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The impact of mood-induction on maladaptive thinking in the vulnerability for depression

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ABSTRACT

Background and objectives: Mind-wandering, and specifically the frequency and content of mind-wandering, plays an important role in the psychological well-being of individuals. Repetitive negative thinking has been associated with a high risk to develop and maintain Major Depressive Disorder. We here combined paradigms and techniques from cognitive sciences and experimental clinical psychology to study the transdiagnostic psychiatric phenomenon of repetitive negative thinking. This allowed us to investigate the adjustability of the content and characteristics of mind-wandering in individuals varying in their susceptibility to negative affect.

Methods: Participants high (n = 42) or low (n = 40) on their vulnerability for negative affect and depression performed a Sustained Attention to Response Task (SART) after a single session of positive fantasizing and a single session of stress induction in a cross-over design. Affective states were measured before and after the interventions.

Results: After stress, negative affect increased, while after fantasizing both positive affect increased and negative affect decreased. Thoughts were less off-task, past-related and negative after fantasizing compared to after stress. Individuals more susceptible to negative affect showed more off-task thinking after stress than after fantasizing compared to individuals low on this.

Limitations: In this cross-over design, no baseline measurement was included, limiting comparison to ‘uninduced’ mind-wandering. Inclusion of self-related concerns in the SART could have led to negative priming.

Conclusions: Stress-induced negative thinking underlying vulnerability for depression could be partially countered by fantasizing in a non-clinical sample, which may inform the development of treatments for depression and other disorders characterized by maladaptive thinking.

1. Introduction

Even though you truly intend to read this full article, your mind may drift off. Drifting off is something that occurs in every individual (Killingsworth & Gilbert, 2010), but has different characteristics in individuals with psychopathology. In individuals with Major Depressive Disorder (MDD), the thoughts that occur during mind-wandering will frequently be negative and self-related (Hoffmann, Banzhaf, Kanske, Bermpohl, & Singer, 2016). This characteristic repetitive thought pattern is referred to as ‘perseverative cognition’ or rumination (Brosschot, Verkuil, & Thayer, 2010; Ottaviani et al., 2015) and has been proposed to be a key factor in the development and perpetuation of MDD (Brosschot et al., 2010; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Maladaptive mind-wandering can be elicited by high levels of stress and sustain negative emotions that can enhance risk factors for MDD (Marchetti, Koster, Klinger, & Alloy, 2016). Not only MDD, but also other psychiatric disorders such as Attention Deficit Hyperactivity Disorder (Seli, Smallwood, Cheyne, & Smilek, 2015), schizophrenia (Shin et al., 2015), and Generalized Anxiety Disorder (American Psychiatric Association, 2022) have been associated with abnormalities in mind-wandering. This suggests that mind-wandering, and specifically the frequency and content of mind-wandering, plays an important role in the psychological well-being of individuals and may serve as a transdiagnostic therapeutic target for lowering the burden of psychiatric

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disorders.

Mind-wandering may be specifically relevant to understanding abnormalities in mood because a direct relationship between mind-wandering and mood has been found (Smallwood & Andrews-Hanna, 2013). For example, negative mood induction by emotional videos and negative affirmations was found to affect the frequency, content and temporal-orientation of mind-wandering (Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood & O'Connor, 2011), with larger effects in those vulnerable for MDD (Smallwood & O'Connor, 2011). Furthermore, a small increase in future-related thinking was found after a positive mood induction, especially in individuals low on self-reported depressive symptoms (Smallwood & O'Connor, 2011). This suggests that mind-wandering characteristics can be adjusted by mood-induction.

In mind-wandering studies, the effects of mood-induction techniques on mind-wandering in healthy individuals are often studied using laboratory tasks that examine momentary thoughts using a task-based assay (e.g., Smallwood et al., 2009; Smallwood & O'Connor, 2011), such as the Sustained Attention to Response Task (SART). It has been shown that difficulty in disengaging from an off-task thought (as is characteristic of rumination) during the SART was associated with increased variability in task performance (van Vugt & Broers, 2016). In clinical research, on the other hand, effects of therapeutic techniques on ruminative thoughts are often measured based on retrospective self-report questionnaires (e.g. Jones, Siegle, & Thase, 2008; Watkins & Roberts, 2020), which does not allow to study the in-the-moment thinking (i.e. mind-wandering). We therefore propose to study clinically relevant effects of mood induction using a task-based assay. Because positive and negative mood may differentially affect content of thinking, we further suggest that studying mood-induction effects is necessary to understand how maladaptive thinking in individuals at risk for depression is adjustable. As a first step, we study how maladaptive thinking can be altered by mood-induction techniques using a cross-over design comparing two mood-induction techniques in a non-clinical sample that varied in their susceptibility for perseverative cognition.

The aim of the current study is to investigate the adjustability of the content and characteristics of mind-wandering by positive and negative mood induction in individuals at varying susceptibility to maladaptive thinking and experiencing negative affect. To this end, we will contrast a single-session of positive self-related fantasizing with a single-session of social-stress induction using a task-based assay in the context of a cross-over experimental design and compare individuals scoring high vs. low on neuroticism and worrying. The content and characteristics of mind-wandering will be indexed by the frequency, stickiness, valence, temporal orientation, and self-relatedness of spontaneous thoughts during the SART. This could give insight into the mechanisms underlying adjustability of the content and characteristics of mind-wandering in individuals varying in their susceptibility to maladaptive mind-wandering, which could inform therapeutic interventions.

