Attentional Control and Estimation of the Probability of Positive and Negative Events

Robert W. Booth, Sabancı University, Turkey

Dinkar Sharma, University of Kent, UK

Please cite as:

Booth, R.W., & Sharma, D. (2019). Attentional control and estimation of the probability of positive and negative events. *Cognition and Emotion*. Article accepted for publication.

Author Note

Robert W. Booth, Faculty of Arts and Social Sciences, Sabancı University, Turkey; Dinkar Sharma, Centre for Cognitive Neuroscience and Cognitive Systems, School of Psychology, University of Kent, UK.

Please address correspondence to Robert W. Booth, Sabancı University, Faculty of Arts and Social Sciences, Orhanlı – Tuzla, 34956, İstanbul, Turkey. Tel: (+90) 216 483 9242. Email: rob.booth.psych@gmail.com

Abstract

People high in negative affect tend to think negative events are more likely than positive events ('probability bias'). Studies have found that weak attentional control exaggerates another negative affect-related cognitive bias – attentional bias – but it is not clear why this might be. We therefore wanted to know whether weak attentional control would be related to probability bias too. Four studies, with predominantly female student samples (N = 857), revealed correlations of around -.38 between attentional control and probability bias. This remained significant when trait anxiety and depression were controlled; there were no interactions between attentional control and negative affect. Studies 3 and 4 found that attentional control's relationship with probability bias was partly mediated by emotion regulation ability. These results suggest attentional control is important for regulating affect-related cognitive biases, and for emotion regulation in general. Furthermore, because cognitive biases are thought to be important for maintaining emotional disorders, these results are also consistent with weak attentional control being a risk factor for these disorders.

Keywords: Probability bias; attentional control; trait anxiety; depression; negative affect

Attentional Control and Estimation of the Probability of Positive and Negative Events

People high in negative affect, such as anxiety or depression, show cognitive biases concerning their processing of negative information (e.g. Mathews, Mackintosh, & Fulcher, 1997; Mathews & MacLeod, 2005). This article examines the relationship between one of these biases, probability bias, and attentional control.

Probability Bias

Probability bias is the tendency to think negative events are more likely than positive events. It reliably correlates with trait anxiety in adults (Butler & Mathews, 1987; Mitte, 2007; Stöber, 1997) and children (Canterbury et al., 2004; Muris & van der Heiden, 2006). It has also been reported in patients with generalised anxiety disorder (Butler & Mathews, 1983; Dalgleish, Neshat-Doost, Moradi, Canterbury, & Yule, 2003), social anxiety disorder (Foa, Franklin, Perry, & Herbert, 1996; Gilboa-Schechtman, Franklin, & Foa, 2000; McManus, Clark, & Hackmann, 2000; Voncken, Bögels, & de Vries, 2003), agoraphobia (McNally & Foa, 1987; Poulton & Andrews, 1996), height-phobia (Menzies & Clarke, 1995), and acute stress disorder (Smith & Bryant, 2000; Warda & Bryant, 1998). It has also been reported in nonclinical high-depression students (Alloy & Ahrens, 1987; Butler & Mathews, 1987; although see Mitte, 2007; Stöber, 1997) and children (Muris & van der Heiden, 2006), and in patients with major depression (Butler & Mathews, 1983).

Probability bias is very relevant for understanding emotional disorders and their aetiology, because it is clearly relevant to worry, the key diagnostic symptom of anxiety disorders (American Psychiatric Association, 2013): indeed, it correlates with trait worry (Constans, 2001; A. K. MacLeod, Williams, & Bekerian, 1991). Foa and Kozak (1986) suggested probability bias is a primary cognitive feature of anxiety disorders (see also Grupe & Nitschke, 2013), and is important for their maintenance. Probability bias has been shown to improve during cognitive behaviour therapy (Benbow & Anderson, 2019; Foa et al., 1996). However, the relationship between probability bias and attentional control has never been studied.

