

Original Papers

Polish Psychological Bulletin
2012, vol.43(4), 272-277
DOI - 10.2478/v10059-012-0030-5

Borysław Paulewicz*

Agata Blaut**

Joanna Kłosowska**

Cognitive effects of attentional training depend on attentional control

Abstract: Attentional bias is assumed to be partly responsible for the onset and maintenance of anxiety by major cognitive theories of emotional disorders. Although much is already known about the therapeutic effects of attentional bias training, only a few studies have examined the mechanism responsible for these effects. In order to test if low-level, cognitive effects of attentional bias training depend on attentional control, 73 participants, who completed the STAI-x2 and the ACS questionnaires, were randomly assigned to a control ($n = 37$) or attentional training group ($n = 36$). The attentional manipulation was followed by a search task, during which novel neutral or negative faces could be presented within an array of all-neutral, all-negative or all-positive faces. It was found that individuals with higher ACS score displayed stronger attentional training effects, i.e., they were less accurate in detecting distinctive negative faces, and this effect was not found to be associated with STAI-x2 score. These results show that there is individual variability even in immediate, cognitive effects of attentional bias modification and that special abilities, such as attentional control, might be required for attentional training to be efficient.

Keywords: attentional bias, anxiety, attentional control, cognitive bias modification

According to major cognitive theories of anxiety and affective disorders attentional bias is not only a symptom, but also a risk factor responsible for the onset and maintenance of these disorders (Clark, Beck, & Alford, 1999; Mathews & MacLeod, 1994; Williams, Watts, MacLeod, & Mathews, 1997). It is known that depression and anxiety are associated with a tendency to attend to negative or threatening information or with difficulties in disengaging attention from them (Cisler & Koster, 2010). A similar effect has been observed in patients suffering from various emotional disorders, as well as in healthy individuals with elevated trait or state anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007).

The pivotal study by MacLeod, Rutherford, Campbell, Ebsworthy, & Holker (2002) has given rise to an increasing interest in this subject, mainly because of the emergence of a group of methods collectively called Cognitive Bias Modification (CBM, for a review, see MacLeod, 2012). The idea behind CBM is to use experimental procedures

of cognitive psychology in order to change the direction or intensity of a given form of cognitive bias. A good illustration of how CBM works is attentional bias modification (CBM-A) with a modified dot-probe task.

At present, the dot-probe task seems to be the most popular task used to measure or alter attentional bias (MacLeod, Matthews, & Tata, 1986; Hakamata et al., 2010). It consists of a series of trials during which simultaneously presented emotional and neutral cues are replaced by a probe appearing in place of the preceding emotional (congruent position) or neutral (incongruent position) stimulus. When the congruent position probability is .5, directing attention towards a given stimulus class results in differences in an average reaction time for congruent and incongruent positions – an attentional bias effect. If, on the other hand, the congruent position probability is significantly lower than .5, it is beneficial for task performance to direct attention away from emotional stimuli or towards neutral ones. It turns out that participants engaging in the training

* University of Social Sciences and Humanities, Faculty in Katowice

** Jagiellonian University

Correspondence concerning this article should be addressed to Borysław Paulewicz, University of Social Sciences and Humanities, Faculty in Katowice, Kossutha 9, 40-844 Katowice, Poland. e-mail: bpaulewicz@swps.edu.pl

version of the dot-probe task learn to direct their attention in accordance with the imposed contingency (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002).

The effectiveness of CBM is of major theoretical and practical significance. It is this approach that for the first time allows to directly test causal hypotheses about the role of cognitive biases in emotional disorders (Mathews & MacLeod, 2002). There is also substantial evidence showing non-trivial, practically important therapeutic effects of CBM, especially in anxiety and anxiety disorders (e.g., Amir, Beard, Burns, & Bomyea, 2009; Hakamata et al., 2010). Thus, certain authors suggest that from now on studies should address the issue of the mechanism responsible for the effectiveness and efficiency of CBM methods (Bar-Haim, 2010; MacLeod, Koster, & Fox, 2009).