2. Materials and methods

2.1. Participants

In total, 249 university students were screened of which 82 participants were invited for participation based on their accumulated score on the Dutch version of the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) and the Neuroticism scale of the Dutch NEO Five-Factor Inventory (NEO-FFI; Costa & McCrae, 1995). Forty participants were categorized as being 'low in susceptibility to negative affect' (low-SNA; total score $\leq$70) and 42 participants were categorized as being 'high in susceptibility to negative affect' (high-SNA; total score $\geq$90), of which respectively 40 and 39 participants were included in the analyses (see *2.6 Sample size* and *3.1 Participant flow*). More information about the cut-off scores for participant selection can be found in Supplementary Materials 1. The study was approved by the ethical committee of the faculty of Behavioral and Social Sciences of the University of Groningen (ECP number: 16239-SP-N) and all participants provided written Informed Consent. The study was conducted in agreement with the Declaration of Helsinki (World Medical Association, 2013).

2.2. Screening measures on susceptibility to negative affect

The PSWQ questionnaire contains 16 items to examine excessiveness and uncontrollability of worry. Participants rated the extent to which they recognize themselves in statements about the excessiveness and uncontrollability of worries on a Likert-Scale ranging from 1 (not at all typical of me) to 5 (very typical of me).

The Neuroticism, Extraversion and Conscientiousness scale of the NEO-FFI consists of 36 statements relating to these three personality traits, and participants were instructed to rate the extent to which they recognized themselves in these statements. These scales were administered at the screening phase. Only the Neuroticism scale was used for screening, the scales on Extraversion and Conscientiousness were used for sample description as they have previously been related to the risk of developing affective psychopathology (Karsten et al., 2012).

The PSWQ and Neuroticism scale have been found to be strongly correlated in the current study ($r = 0.8, p < .001$) and in a previous study (Servaas, Riese, Ormel, & Aleman, 2014), and are therefore combined as a measure of susceptibility to negative affect that coincides with worrying.

2.3. Outcome measures

2.3.1. Questionnaire on mood induction effects

To verify the effect of the interventions on mood state, the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) was administered. This questionnaire asked participants about the extent to which they experienced certain feelings and emotions at that moment in time. Ratings were given on a Likert-scale ranging from 1 (very slightly or not at all) to 5 (extremely).

2.3.2. Sustained attention to Response Task (SART)

To examine the effects of the interventions on mind-wandering behavior, an adapted version of the SART from McVay and Kane (2013) was used. This is a long and deliberately boring, mind-wandering-inducing go-/no-go task. Participants had to press a button whenever a word appeared in lower case (e.g., "home") and to withhold a response when they saw a word in upper case (e.g., "BOAT"), which occurred only in approximately 10% of trials. In total, 192 English-to-Dutch translated words were used (van Vugt & Broers, 2016) quasi-randomly drawn from the Battig-Montague word pool (Battig & Montague, 1969). Words were presented for 0.3 s each and subsequently masked for 0.3 s. Participants had 3.6 s starting at stimulus onset to respond. To reduce predictability of stimulus onset, the between-trial interval (ISI) was varied randomly between 1.5 and 2.1 s (see Figure 1A Supplementary materials 2). Stimulus presentation and response registration were controlled with PsychoPy 1.8 (Peirce, 2007).

To maximize the probability of self-related ruminative thinking occurring, we incorporated words that referred to participants' own concerns (McVay & Kane, 2013). The concern words were extracted from the Dutch version of the Personal Concern Inventory (Cox & Klinger, 2004). This questionnaire asks about participants' current concerns and/or goals in their lives that concern the coming year and their importance. Two of the most important concerns were extracted and transformed to a set of three words describing the concern. These words were presented in the task as triplets of word stimuli sequentially shown to the participants as go-stimuli. As a control condition, concerns of other participants are used, for which we chose concerns that had a minimal overlap with the participants' own concerns.

Similar to the study of van Vugt and Broers (2016), thought probes were used that probed subjective experience of participants at that particular moment in the task. In total, we probed subjective experience on five different dimensions: occurrence, stickiness (how difficult it is to disengage from the thought), temporal orientation, valence and self-relatedness of off-task thoughts (see Supplementary Materials 3). Together these questions give a comprehensive description of thinking and allow us to identify the characteristics of ruminative thinking (sticky, negative, past- and self-related mind-wandering).

More information about the task design can be found in the Supplementary Materials 2.

2.4. Interventions

Interventions used to induce negative and positive mood, respectively, were the public speaking task adapted from the Trier Social Stress Task (Kirschbaum, Pirke, & Hellhammer, 1993) and a positive fantasizing challenge based on the Preventive Cognitive Therapy intervention (Bockting et al., 2005).

