Budapest University of Technology and Economics
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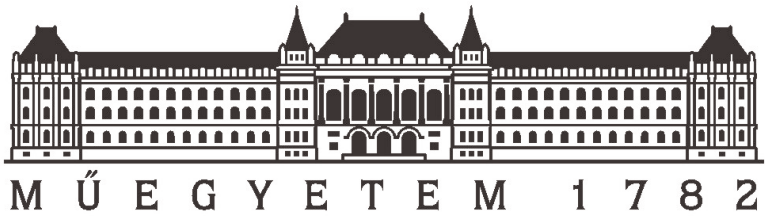

Cognitive control, trait anxiety and trait worry

Interplay of trait anxiety and trait worry in determining the performance in tasks requiring cognitive control

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PhD Thesis booklet

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Budapest, 2014

Introduction

The disruptive effect of anxiety on information processing is a well-known phenomenon, often experienced even in everyday life. It is demonstrated by a vast amount of empirical data; much theoretical effort has been directed to describing its causal relations and boundary conditions (see e.g., Zeidner, 1998; Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007). The link between anxiety and higher-order mental processes, however, has also a different face: Some investigators termed anxiety as the "shadow of intelligence", because higher-order, complex cognitive functions, such as prospection, planning and problem-solving, might underlie anxious experience (Liddel, 1949; Barlow, 2002). This set of complex cognitive functions is often called cognitive control processes or executive functions to refer to a set of cognitive functions which require mental effort and conscious attention and involve the coordination of basic, subordinate processing. The work summarized in this dissertation is aimed to investigate the link between anxiety and cognitive control processes. We examined the interplay of two related concepts, trait worry and trait anxiety, in determining performance in tasks which require cognitive control.

The first concept of interest is ***trait anxiety***, which can be defined as a general tendency to experience the physiological and psychological signs and symptoms of anxiety (e.g. Spielberger, 1972). Trait anxiety is associated with several distinct states of pathological anxiety: high levels of trait anxiety are observed in different types of anxiety disorders described by the major psychiatric nosological systems (e.g. the fifth version of the Diagnostic and Statistical Manual of Mental Disorders, DSM-V, American Psychiatric Association, 2013). Several lines of research prove that anxiety in general, and trait anxiety, in particular, are associated with impaired cognitive control processes, mainly because in high trait anxious individuals, worrisome thoughts and threatening external stimuli distract attention from task-relevant processing. One of the most prominent theories explaining this deleterious effect is the attentional control theory (Eysenck et al., 2007). This theory differentiates between attentional processes driven either by environmental stimuli or by higher-order goals and postulates that trait anxiety shifts the balance between goal driven and stimulus driven attention in the favour of the latter. This might impair cognitive control functions, which always involve goal-driven processing.

The second concept is ***trait worry***, which can be defined as a tendency to engage in a mostly verbal thought activity aimed to plan and prepare for possible future negative events and generate possible solutions for these adverse possibilities (Borkovec, Robinson, Pruzinsky, & DePree 1983; Barlow, 2002; Sibrava & Borkovec, 2006). Furthermore, worrying involves the selective processing of abstract, verbal representations, and thus enables to deal with future threats in a more abstract, verbal way and thus avoids disturbing mental imagery and/or emotional processing (Sibrava & Borkovec, 2006; Roemer, Salters, Raffa, & Orsillo, 2005). Whereas trait anxiety is characteristic of all anxiety

disorders, pathological levels of excessive worrying are linked to one specific anxiety disorder, Generalized Anxiety Disorder (GAD, APA, 2013). Although worrisome thoughts might often interfere with ongoing processing in tasks requiring cognitive control (see above), the very process of worrying might require cognitive control processes: planning, problem-solving and selective processing of information are concepts which are usually associated with cognitive control.

Importantly, as worrying itself is a manifestation or sign of anxiety; consequently, the two constructs, trait worry and trait anxiety, are correlated. Thus, paradoxically, two related constructs might be oppositely linked to cognitive control, and they might cancel out or weaken each other's effect. This phenomenon is called suppression (Cohen, Cohen, West, & Aiken, 2003; Horst, 1941), or a suppression/suppressor situation (Paulhus, Robins, Trzesniewski, & Tracy, 2004). It can be demonstrated in regression models with more than one predictor in all cases where "the relationship between the independent or causal variables is hiding or suppressing their relationship with Y [the criterion variable], which would be larger or possibly of opposite sign were they not correlated" (Cohen et al., 2003, p. 78).