Deeper understanding of the mechanisms of CBM seems to be necessary in order to improve its efficiency and identify the limits of its applicability. Only a few such attempts have been made to date. Some researchers used special tasks, e.g., Heeren, Lievens, & Philippot (2011) used specific version of the dot-probe task assumed to induce attentional engagement towards neutral stimuli, disengagement from negative stimuli or both effects at the same time. In some studies, conclusions about the mechanism were based on the usage of additional measures of CBM effects, e.g., testing if altering one form of bias affects another form (Amir, Bomyea, & Beard, 2010; Tran, Hertel, & Joorman, 2011), or using different presentation times to investigate which stage of processing, early or late, is affected (Koster, Baert, Bockstaele, & de Raedt, 2010). However, with the exception of Baert, De Raedt, Schacht, & Koster's (2010) study, these studies did not address the issue of individual differences in the susceptibility to CBM.

In our opinion, there are both theoretical and empirical reasons to choose attentional control as a plausible candidate for a CBM effect moderator. Theoretical justification is provided by Eysenck's attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), according to which anxiety impairs top-down attentional control processes, especially the inhibition of automatic responses and shifting of the attentional focus. Based on this assumption it is reasonable to presume that, to the extent that anxiety has such effect, one might expect less improvement after attentional training. Empirical justification is provided by Klumpp & Amir (2009), Derryberry & Reed (2002) and Lonigan & Vasey (2009).

In Klumpp & Amir's (2009) experiment, training attention away from negative stimuli or towards negative stimuli was compared with no training with respect to changes in vulnerability to stressful events. Quite unexpectedly, after completing the stressful task, both experimental groups demonstrated a lower level of state anxiety than the control group. Authors interpreted their findings as implying that CBM-A does not necessarily induce a specific change in attentional bias, but improves control over attentional

effects associated with a given stimulus class. This hypothesis is partly supported by neuroimaging studies (Browning, Holmes, Murphy, Goodwin, & Harmer, 2010) showing that following CBM-A it is possible to observe changes in activation patterns in the frontal lobes, the area known to be strongly related to executive functions. Still, it should be noted that the idea that CBM-A is insensitive to the direction of the induced bias (towards or away from negative stimuli) seems to have limited validity, as in some studies (see for example MacLeod et al., 2002) it has been found that training attention towards negative stimuli does in fact increase vulnerability to stressful events.

Finally, Derryberry & Reed (2002), as well as Lonigan & Vasey (2009) tested for interactive effects of attentional control and anxiety on attentional bias. In both studies, the attentional bias effect was found only in those participants who were highly anxious and had low attentional control. These results indicate that attentional control could make anxious participants less susceptible to task-irrelevant negative stimuli. Based on the above theoretical and empirical results, it is natural to ask if proximal, i.e., immediate, cognitive effects of CBM-A depend on attentional control. The exact purpose of our study was to answer this question.

Method

Overview of the procedure

In order to investigate how proximal, cognitive effects of attentional training depend on attentional control, attentional bias was measured or trained by means of the dot-probe task, the Attentional Control Scale (Fajkowska & Derryberry, 2010) was used to measure attentional control, and the emotional visual search task was used to measure proximal effects of attentional training. In this respect, the procedure in this study differs from the one used in the studies by Derryberry & Reed (2002) and Lonigan & Vasey (2009). In these observational studies, interactive effect of anxiety and attentional control was measured with the dot-probe task (Lonigan & Vasey, 2009) or the lateralized cues task (Derryberry & Reed, 2002). It could be argued, however, that the visual search task is better suited for this purpose, since the moderating effect of attentional control should be more pronounced under greater attentional load, and greater attentional load can be easily achieved by controlling the number of distractors, the target-distractor and the distractor-distractor similarity (Duncan & Humphreys, 1989). Since the visual search task was used as a special measure of the attentional bias effect, there was no need for the dot-probe post-test.

Participant characteristics

The participants were 73 undergraduate Jagiellonian University students (69 female and 4 male, mean age = 21, $sd = 1.8$), who completed the study in exchange for course

credit. They were assigned either to the attentional training ($n = 36$) or to the control condition ($n = 37$). Assignment to the groups was random and the experimenter was blind to condition.

Materials

Questionnaires. Trait anxiety was measured with the STAI-x2 questionnaire (Spielberger, Strelau, Tysarczyk, & Wrześniewski, 1987). This self-descriptive measure consists of 20 questions rating typical intensity of various anxiety symptoms. Attentional control was measured with the Attentional Control Scale (ACS, Fajkowska & Derryberry, 2010), a self-descriptive measure consisting of 20 questions rating the multi-tasking ability and the sensitivity to distraction.

