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Training working memory to improve attentional control in anxiety: A proof-of-principle study using behavioral and electrophysiological measures

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ABSTRACT

Trait anxiety is associated with impairments in attentional control and processing efficiency (see Berggren & Derakshan, 2013, for a review). Working memory training using the adaptive dual n-back task has shown to improve attentional control in subclinical depression with transfer effects at the behavioral and neural level on a working memory task (Owens, Koster, & Derakshan, 2013). Here, we examined the beneficial effects of working memory training on attentional control in pre-selected high trait anxious individuals who underwent a three week daily training intervention using the adaptive dual n-back task. Pre and post outcome measures of attentional control were assessed using a Flanker task that included a stress induction and an emotional a Antisaccade task (with angry and neutral faces as target). Resting state EEG (theta/beta ratio) was recorded to as a neural marker of trait attentional control. Our results showed that adaptive working memory training improved attentional control with transfer effects on the Flanker task and resting state EEG, but effects of training on the Antisaccade task were less conclusive. Finally, training related gains were associated with lower levels of trait anxiety at post (vs pre) intervention. Our results demonstrate that adaptive working memory training in anxiety can have beneficial effects on attentional control and cognitive performance that may protect against emotional vulnerability in individuals at risk of developing clinical anxiety.

1. Introduction

Cognitive views on anxiety pose that deficits in attentional processes can causally contribute to the etiology and maintenance of anxiety (see Eysenck, 1992; Mogg & Bradley, 1998; Mathews & MacLeod, 2005 for reviews). Despite a wealth of findings and substantial progress in such research, it is still unclear whether attentional processes indeed play a causal role in anxiety (Van Bockstaele et al., 2014). In recent years, innovative methods have manipulated attentional processes to understand if there is a causal relationship between attentional processes and anxiety. So far, most research has focused on manipulating attentional bias which involves reducing exaggerated attention to fear-relevant information in anxiety (see Koster, Fox, & MacLeod, 2009). Based on theories of attentional control and anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007), the current study is among the first to examine the effect of manipulating cognitive control on anxiety related distractibility and anxiety vulnerability at the behavioral and neural level. We start with a basic description of attentional control theory (ACT) and then explain the relevance of manipulating attentional control.

1.1. Attentional control theory

The attentional system can be divided into two sub-systems, a top–down (goal-directed, volitional) and bottom–up (stimulus-driven, reflexive) subsystem (Corbetta & Shulman, 2002). ACT (Eysenck et al., 2007) claims that anxiety impairs the balance between these subsystems by reducing the influence of top–down, goal directed processes biasing the increased influence of bottom–up, stimulus driven processes (Miyake et al., 2000). Substantial evidence using a multitude of methods now shows that anxiety impairs the efficiency by which the main central executive functions of working memory, namely the inhibition, shifting and updating of information, guide goal-directed behavior, reducing

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attentional control (see Berggren & Derakshan, 2013a,b; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011, for reviews). Extending the main assumptions of ACT (see Berggren & Derakshan, 2013a,b), it seems that establishing a causal mechanism by which impaired attentional control can exacerbate anxiety's effects on performance outcome(s) through its emphasis on attention and maintenance on worrisome and ruminative thoughts, is imperative. A direct impact of reduced attentional control is the 'hidden' cost of compensatory processes that serve to maintain performance outcomes in high anxious individuals (e.g., Ansari & Derakshan, 2011a; Basten, Stelzel, & Fiebach, 2011, 2012; Righi, Mecacci, & Viggiano, 2009) exaggerating in turn the effects of anxiety on processing efficiency.

Recent theoretical accounts indicate a strong link between attentional control and working memory (see, Shipstead, Lindsey, Marshall, & Engle, 2014) as successful operation of working memory requires efficient use of attentional control in order to suppress task irrelevant information while processing goal-relevant information. Recent findings (e.g., Qi et al., 2014a) have confirmed the long standing assumption (see, Eysenck & Derakshan, 1998) that anxiety is associated with reduced working memory capacity. Working memory can possibly mediate the relationship between anxiety and cognitive performance (Qi et al., 2014b; Owens, Stevenson, Hadwin, & Norgate, 2012), with impairments in working memory capacity exaggerating the effects of anxiety on cognitive performance (Wright, Dobson, & Sears, 2014).