Attentional Control and Negative Affect

We examined the relationship between probability bias and attentional control because poor attentional control exaggerates the expression of another negatıve affect-related cognitive bias: attentional bias. Derryberry and Reed (2002), Lonigan and Vasey (2009), Helzer, Connor-Smith, and Reed (2009), and Susa, Benga, Pitică, and Miclea (2014) have all found that people higher in negative affect were more likely to attend to threatening stimuli than neutral stimuli, but only if they were also low in attentional control, which they assessed using Derryberry and Reed's Attentional Control Scale. Booth, Mackintosh and Sharma (2017) and Reinholdt-Dunne, Mogg, and Bradley (2009) found similar results using behavioural operationalisations of attentional control.

Based on this evidence, one could conclude that weak attentional control might be a risk factor for emotional disorders (De Raedt & Koster, 2010; Hirsch & Mathews, 2012; Mathews & MacLeod, 2005; see also Ouimet, Gawronski, & Dozois, 2009). This is because attentional bias is thought to maintain, or even cause, high negative affect (Browning, Holmes, Charles, Cowen, & Harmer, 2012; C. MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002): weak attentional control is related to clinical symptoms and behavioural issues in emotional disorders (de Panfilis, Meehan, Cain, & Clarkin, 2013; Mills et al., 2016; Muris, 2006; Muris, Meesters, & Rompelberg, 2007).

However, one issue with this conclusion is that there are multiple reasons why weak attentional control might exaggerate attentional bias. Attentional bias can be considered a failure of selective attention (Eysenck, Derakshan, Santos, & Calvo, 2007): attention is focused on task-relevant cues, and is then captured by task-irrelevant threat cues. Poor attentional control is likely to exaggerate any such failure. At the same time, attentional control might play a more direct role in the expression of cognitive biases, because attentional control has been implicated in emotion regulation and expression (Koole, van Dillen, & Sheppes, 2011; Mathews & MacLeod, 2005; Ouimet et al., 2009). Attentional control, and its close correlate working memory capacity, have been found to be related to regulation of emotion (Schmeichel, 2007; Wegner, Erber, & Zanakos, 1993) and responses to emotional stimuli (Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Schmeichel, Volokhov, & Demaree, 2008). So people with weak attentional control might show a more exaggerated emotional response to threatening stimuli, which might cause them to show a larger attentional bias (Mathews & Mackintosh, 1998; Wilson & MacLeod, 2003).

In other words, it is not clear why attentional control influences the expression of attentional bias, and therefore it is not clear whether, and how, weak attentional control increases the risk of emotional disorders. Studies on attentional control and interpretive bias, another cognitive bias associated with negative affect, have yielded inconsistent results (Booth et al., 2017; Muris et al., 2007; Salemink, Friese, Drake, Mackintosh, & Hoppitt, 2013; Salemink & Wiers, 2012; see also Booth et al., 2019), so it may be that this effect is specific to attentional bias, and does not apply to other cognitive biases. Given its relevance for worry, probability bias may be at least as important in the aetiology of negative affect than attentional bias (Foa & Kozak, 1986; Grupe & Nitschke, 2013), so we wanted to know whether it was related to weak attentional control in a similar way. If so, this would support the idea that weak attentional control is a general risk factor for emotional disorders.

The Present Studies

We tested, for the first time, attentional control's relationship with probability bias. Based on the literature above, we predicted that weak attentional control would correlate with probability bias, and/or would exaggerate the relationship between negative affect and probability bias. Because we wanted to compare our results to those of the attentional bias studies reviewed above, we used the same self-report measure of attentional control that most of these studies used, the Attentional Control Scale (Derryberry & Reed, 2002; see General Discussion). We examined this in four samples of predominantly young, female students. To foreshadow the results, in Studies 1 and 2 we found that weak attentional control reliably predicted probability bias. Based on these results, in Studies 3 and 4 we investigated whether attentional control's relationship with probability bias was mediated by emotion regulation ability.

Study 1

All studies were approved by the Psychology Ethics Committee at the University of Kent, and were planned to achieve at least .80 power to detect a relationship of $f^2 = .03$. Data may be retrieved from http://doi.org/10.17605/OSF.IO/8WV7X. In Study 1, we assessed attentional control, trait anxiety, depression, and probability bias.