2.4.1. Public speaking task

The public speaking task is a widely used task that has been shown to reliably induce stress, as evidenced for example by rises in cortisol levels and other physiological stress parameters (Kirschbaum et al., 1993; Young, Lopez, Murphy-Weinberg, Watson, & Akil, 2000). The task as used in the current study consisted of a preparation phase and a presentation phase of 5 min each. Participants were instructed to prepare and present a 5-min speech for a job interview in English (i.e., not their native language). They were told that a video camera would be used to record their speech and that they would be judged on their grammar and vocabulary. Participants could make notes during the preparation but were told afterwards that they could not bring their notes with them during the presentation. After the 5-min preparation phase, participants had to present themselves for 5 min to a jury member who carried a blank facial expression and a video camera. The jury member did not reply to the participants using words or facial expressions. Only when participants stopped speaking, the jury member neutrally said "Please continue, you still have time". When the 5 min were over, participants were asked to leave the interview room.

2.4.2. Positive fantasizing

The positive fantasizing technique was isolated and adapted from the Preventive Cognitive Therapy protocol (Bockting et al., 2005). Preventive Cognitive Therapy focuses on identifying dysfunctional attitudes and beliefs and challenging these using the positive fantasizing technique, also called the positive-challenging technique. The current study focused on the positive fantasizing aspect of the challenge technique to induce a positive mood.

Between five and one days prior to the lab session participants were asked to fill out the Dysfunctional Attitude Scale (DAS-A; Weissman & Beck, 1978) to present them with ideas about possible life rules they could hold—i.e., statements describing attitudes or beliefs about themselves and how they lead their life. In the DAS, participants indicated the extent to which they recognized themselves in different attitudes (e.g., "People will probably think less of me if I make a mistake"). The DAS included 10 positively formulated items and 30 negatively formulated items which were rated on a Likert Scale ranging from 1 (totally disagree) to 7 (strongly agree).

At the start of the positive fantasizing intervention, the DAS questionnaire was shown again to the participants. Participants were asked to pick a positively formulated life rule from the DAS that attracted them, to pick a negative life rule from the DAS and rephrase it to a positive life rule, or, alternatively, to develop a new positive life rule themselves. An example of a positive life rule is: 'People still like me, even if I make many mistakes.' This life rule was then used to work with using the positive fantasizing technique. Specifically, participants were guided to visualize and experience the feelings that would be elicited when using this positive life rule in a 'dreamworld' for 10 min, by asking them questions such as 'How would you experience living with this life rule?' and 'What would it feel like living with this life rule?'. Participants were told that this ideal world did not have to be realistic. Furthermore, we asked them to think about how they could live more according to this life rule; indicating what concrete actions they could take.

2.5. Procedure

Participants were recruited to participate in a study measuring "the effects of social interactions on sustained attention". The study consisted of three sessions: an online screening session, an online questionnaire session, and a lab session (see Figure 2 in Supplementary materials 4).

2.5.1. Screening session

After participants registered for participation in the study, they received an online link to the screening questionnaires that were administered online, using anonymous Google Forms on which participants identified themselves with their participant code. Completing the questionnaires took approximately 20 min. Participants were compensated with 0.3 SONA study points (study points for participating in research needed for the bachelor Psychology) or 2 Euros for their participation in the screening phase. Participants that were found eligible for participation were invited for following sessions until a number of 40 analyzable participants per group was reached.

2.5.2. Questionnaire session

In the online questionnaire session, participants completed the DAS and the PCI. Between five and one days prior to the lab session participants received an e-mail with an online link to the questionnaires using Google Forms.

2.5.3. Lab session

In the lab, participants started by completing the PANAS as a baseline measure of their affective states at that moment. Following this, the first intervention was performed, which could be either the public speaking test or positive fantasizing. The order of interventions was counterbalanced and pseudorandomized across participants. After the first intervention, the PANAS was administered again to verify the effect of the intervention on affect, followed by the SART task. When the first intervention was the public speaking task, a short debriefing took place after SART performance to explain the reasons for this disruptive manipulation. This was done to give participants the assurance that they will in fact not be judged on their performance of the task, and to prevent overflow effects onto the second intervention. After a short break, the same sequence was followed (i.e., PANAS - intervention – PANAS - SART) using the other intervention. The experiment ended with a general debriefing during which participants were told about the purpose of the study. The lab session lasted approximately 100 min. Participants received 3.0 SONA credit points or 16 Euros for their participation in the study.

2.6. Sample size

Our study consists of two experiments. In the first experiment, which was preregistered on the Open Science Framework; https://osf.io/m97pd, we used a sample size of $n = 20$ participants per group ($n = 40$ in total). In this initial study, Bayes Factors showed that we could not distinguish between the alternative hypothesis and the null hypothesis (see Supplementary Materials 5). Therefore, another study with $n = 20$ participants per group was performed to double the sample size to $n = 40$ per group ($n = 80$ in total). Bayes Factors then showed that, we did have sufficient data to distinguish between the alternative hypothesis. For the current analysis, we pooled data from the two identical studies. We in total recruited $n = 82$ participants because we replaced two participants from the pooled set that were not analyzable (because of withdrawal and poor task-performance). One participant that was excluded because of poor task performance could not be replaced because of time constraints (see also *3.1 Participant flow*).

