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BRIEF ARTICLE

Limited generalisation of changes in attentional bias following attentional bias modification with the visual probe task

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ABSTRACT
Although attentional bias modification (ABM) can change anxiety, recent studies failed to replicate such effects, possibly because the visual probe ABM failed to induce changes in attentional bias (AB). We investigated whether visual probe ABM generalised to different measures of AB besides the visual probe task (VPT), and thus whether ABM genuinely changes attentional processing. We trained participants ($N = 60$) to either attend towards or away from angry facial expressions, and we examined training effects on the dot probe task, the exogenous cueing task, and the visual search task. We found a small change in AB in the VPT, but this effect did not transfer to the exogenous cueing task or the visual search task. Our study shows that ABM does not necessarily lead to generalised effects on AB. This finding can be explained by the poor psychometric properties of the AB measures.

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Attentional bias; ABM; cognitive bias modification; anxiety; generalisation

Attentional bias (AB: the preferential allocation of attention to certain stimuli) for threatening stimuli has been argued to contribute to the development and maintenance of anxiety (for a review, see Van Bockstaele et al., 2014). MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) trained participants to either avoid or attend to threat through an adaptation of the visual probe task (VPT). In this task, participants respond to a target that is preceded by a threatening and a neutral cue. AB towards threat is inferred from faster reaction times (RTs) on trials where the target and threatening cue appear in the same location (congruent trials) than on trials where the target and threatening cue appear in opposite locations (incongruent trials). MacLeod et al. trained participants to either avoid or attend to threat by presenting a majority of incongruent or congruent trials. This attentional bias modification (ABM) procedure increased AB in the attend threat group and decreased AB in the avoid threat group. Furthermore, the avoid threat group reported less anxiety in a subsequent stressful task than the attend threat group, demonstrating AB can causally influence anxiety.

ABM has since been found to reduce clinical anxiety (e.g., Amir et al., 2009). However, several studies have struggled to replicate these early findings (for an overview, see Clarke, Notebaert, & MacLeod, 2014). Clarke et al. argued that in the large majority of these null-results, ABM did not change AB. If the therapeutic effect of ABM depends on the successful manipulation of AB, fundamental research on how and when ABM leads to changes in AB becomes increasingly more important. Despite the importance of the idea that ABM should induce changes in AB, this assumption has been largely neglected. In most ABM studies to date, participants' AB is both manipulated and assessed using the VPT. Changes in AB scores may reflect genuine changes in AB as a psychological construct, but they may just as well reflect mere practice with the VPT. If VPT ABM has a genuine effect on AB, this change in AB should transfer to other measures of AB.

In two studies, Amir and colleagues (Amir et al., 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008) trained participants with a VPT and assessed changes in AB with an emotional exogenous cueing

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task. In this task targets are preceded by a single threatening or neutral cue. Although they found that the visual probe ABM did have an effect on AB in the exogenous cueing task, several researchers have failed to replicate this finding using similar procedures (e.g., Boettcher, Berger, & Renneberg, 2012; Enock, Hofmann, & McNally, 2014; Julian, Beard, Schmidt, Powers, & Smits, 2012).

The main goal of the present study was to investigate whether changes in AB in the VPT transfer to different measures of AB. We measured participants' AB using the VPT, the exogenous cueing task, and the visual search task, both before and after visual probe ABM. If the visual probe training genuinely influences participants' attentional processing of threat, then AB scores on all three paradigms should change following ABM. A secondary aim of our study was to replicate the finding of MacLeod et al. (2002) that ABM reduces individuals' anxiety in response to a stressor. Finally, we addressed the reliability and convergent validity of the three AB measures.

Method

Participants

Sixty-one university students (16 men, 44 women, 1 missing value, average age = 23.28, SD = 7.16) participated in exchange for course credits or €10. All participants provided written informed consent.

