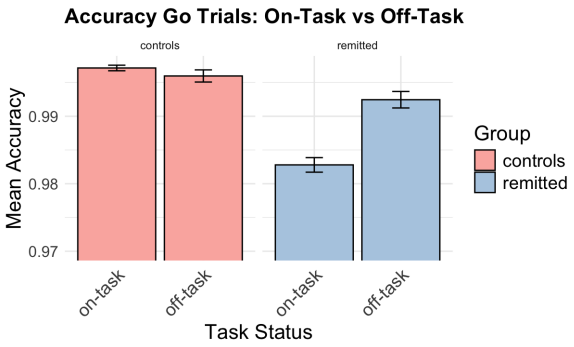

Figure 3.5: Mean accuracy between on-task and off-task conditions by group at go trials. Being on-task was linked to higher mean accuracy compared to being off-task for ND controls however, being on-task was linked to lower mean accuracy compared to being off-task for rMDD subjects. Error bars reflect standard errors.

the likelihood of being on-task (compared to baseline) was significantly greater for the rMDD group compared to the control group [Figure 3.6A].

4 Discussion

The main goals of this study were to explore how mindfulness and positive fantasizing influence PC in rMDD and ND individuals and to examine whether these interventions differentially affect PC between the two groups. To this end, we compared performances on an app-based version of the SART between ND and rMDD individuals, examining the effects of mindfulness and positive fantasizing on SART accuracy and response times. Additionally, we compared their responses to thought probes across these conditions. The SART was chosen as it combines self-report of the thinking process with detailed task performance measures, making it a valuable objective behavioral measure of PC, as supported by Van Vugt & Broers (2016), who found that more PC-like off-task patterns were associated with worse and more variable task performance.

In line with the findings of Kappes & Oettingen (2011), who observed reductions in response times on a flanker task following a fantasizing intervention, our study also demonstrated that both mindfulness and positive fantasizing interventions led to decreased response times compared to baseline in the SART task for both rMDD and ND groups. Moreover, we observed that mindfulness increased accuracy compared to baseline for both groups at go trials. This finding is consistent with the study by Deng et al. (2014), which found that the error rate of targets in the SART was negatively correlated with mindfulness, indicating that higher mindfulness was associated with fewer errors. Similarly, positive fantasizing also increased accuracy at go trials, but this effect was observed only in ND controls. It is worth noting, however, that while these previous studies were conducted in controlled lab settings, our task was administered via a phone app, which could introduce different dynamics in participant engagement and performance.

Similar to the findings of Van Vugt & Broers (2016), our study showed that thought contents impact task performance. Specifically, our results indicate that on-task thinking was associated with lower response times compared to off-task thinking for both ND and rMDD groups. This aligns with Van Vugt & Broers (2016) observations that the stickiness of off-task thinking increased response time variability. This is particularly noteworthy finding, as it highlights that, despite the app-based nature of the task, the link between thought patterns and task performance is still clearly observable, similar to what is typically seen in traditional lab settings.

Surprisingly, the ND controls exhibited a significantly larger difference in response times between on-task and off-task conditions compared to the rMDD subjects. In addition, being on-task was associated with higher mean accuracy in ND controls, while for rMDD individuals, being on-task was associated with lower mean accuracy compared to being off-task during go trials. These findings can be interpreted in the context of previous research by Farrin et al. (2003), who observed that depressed individuals reported higher incidences of cognitive failures on a cognitive failure questionnaire compared to non-depressed individuals. Farrin et al. (2003) found that depressed men made more errors on the SART and reported more cognitive failures than non-depressed men. They suggested that the heightened subjective sense of cognitive failure in depressed individuals might be due to their catastrophic response to errors, leading to increased self-monitoring and using up more mental energy to stay focused. This could explain the strong relationship between self-reported cognitive failures and depression. In line with Farrin's findings, our results suggest that rMDD individuals might frequently assume to be off-task due to their heightened sensitivity to errors and cognitive slips, even when their task performance does not necessarily reflect significant lapses in attention. This could indicate that rMDD individuals have a tendency to catastrophically respond to perceived cognitive failures, leading to a subjective experience of being off-task. On the other hand, the larger off-task versus on-task difference in response times observed in ND controls compared to rMDD subjects, and the associated higher mean accuracy in ND controls when on-task, suggests that they might have a