2.7. Data analysis

After data preparation (see Supplementary Materials 6), we used generalized additive modeling (GAM; Wood, 2017; see van Rij, Hendriks, van Rijn, Baayen, & Wood, 2019 and Wieling, 2018 for introductions) to examine the effects of mood-inductions on mood state, measured with the PANAS, SART performance and thought probes. GAM is a statistical technique similar to generalized regression except that it does not only allow for modeling linear trends (similar to GLM) but also non-linear trends over time. Next to a random intercept and slope, a random smoothing function can be added to explain non-linear random variation over time.

2.7.1. PANAS

To examine the effects of the mood-induction interventions on mood state and the differential effects of mood-induction interventions between individuals high vs. low susceptible to negative affect, a GAMs with *PANAS scores* as dependent variable and *affect state* (positive vs. negative), *intervention* (fantasizing vs. stress), *session* (pre vs. post) and *group* (high-SNA vs. low-SNA) as predictors was used. Moreover, the relationship between changes in PANAS scores (post-intervention – pre-intervention) and the frequency of mind-wandering after stress and positive fantasizing was explored using Pearson's correlation coefficient.

2.7.2. SART task performance

In order to check how reliable participants' self-reports of their on- vs. off-task behavior were, we included SART task performance (no-go accuracy, RT, RTvar) as dependent variable and on-/off-task behavior as predictor within the GAMs.

2.7.3. Thought probes

To examine the effects of mood-induction interventions on the content and characteristics of mind-wandering across groups we included the variables *session* (first vs. second SART performance) and *intervention* (fantasizing vs. stress) within the GAMs as possible predictor. Second, to examine whether the extent to which mood-induction interventions could affect the characteristics of mind-wandering depended on differences in the susceptibility to negative affect, we included the variable *group* (high vs. low susceptible to negative affect) in interaction with *session* and *intervention* as a predictor within the GAMs. To examine changes in the frequency of off-task thinking over time, a smoothing function effect for block was used that reflected the time course. For more detailed statistical model descriptions see Supplementary Materials 7.

To examine the significance of the predictors and smoothing (time course) functions, we used a backward fitting model procedure. After raw data visualization, the full model was inspected and step-by-step compared with a simpler model. Akaike information criterion (AIC) model selection was used to determine significant effects. A model that was more than 2 AIC units lower than the simpler model was considered significantly better (Akaike, 2011). The best model was then further studied by checking the summary output of the model resulting in z-scores for the frequency of mind-wandering, and t-scores for the PANAS results and the stickiness and content variables of mind-wandering. In case the summary output showed a significant interaction between affect states, intervention and session on PANAS scores, post-hoc paired t-tests were conducted to examine the specific differences between interventions and affect states.

3. Results

3.1. Participant flow

In total, 249 university students were screened of which 82 participants were invited for participation. Of these, forty participants were categorized as being 'low in susceptibility to negative affect' (low-SNA) and 42 participants were categorized as being 'high in susceptibility to negative affect' (high-SNA), of which respectively 40 and 39 participants were included in the analyses. See Fig. 1 for a flow diagram of the study.

3.2. Sample characteristics

The low-SNA group had a significantly higher male/female ratio than the high-SNA group [see Table 1; $\chi^2(1) = 5.3$, $p = .02$]. Sample characteristics as described in Table 1 were not normally distributed. Therefore, medians were calculated per group and Mann-Whitney tests were conducted to examine group differences. The high-SNA group showed significantly higher scores on the Neuroticism scale of the NEO-FFI and the PSWQ [$U(N_{high} = 39, N_{low} = 40) = 1555.0$, $p < .001$, $BF_{10} = 34594.6$; $U(N_{high} = 39, N_{low} = 40) = 1559.5$, $p < .001$, $BF_{10} = 11008.6$, respectively] and significantly lower scores on the Extraversion and Conscientiousness scales of the NEO-FFI [$U(N_{high} = 39, N_{low} = 40) = 317.5$, $p < .001$, $BF_{10} = 191.2$; $U(N_{high} = 39, N_{low} = 40) = 425.5$, $p < .001$, $BF_{10} = 53.6$, respectively] compared to the low-SNA group. Moreover, the high-SNA group showed significantly higher scores on the negative affect scale of the PANAS at baseline compared to the low-SNA group [$U(N_{high} = 39, N_{low} = 40) = 1141.5$, $p < .001$, $BF_{10} = 23.2$], whereas no differences were observed for positive affect [$U(N_{high} = 39, N_{low} = 40) = 709.0$, $p = .5$, $BF_{10} = 0.3$].

