NeuroImage 151 (2017) 81–91

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

Imaging the neural effects of cognitive bias modification training

Corinde E. Wiers[a,*], Reinout W. Wiers[b]

[a] National Institute on Alcohol Abuse and Alcoholism, Laboratory of Neuroimaging, National Institutes of Health, Bethesda, MD, USA
[b] Addiction Development and Psychopathology (ADAPT) Lab, Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands

ARTICLE INFO

Keywords:
Cognitive bias modification
CBM
Addiction
Anxiety
Bias
Depression
Implicit measures
Neuroimaging

ABSTRACT

Cognitive bias modification (CBM) was first developed as an experimental tool to examine the causal role of cognitive biases, and later developed into complementary interventions in experimental psychopathology research. CBM involves the "re-training" of implicit biases by means of multiple trials of computerized tasks, and has been demonstrated to change anxious, depressive and drug-seeking behavior, including clinically relevant effects. Recently, the field has progressed by combining CBM with neuroimaging techniques, which provides insight into neural mechanisms underlying how CBM affects implicit biases in anxiety, depression, and addiction, and potentially other pathologies. This narrative literature review summarizes the state of the art of studies on the neural effects of CBM and provides directions for future research in the field. A total of 13 published studies were found and discussed: $n = 9$ in anxiety, $n = 2$ in depressive behavior, and $n = 2$ in addiction.

Introduction

Cognitive bias modification training (CBM) refers to computerized tasks that aim to re-train cognitive biases. Cognitive biases are a broad class of automatically activated processes that may persist even when they conflict with conscious goals. For example, the attention of an individual addicted to alcohol may be captured by an alcohol cue, and the same cue may elicit an action tendency to approach the stimulus (Wiers et al., 2007), while the same patient may hold conscious beliefs that these drinks should be avoided to avoid further harms. For individuals with depressive symptoms (both clinical and non-clinical) a bias toward negative stimuli has been reported (Peckham et al., 2010), and a core feature of people with anxieties (clinical and non-clinical) is increased attention for threat-relevant cues, i.e., an attentional bias or vigilance for threatening stimuli (meta-analysis: Bar-Haim et al., 2007).

Measuring cognitive biases

Cognitive biases can be tested with computer-based tasks, and may be considered "automatic" if task instructions are indirect (i.e., if participants are largely unaware of the task's outcome measures (but see Gawronski et al., 2006), or if the outcome measures involve subtle behavioral effects that are not directly under conscious control (De Houwer, 2006; Stacy and Wiers, 2010)). Automatic measures may be less susceptible to social desirability than explicit measures, such as subjective craving (De Houwer, 2006). The most frequently used task for attentional biases is the Dot Probe Task, in which pairs of target-relevant (e.g., emotionally or drug-related) and neutral images are presented on a computer screen for a brief period of time (typically 500 ms) (MacLeod et al., 2002). A probe-stimulus is then presented at the location of one of the cues, and participants are required to identify the probe (originally, the probe consisted of one or two dots) using button presses. When participants tend to be relatively fast to respond to probes appearing at the position of the disorder-relevant pictures, this can be used as a measure for an attentional bias toward that stimulus category. For example, drug abusers have been shown to fixate longer on drug-related cues than neutral cues (Field et al., 2013), but negative findings have also been reported (Townshend and Duka, 2007; Wiers et al., 2016) and temporal dynamics strongly modulate the bias (Noel et al., 2006; Townshend and Duka, 2007; Vollstadt-Klein et al., 2009). Anxiety is related to fast attentional bias toward threat, likely in a complex, time-dependent fashion (Bar-Haim et al., 2007; Koster et al., 2006; MacLeod and Mathews, 1988; Mogg et al., 2004). Individuals with depression have also shown stronger attention biases toward negative stimuli on the dot probe task compared to controls (Peckham et al., 2010), which is most consistently observed for cues that are presented for longer than a second (De Raedt and Koster, 2010). Biased action-tendencies can be assessed with the Approach Avoidance Task (AAT) in which participants push and pull pictorial

