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Induced Worrying Impairs Updating Efficiency

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Abstract

In the attentional control theory of anxiety, Eysenck, Derakshan, Santos, and Calvo (2007) propose that worrying depletes cognitive resources, thereby reducing the efficiency of cognitive task performance in anxious participants. However, most of the research supporting this hypothesis does not directly address the contribution of worrying to the association between anxiety and cognitive task performance. In the present study we examined the direct effect of induced worrying on cognitive performance in an undergraduate sample, with participants with a high tendency to worry (N=36) and participants with a low tendency to worry (N=30). We used an n-back task to measure their capacity to actively update the content of working memory. Results indicate that a worry-induction decreases general updating efficiency. This decrease in updating efficiency was most pronounced immediately after the worry-induction and disappeared towards the end of the experiment. There was no difference in updating efficiency between participants with a high and low tendency to worry. We can conclude that a worry-induction impairs the updating capacity of working memory, unrelated to a person's inherent tendency to worry.

Keywords: Worrying; Worry-induction; Anxiety; Updating; Attentional control; Working memory

Introduction

Worrying can be described as uncontrollable thought activity, typically involving concerns about future events with a possible negative outcome [1-3]. The tendency to worry is normally distributed, with high-worriers being characterized by higher uncontrollability of negative thought intrusions as opposed to low-worriers [3]. Chronic, excessive, and uncontrollable worry has an adverse impact on affective states [4], and is the defining diagnostic criterion of the Generalized Anxiety Disorder (GAD) (American Psychiatric Association). Despite the clinical relevance of worrying, its underlying cognitive mechanisms remain poorly understood. The purpose of our study is to gain more insight into this matter by clarifying the relationship between worrying and attentional control.

In their attentional control theory (ACT) of anxiety, Eysenck et al. [5] propose that worrying, which is the cognitive component of anxiety, is responsible for depleting attentional control capacity, thereby reducing the efficiency of cognitive task performance. Consistent with this view, several experimental studies have successfully demonstrated that anxiety negatively affects performance efficiency, usually reflected by slower reaction times in solving cognitive tasks. On the other hand, performance effectiveness, usually measured by task accuracy, seems less affected by anxiety [6]. In line with this notion, several studies in the past 20 years were able to indicate that anxiety is specifically associated with reduced attentional control efficiency, such as inhibition impairments [7] and shifting impairments [8].

Although the studies mentioned above suggest that worrying is responsible for consuming attentional control capacity in anxious participants, they do not directly address the contribution of worrying to the association between anxiety and cognitive performance. The ACT holds that worrying is responsible for depleting attentional control capacity, but previous studies mainly focused on anxiety. Therefore it is crucial to investigate the association between worrying and attentional control. Yet, only a few studies have addressed this issue at present. Studies investigating attentional control generally use the taxonomy of Miyake et al. [9] to distinguish between three factors of attentional control: inhibition, shifting, and updating. The relation between worrying and inhibition was studied by Brown [10] who found that trait worry is associated with an impaired ability to inhibit negative words. A study by Beckwé et al. [11] recently indicated that high-worriers show shifting impairments when the verbal stimuli are personally relevant for them. As far as we know, the relationship between worrying and updating capacity, which represents the focus of the present investigation, has never been investigated before. In line with the ACT, and because previous research indicates that other factors of attentional control (inhibition and shifting) are impaired in high-worriers, we expect that high-worriers will show a reduced updating efficiency when compared to low-worriers.

Importantly, most studies in this field are correlational in nature, investigating the correlation between cognitive task performance and scores on questionnaires measuring trait anxiety or trait worrying. These correlational studies do not allow us to draw any causal conclusions about the relationship between attentional control and anxiety or worrying. In the present study, we have therefore opted for a worry-induction to investigate the direct influence of state worry on attentional control. We will do this using the only worry-induction that is described in relevant literature, a manipulation developed by McLaughlin et al. [12]. During this worry-induction participants are instructed to worry during 5 min about their favorite worry themes. In line with the ACT, we expect a worry-induction to impair general updating efficiency. If so, this would support the notion that worrying directly depletes cognitive resources. High-worriers inherently have more difficulties to control these induced negative thought intrusions than low-worriers [3]. Therefore we will compare the effect of the worry-induction on updating efficiency between high- and low-worriers. Since high-worriers are characterized by higher uncontrollability of negative thought intrusions, we expect that the

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worry-induction will have a bigger impact on high-worriers' updating function.