3.3. Mood induction effects

We checked whether the induction techniques worked by investigating the effects of interventions, sessions and affect states on PANAS scores. Model comparisons showed a significant 3-way interaction between affect, session, and condition [$\Delta AIC = -45.1$; $t = -7.1$; $p < .0001$]. Post-hoc paired t-tests showed that positive affect increased, and negative affect decreased following positive fantasizing [Wilcoxon test $Z = 247.0$, $p < .001$, $BF_{10} = 30754.7$ and $Z = 1973.0$, $p < .001$, $BF_{10} = 16050.2$ respectively]. Conversely, negative affect increased after stress [$Z = 26.5$, $p < .001$, $BF_{10} = 13264.7$], whereas no significant difference in positive affect was observed after stress induction [$Z = 1228.0$, $p = .9$, $BF_{10} = 0.1$]. The two interventions did not differ in their effect for the low vs high-SNA groups [$\Delta AIC = 1.9$]. No significant relationship was found between changes in positive affect and frequency of off-task thinking after the fantasizing intervention [$r(77) = -.1$, $p = .4$, $BF_{10} = 0.2$], nor after the stress intervention [$r(77) = .1$, $p = .6$, $BF_{10} = 0.2$]. Moreover, no significant relationship was found between changes in negative affect and frequency of off-task thinking after the fantasizing intervention [$r(77) = -.1$, $p = .9$, $BF_{10} = 0.1$], nor after the stress intervention [$r(77) = .1$, $p = .6$, $BF_{10} = 0.2$].

3.4. Intervention effects on SART performance

As predicted, we found that no-go accuracy was higher (M = 0.5, SE = 0.01) when participants reported being on-task, relative to when they reported being off-task (M = 0.3, SE = 0.01) [$\Delta AIC = -179.7$; $Z = -13.0$, $p < .0001$]. This suggests that subjective mental states are reported reliably. On the other hand, no difference in log-transformed mean response times between on- and off-task states was found [$\Delta AIC = 0.2$]. We found that log-transformed RT variability was slightly higher on on-task trials ($\mu = 2.1$, SEM = 0.01) vs. on off-task trials ($\mu = 2.0$, SEM = 0.02) [$\Delta AIC = -4.0$; $t = 2.5$; $p = .01$]. This could suggest that participants are engaged in automatic responses when they are off-task,

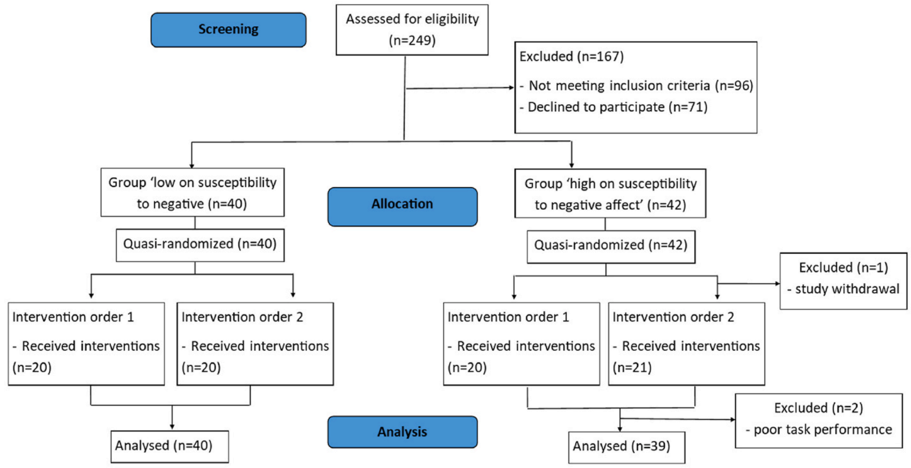

Fig. 1. Flow diagram of the cross-over randomized controlled trial. In intervention order 1, participants start with the positive fantasizing technique, followed by the stress-inducing task. In intervention order 2, participants start with the stress-inducing task, followed by the positive fantasizing technique. Two participants were excluded due to poor task performance (i.e., go trial error rate >50%).

Table 1
Sample characteristics of the high-SNA group (i.e., high in susceptibility to negative affect) and the low-SNA group (i.e., low in susceptibility to negative affect).

	High-SNA (n = 39)	Low-SNA (n = 40)	Sig.
Male/female ratio	5/34	14/26	*
Age (years)	19.0	20.0	
Neuroticism	40.0	24.0	***
Extraversion	39.0	47.0	***
Conscientiousness	42.0	47.0	***
PSWQ	62.0	34.5	***
Total (score on Neuroticism + PSWQ)	99.0	58.0	***
Baseline PANAS positive affect	25.0	27.0	
Baseline PANAS negative affect	15.0	12.0	***

Note. between-group significance * $p < .05$; ***$p < .001$.

which is associated with shorter response times that are less variable.

3.5. Mind-wandering characteristics in low vs. high susceptibility to negative affect

We next examined whether individuals' susceptibility to negative affect was associated with a difference in the content and characteristics of mind-wandering, and whether this was affected by the two mood-induction interventions. We found that the high-SNA group reported less on-task thinking compared to the low-SNA group [$\Delta AIC = -22.9$; $Z = 3.2$; $p = .001$]. Moreover, participants in the high-SNA group reported more sticky thoughts than participants in the low-SNA group [$\Delta AIC = -3.7$; $t = 3.7$, $p < .001$]. For the valence, temporal orientation, and self-relatedness of off-task thinking no group differences were observed [$\Delta AIC = -0.1$; $\Delta AIC = 0.9$; $\Delta AIC = 0.7$, respectively].