Materials

The experiment was programmed using Inquisit 3 (2010). We used the same 96 pictures (happy and angry expression from 24 female and 24 male actors, see appendix) from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998) in all three AB tasks. For practice and neutral filler trials (see below), we selected the angry, happy, and neutral expressions from another 4 female and 4 male actors.

Questionnaires

State and trait anxiety were assessed using the Dutch translations of the State and Trait Anxiety Inventory (STAI-S and STAI-T: van der Ploeg, Defares, & Spielberger, 1980). The STAI-S measures present levels of anxiety; the STAI-T measures more general emotional distress over a longer period of time. We also created a negative mood scale, on which participants indicated on 9-point Likert scales how anxious, stressed, uncomfortable, and unhappy they felt.

Visual probe task

All stimuli were presented against a black background. Each trial started with the presentation of a white fixation cross and two grey rectangles, one above and one below the fixation cross. After 500 ms, two cue pictures appeared on the screen, one in each of the grey rectangles. After 500 ms they were masked by grey rectangles for 20 ms, and the target ("E" or "F") appeared. Participants were required to respond as fast and accurately as possible to the identity of the target by pressing one of two response buttons. The inter-trial interval was 500 ms. The happy and angry cue pictures were each divided in two non-overlapping subsets. Angry pictures from one subset were randomly paired with happy pictures from the other subset, and vice versa. On congruent trials, the target appeared on the location of the angry face. On incongruent trials, the target appeared at the location of the happy face. We also included neutral trials, with neutral faces as cues and the target could appear at the location of either cue. Targets were equally often an "E" or an "F", and they appeared equally often in the upper and lower location. The cue pictures consisted equally often of male and female faces, and each individual cue picture was used equally often.

The VPT consisted of four different phases. First, participants completed a *practice phase* consisting of eight neutral trials with error feedback. The data of this phase were not analysed. The second phase, the *pre-training assessment phase*, consisted of 48 congruent trials, 48 incongruent trials, and 24 neutral trials. In the third phase, the *ABM phase*, participants were assigned to one of two training groups. In the attend threat group, the ABM phase consisted of 3 blocks, with each block consisting of 96 congruent trials and 24 neutral trials. In the avoid threat group, the ABM phase consisted of three blocks, and each block consisted of 96 incongruent trials and 24 neutral trials. Finally, the fourth phase was the *post-training assessment phase*, which was identical to the pre-training assessment phase.

Exogenous cueing task

All stimuli in the exogenous cueing task were presented against a black background. Each trial started with the presentation of a fixation cross and two grey rectangles, one above and one below the fixation cross. After 500ms, a single cue picture appeared on the screen, either in the upper or the lower rectangle. The cue picture remained on the screen for 500ms, followed by a 20ms mask. Next, a target stimulus ("E" or "F") appeared, either in the cued location (valid trials) or in the non-cued location (invalid trials). Participants responded as fast and accurately as possible to the identity of the target by pressing one of two response buttons. The inter-trial interval was 500 ms.

The exogenous cueing task consisted of two phases. In a *practice phase*, we presented four valid and four invalid practice trials with neutral faces as cues. In the actual *test phase*, four different trial types—depending on the validity of the cue and the emotional value of the cue: valid angry, invalid angry, valid happy, invalid happy—were presented 24 times, for a total of 96 trials. All faces were presented equally often, targets were equally often an "E" or an "F", and cues and targets were presented equally often in the upper and lower location.

Visual search task

In the visual search task, a fixation cross was presented for 500 ms on a black background, after which 8 pictures appeared in a 3 × 3 grid, with the middle position empty. In line with De Voogd, Wiers, Prins, and Salemink (2014), the visual search task consisted of two critical blocks. In a find-angry block, we presented 48 trials with 1 angry target amidst 7 happy distractors. In a find-happy block, we presented 48 trials with 1 happy target amidst 7 angry distractors. Participants were required to click as fast as possible on the target face. The order of the two critical blocks was counterbalanced across participants. All faces were presented equally often, and target faces appeared equally often in each of the eight possible locations. The pictures were erased as soon as the participant clicked on one of the faces, and the next trial started 500ms later. Before each block, we included a corresponding practice phase consisting of eight trials.