Figure 1 depicts the hypothesized interplay between trait worry, trait anxiety in determining performance in tasks requiring cognitive control. We hypothesize that cognitive control processes underlie worrying, thus individuals with high levels of trait worry might be able to effectively recruit these control processes in tasks requiring cognitive control, and consequently might perform well in such tasks (Figure 1A, line 1). On the other hand, high levels of worrying appear in anxious states (Figure 1A, line 2), which is associated with adverse-effects on cognitive control and thus deteriorates performance (Figure 1A, line 3) – thus, at the surface level, no relationship between trait worry and performance will be shown (Figure 1B). After controlling the effect of trait anxiety, however, the positive association between cognitive control and trait worry emerges (Figure 1C).

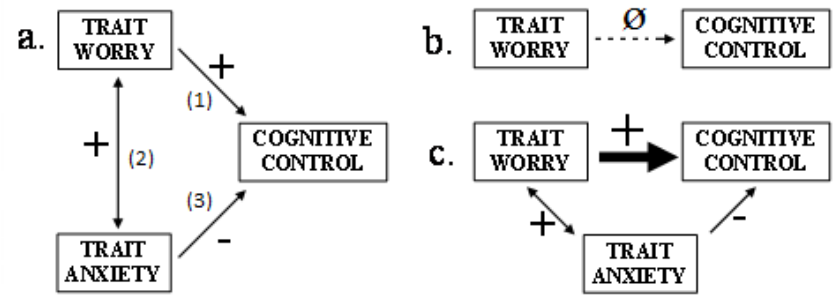

Figure 1: Suppressor situation involving trait anxiety, trait worry and cognitive control

Aims

The main aim of the work summarized in this dissertation was to test the claim that there is an interplay between trait worry and trait anxiety in determining performance in tasks requiring cognitive control. As cognitive control is a multifaceted construct, with many different conceptualizations, with overlapping but not identical concepts, a further aim of the work described in this dissertation was to investigate which aspect of cognitive control might be involved in the suggested interplay. As a prerequisite of this work, we also aimed to construct a valid Hungarian instrument of worry.

Two main hypotheses were tested in the majority of the studies (complemented by further specific hypotheses in some of the studies): According to **Hypothesis 1**, trait worry, as measured by the Penn State Worry Questionnaire (PSWQ, Meyer, Miller, Metzger, & Borkovec, 1990), is associated with good performance in tasks requiring cognitive control. According to **Hypothesis 2**, trait anxiety, as measured by the Spielberger State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970, Hungarian Version, Sipos, & Sipos, 1983), modifies the link between trait worry and cognitive control. Specifically, it was predicted that there is a positive link between trait worry and cognitive control and a negative link between trait anxiety and cognitive control. This yields a suppressor situation with the two opposing effects weakening or even cancelling out each other's effect (in this latter case, off course, Hypothesis 1 is necessarily wrong).

New scientific results

Thesis 1: The Hungarian version of the Penn State Worry Questionnaire (PSWQ) is a valid measure of excessive pathological worrying, and is related to trait anxiety

In Thesis 1, the Hungarian version of the PSWQ was constructed, examining its reliability, validity and factor structure. Two studies were conducted: reliability and factor structure of the scale was investigated in Study 1, whereas validity of the scale was investigated in Study 2. Furthermore, the relations between this inventory and the STAI-T were investigated by pooling the samples of Study 1 and 2 together.

The results of Study 1-2 indicate that the Hungarian version of the PSWQ is reliable and valid measure of excessive, frequent worrying. Furthermore, the latent structure of the Hungarian PSWQ consist of one general trait factor measuring pathological worrying and two method factors related to the wording of the items.