Method

Participants and procedure. Two hundred and forty-three undergraduates from the University of Kent participated for course credit. Participants were told the study was about predictors of estimation ability, and completed the scales online. Five participants were excluded for reporting a current psychiatric diagnosis other than an anxiety or affective disorder, leaving a final sample of 238 (35 males; $M_{age} = 19.25$, $SD_{age} = 2.07$; 195 identified themselves as British).

Measures. Participants first completed the State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), which includes two 20-item subscales assessing how participants feel 'right now, at this moment' (state anxiety, STAI-S) and how they feel 'generally, in [their] life' (trait anxiety, STAI-T). Participants respond on a 1-4 scale. State items include 'I am tense' and 'I feel nervous'; trait items include 'I worry too much over something that really doesn't matter' and 'I have disturbing thoughts.' Internal consistency of both scales was good; see Table 1 for Cronbach's α for all predictors.

Participants next completed the Beck Anxiety Inventory - Trait (BAIT; Kohn, Kantor, DeCicco, & Beck, 2008), which asks participants to rate how often they are 'bothered' by 21 cognitive and somatic symptoms on a day-to-day basis, on a 0-3 scale. Symptoms include 'nervous', 'fear of dying' and 'feeling of choking.' We included this because the specificity of the STAI has been questioned (e.g. Bados, Gómez-Benito, & Balaguer, 2010); however, the results for the two scales are very similar across all four studies, so we focus on the STAI.

Participants next completed the Attentional Control Scale (ACS; Derryberry & Reed, 2002), which asks participants how often 20 statements apply to them. They respond on a 1-4 scale. Items include 'I have trouble carrying on two conversations at once' and 'When I am working hard on something, I still get distracted by events around me.'

Next, we presented the Beck Depression Inventory-II (BDI; Beck, Steer, & Brown, 1996). Participants read 21 groups of four statements, and must choose the one statement which 'best describes the way [they] have been feeling during the past two weeks.' Each group of statements measures the severity of a particular cognitive or somatic symptom of depression, including sadness, loss of pleasure, and changes in sleeping pattern.

Participants then completed the Marlowe-Crowne social desirability scale (MCSD; Crowne & Marlowe, 1964). This presents 33 statements such as 'I have never intensely disliked anyone' and 'I am always willing to admit it when I make a mistake', and asks participants whether each statement is true of them. We routinely include this control variable in our studies because participants may not be honest about their negative affect. In these studies the scale showed less-than-ideal psychometric performance so we did not include it in our analyses, but we do include it in Tables 1-4.

Finally, participants completed our measure of probability bias. Twenty positive events, such as 'You will become well-known for an outstanding accomplishment', and 20 negative events, such as 'The next exam you sit will be unusually hard', were presented in a random order. These were partly adaptations of events used in previous studies (Butler & Mathews, 1987; Stöber, 1997), and partly original events (see Appendix). While we would normally prefer to use a validated instrument, probability bias has always been measured by self-report, with individual research groups usually creating their own instrument; so we did the same. The advantage of this is that events can be presented which are particularly relevant for the test population – in our case, UK students. For each event, participants were first asked 'What is the probability that this would happen to you?' They answered on verbal Likert scales (Mitte, 2007; see also Nesse & Klaas, 1994). There were seven response options: 'Would never happen to me'; 'Would probably not happen to me'; 'Might not happen to me'; 'Might happen, might not'; 'Might happen to me'; 'Would probably happen to me'; and 'Would definitely happen to me.' For analysis, these were assigned scores of 1-7 respectively. Probability bias was calculated as the participant's mean probability for negative events minus their mean probability for positive events. We simultaneously measured cost bias, the tendency to think negative events would affect one's life more than positive events. Results concerning cost bias were inconsistent between Studies 1 and 2, so we abandoned it and, for want of space, do not discuss it further in this article. See Tables 1 and 2 for basic results, and the Supplemental Materials for discussion.

Results

Bivariate correlations are presented in Table 1. Trait anxiety, state anxiety, and depression positively predicted probability bias. Importantly, attentional control negatively predicted probability bias: it showed a positive relationship with the perceived probability of positive events, and a similar-sized negative relationship with the perceived probability of negative events.