Anagram stress task

The anagram stress task was modelled after the task used by Salemink, van den Hout, and Kindt (2007). Participants were required to solve 15 anagrams that were presented for 10 seconds on the computer screen. They were told that the test was designed to give an estimate of their verbal intelligence, and that university students with average intelligence levels could solve at least 7 of the 15 anagrams within the given time frame. In reality, 10 of the anagrams were very difficult or impossible to solve within 10 seconds. The remaining five anagrams consisted of four to seven letters, and were easy to moderately difficult.

Procedure

Participants first completed the STAI-T, STAI-S, and the mood scales. Next, they completed the visual search task, the exogenous cueing task, and the VPT assessment phases in this fixed order. Participants then completed either the attend threat or the avoid threat training. After the training, we measured AB using the assessment versions of the VPT, the exogenous cueing task, and the visual search task, in this order. Next, participants again completed the STAI-S and the mood scales, and they started the anagram stress test. Finally, they completed the STAI-S and the mood scales for a third time, and they were debriefed and rewarded.

Results

Data reduction and outlier analysis

We used the same strategy to remove outliers for all three AB tasks. We first calculated participant's error percentages and removed errors. Next, we calculated the group mean RT and we removed all responses deviating more than three SDs from the group mean. Then, we calculated individual mean RT, and for each participant, we removed all responses deviating more than three SDs from these means. Finally, we removed the data of the neutral trials and the training blocks in the VPT. The data of one participant were removed completely for all further analyses, because this participant made too many errors on the VPT (participant's score = 81.83%, group mean = 93.70%, SD = 3.64). One participant made too many errors on the visual search task (participant's score = 93.75%, group mean = 98.47%, SD = 1.40). Therefore, we set the visual search task scores for this participant to missing.

For the VPT, we calculated pre- and post-training AB scores by subtracting the average RT on congruent trials from the average RT on incongruent trials. In line with Mogg, Holmes, Garner, and Bradley (2008), we calculated AB scores in the exogenous cueing task as follows: AB = [(mean RT invalid angry minus mean RT valid angry) minus (mean RT invalid happy minus mean RT valid happy)]. For the visual search task, we calculated pre- and post-training AB scores by subtracting the average RT in the find-angry blocks from the average RT in the find-happy blocks (De Voogd et al., 2014). For all AB scores, positive scores reflect an AB for angry faces, while negative scores reflect attentional avoidance of angry faces.

Group characteristics and pre-training AB

The training groups were similar in terms of gender distribution, $\chi^2(1) = 0.05$, $p = .82$, age, and baseline STAI-scores, all $ts < 0.74$, all $ps > .46$. Average scores on the STAI-T and the STAI-S at the beginning of our experiment were 42.55 (SD = 8.62, range 21–60) and 36.10 (SD = 8.46, range 23–62), respectively. One-sample *t*-tests showed that the AB for angry faces was larger than zero in the VPT, $t(59) = 2.26$, $p < .05$, but not in the exogenous cueing task, $t(59) = 1.70$, $p = .10$, or the visual search task, $t(58) = 1.37$, $p > .17$. Comparing AB in median split high and low trait anxious participants, we found that high trait anxious individuals had a marginally larger AB for angry faces ($M = 16.47$, SD = 39.24) than low trait anxious individuals ($M = -0.65$, SD = 28.29) on the exogenous cueing task, $F(1, 58) = 3.80$, $p = .06$, but not on the VPT or the visual search task, both $Fs < 1$. There was a marginal correlation between trait anxiety and AB in the visual search task, $r = .24$, $p = .07$, all other $rs < .18$, all $ps > .17$.