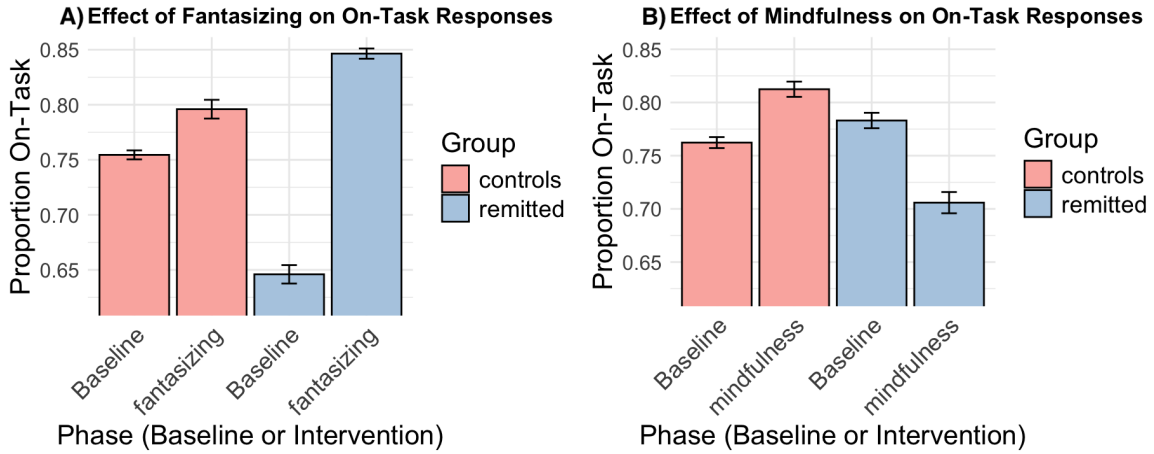

Figure 3.6: (A) Effect of fantasizing on being on-task. Fantasizing significantly increased the odds of being on-task compared to baseline for both rMDD and ND groups. (B) Effect of mindfulness on being on-task. Mindfulness increased the odds of being on-task compared to baseline for ND controls while it decreased the likelihood of being on-task for rMDD individuals. Error bars reflect standard errors.

better understanding of their thought content. ND controls' task performance aligns more closely with their self-reported thought content, indicating that they can more accurately assess when they are truly off-task or on-task. In contrast, the rMDD group's reported off-task thoughts might be influenced by their (potential) depressive cognitive biases, causing them to misinterpret their thought content and performance.

Another puzzling finding in our study was that being on-task was linked to lower mean accuracy compared to being off-task for rMDD individuals at go trials. This might be linked to the tendency of rMDD individuals to more frequently report being off-task, as discussed previously. Their potential misinterpretation of their thought content, influenced by their heightened sensitivity to errors and cognitive slips (Farrin et al., 2003), might lead to believe they are off-task when they are actually not. Consequently, this misinterpretation could results in better accuracy when they are not actively trying to monitor their performance, explaining the lower accuracy when they are on-task. Furthermore, this pattern might reflect a speed-accuracy trade-off. Helton et al. (2009), using the SART task, found that faster response times were correlated with higher error rates, suggesting that participants may sacrifice accuracy when they respond more quickly. In our study, being on-task was associated with lower response times for rMDD individuals at go trials, indicating that the lower accuracy observed during on-task conditions could be a result of participants prioritizing speed over accuracy, thereby reflecting the speed-accuracy trade-off described by Helton et al. (2009).

Moreover, our findings contrast with those of Besten et al. (2023), who found no main effect of the intervention on the frequency of off-task thinking and no significant change in on-task thinking over time after a single session of positive fantasizing and a single session of stress induction. It is important to note that in the study by Besten et al. (2023), participants received much less practice, which could partly explain the differences in outcomes. In our study, fantasizing significantly increased the odds of being on-task compared to baseline for both groups, suggesting that the level of practice or exposure to the intervention may play a crucial role in its effectiveness. A perplexing finding in our study was that overall, mindfulness decreased the odds of being on-task for rMDD individuals compared to baseline. This could be explained in the context of Feld-

man's study (Feldman et al., 2010), which explored the diversity of mind-wandering and its impact on task performance through different interventions. They found that in comparison to other conditions, the mindfulness group reported an increase in negative thoughts during the induction process and the frequency of these negative thoughts was not related to negative reactions. This suggests that mindfulness helped individuals observe their thoughts without being emotionally affected by them. In our study, the observed decrease in on-task thinking among rMDD individuals following mindfulness could indicate that mindfulness enhances awareness of thoughts without necessarily improving task engagement. Similar to Feldman's findings, our results suggest that mindfulness may decouple the presence of thoughts from emotional reactivity and task performance. Therefore, while mindfulness may increase awareness of internal experiences, it may not always translate to increased task focus, particularly in individuals with a history of depression.