In the present study, we used an n-back task to measure the updating capacity. In an n-back task, subjects are presented with a sequence of stimuli, and they are asked to indicate whether the current stimulus is the same stimulus as the one "n" steps earlier in the sequence. The value of "n" can be adjusted to make the task more, or less, difficult. For example, when the letters "A", "B", "C", "D", and "B" are presented in a 3-back task, the second "B" requires a positive answer (the stimulus is the same as the one three stimuli earlier). According to Miyake et al. [9], the n-back task is a prototypical updating task. When "n" equals 2 or more, it is not enough to simply keep a representation of recently presented items in mind, the working memory needs to be updated continuously to keep track of what the current stimulus must be compared to. To accomplish the task, the subjects need to actively maintain and manipulate information in working memory. This task thus requires a high degree of attentional control [5] and is therefore highly suited to study the effect of a worry-induction on attentional control in high- and low-worriers.

In accordance with current literature [10,11], we hypothesize that high-worriers will show a reduced updating efficiency when compared to low-worriers. Second, we expect a worry-induction to reduce performance efficiency on an n-back task. Finally, we expect the worry-induction to particularly impair high-worriers' updating efficiency.

Method

Participants

66 students (43 females), with an average age of 20.56 years (*SD*=2.71) participated in the experiment. They were randomly assigned to the worry-induction condition or control condition, and after the experiment they were divided in a low-worry group and a high-worry group based on a median split of their scores on the Penn-State Worry Questionnaire (PSWQ). This division leads to four conditions (Table 1) in which participants did not differ in age (between conditions: $F(3, 63)=0.99$, $p=0.323$ and between groups: $F(3, 63)=0.23$, $p=0.630$), or female/male ratio (between conditions: $\chi^2(1, 65)=0.85$, $p=0.532$ and between groups: $\chi^2(1, 65)=0.19$, $p=0.144$). As expected, there was a significant difference in PSWQ between high-worriers and low-worriers ($t(1, 65)=36.90$, $p<0.05$). There was no significant difference in state anxiety scores between high-worriers and low-worriers ($t(1, 65)=0.20$, $p=0.734$). Importantly, the difference in PSWQ and state anxiety scores did not significantly differ between the worry-induction condition and the control condition (respectively, $t(1, 65)=0.16$, $p=0.755$, and $t(1, 65)=0.003$, $p=0.968$). For additional details on the participants in each condition, see Table 1.

Materials

Self-report questionnaires:

The Penn-state worry questionnaire (PSWQ): The PSWQ [13,14] is a 16-item questionnaire that assesses the tendency to worry. The items are rated on a 5-point scale for the degree to which they characterize the participant. The Dutch version of the PSWQ has an adequate reliability and high internal consistency [15,16].

The state anxiety scale of the state-trait anxiety inventory (STAI). The STAI [17,18] is a 40-item self-report scale designed to measure two distinct anxiety concepts: state anxiety and trait anxiety. Respondents in our experiment only completed the state anxiety scale, which measures the present level of anxiety. Respondents are presented with a number of statements, and are asked to indicate the degree to which they apply to them, ranging from not at all (1) to very much (4). Good validity is reported for the Dutch version of the STAI [18].

Apparatus and stimuli

The n-back task was conducted on IBM-compatible Pentium 4 personal computers with a 17 inch screen, using E-prime Psychology Software Tools Inc. version 2.0 software [19]. Stimuli were 7 mm high letters in black font, centrally presented against a white background.

Procedure

The experiment took place in individual testing cubicles of the psychology lab of the VUB. After completing the informed consent form, participants were randomly assigned to the worry-induction condition or control condition. In the worry-induction condition we first induced worry using the manipulation developed by McLaughlin et al. [12]. In the control condition participants performed a cognitive task that lasted as long as the worry-induction.