Effects of ABM on measures of AB

There were no a priori differences between our two training groups in any of the AB measures, all $ts < 1$. We conducted 2 × 2 repeated measures ANOVAs on the scores of all three AB measures separately, each time with Experiment Phase (pre- versus post-training) as a within subjects factor and Training Group (attend versus avoid threat) as a between subjects factor. For the VPT, the main effects of Training Group and Experiment Phase were not significant, both $Fs < 2.40$, both $ps > .12$. The crucial interaction effect was marginally significant, $F(1, 58) = 2.88$, $p = .095$, Cohen's $f = 0.22$ (see Figure 1(a)).[1] Follow-up comparisons within each group revealed no change in AB in the attend threat

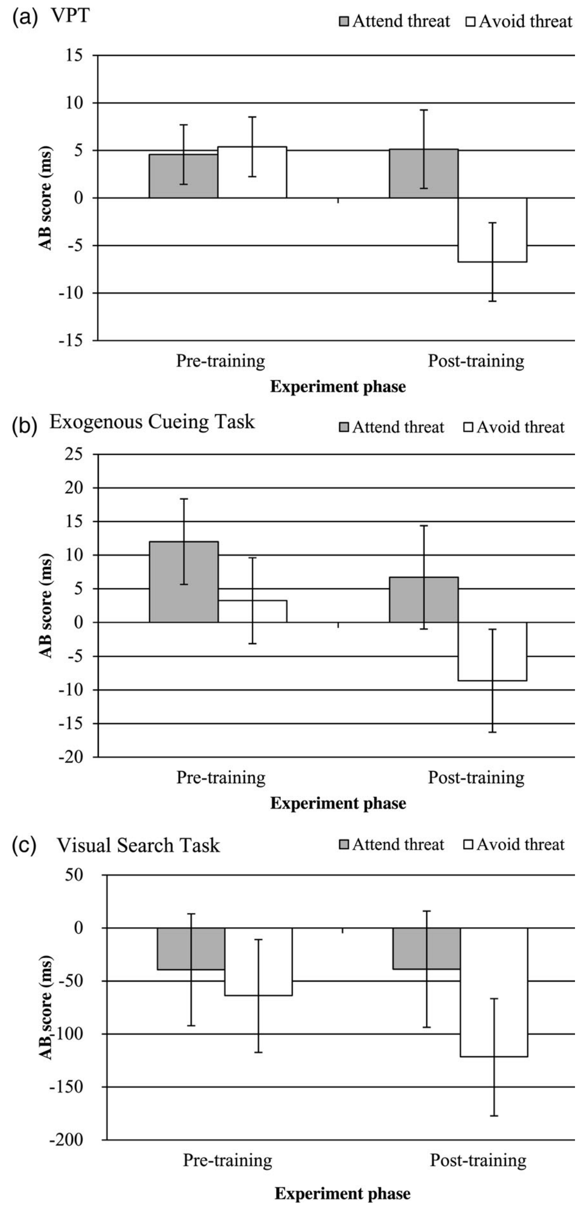

Figure 1. AB scores (±1 SE) in the VPT (panel a), the exogenous cueing task (panel b), and the visual search task (panel c) as a function of Experiment Phase and Training Group.

[1]Effect sizes for within-group differences and interactions were estimated using Cohen's f, with values from 0.10 representing small effects, values from 0.25 representing medium effects and values from 0.40 representing large effects (Cohen, 1992). We calculated f using the following formula: $f = \sqrt{[\eta_p^2/(1 - \eta_p^2)]}$.

group, $F < 1$, but a significant decrease in AB from pre-training to post-training in the avoid threat group, $F(1, 29) = 7.82$, $p < .01$, $f = 0.52$. These results illustrate that the visual probe training was successful in inducing attentional avoidance of angry faces in the avoid threat group, although it failed to increase the AB for angry faces in the attend threat group.