Stimuli. Pictures of facial expressions from the Radboud Faces Database (Langner et al., 2010) were used as stimuli in the dot-probe task. These were negative and neutral expressions of 38 Caucasian female and male actors, all with their mouth closed. The pictures used in the search task were taken from the NimStim database (Tottenham et al., 2009). These were neutral, negative and positive facial expressions of 24 Caucasian female and male actors, with their mouth open or closed.

The dot-probe task. The dot-probe task consisted of 384 trials, divided into two 192 trial blocks. The beginning of each trial was signalled by a white cross presented centrally for 500 ms. This fixation point was replaced by a 500 ms presentation of neutral and negative facial expressions of the same actor, placed horizontally, in equal distance from the screen center. Following the termination of the display of faces, a white line segment (slash or backslash) appeared either in a neutral (incongruent) or negative (congruent) position. The participants were instructed to detect as quickly and accurately as possible the direction of the line by pressing one of the arrow keys. At the typical distance from the screen, of about 67 cm, the pictures spanned a rectangular area of $5^\circ \times 7^\circ$ and were separated by a 4° horizontal distance between the nearby edges. The line segment was a diagonal of a $0.6^\circ \times 0.2^\circ$ rectangle. The picture pairs were randomized for each participant in such a way that a given pair could be repeated only after the whole set was exhausted. The direction of the line segment and the position (left or right) of the negative picture was randomized for each participant.

The visual search task. This task was similar to the one used in Pinkham, Griffin, Baron, Sasson & Gur's (2010) study. Each of the 126 trials began with a 1 s presentation of a white cross, serving as a fixation point. The following 9 pictures were presented in random order in a 3x3 matrix. Each picture in a given matrix represented a facial expression of a different actor and either in all of the pictures the mouth was open or in all of them the mouth was closed. The participants were instructed to decide,

using the arrow keys, if a distinctive facial expression, e.g., a negative expression among the neutral ones, was present. The target was present in exactly half of the trials, and it could be a negative face among neutral ones, a negative face among positive ones or a neutral face among negative ones. Because of the task difficulty, some of the possible combinations of the target-distractor valences were excluded (e.g., there was no condition with a positive target among negative distractors). At the typical distance of 67 cm from the screen each picture occupied an area of $4^\circ \times 5^\circ$ and was separated from the other pictures by 0.5° .

Procedure

Separate groups of about 10 to 15 participants were tested in a sound-attenuated room. They were told that the purpose of the study was to examine the relationship between mood and attention. After they were seated in front of a computer screen, the participants filled out a written informed consent form, the ACS and the STAI-x2 questionnaires, in random order. After that, all the instructions were shown on the computer screen. Before each task, the participants engaged in practice sessions consisting of 8 trials. The beginning of each task was self-paced and signaled by a message on the computer screen. The dot-probe task was completed first, followed by the search task. The attention training and the control groups differed only in the congruent position probability. In the control group, the target stimulus in the dot-probe task appeared in a congruent position in half of the trials, whereas it never appeared in this position in the attentional training group. At the end of the session, the participants were asked to guess the purpose of the procedure. No one correctly guessed the exact purpose or the hypotheses. A full debriefing was provided. Each experimental session took approximately 45 minutes to complete.

Results

Inter-group differences at pretesting. Inter-group differences at pretesting are summarized in Table 1. None of the differences were statistically significant.

Table 1. Participant Characteristics.

	Group	
	<i>Training</i>	<i>Control</i>
	<i>M (SD)</i>	<i>M (SD)</i>
<i>Age</i>	21 (1.7)	21 (1.8)
<i>STAI-x2</i>	43 (9.5)	45 (7.9)
<i>ACS</i>	53 (6.0)	51 (6.5)
<i>Gender ratio (f/m)</i>	36/0	33/4

Effects of attentional training and attentional control in the search task. Proportion of error responses ranged from .34 to .12, with the average of .21, so reaction time was not a valid measure of task performance, and only response accuracy was analyzed. All conditions in which the target was present were classified according to the target valence as negative (negative target among neutral or positive distractors) or neutral trials (neutral target among negative or positive distractors). Following Jaeger's (2008) recommendation, generalized linear mixed models with binomial distribution (mixed logistic regression) were fitted to the accuracy data. This has the advantage of avoiding unnecessary loss of power resulting from violation of the linear model assumptions, and it does not introduce interaction artifacts that may easily appear when the general linear model is applied to binomial data. The group factor (attentional training or control group), the valence factor (negative or neutral), and either the ACS or the STAI-x2 score, as well as all possible interactions were included as fixed effect terms, and the subject-specific average accuracy was included as a random factor. The questionnaire scores were mean-centered.