* Corresponding author at: National Institute on Alcohol Abuse and Alcoholism, Laboratory of Neuroimaging, National Institutes of Health, 10 Center Drive, Room B2L124, Bethesda, MD, 20892, USA.
E-mail address: corinde.wiers@nih.gov (C.E. Wiers).

http://dx.doi.org/10.1016/j.neuroimage.2016.07.041
Received 9 March 2016; Accepted 19 July 2016
Available online 21 July 2016
1053-8119/

cues (target-relevant/neutral) with a joystick (Rinck and Becker, 2007). Individuals with social anxiety (Heuer et al., 2007; Roelofs et al., 2010), and depression (Seidel et al., 2010) have been shown to faster avoid than approach emotional facial cues than controls, whereas heavy drinkers (Wiers et al., 2009), patients with alcohol use disorder (AUD) (Ernst et al., 2014; Wiers et al., 2014), heroin abusers (Zhou et al., 2012), and heavy cannabis users (Cousijn et al., 2011) have been shown to faster approach than avoid drug cues compared to non-addicted control groups. Since cognitive biases have been found to be correlated with a variety of psychopathological problems (Williams et al., 1996), including explicit craving scores in drug users (Mogg et al., 2005; Wiers et al., 2013a), anxiety scores (Bar-Haim et al., 2007), and depression severity (Beevers et al., 2011), these biases may be clinically relevant outcome measures. Bar-Haim and colleagues, however, found that for PTSD, greater attentional threat avoidance predicted greater PTSD symptoms (Sipos et al., 2014; Wald et al., 2013), which makes the clinical efficacy of avoiding threat CBM interventions questionable for this disorder. While many other cognitive biases have also been identified in various psychopathologies (e.g., interpretive biases, expectancy bias, recall bias), the current review will focus specifically on those that have been investigated in conjunction with neuroimaging: the attentional and approach bias.

Behavioral and clinical effects of CBM

Even more interesting is the possibility that cognitive biases not only correlate with but also cause mental health problems. The first CBM interventions were designed to directly manipulate cognitive biases in psychopathology, with the primary goal of testing causality of the bias for problem-behaviors (MacLeod et al., 2002; Mathews and Mackintosh, 2000). Tasks were adapted in order to directly manipulate the cognitive bias and study effects on behavior. People can be trained either toward the disorder-relevant cues (e.g., threat or alcohol cues), which typically increases disorder-relevant symptoms or away from the disorder-relevant cues, which reduces disorder-relevant symptoms (Field and Eastwood, 2005; MacLeod et al., 2002). In clinical samples, training away from the disorder-relevant stimuli is usually compared with a condition in which no contingency is changed, i.e., continued assessment. For example, Field et al. (2009a) aimed to manipulate smokers' attentional biases for smoking cues by always pairing the probe with neutral cues (“avoid smoking”), always with smoking cues (“attend smoking”) or probes were paired with the two categories with equal probability (control group, no change). The manipulation decreased, increased and did not change participants' attentional biases for smoking cues respectively (Field et al., 2009a). Regarding smoking, a recent study found that repeated attentional retraining helped heavy smokers to succeed in their quit attempt, doubling the chance to successfully abstain from smoking half a year later (Elfeddali et al., in press).