Thesis 2. Trait worry, trait anxiety and future-oriented decision making

In Thesis 2, the relationship between trait worry, trait anxiety and future-oriented decision making was investigated using the Iowa Gambling Task (IGT, Bechara, A.R. Damasio, H. Damasio,

& Anderson, 1994). This task was developed to test the somatic marker theory of Antonio Damasio (1994); it involves decision making based on the weighting of short-term and long-term rewards and losses. Both automatic and controlled processes are suggested to be involved in the task (Bechara, H. Damasio, Tranel, & A.R. Damasio, 1997). Better IGT performance associated with trait worry was observed by Mueller et al. (2010), but not by Drost et al. (2014), thus Study 3 aimed to add further empirical data to investigate this issue. Moreover, we also aimed to investigate the interplay of trait worry and trait anxiety in determining IGT performance – this issue has not been investigated yet.

The results of Study 3 indicate that participants with high levels of trait worry perform better in the IGT than participants with low levels of worrying. The good decision-making performance associated with trait worry was characteristic in the second phase of the task, when cognitive control processes are presumably required for good decision-making performance. This suggests that the beneficial effects of worrying on the IGT might be mediated by controlled processing and cognitive control. The positive effect of trait worry was not overshadowed by the opposite effects of trait anxiety, thus we did not observe a suppressor situation.

Thesis 3. The interplay of trait worry and trait anxiety in determining performance in "classic" tasks of cognitive control

In Thesis 3, work is summarized which investigated whether trait worry and trait anxiety affects performance in "classic tasks" of cognitive control. In Study 4, a simple and a complex span task were performed by the participants. Specifically, we investigated the interplay of trait worry and trait anxiety regarding performance on the Digit Span Task (Jacobs, 1887) and on the Listening Span Task (Daneman & Blennerhassett, 1984). In Study 5, two additional tasks were used: the verbal fluency task is an often used neuropsychological task, linked to frontal lobe function and cognitive control (Costafreda, Lee, Everitt, Brammer, & David, 2006) and can be linked to operations of the central executive and the SAS (Baddeley, 1996). The second task was the n-back task, which is one of the most popular working memory task used in neuroimaging studies (Owen, McMillan, Laird, & Bullmore, 2005) and involves the continuous updating of information.

The results of Study 4-5 indicate that there is no general link between trait worry and performance in "classic tasks" of cognitive control. A clear indication for a suppressor situation, however, was found in the verbal fluency task: after controlling their shared variance, trait worry was related to better, whereas trait anxiety was associated with worse verbal fluency performance. Moreover, the positive link between trait worry and verbal fluency was mediated by a component of semantic retrieval which is linked to frontal lobe function (flexible switching during the semantic retrieval process). Finally, once the effect of trait anxiety was held constant, higher levels of trait worry were associated with lower levels of intrusion errors in the listening span task.

Thesis 4. Trait worry, trait anxiety and episodic memory: the role of strategic retrieval

The work summarized in Thesis 4 has a somewhat narrower scope, as it focuses on cognitive control in one specific domain of cognition: episodic retrieval. The retrieval of past events and episodes can be relatively effortless and can occur in a relatively automatic fashion if appropriate retrieval cues are present. In other cases, however, it might require cognitive control, in particular when no retrieval cues are present (Brand & Markowitch, 2008). Moreover, encoding of the items might also require cognitive control. In Study 6-8, participants conducted episodic memory tasks, in which the way of retrieval was systematically varied to manipulate the cognitive control requirement of the task. The interplay of trait worry and trait anxiety was investigated by using retrieval tasks which do and which do not require cognitive control. In an additional analysis, the recall-pattern was further analysed to investigate how the anxiety measures are associated with the dynamics of recall.

The results of Study 6-8 indicate an interplay of trait worry and trait anxiety in determining performance in tasks requiring strategic retrieval. After controlling their shared variance, trait worry was positively related, whereas trait anxiety was negatively related to performance in those episodic memory tasks, in which no cues where provided to aid the recall of previously encoded information. This effect, however, was absent if appropriate retrieval cues were provided. Follow up analyses of recall dynamics indicated that this effect is mediated by the temporal reinstatement of the study-period.