Worry-induction in worry-induction condition [12]: Before beginning the actual computer-experiment, participants were asked to write down their three most common worry topics. Worry was defined as intrusive thoughts or images about future events whose outcomes are uncertain, and contain the possibility of one or more negative outcome. Definitions of thoughts ("words that you say to yourself in your head"), and images ("pictures in your mind"), and some examples of worry topics were provided. Worry was induced during 5 min, starting with the following instructions: "When I give the starting sign, I want you to spend 5 min worrying about the worry topics you have just written down. You may close your eyes and start worrying about your most worrisome topic in the way you usually do, but as intensely as possible, until I ask you to stop and to open your eyes. During the worrying process, you may continue worrying about the first most worrisome topic, or you may change topics if the changes occur naturally during the worry process. You may now close your eyes and start worrying" [12]. Every minute, participants were asked to fill in a sheet asking for (1) the content of their thoughts; (2) whether their thoughts involved something that happened in the past, in the present moment, or might happen in the future; and (3) whether their thoughts involved primarily imagery or verbal-linguistic thought. Immediately after this manipulation, participants in the worry-induction condition ran through the instructions of the computer experiment and completed an n-back task.

Cognitive task in control condition: Before beginning the actual

	Worry-Induction Condition		Control Condition	
	high-worriers (*N*=24)	low-worriers (*N*=18)	high-worriers (*N*=12)	low-worriers (*N*=12)
Female/male ratio	19/5	8/10	7/5	9/3
Age	20.71 (2.27)	20.94 (2.96)	20.58 (2.84)	19.67 (3.14)
PSWQ score	57.92 (5.67)	39.44 (6.89)	54.25 (4.05)	41.00 (6.84)
State anxiety score	38.17 (10.82)	41.83 (11.32)	45.08 (11.83)	35.58 (12.13)

Table 1: Mean participant characteristics according to experimental condition (SD between parentheses).

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computer-experiment, participants were asked to count down in steps of 4 starting from 864 (860, 856, 852, 848, 844,...) during 5 min. After every minute, we asked the participants to write down at which number they were (analogous with the recording of the worry-themes in the worrier worry-induction condition). It is very important to have a control task in the control condition, because if not, differences between the control condition and the worry-induction condition could be due to cognitive fatigue. Immediately after this cognitive task, participants in the control condition ran through the instructions of the actual computer experiment and completed an n-back task.

N-back task: Each participant completed a 2-back task, followed by a 3-back task. In the 2-back task, participants had to indicate whether the presented letter was the same as the one presented 2 letters earlier. If this was the case, they had to press the number "1" on an azerty keyboard. If not, they had to press "2". Stimuli were consonants of the alphabet, randomly presented during 500 ms on a computer screen. There was a 3000 ms interval between the disappearance of a letter and the appearance of the next letter. The task consisted of instructions, one example (which could be repeated if necessary), 20 practice trials (could be repeated if the participants thought this was necessary) and 3 blocks of 30 experimental trials. The 3-back task was the same, except that participants now were asked whether the presented letter was the same as the one presented 3 letters earlier. Participants were asked to perform the task as quickly as possible without sacrificing accuracy. Accuracy and reaction time (the time interval between the presentation of each letter and the response) was recorded and served as dependent variables of task performance. After the n-back task, all participants filled out the PSWQ and state anxiety scale of the STAI. At the end of the experiment, the goal of the study was explained and questions could be asked. This study was approved by the Ethics Committee of the Vrije Universiteit Brussel (VUB).

Results

All participants had an accuracy rate of 50% or more, there was no need to exclude participants from the analyses.

We analyzed the data of the 2-back task and the 3-back task separately. We discovered that there was only a significant effect of the worry-induction on updating efficiency in the 2-back task, and not in the 3-back task.

We conducted two 2 × 2 ANOVA's with Condition (worry-induction, control) and Group (high-worriers, low-worriers) as between-subjects factors on respectively (1) the RT of the 2-back task and (2) the RT of the 3-back task. Analysis revealed an effect of the worry-induction on updating efficiency (RT) in the 2-back task, but not in the 3-back task. More precisely, a main effect of the factor Condition, $F(1, 65)=9.06$, $p=0.004$, indicated that participants were slower to execute the 2-back task in the worry-induction condition (M=841 ms, SD=202) as opposed to the control condition (M=689 ms, SD=183). These results remained significant after we controlled for the effect of State anxiety, $F(1, 65)=8.91$, $p=0.004$. In the 3-back task the difference in RT was not significantly different for participants in the worry-induction condition versus participants in the control condition, $F(1, 65)=0.20$, $p=0.655$. Other main/interaction effects were not significant.