Manipulation of approach biases have used training versions of the AAT, in which task-irrelevant display features of stimuli were selectively approached or avoided. For example, patients with AUD were trained to push alcohol cues more frequently than soft drink cues, by manipulating the format of the cues (landscape or portrait), according to which participants were instructed to push/pull (Wiers et al., 2011). In this way, one group of patients systematically pushed alcohol cues away, and pulled non-alcoholic beverages, while another group equally often pushed and pulled alcohol and soft drinks or did not train at all (Eberl et al., 2013; Wiers et al., 2011). CBM tasks have often (but not always) been found to change the targeted cognitive biases, and when they did, often (but not always) the relevant behavior was also influenced (Clarke et al., 2014b). For example, changing an approach-bias for alcohol resulted in reductions in drinking in students (Wiers et al., 2010) and in relapse in patients with AUD (Eberl et al., 2013; Wiers et al., 2011; Manning et al., 2016). CBM has further shown clinical effects for treatment in anxiety (Amir et al., 2009; Linetzky et al., 2015; Schmidt et al., 2009), depression (Peckham et al., 2010) and addiction (Eberl et al., 2013; Schoenmakers et al., 2010; Wiers et al., 2011). Despite studies reporting negative results of CBM in student samples (Field et al., 2007; Schoenmakers et al., 2007) and a critical meta-analysis of effects in anxiety (Cristea et al., 2015), there is evidence that CBM helps at least a subgroup of patients with anxiety and addiction problems (Linetzky et al., 2015; Wiers et al., 2013b). The relevant question for such applications appears not to be whether CBM works in general, but when it works, for instance in relation to motivation (Gladwin et al., 2016). However, evidence of behavioral effects of CBM in depression has been relatively weak so far (Hallion and Ruscio, 2011). In summary, while results in student-samples and in internet-trials have been weak, there is substantial evidence that varieties of CBM can produce clinically meaningful effects in patients with alcohol dependence and in patients with anxiety.

Given the state of affairs in addiction, where several studies found a clinically relevant add-on effect of CBM when combined with CBT (Eberl et al., 2013; Schoenmakers et al., 2010; Wiers et al., 2011), and no differential training effect was found for CBM alone (Lindgren et al., 2015; Wiers et al., 2015c), it appears likely that CBM affects different processes than CBT. Theoretically, CBT (especially when combined with motivational interviewing) provides an alternative long-term perspective to continued alcohol or drug use, and some strategic techniques to accomplish that goal. However, for some patients increased motivation and strategies are not enough when faced with conditioned stimuli related to their addiction, and triggering a cascade of appetitive processes (attentional bias, positive memory associations, approach bias), especially when control is suboptimal, e.g., under conditions of stress or fatigue. For those patients, CBM appears to be a helpful add-on to CBT. Nevertheless, applying CBM without also addressing long-term motivation to change behavior appears to have little chance of success (Kerst and Waters, 2014; Lindgren et al., 2015).

Neural processes underlying cognitive biases

There is a growing literature on neural correlates of cognitive bias in anxiety, depression and addiction at “baseline”, before CBM training. For anxiety, performance on the dot probe task has been consistently associated with perturbed activation in brain regions involved with emotional processing (i.e., the amygdala) and attentional control (i.e., the lateral prefrontal cortex and anterior cingulate) (White et al., 2016). That is, anxious individuals have shown increased activation on the anxiety Dot Probe task in the amygdala (Monk et al., 2006), lateral PFC (Britton et al., 2012; Telzer et al., 2008) and dorsal anterior cingulate (dACC) (Choi et al., 2016; Price et al., 2014). Anxiety has also been associated with impaired connectivity of frontal cortical regions with the amygdala (Carlson et al., 2013; Hardee et al., 2013) and with the (para)hippocampus (Price et al., 2014), suggesting impaired attentional control to the exposure of threat Various EEG studies suggest a brain circuitry involved in rapid responses to threat in anxiety, including greater amplitudes of early components (P2 and *C*1) to threat faces in high- versus low anxious individuals (Bar-Haim et al., 2005; Eldar et al., 2010). For depression, a similar role of altered PFC function during biased attention for negative stimuli has been suggested. Individuals with high symptoms of depression indeed showed weaker activation in the lateral PFC when shifting attention away from negative stimuli, than individuals with few symptoms (Beevers et al., 2010). An imbalance between bottom-up and top-down neuronal circuits has been proposed in addiction (Volkow et al., 2013). In abstinent patients with AUD, the alcohol approach bias was associated with an increased response in the nucleus accumbens (NAcc), and medial prefrontal cortex (mPFC) compared to controls (Ernst et al., 2014; Wiers et al., 2014). Activation in the amygdala was further positively associated with craving within the alcohol group (Wiers et al., 2014). Moreover, alcohol attentional bias scores correlated with alcohol-cue induced activation in mesocorticolimbic reward system in