3.6. Adjusting thoughts by mood-induction

3.6.1. Frequency of on-task thinking

A significant interaction effect between session and intervention was found [$\Delta AIC = -6.0$; $Z = -2.8$; $p < .01$]. Participants were more off-task after the stress induction compared to after fantasizing (see Fig. 2A), but

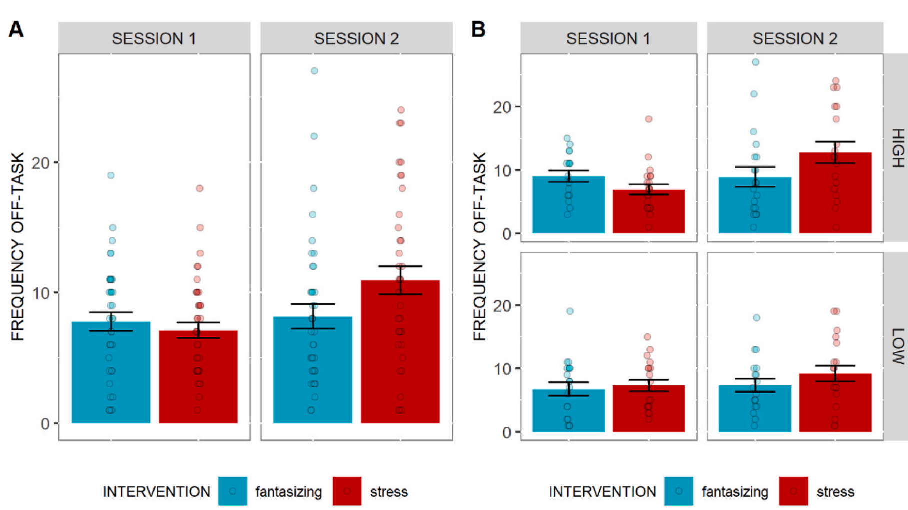

Fig. 2. A) Bar plot reflecting the mean frequency across participants and standard errors of the mean of off-task thinking after both interventions per session. Individual data points reflect the absolute frequency separately per participant. B) Bar plot with the mean frequency across participants and standard errors of the mean of off-task thinking in both interventions per session and group. Individual data points reflect the absolute frequency for each participant.

only when fantasizing was the first intervention. Furthermore, a significant interaction between intervention and group [$Z = -2.7$; $p < .01$] and significant three-way interaction of session x condition x group was found [ΔAIC = −14.1; $Z = 4.4$; $p < .0001$]. Individuals high-SNA report more off-task thinking after stress compared to individuals low-SNA, only when fantasizing was the first performed intervention (see Fig. 2B). No main effect of intervention on the frequency of off-task thinking was found [ΔAIC = −1.8] and the frequency of on-task thinking did not change significantly over time [ΔAIC = 1.4].

3.6.2. Stickiness of off-task thoughts

No significant effect of interventions on the difficulty to disengage from off-task thoughts –i.e., stickiness of off-task thinking– [ΔAIC = −0.5], nor an interaction effect between intervention and session [ΔAIC = 0.6] was found. Moreover, no interaction effect between intervention and group [ΔAIC = 0.4], nor an interaction effect between intervention, session and group was found [ΔAIC = 0.6].

3.6.3. Valence of off-task thoughts

Interventions significantly affected the valence of participants' self-reported off-task thoughts [ΔAIC = −2.3; $t = 3.7$; $p = .0001$]. Thoughts were more negative after stress than after fantasizing (see Fig. 3A). Moreover, the interventions had a different effect on the valence of off-task thinking in the different sessions [ΔAIC = −2.7; $t = -2.5$; $p = .01$]. As Fig. 3B shows, off-task thoughts were less negative following fantasizing if it was preceded by stress, and more negative following stress if it was preceded by fantasizing. No interaction effect between intervention and group, nor an interaction effect between intervention, session and group [ΔAIC = 0.7] on the valence of off-task thoughts was found [ΔAIC = 0.8].

3.6.4. Temporal orientation of off-task thoughts

We found a small main effect of intervention on the temporal orientation of off-task thinking [ΔAIC = −2.5; $t = 2.36$; $p = .02$]. The data visualization shows that participants reported more future-related and less past-related off-task thinking after fantasizing compared to after stress (see Fig. 4). No interaction effect between intervention and session [ΔAIC = 1.1], nor an interaction effect between intervention and group [ΔAIC = 0.7] or an interaction effect between intervention, session and group [ΔAIC = 1.1] was found.

3.6.5. Self-relatedness of off-task thoughts

No effects of intervention [ΔAIC = 0.9], intervention by session [ΔAIC = 1.1], intervention by group [ΔAIC = 0.9] and intervention by session and group [ΔAIC = 1.0] on the self-relatedness of off-task thinking were found.