Because the worry-induction seemed to have a different effect on task performance in the 2-back task as opposed to in the 3-back task, we analyzed the effect of the worry-induction over time more in detail.

We conducted the same ANOVA as above on respectively the RTs in the first third of the 2-back task and the RTs in the last third of the 2-back task. Results indicated that the difference in RT between the worry-induction condition and control condition was the most striking in the first third of the 2-back task ($F(1, 65)=9.61$, $p=0.003$, RTs respectively: M=854 ms, SD=268 and M=664 ms, SD=185), and disappeared in the last third of the 2-back task ($F(1, 65)=0.53$, $p=0.471$, RTs respectively: M=782 ms, SD=202 and M=743 ms, SD=229). Other main/interaction effects were not significant. Figure 1 gives an overview of the evolution of the mean RTs in the 2-back task in the worry-induction condition versus control condition (Figure 1).

The same analyses carried out on accuracy (in percentages) yielded no significant effects with the factors Condition (no differences in accuracy between the worry-induction condition and control condition) or Group (no differences in accuracy between high-worriers and low-worriers). There was a significant effect of the within-subjects factor Task, $F(1, 65)=13.65$, $p<0.001$, indicating that participant were more precise to execute the 2-back task (M=82.17%, SD=12.07) as opposed to the 3-back task (M=76.38%, SD=14.98). Table 2 gives an overview of mean RTs and accuracy in the four conditions (Table 2).

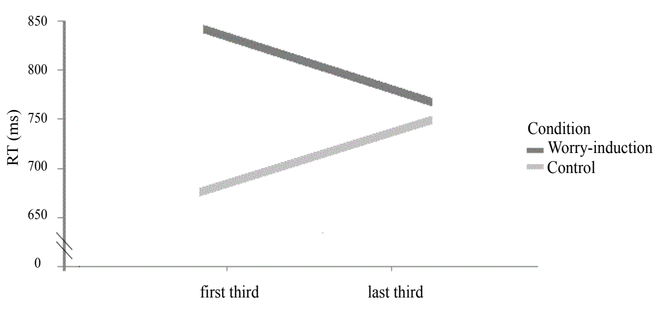

Figure 1: Evolution of RTs in the 2-back task for the worry-induction condition and the control condition.

	2-Back Task		3-Back Task	
	ACC (%)	**RT (ms)**	**ACC (%)**	**RT (ms)**
Control Condition				
All participants (N=24)	78.04 (12.12)	689*(183)	73.73 (16.85)	781 (330)
• high-worriers (N=12)	73.00 (13.35)	693 (187)	73.96 (21.01)	718 (281)
• low-worriers (N=12)	83.08 (8.57)	684 (186)	73.50 (12.34)	845 (374)
Worry-induction Condition				
All participants (N=42)	84.54 (11.53)	841* (202)	77.89 (13.79)	813 (236)
• high-worriers (N=24)	84.48 (12.19)	837 (156)	81.50 (12.02)	817 (244)
• low-worriers (N=18)	84.61 (10.92)	847 (256)	73.05 (14.81)	809 (231)

* significantly different, p=0.004

Table 2: Mean N-back performance as a function of experimental condition (SD between parentheses).

In sum, consistent with our hypothesis, the analyses revealed an effect of the worry-induction on updating efficiency, i.e. the RT of the n-back task, and not on updating effectivity, i.e., the accuracy of the n-back task. However, there was no difference in RT between high-worriers and low-worriers.

Discussion

According to the ACT, worrying depletes attentional control efficiency in anxious persons. However, studies substantiating this claim are currently lacking. Therefore, the present study investigated the effect of a worry-induction on the capacity to update the content of working memory in high-worriers and low-worriers. We expected (1) high-worriers to show reduced updating efficiency when compared to low-worriers, (2) a worry-induction to reduce performance efficiency on an n-back task, and (3) the worry-induction to particularly impair high-worriers' updating capacity. The results indicate that a worry-induction decreases updating efficiency in the n-back task. However, there was no difference in updating efficiency between participants with a high and low tendency to worry.