We wanted to check that attentional control's relationship with probability bias was not an artefact of the relationship between attentional control and anxiety or depression (see General Discussion). To investigate this, probability bias was regressed on STAI-T trait anxiety and depression, with attentional control entered in a second block. The first block model was significant, $R = .59$, $R^2 = .34$, $F\ (2, 235) = 61.37$, $p < .001$. Both trait anxiety, standardised $\beta = .44$, $t\ (235) = 5.95$, $p < .001$, and depression, $\beta = .18$, $t\ (235) = 2.40$, $p = .02$, significantly predicted probability bias. Adding attentional control significantly improved model fit, $\beta = .13$, R^2 change = .013, $F_{\text{change}}\ (1, 234) = 4.88$, $p = .03$ (multicollinearity tolerances > 0.48), showing that the relationship between attentional control and probability bias is independent of anxiety and depression.

In the literature, attentional control moderates the relationship between negative affect and attentional bias, so moderated regression was used to check for any interaction between trait anxiety or depression and attentional control. Probability bias was first regressed on mean-centred trait anxiety and attentional control, with their interaction entered in a second step. The interaction did not significantly improve model fit, R^2 change = .002, $F\ (1, 234) = 0.86$, $p = .35$, indicating there was no interaction between the predictors. We repeated this analysis as a Bayesian linear regression, using JASP (JASP Team, 2018). This approach allows one to calculate how much more likely the observed data are if the tested effect is absent in the population, relative to if the tested effect is present in the population (BF_{01}). The evidence for the interaction's being absent was much stronger than the evidence for it being present, $BF_{01} = 5.08$. The same analyses were repeated with depression replacing trait anxiety: again, adding the interaction term did not improve model fit, R^2 change = .004,

F_{change} (1, 234) = 1.37, p = .24, and there was good evidence that no interaction was present, BF_{01} = 3.47.

Discussion

Attentional control negatively predicted probability bias. However, this was independent of, and did not interact with, negative affect (anxiety and depression).

These results show for the first time that attentional control is important for the regulation of probability bias. They join findings on attentional biases (Booth et al., 2017; Derryberry & Reed, 2002; Reinholdt-Dunne et al., 2009) in suggesting a general role for attentional control in cognitive biases, and in the processing of emotional information. Since cognitive biases are thought to help cause and/or maintain anxiety (C. MacLeod et al., 2002), these findings reinforce the idea that weaker attentional control may be a risk factor for anxiety disorders.

Study 2

It is possible the results of Study 1 do not reflect a probability bias per se, but rather a tendency to endorse negative items more than positive items. We thought it was important to confirm our interpretation of Study 1's results. Study 2, therefore, replicated Study 1 except that we also asked participants about the probability of positive and negative events happening to a peer from their class at university. Typically, anxious or depressed people think negative events are more likely to happen to themselves, but are not necessarily more likely to happen to other people (e.g. Butler & Mathews, 1987; Canterbury et al., 2004; Muris & van der Heiden, 2006), so if our interpretation of Study 1's results is correct, attentional control should predict probability bias referenced to the participants themselves, but not probability bias referenced to the peer.

Method

Participants and procedure. One hundred and ninety-one undergraduates from the University of Kent participated for course credit. Six were excluded for reporting a current psychiatric diagnosis other than an anxiety or affective disorder, leaving a final sample of 185 (156 females, 27 males, 1 other, and 1 did not report their gender; $M_{age} = 20.39$, $SD_{age} = 5.38$; 150 identified as British).

Measures. These were the same as for Study 1, except for the bias measure. This asked participants about 20 positive and 20 negative events as before, but was split into two halves. In the first half, participants were instructed to rate the probability of each event happening to themselves as before, and their answers were used to calculate probability bias for the self. For the second half, participants were told: "Imagine you have a friend in your class, called Sam. Sam is a typical student in your class. In this part of the study, you must estimate the probability of various events happening to Sam, and how much they would affect Sam's life if they did. Please answer each question truthfully, without overthinking it." All 40 events were then presented again, in a newly-randomised order, and participants rated the probability of each event happening to 'Sam' (see Butler & Mathews, 1987). 'Sam' is gender-ambiguous in English. These items were used to calculate probability bias for a peer.