When the STAI-x2 scores were included as predictors, no significant effects associated with this variable were observed. However, when the ACS score was included, interactive effects were found. These are illustrated with model fit summaries in Tables 2 and 3, representing two separate equivalent parametrizations. In Table 2 below, the coefficients represent the intercepts and slopes and the interactive effects *within* the group × valence conditions.

Table 2. Summary statistics of binomial generalized linear mixed effects model for the search task data. Separate intercepts and slopes parametrization.

Coefficient	Estimate	Std. Error	<i>z</i>	<i>p</i>
Control:Neutral	0.12	0.06	1.99	0.047
Training:Neutral	0.23	0.06	3.72	0.000
Control:Negative	1.63	0.08	20.84	0.000
Training:Negative	1.45	0.08	19.10	0.000
Control:Neutral:ACS	0.00	0.01	0.06	0.956
Training:Neutral:ACS	0.00	0.01	0.16	0.869
Control:Negative:ACS	0.01	0.01	0.71	0.375
Training:Negative:ACS	-0.03	0.01	-2.22	0.010

All the intercepts (the first four rows of the regression table) were significant, indicating that in every condition the performance was above the chance level. Under this parametrization, ACS was not found to be significantly related to accuracy ($|z| < 0.8$) with the exception of negative targets in the training group ($z = -2.22, p = .01$): the higher

the participants scored on the ACS, the lower the accuracy of detecting negative targets was found to be in this group, suggesting that proximal attentional training effect might depend on attentional control. This conclusion is further supported by the standard parametrization model fit summary, presented in Table 3.

Table 3. Summary statistics of binomial generalized linear mixed effects model for the search task data. Standard parametrization.

Coefficient	Estimate	Std. Error	<i>z</i>	<i>p</i>
(group=Control, valence=Neutral, mean ACS)	0.12	0.06	1.99	0.047
Training	0.11	0.09	1.26	0.207
Negative	1.51	0.09	16.16	0.000
ACS	0.00	0.01	0.06	0.956
Training:Negative	-0.28	0.13	-2.13	0.033
Training:ACS	0.00	0.01	0.09	0.932
Negative:ACS	0.01	0.01	0.71	0.480
Training:Negative:ACS	-0.04	0.02	-2.10	0.035

The significant negative target superiority effect (negative vs. neutral target effect), observed in average ACS scorers in the control group ($z = 16.16, p < .001$), was significantly lower in the training group and the ACS × valence interaction, which was non-significant in the control group ($z = 0.71, p = .48$), was significantly different in the attentional training group ($z = -2.10, p = .04$). It is also worth noticing that neither the ACS score nor attentional training had any detectable impact on the neutral target detection probability. The agreement between the model predictions and data is depicted in Figure 1. As can be seen, a great majority of the aggregated accuracy scores fall within 95 percent predictive intervals, indicating that overdispersion was not substantial.

Discussion

Our results show that proximal effects of attentional training based on a modified dot-probe task depend on attentional control. In both groups, the negative targets in the search task were easier to detect than the neutral ones, but this effect was lowered as a result of attentional training, showing at the very least that the training procedure was effective and that this particular version of the search task can be used as a measure of proximal attentional training effects. The influence of attentional training on the search task performance was further found to be related to the attentional control: participants with a higher attentional control showed stronger proximal, attentional effects of training.