Thesis 5. The role of goal-attainment in episodic retrieval. The role of trait anxiety and trait worry

In the work related to Thesis 5, we investigated the role of goal-attainment in strategic retrieval, and we tested whether the construct of goal-attainment could be related to the suppressor situation found in the three studies of Thesis 4, involving trait worry, trait anxiety and strategic retrieval. First, we conducted a series of four studies (Study 9-12) in which we tested, whether goal-attainment is a crucial factor in determining the inhibition of nonrelevant memory traces, as assessed by the directed forgetting procedure (e.g. Bjork, 1989). We tested, whether the directed forgetting effect is present by observing another learner who takes part in the experiment. As the effects of directed forgetting can only be examined in a between-subject fashion (i.e. comparing the means of two groups), a new task was constructed in which individual differences in the effect of goal-attainment could be investigated. In this new task, participants had to complete category-word stem pairs (e.g. fruit- ap _ _ _), and in half of the categories, this work was interrupted (i.e. no goal attainment). The effect of goal-attainment was assessed by recall of words from interrupted and completed categories (Study 13).

The results of Study 9-12 indicate that goal-relevance is a crucial factor in the directed forgetting experiment. The directed forgetting effect only appeared for observers, if the instruction prompted goal-sharing between models and observers. This indicates that the adaptive activation and suppression of episodic memory representations is a goal-directed process. In Study 13, we found further evidence that goal-attainment is a crucial factor especially in strategic recall. In this task, however, no suppressor effect involving trait worry and trait anxiety emerged.

Conclusions

The work summarized in this dissertation investigated the possibility that cognitive control processes underlie the tendency to engage in worrying. Using hierarchical linear regression analysis, it was shown that after controlling its shared variance with trait anxiety, trait worry was associated with better performance in tasks requiring strategic, controlled retrieval of information. In other tasks of cognitive control, no similar effects were found.

The partial effect of trait worry can be defined as the effect of trait worry, once the effect of trait anxiety is held constant. This means that, at every level of trait anxiety, participants can be categorized as having relatively high or low levels of trait worry. Thus, our results indicate that those individuals, who exert a relatively high levels of worrying, as compared to their trait anxiety level will perform well in tasks which require the strategic, controlled retrieval of information.

Two explanations for this rather specific link between trait worry and strategic retrieval are suggested. First, it might be caused by a common background variable: the ease of complex processing and manipulation of verbal information. The superiority in this ability would evidently enhance the formulation of verbal worries and thus lead to an increased tendency to worry. Furthermore, it would lead to better performance in tasks requiring the controlled, strategic manipulation of verbal material (e.g. in a letter fluency task or during free recall). Finally, on the neural level, the common pathways of verbal processing, strategic retrieval and worrying might be found in the networks of the left prefrontal cortex.

Second, slightly more speculative explanation considers the role of interference sensitivity and temporal context: effective interference resolution might be a common requirement in the tasks requiring strategic retrieval of information, because competing cue-target associations have to be inhibited. A common underlying process of trait worry and interference resolution might be the functioning of the behavioural inhibition system, which is suggested to be a common final neural and functional pathway for anxiety and memory (Gray & McNaughton, 2000; McNaughton, 1997; McNaughton & Wickens, 2003).

To sum up, the work summarized in this dissertation revealed a specific link between trait worry and performance in tasks requiring strategic retrieval, providing evidence that some kind of

cognitive control processes might underlie anxiety, thus supporting the assumption that anxiety is the shadow of intelligence (Liddel, 1949; Barlow, 2002). Further research is warranted to justify the causal mechanisms of this link and to reveal the brain networks which could be responsible for the reported relationship.

List of publications related to the thesis

1. Pajkossy, P., Simor, P., Szendi, I., Racsmány, M. (in press). Hungarian Validation of the Penn State Worry Questionnaire (PSWQ) - Comparing Latent Models with One or Two Method Factors Using Both Paper-pencil and Online Versions of the PSWQ. *European Journal of Psychological Assessment.*
2. Pajkossy, P., Dezső, L., Zoltay Paprika, Z. (2011). The Opposite Effect of Trait and State Anxiety on Iowa Gambling Task. *Learning & Perception 1*, 279-295.
3. Pajkossy, P, Racsmány, M. (2014). Beneficial effect of trait worry on episodic retrieval: A link overshadowed by trait anxiety. *Personality & Individual Differences 60*, Supplement, p S52.
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