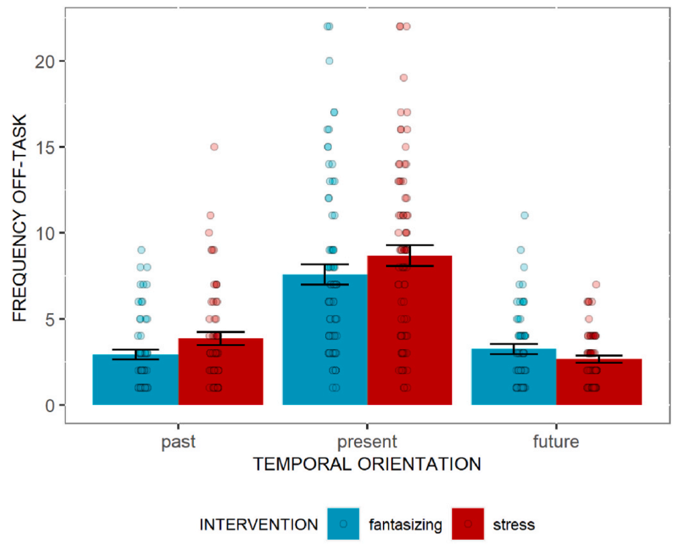

Fig. 4. Bar plot reflecting the mean frequency across participants and standard errors of the mean of past-related, present-related and future-related off-task thinking after both interventions. Individual data points reflect the absolute frequency for each participant.

4. Discussion

The goals of the study were to 1) examine whether the content and characteristics of mind-wandering could be manipulated by self-relevant positive- and negative-mood induction interventions and 2) whether the extent to which mind-wandering could be manipulated depended on individuals' susceptibility to negative affect. Our results suggests that the frequency and content of mind-wandering can indeed be adjusted by self-relevant mood-induction interventions. The magnitude of the intervention effects on the frequency of mind-wandering depended on participants' susceptibility to negative affect. Conversely, the magnitude of effects on the content of mind-wandering (i.e., valence and temporal orientation of thinking) did not depend on individuals' susceptibility to negative affect. This suggests that in individuals vulnerable for negative affect, mind-wandering may be adjusted using self-relevant mood-induction techniques, independent of the content of mind-wandering.

In line with earlier research, the frequency of off-task thinking was found to be mood-dependent (Killingsworth & Gilbert, 2010; Ruby, Smallwood, Engen, & Singer, 2013; Smallwood et al., 2009; Stawarczyk, Majerus, & D'Argembeau, 2013). Specifically, the frequency of

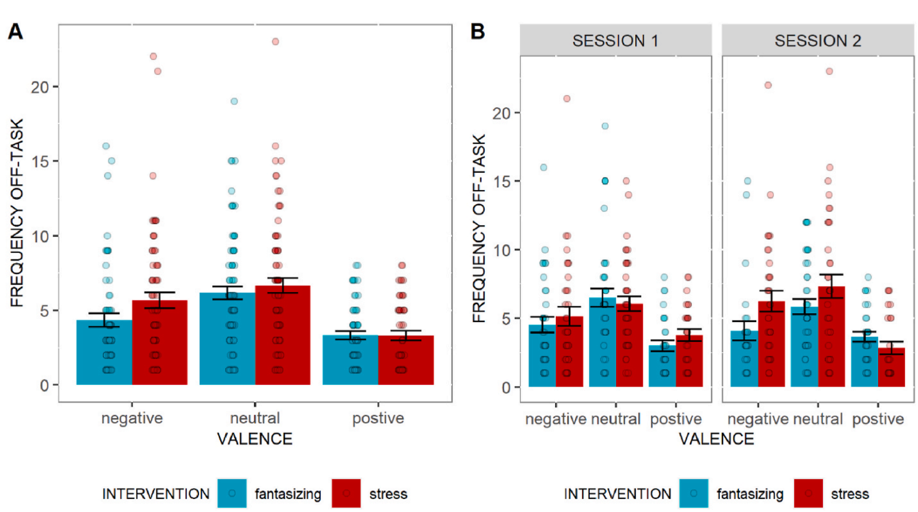

Fig. 3. A) Bar plot reflecting the mean frequency across participants and standard errors of the mean of negative, neutral and positive off-task thoughts after both interventions. Individual data points reflect the absolute frequency separately for each participant. B) Bar plot with the mean frequency across participants and standard errors of the mean of negative, neutral and positive off-task thoughts after both interventions per session. Individual data points reflect the absolute frequency for each participant.

self-reported off-task thinking was higher after negative-mood induction following stress compared to after the induction of a positive mood through fantasizing. This effect seems to be mainly driven by high-SNA individuals, given the observed differential effect of the interventions on the frequency of thought in individuals high-SNA vs. low-SNA. Results showed that participants that score high on susceptibility to negative affect reported more off-task thinking only when they underwent the stress intervention in the second session compared to individuals that score low on this. This suggests that the frequency of thoughts could indeed be adjusted by mood-induction procedures, and that the magnitude of the effects of such procedures depends on individuals' susceptibility to negative affect and the order of the interventions.