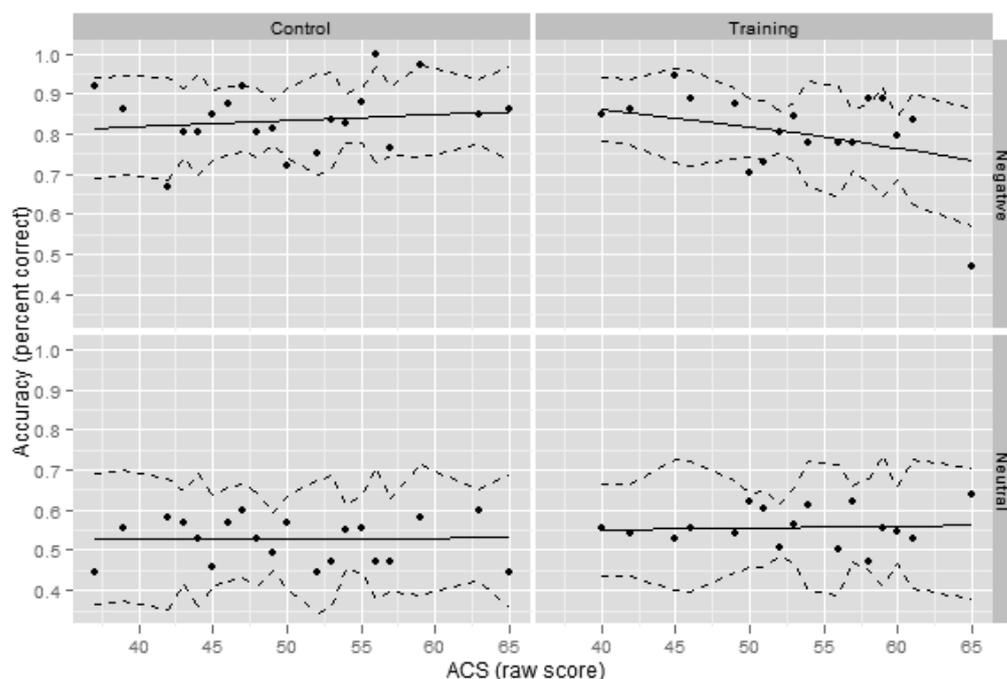


Figure 1. Aggregated accuracy scores for the negative and neutral targets in the search task.

Note. Solid lines represent the model fit based on fixed effects only, dotted lines represent 95% predictive intervals based on the fixed and random effects.

At least two important limitations of the present study should be mentioned, i.e., the self-descriptive nature of the attentional control measure and absence of mood-related measures of attentional training effects. The only consequence of the latter problem is the limited generality but not the validity of the conclusions, therefore we will not discuss this issue any further.

Quite likely, attentional control is difficult to estimate by introspection or unaided self-observation, however, performance measures of executive functions are also problematic in certain respects, especially when used at the initial, more exploratory stage of research. For example, measures of different executive functions are sometimes uncorrelated, as can be different measures of the same executive function (Chan, Shum, Touloupoulou, & Chen, 2008). In practice, this forces the experimenter to choose a specific executive function or functions of interest in advance. Since, to the best of our knowledge, our experiment is the first one to address the issue of interactive effects of CBM-A and attentional control, instead, we decided to use a questionnaire measure, which is possibly broader in its scope.

Keeping these limitations in mind, one may conclude that there are individual differences that influence the susceptibility to attentional training. Specifically, the efficiency, or possibly even the effectiveness, of such training protocols seem to depend on executive functions. It should be stressed that the presence of attentional control

effects is as important here as is the lack of significant anxiety-related effects, since both variables are known to be correlated (Fajkowska & Derryberry, 2010) and it seems plausible that anxiety could act as a CBM-A moderator, becoming a confounder in our study. Because of the self-descriptive nature of the attentional control measure, it is impossible to identify specific executive functions responsible for the observed differences in the training effects, but a few detailed conclusions about the mechanism of CBM-A are possible to be put forward.

Typically, CBM-A is a special case of associative learning. There are at least two, non-exclusive general ways in which individual differences can moderate the CBM-A effects. One way is by affecting the learning stage. Attentional control may thus influence how easily participants learn the contingencies present in the task, and lower attentional control may have detrimental effects on learning, because of a higher sensitivity to distraction associated, by definition, with low attentional control.

The other possibility is that individual differences may influence the extent to which specific associations, once learned, influence participants' behavior. It might be easier for participants with higher attentional control to change – intentionally or not – the way their attention reacts to the presence of certain task-irrelevant stimuli. Also, lower attentional control may be associated with a greater difficulty in ignoring threatening distractors, even if these were known to be task-irrelevant; hence, the

anxiety-related attentional bias would be more pronounced in high anxiety / low attentional control participants, as was found by Derryberry & Reed, (2002) and Lonigan & Vasey (2009).

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