To our knowledge, these data are the first to show a causal relationship between induced state worry and decreased efficiency of the updating function in working memory. The results empirically confirm Eyseck et al.'s ACT [5]. As expected, the worry-induction caused a decrease in processing efficiency, i.e., respondents were slower completing the n-back task after a worry-induction. Also in line with the ACT, the effectivity, i.e., the accuracy of the task completion was not affected. Since our worry-induction directly impairs task performance, this study is the first indication of a direct causal relationship between worrying and reduced attentional control efficiency. Importantly, these results remained significant when we controlled for state anxiety. This suggests that it is indeed the cognitive component of anxiety, which is worrying, that depletes cognitive resources, herby reducing the efficiency of cognitive task performance.

Interestingly, there was no significant difference in task performance between participants with a high versus low tendency to worry. These findings are in contrast with our prediction based on the ACT, namely that high-worriers' updating efficiency would be more impaired. We have three possible explanations for the lack of an association between high tendencies to worry and reduced attentional control efficiency. First, it is possible that there is only a difference in attention control efficiency between high- and low-worriers when worry-related material is used. In one of our earlier experiments we found trait worry to be associated with reduced attentional control, but only when the stimuli used reflected personally relevant worry-themes [11]. The role of personal relevance can be determined in future research investigating the relation between updating efficiency and worrying using worry-related material. Secondly, this discordance could be due to the fact that we did not select respondents with extremely high versus extremely low trait worry-scores. Future research should thus attempt to include respondents with a broad range of scores on questionnaires measuring the tendency to worry. Third, it is possible that worrying is largely automated in some high-worriers. Contrary to our hypothesis, worrying would thus consume less cognitive capacity in these high-worriers. Consequently and paradoxically, these high-worriers would have more attentional control capacity available for task performance after a worry-induction as opposed to low-worriers [20,21] and thereby neutralize differences between the two groups. Because of these issues, it seems important to further investigate the connection between trait worry and attentional control.

Respondents performed worse after a worry-induction, but only during the 2-back task, and not during the 3-back task. One possible explanation is that the 3-back task already requires a lot of cognitive capacity, possibly flattening out an additional effect of a worrying induction. However, respondents were not significantly slower when completing the 3-back task than they were completing the 2-back task ($F(1, 62)=0.001$, $p=0.970$). This suggests that the 3-back task was not more difficult for the respondents, after having had the opportunity to practice the 2-back task. A more likely explanation is that the effect of the worry-induction had worn out during the 3-back task. All respondents completed the 2-back task before the 3-back task. To exclude this, the presentation of the 2-back and the 3-back task could be counterbalanced. However, we chose to present the 2-back task first, in order to allow participants to get used to the n-back task, since starting with a 3-back task is quite difficult, hereby potentially masking possible effects of a worry-induction. Nevertheless, when we divided the data of the 2-back task in three parts, we see indeed that the difference in RT between the worry-induction condition and the control condition is most striking for the first third of the 2-back task. In the final third of the 2-back, there is no longer a significant difference between the conditions. We can thus conclude that the worry-induction only affected processing efficiency in the beginning of our experiment. It is therefore important to keep in mind that the worry-induction had a short-lasting effect, and that possible effects of a worry-induction could remain hidden in studies that employ a longer experiment. Therefore it's important in future research to regularly repeat the worry-induction during the experiment, or analyze the data from immediately after the worry-induction separately.

There are some limitations to this study. First, we found that a worry-induction depleted updating efficiency, and these results remained significant when we controlled for state anxiety (measured with the STAI). However, in order to be able to see whether state worrying is a better predictor of reduced updating capacity than state anxiety, future research should include an anxiety-induction condition to the design. Second, since we conducted this study in a healthy sample of undergraduates, our results might underestimate the association between state anxiety and attentional control impairments. The same is true for the association between trait worrying and reduced updating capacity, since participants in a clinical sample are more likely to suffer from pathological worry. Future research will be needed to generalize these results to a clinical sample.

In conclusion, the current study investigated the effect of a worry-induction on the capacity to update the content of working memory in high-worriers and low-worriers. Results show a causal relationship between state worry and reduced attentional control. Induced worry decreases updating efficiency, but only shortly after the worry-induction. There was no difference in updating efficiency between participants with a high and low tendency to worry. We can conclude that a worry-induction impairs the updating capacity of working memory, unrelated to a person's tendency to worry.

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