For the exogenous cueing task, the repeated measures ANOVA yielded no significant main effects, both $Fs < 2.62$, both $ps > .10$. The crucial interaction also failed to reach significance, $F < 1$, $p = .62$, $f = 0.06$. Exploratory follow-up contrast comparisons revealed no increase in AB in the attend threat group, $F < 1$, $p = .63$, $f = 0.09$, and no decrease in AB in the avoid threat group, $F(1, 29) = 2.65$, $p = .11$, $f = 0.30$ (see Figure 1(b)). For the visual search task, the repeated measures ANOVA again yielded neither significant main effects, both $Fs < 1$, nor a significant interaction, $F < 1$, $p = .51$, $f = 0.09$. Exploratory follow-up contrast comparisons revealed no changes in AB from pre- to post-training in either the attend threat group or the avoid threat group, both $Fs < 1$, both $ps > .38$, both $fs < 0.17$ (see Figure 1(c)). In sum, these results indicate that changes in AB following training with the VPT do not necessarily generalise to other measures of AB.

Effects of ABM on stress responsiveness

Using a 3 × 2 repeated measures ANOVA on the state anxiety scores with Experiment Phase (pre-training versus post-training versus post-anagram) as a within subjects factor and Training Group (attend versus avoid threat) as a between subjects factor (Table 1), we only found a main effect of Experiment Phase, $F(2, 57) = 18.80$, $p < .001$, indicating that state anxiety fluctuated throughout the experiment. State anxiety increased from pre-training ($M = 36.10$, SD = 8.46) to post-training ($M = 40.20$, SD = 8.77), $F(1, 59) = 15.28$, $p < .001$, and from post-training to post-anagram ($M = 44.82$, SD = 10.90), $F(1, 59) = 16.28$, $p < .001$. Although these results indicate that our anagram stress task was effective in inducing state anxiety, the attention training had no effect on stress reactivity, as evidenced by the non-significant interaction, $F < 1$, $p = .76$, $f = 0.10$. The same pattern of results was also evident in most of our mood scales, with main effects of Experiment Phase in the ratings of stress, anxiety, and unease (but not unhappiness), all $Fs > 2.96$, all $ps < .07$, but no significant interactions, all $Fs > 1.88$, all $ps > .16$, all $fs < 0.26$.

Psychometric properties of AB measures

For each task, we calculated split half reliability indices by correlating AB scores based only on odd versus even trials. For both the pre-training and the post-training assessment phases, the split half reliabilities of the VPT and the exogenous cueing task were very poor, with non-significant negative correlations, all $rs < -.07$, all $ps > .11$. For the visual search task, the split half reliability was satisfactory, with $r = .43$, $p < .005$, and $r = .59$, $p < .001$, in the pre-training and post-training phase, respectively. The convergent validity of the AB measures was assessed by correlating the AB scores of the three attention tasks with each other, both before and after the training phase. Before the training, none of the correlations were significant, all $rs < .20$, all $ps > .14$. After the training phase, only the correlation between the AB score in the VPT and the AB score in the exogenous cueing task proved significant, $r = .43$, $p < .005$; both other $rs < .13$, both other $ps > .34$. These analyses indicate that only the visual search task gives a reliable estimate of participants' AB and that the convergent validity of the three AB measures was poor.

Discussion

In order to demonstrate that visual probe ABM changes the attentional processing of threat,

Table 1. State anxiety and negative mood scores for the two attention groups over time.