Lastly, our study revealed that mindfulness was associated with a decrease in accuracy during no-go trials for both rMDD and ND groups. This outcome can be interpreted in light of Feldman's research (Feldman et al., 2010), which suggested that while mindfulness increased awareness of internal thoughts, it did not necessarily mitigate negative reactivity or enhance task performance. In our study, this increased self-awareness might have led participants to become more attuned to their intrusive thoughts, potentially amplifying cognitive distractions and impairing their ability to inhibit inappropriate responses during no-go trials. Furthermore, Ottaviani et al. (2015) demonstrated that PC was associated greater cognitive effort to inhibit intrusive thoughts and increased interference with ongoing tasks. This cognitive rigidity, as described by Ottaviani et al. (2015), could explain why heightened awareness in mindfulness did not translate into better inhibitory control but rather exacerbated difficulties in maintaining focus and accuracy, particularly in tasks requiring high levels of cognitive inhibition. Additionally, we found a decrease in accuracy at no-go trials for ND controls following positive fantasizing. This may be understood in the context of cognitive demands of mental imagery. As suggested by RN (1971), tasks involving mental imagery, such as positive fantasizing, require a shift of attention away from external sensory input and toward internally generated images or scenarios (Smallwood & Schooler, 2013; Smallwood, O'Connor, et al., 2004). This internally focused attention might share information-processing characteristics with mind wandering (presumably PC too), potentially reducing the cognitive resources available for tasks requiring external attentional control, such as inhibiting responses during no-go trials. This could explain why positive fantasizing, although intended to generate positive internal experiences, led to a decreased in accuracy in tasks requiring strong inhibitory control in ND controls.

In summary, we compared performances on an app-based version of SART between ND and rMDD individuals to examine the effects of mindfulness and positive fantasizing on accuracy and response times. The SART, integrating self-reported thoughts with task performance, was selected as a robust objective measure of PC, with prior findings indicating that more PC-like thought patterns are linked to poorer and more variable task performance (Van Vugt & Broers, 2016). We hypothesized that self-reported PC in the SART would reduce and task performance would improve after interventions. Consistent with our hypothesis we found that both interventions caused a decrease in response time in both rMDD subjects and ND controls. Additionally, mindfulness increased accuracy at go trials for both groups, while fantasizing improved accuracy at go trials only for ND controls. Given that PC-like thought patterns have been associated with poorer and more variable task performance, the observed improvements in response time and accuracy (at go trials) suggest that both mindfulness and fantasizing effectively mitigated PC, enhancing overall task performance. Since go trials require a habitual response, the improvement in accuracy at go trials may reflect a general increase in focus or attention on the task at hand, indicating that these interventions helped reduce the cognitive distractions typically associated with PC. As we hypothesized, fantasizing increased on-task thinking, suggesting a reduction in self-reported PC, a form of off-task thinking. A similar effect was observed in mindfulness in ND controls. Surprisingly, mindfulness led to a decrease in on-task thinking in rMDD indi-

viduals and reduced accuracy during no-go trials in both groups. This suggests that while mindfulness increases internal awareness, it may not necessarily enhance inhibitory control or task performance. Instead, it could heighten sensitivity to intrusive thoughts, thereby impairing focus and response inhibition. As Feldman et al. (2010) indicates, mindfulness can raise self-awareness without improving task engagement. Therefore, in some cases, mindfulness might inadvertently worsen task performance and increase off-task or PC-like thinking due to its effect on enhancing internal awareness. Moreover, ND controls showed a larger difference in mean response times between on-task and off-task conditions, with higher accuracy when on-task, while rMDD individuals had a lower accuracy when on-task. Previous research suggests that rMDD individuals may perceive themselves as off-task more frequently due to heightened sensitivity to errors, leading to a subjective sense of cognitive failure even when their task performance does not necessarily reflect significant lapses in attention. In contrast, ND controls align their task performance more accurately with their self-reported thought content, indicating better self-assessment and focus.