Whereas no changes in the stickiness of off-task thoughts were observed, the content of off-task thinking was affected by mood-induction. Thoughts were more future-related, less past-related and less negative after fantasizing compared to after stress. These results are in line with earlier research, where researchers found that positive and negative mood-induction techniques using emotional videos and positive/negative affirmations immediately changed the content of mind-wandering in healthy individuals (Smallwood et al., 2009; Smallwood & O'Connor, 2011). Moreover, they found that the magnitude of mood-induction effects on mind-wandering was correlated with self-reported depressive symptoms. This is in contrast with the current results where the content of thought patterns was not differentially affected by interventions in individuals high-SNA vs. low-SNA. The current results suggest that self-relevant mood-induction techniques do not differ in their effect on the content of off-task thoughts (temporal orientation, valence, self-relatedness) in individuals high compared to individuals low on susceptibility to negative affect. The current study differs from previous studies (Smallwood et al., 2009; Smallwood & O'Connor, 2011) in the methods used to induce mood and the groups studied. Whereas previous studies used emotional videos and positive/negative affirmations to induce positive and negative mood in healthy individuals (Smallwood et al., 2009; Smallwood & O'Connor, 2011), the current study used stress and fantasizing about functional attitudes (e.g., "When I make mistakes, I am still valuable") as a more self-relevant method to induce negative and positive moods in healthy individuals at high vs. low risk of depression.

Interestingly, the intervention order seemed to have an effect on the extent to which mood-induction techniques had an effect on subsequent thought patterns. Individuals that score high on susceptibility to negative affect reported more off-task thinking compared to individuals that score low on this only when participants underwent stress in the second session (after fantasizing). This could suggest that individuals who are more susceptible to negative affect are more vulnerable for psychological stress when they are first trained with the positive fantasizing technique resulting in more off-task thinking after stress compared to after fantasizing. A similar intervention order effect was also found for the valence of off-task thoughts, independent of susceptibility to negative affect. More research into the timing of mood-induction interventions is necessary to solidify these effects.

Another interesting finding was that the manipulation checks used to examine whether the mood-induction techniques had the expected effect on affective states showed that positive fantasizing did not only increase positive affect but also decreased negative affect. Stress induction on the other hand only affected the negative affect domain. These results demonstrated a cross-valence potency of this technique in not only reducing negative affect but also turning mind-wandering into a more adaptive form. Whether 10-min fantasizing practice would have the same effect in individuals at high risk for depressive relapse is unknown but interesting to further investigate. Similarly, it remains to be investigated for how long these effects persist.

4.1. Limitations and future research

Mood-induction effects did not significantly change over time. Yet, the reliability of these effects could not be established statistically since we had too little data. In the current study the effects of 10-min mood-induction techniques were examined, but it would also be interesting to study whether applying these interventions for longer or in multiple sessions would give longer lasting effects, and whether the time-course differentiates individuals at risk for recurrent affective psychopathology from those at low risk.

For future studies, some methodological improvements could be considered. The SART included concern-triplets to induce mind-wandering which could have a negative priming effect. However, exploratory analysis show that concern-triplets did not affect the frequency of off-task thinking in the current dataset (see Supplementary Materials 8). Moreover, the design of the SART was such that thought probes asking about the participants' current thought was always shown after a no-go trial. Participants could therefore possibly predict the appearance of a thought probe, which could have affected their thoughts. Furthermore, there has been some debate about the categorization of task-related thoughts as on-task or off-task thoughts, which could affect the results on the frequency of mind-wandering (Kawagoe & Kase, 2021). Exploratory analyses show that the results are similar when not including task-related thoughts as on-task thinking in the analyses (see Supplementary Materials 9). Besides, we examined thoughts using self-report, which has limitations (Weinstein, 2018). Adding objective measurements such as neurophysiological measurements could circumvent such limitations. Finally, the current study does not provide a baseline assessment of mind-wandering, which could limit the interpretation of group effects.

4.2. Conclusions

In conclusion, our cross-over experimental study demonstrated that the frequency and content of mind-wandering is mood-dependent. Ten-minute mood-induction interventions can adjust the frequency, valence, and temporal orientation of self-reported off-task thoughts in healthy individuals varying in susceptibility to negative affect in a valence specific way. Individuals high on susceptibility to negative affect showed more off-task thinking after stress than after fantasizing compared to individuals low on susceptibility to negative affect. This effect was not found for the content of mind-wandering. Further research using moment-by-moment capturing of thought patterns in combination with (neuro)psychological measurements instead of retrospective self-report should be conducted to gain further insight into the adjustability of maladaptive mind-wandering by mood-induction interventions. This may provide input for the development of treatments for mood disorders such as depression, though non-clinical results may not necessarily translate to clinical samples. Therefore, the current study should be repeated in a clinical sample.

Author note

All data for the study and analysis code have been made publicly available at the Open Science Framework and can be accessed at: https://osf.io/zab4z/. The study's design and analysis plan were preregistered: https://osf.io/m97pd/. A preprint of the full article is available at: https://osf.io/svx52/. The authors have no competing interests to declare that are relevant to the content of this article. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Marlijn E. Besten: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Marie-José van Tol:** Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing. **Jacolien**

C. van Rij: Formal analysis, Methodology. **Marieke K. van Vugt:** Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

All data for the study and analysis code have been made publicly available at the Open Science Framework and can be accessed at: https://osf.io/zab4z/

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2023.101888.

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