	Attend threat group						*Avoid threat group*					
	Pre-training		*Post-training*		*Post-anagram*		*Pre-training*		*Post-training*		*Post-anagram*	
	M	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD
STAI-S	36.90	7.81	41.00	8.42	44.77	9.62	35.30	9.12	39.40	9.18	44.87	12.22
Anxiety	1.90	1.42	1.53	1.20	2.10	1.63	1.43	0.82	1.77	1.48	2.17	1.39
Unhappy	2.60	1.75	3.00	2.12	2.97	2.01	2.00	1.05	2.23	1.43	2.57	1.65
Unease	1.93	1.14	2.23	1.63	2.93	1.84	1.77	1.01	2.63	1.92	3.33	2.17
Stress	3.23	2.01	2.57	2.10	2.80	2.14	2.83	1.90	2.90	1.84	3.83	2.34

changes in AB as measured with the VPT should transfer to other measures of AB. Before and after visual probe ABM, we assessed AB using three well-known paradigms. Our results showed that visual probe ABM had some influence on AB as measured with the VPT, although this effect was only significant in the avoid threat group. This result suggests that changing visual probe AB through visual probe ABM may in itself be difficult. Furthermore, we found no influence of visual probe training on the other measures of AB, suggesting that visual probe training may not influence AB as a psychological construct.

A possible explanation for this lack of transfer is the relatively weak visual probe training effect. As indicated earlier, our training only had a marginal effect on AB in the VPT, which was only significant in the avoid threat group. Hence, the visual probe training effect may have been too weak to influence the other AB measures. Related to this, our single-session training phase of 288 trials may have been too short to induce lasting changes in AB. In ABM studies, the training phase sometimes extends over several thousands of trials (e.g., see MacLeod & Bridle, 2009). It is possible that the induced changes in AB in our study were too short-lived to influence later AB measurements or emotional responses during the stress task. Nevertheless, the short duration of our training is unlikely to fully accounts for our results. Amir et al. (2008; see also MacLeod et al., 2002) found a strong impact of ABM on anxiety after a training phase of only 128 trials and studies with longer training phases have not always been successful in changing AB (e.g., Carlbring et al., 2012). Another explanation is that the post-training visual probe assessment of AB may have countered possible changes in AB, making it less likely to pick up these changes in the other AB tasks. This issue could in part be resolved by assessing AB with the VPT *after* the assessment of AB with other AB tasks (Wiers, Rinck, Kordts, Houben, & Strack, 2010).

Another line of explanations relates to the psychometric properties of the AB measures. Although we did find some training effects in the VPT, its unreliability (see also Schmukle, 2005) could account for numerous failures to demonstrate changes in AB in the literature (Clarke et al., 2014). Also, the poor convergent validity of the measures suggests that they have different procedural features or that they even measure different underlying processes. In terms of task properties, the VPT is an *irrelevant* feature task *with* competing stimuli, whereas the exogenous cueing task is an irrelevant feature task *without* competing stimuli, and the visual search task is a *relevant* feature task with competing stimuli. In addition to the large measurement error in the VPT and the exogenous cueing task, such different task characteristics and/or different underlying processes would lead to a poor convergent validity and make transfer of training effects across different tasks less likely. This leads to several questions that should be addressed in future work. For instance, if three often used measures of AB actually measure different processes, one could question the notion of AB as a single psychological construct. A more systematic analysis and comparison of different AB measures is warranted to shed light on our conceptualisation of AB and to fully address the applied potential of ABM.

Our study also presents some reason for optimism. Contrary to the other tasks, the split half reliability of the visual search task was satisfactory. Pre-training AB in the visual search task also correlated modestly with trait anxiety, confirming the idea that an AB towards threat—provided that it is measured reliably—is a characteristic of anxiety. Given its better psychometric properties, it may prove fruitful to investigate the potential of the visual search task as a training task. Although some researchers have shown that visual search ABM can change AB as well as anxiety (e.g., De Voogd et al., 2014; Waters, Pittaway, Mogg, Bradley, & Pine, 2013; but see Kruijt, Putman, & Van der Does, 2013), no research to date has directly compared the effects of visual search ABM with those of visual probe ABM.