Lastly, we observed a decrease in accuracy at no-go trials for ND controls following positive fantasizing. This effect might be due to the cognitive demands of mental imagery, which shifts attention away from external tasks and reduces resources inhibitory control. Thus, while positive fantasizing is intended to create positive internal experiences, it may inadvertently impair performance on tasks requiring strong attentional control. Overall, our findings suggest that while both mindfulness and positive fantasizing can mitigate PC, their effects vary between ND and rMDD individuals. Mindfulness appears to mitigate PC more effectively in ND controls by increasing on-task thinking and improving accuracy during habitual tasks. However, in rMDD individuals, the heightened internal awareness fostered by mindfulness may lead to increased sensitivity to intrusive thoughts, paradoxically reducing task focus and inhibitory control. Positive fantasizing, on the other hand, improves on-task thinking and accuracy in ND controls but may introduce cognitive challenges that impair inhibitory control, as seen in the decrease in no-go trial accuracy. Thus, the interventions' effects on PC are nuanced, with differences in cognitive profiles between ND and rMDD individuals influencing the outcomes.

4.1 Limitations and future research

One of the limitations of this study is the data collection process, which was impacted by the COVID-19 pandemic. During the pandemic, 47 participants were included in the study. The pandemic may have affected participants' mood and PC (Hossain et al., 2020), potentially influencing their task performance. The elevated mental health issues such as anxiety, depression, and stress widely reported during the pandemic may have reinforced participants' susceptibility to PC and impaired cognitive performance, thereby affecting the reliability of our findings when generalized to the broader population.

Another limitation is that despite a month-long wash-out period between phases, the prolonged exposure to the SART task may have led to improvements in performance due to increased familiarity with the task. This makes it difficult to distinguish whether the observed performance enhancements, especially during the second intervention, were due to the effect of interventions or simply the result of automatic training.

Additionally, the uncontrolled environment in which participants performed the SART task could have introduced external factors that influenced their performance and their self-reported thought content.

Lastly, while a significant number of drop-outs after the baseline phase could have impacted the overall results, we used LME models to minimize this issues. These models compare each participant's data with their own baseline, allowing us to mitigate the potential skew in results due to missing induction phase data. However, the absence of data from these participants during the induction phase still means that the full impact of the interventions on them could not be assessed.

Future studies can improve by methodological enhancements. Firstly, the results of thought probes analysis could be different due to the existing debate about the categorization of task-related thoughts as on-task or off-task thoughts (Kawagoe & Kase, 2021). Moreover, the SART was de-

signed so that thought probes asking about participants' current thoughts always appeared after a no-go trial. As a result, participants might have been able to predict the appearance of a thought probe, potentially influencing their responses (Besten et al., 2023, 2024).

5 Conclusions

In short, our study explored the effects of positive fantasizing and mindfulness on attentional processing and PC in ND and rMDD individuals. Using an app-based version of SART, we assessed how these interventions influenced accuracy, response times, and responses to thought probes. Our findings indicate that both interventions can influence PC but with differing impacts across groups. Mindfulness reduced response times and increased accuracy at go trials for both groups, suggesting a general reduction in PC. However, it also decreased accuracy at no-go trials and reduced on-task thinking in rMDD individuals. Positive fantasizing similarly reduced response times and improved go trial accuracy, but only for ND controls, while decreasing no-go trial accuracy in this group, suggesting its benefits for reducing PC may be more effective in ND individuals, particularly in terms of task performance. However, positive fantasizing had a more pronounced effect in the rMDD group for increasing on-task thinking and, consequently, decreasing off-task thinking. Overall, while both interventions appeared to enhance general task focus by reducing response times and improving go trial accuracy, they also tended to impair inhibitory control, as evidenced by decreased accuracy at no-go trials.

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A Appendix

The thought probes (multiple choices) and their (possible) choices are:

0) What were you just thinking about?
a) I was fully focused on the task
b) I was evaluating aspects of the task
c) I was thinking about personal things
d) I was distracted by my environment
e) I was daydreaming (I was thinking about task-unrelated things)
f) I was not paying attention but was not thinking about something specific

1) How difficult was it to let go of the thought?
a) Very difficult
b) Difficult
c) Neither difficult nor easy
d) Easy
e) Very easy

2) What was the temporal orientation of your thought?
a) Past
b) Present
c) Future

3) Were your thoughts negatively, neutrally, or positively valenced?
a) Negative
b) Neutral
c) Positive