1.2. Manipulating attentional control

Adaptive cognitive training paradigms using the dual n-back training paradigm (Jaeggi et al., 2003) have been successful in improving a number executive processes such as general fluid intelligence (Au et al., 2014), inhibition and working memory capacity (Owens, Koster, & Derakshan, 2013) and cognitive control (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013), with training-related gains on untrained tasks measuring similar (near transfer) or different (far transfer) processes (but see, Shipstead, Redick, & Engle, 2012a,b). The adaptive dual n-back task is a working memory task where two streams of information – visual and auditory – need to be processed simultaneously. In this task, participants are asked to indicate whether there has been a match either for the visual or auditory information between the current trial and a number (n) trials back in the series. The task can get progressively more difficult with the level of 'n' increasing as participant performance improves, thus, providing an adaptive training. Such adaptive cognitive training techniques hold important implications for improving clinical outcome(s) in emotionally vulnerable populations. For example, Owens et al. (2013) (see also, Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013) using a dual n-back task investigated if training could improve cognitive control in individuals with sub-clinical levels of depression. Adaptive training and non-adaptive control groups underwent the intervention for eight days over a two week period. The adaptive training group's performance could increase in difficulty up to 4-back level while the non-adaptive control group only practiced the 1-back version of the task, without adaptation as a function of performance improvement. Training-related gains were found to transfer to behavioral and neural measures of working memory capacity and the efficiency of filtering of irrelevant information in the adaptive training compared to the control group. Other recent findings have also shown benefits of cognitive training in improvements on cognitive control. For example, Siegle et al. (2014) showed that cognitive control training can have beneficial effects on reducing rumination in clinically depressed patients. Furthermore, Cohen, Mor and Henik (2015) showed training related gains on state rumination using a cognitive control training task that emphasized distractor inhibition. Finally, a study by Bomyea and Amir (2011) demonstrated that cognitive control training led to decreased intrusive thoughts, a hallmark of affective disorders including anxiety disorders.

1.3. The current study

Most studies performed so far have examined the beneficial effects of cognitive control training in the context of depression. Provided the relevance of impaired attentional control in anxiety (cf. Eysenck et al., 2007), the current study sought to determine if daily training for 15 days distributed over a three weeks period on the adaptive dual n-back task can result in improved attentional control in preselected high anxious individuals low on different measures of attentional control (Derryberry & Reed, 2002). We included a training group and an active control group. The training group performed an adaptive dual n-back task and the control group performed a non-adaptive dual 1 back task. To examine transfer of training, pre and post intervention measures of attentional control included: a Flanker task measuring distractor interference, an Antisaccade task with emotional faces as target to assess attentional control and inhibition in relation to emotional material, and resting state EEG (theta/beta) ratio, an index of prefrontal cortex related attentional control (Putman, Verkuil, Elsa Arias-Garcia, Pantazi, & van Schie, 2014). We now describe the selection of this transfer in more detail.

The Flanker task (Eriksen & Eriksen, 1974) was based on a modified version used in Berggren and Derakshan (2013a,b). In this task, two types of arrows (distracter arrow, target arrow) indicating right or left were presented. Participants were instructed to ignore the distracter arrows and indicate the direction of the target arrow. The Flanker task has been used extensively in the literature in studies where distractor interference has been investigated (Lavie, Hirst, de Fockert, & Viding, 2004; Shipstead et al., 2012a,b). Since high working memory capacity has been found to eliminate the adverse effect of acute stress (Otto, Raio, Chiang, Phelps, & Daw, 2013), the Flanker task also included a state anxiety manipulation of presenting loud bursts of white noise randomly in half of the blocks. State anxiety manipulations using white noise have previously found to be successful (see Rossi & Pourtois, 2014). Using this manipulation, we aimed to assess selective attention under challenging conditions where the need to address the task demands is considered to place greater challenges on working memory functions for high anxious individuals (see Berggren, Richards, Taylor, & Derakshan, 2013; Derakshan & Eysenck, 1997).

The Antisaccade task (Hallet, 1978) was based on Derakshan, Ansari, Hansard, Shoker, and Eysenck (2009, Exp 2). This task is a well validated and extensively used measure of attentional control in normal (see Ettinger et al., 2008; Hutton & Ettinger, 2006) and emotionally vulnerable populations suffering from anxiety and depression (see Berrgren & Derakshan, 2013, for a review). During the Antisaccade task, participants are required to saccade towards (prosaccade) or away from (Antisaccade) an abrupt peripheral target flashed on the screen, as quickly as possible. Anxiety has been associated with a slowing on Antisaccade latencies requiring the efficient exercise of attentional control processes of working memory in relation to target inhibition (e.g., Ansari & Derakshan, 2010, 2011a; Derakshan et al., 2009, Exp 1), and when the targets were angry facial expressions of emotion (Derakshan et al., 2009, Exp 2). Here, we used angry and neutral facial expressions as targets and were interested to observe training related gains on antisaccade latencies in relation to the inhibition of angry targets, predicting that training would result in faster antisaccade latencies especially for to-be-inhibited angry targets.

As a neurophysiological measure during the antisaccade trial, keeping with Ansari and Derakshan (2011a), we used Event Related