Our study also has limitations. Besides the relatively short training duration, it is possible that our sample was not large enough to pick up effects of visual probe training on the other tasks. Using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007), our sample proved large enough to find medium to large but not small to medium effects (significant small effects would require $N = 200$). In addition, our VPT differed in some ways from VPTs used in other ABM studies. We used happy rather than neutral faces, and we randomly paired faces of different actors rather than presenting two different facial expressions from the same actor. It is possible that these methodological variations have influenced our results, making a clear-cut comparison with other studies somewhat complicated. Also, several researchers have made a distinction between near transfer (i.e., generalisation to different stimuli) and far transfer (i.e., generalisation to different paradigms, e.g., see Hertel & Mathews, 2011). Some studies in which dot probe training effects did generalise to the exogenous cueing task used different stimuli during the training and the assessment (pictures versus words, e.g., Amir et al., 2008, 2009). Although we intended to maximise the chances of finding evidence for far transfer by using the same stimuli in both the ABM procedure and the AB assessment phases, the results of these previous studies suggest that using new stimuli may actually be a prerequisite for far transfer. Finally, the split half method that we used to assess the reliabilities of the tasks may have yielded somewhat unstable results (for a more stable analysis using Monte-Carlo simulations, e.g., see Enock et al., 2014).

These limitations notwithstanding, our study does have clear implications for ABM. It shows that training AB with the VPT does not necessarily transfer to other measures of AB. This could be in part due to the poor psychometric properties of the VPT. Given the better psychometric properties of the visual search task, it seems worthwhile to invest in the development and testing of the visual search task as a means to assess and change AB.

Disclosure statement

No potential conflict of interest was reported by the authors.

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APPENDIX. List of pictures from the Karolinska directed emotional faces used in the AB tasks

	Female			Male		
	Angry	*Happy*	*Neutral*	*Angry*	*Happy*	*Neutral*
Practice blocks	AF16ANS	AF16HAS	AF16NES	AM29ANS	AM29HAS	AM29NES
	AF32ANS	AF32HAS	AF32NES	BM16ANS	BM16HAS	BM16NES
	BF10ANS	BF10HAS	BF10NES	BM27ANS	BM27HAS	BM27NES
	BF15ANS	BF15HAS	BF15NES	BM32ANS	BM32HAS	BM32NES
Test blocks	AF01ANS	AF01HAS		AM01ANS	AM01HAS	
	AF05ANS	AF05HAS		AM02ANS	AM02HAS	
	AF07ANS	AF07HAS		AM04ANS	AM04HAS	
	AF09ANS	AF09HAS		AM06ANS	AM06HAS	
	AF11ANS	AF11HAS		AM07ANS	AM07HAS	
	AF13ANS	AF13HAS		AM08ANS	AM08HAS	
	AF18ANS	AF18HAS		AM09ANS	AM09HAS	
	AF19ANS	AF19HAS		AM10ANS	AM10HAS	
	AF20ANS	AF20HAS		AM11ANS	AM11HAS	
	AF21ANS	AF21HAS		AM21ANS	AM21HAS	
	AF23ANS	AF23HAS		AM23ANS	AM23HAS	
	AF24ANS	AF24HAS		AM25ANS	AM25HAS	
	AF26ANS	AF26HAS		AM26ANS	AM26HAS	
	AF27ANS	AF27HAS		AM30ANS	AM30HAS	
	AF28ANS	AF28HAS		AM31ANS	AM31HAS	
	AF29ANS	AF29HAS		AM35ANS	AM35HAS	
	AF31ANS	AF31HAS		BM03ANS	BM03HAS	
	BF02ANS	BF02HAS		BM05ANS	BM05HAS	
	BF03ANS	BF03HAS		BM12ANS	BM12HAS	
	BF06ANS	BF06HAS		BM14ANS	BM14HAS	
	BF08ANS	BF08HAS		BM22ANS	BM22HAS	
	BF17ANS	BF17HAS		BM24ANS	BM24HAS	
	BF22ANS	BF22HAS		BM28ANS	BM28HAS	
	BF25ANS	BF25HAS		BM34ANS	BM34HAS	