Results

Correlations and descriptive statistics are presented in Table 2. State anxiety, trait anxiety, and depression predicted probability bias for the self; none of these variables predicted probability bias for a peer. Most importantly, attentional control negatively predicted probability bias for the self, replicating Study 1.

Again, we regressed probability bias for the self on trait anxiety (STAI-T) and depression, with attentional control entered in a second block. The first block model was significant, $R = .58$, $R^2 = .33$, F (2, 182) = 45.59, $p < .001$. Both trait anxiety, standardised β

= .27, t (182) = 3.02, p = .003, and depression, β = .35, t (182) = 3.99, p < .001, significantly predicted probability bias. Adding attentional control significantly improved model fit, β = -.24, R^2 change = .05, F_{change} (1, 181) = 13.15, p < .001 (multicollinearity tolerances > 0.43), showing that the relationship between attentional control and probability bias is independent of anxiety and depression.

Moderated regression was used to check for any interaction between trait anxiety and attentional control. Probability bias for the self was regressed on mean-centred trait anxiety (STAI-T) and attentional control, with their interaction entered in a second step. The interaction did not improve model fit, R^2 change = .002, F_{change} (1, 181) = 0.50, p = .48, BF_{01} = 5.23. The same analyses were then repeated, with depression replacing trait anxiety. Again, the interaction term did not improve model fit, R^2 change = .001, F_{change} (1, 181) = 0.28, p = .60, BF_{01} = 6.11.

Discussion

Study 2 replicated Study 1, finding that attentional control and negative affect (trait anxiety and depression) independently predicted probability bias. Again, there was no interaction. Importantly, attentional control only predicted probability bias regarding the participants' selves, and was not related to their probability estimates regarding another person. This suggests attentional control really does predict probability bias, not merely the tendency to endorse negative items.

Study 3

Studies 1 and 2 present good evidence that weak attentional control is related to probability bias. However, at this stage it is unclear why this might be. The most obvious explanation is that attentional control plays a role in emotion regulation (e.g. Koole et al., 2011); therefore people with weaker attentional control might show a stronger emotional response to potential risk, and so find it harder to perceive positive events as likely and negative events as unlikely. Such perceptions would be adaptive, as they would protect from excessive worry and help maintain motivation. As a first step towards testing these hypotheses, we tested whether the relationship between attentional control and probability bias was mediated by emotion regulation ability. Studies 3 and 4 tested this using two different measures of emotion regulation. To foreshadow the results, we found that emotion regulation partly, but not entirely, explained the relationship between attentional control and probability bias.

Emotion regulation is a broad concept (Koole, 2009), incorporating various cognitions and behaviours which individuals may utilise across varying timescales. In this study, we chose to focus on cognitions which people might have in negative situations, since these seemed most likely to depend on attentional control. We used the Cognitive Emotion Regulation Questionnaire (CERQ, Garnefski, Kraaij, & Spinhoven, 2002), which specifically measures these cognitions.

Method

Participants and procedure. Two hundred and fifteen undergraduates from the University of Kent participated for course credit. Fourteen were excluded for reporting a current psychiatric diagnosis other than an anxiety or affective disorder, leaving a final sample of 201 (179 females, 22 males; $M_{\text{age}} = 19.04$, $SD_{\text{age}} = 1.61$; 158 identified as British).

Measures. Participants completed the STAI-T, BAIT, ACS, and BDI; then they completed the CERQ, our probability bias measure from Study 1, and finally the MCSD.

The Cognitive Emotion Regulation Questionnaire (CERQ, Garnefski et al., 2002) consists of 36 items, addressing what the respondent thinks (not what they do) when confronted with negative or unpleasant situations; items include “I feel that I am the one who is responsible for what has happened”, and “I think about how I can best cope with the situation.” Participants indicate how often they employ each type of thought, on a 1 (“almost never") to 5 ("almost always") scale. The 36 items assess nine distinct emotion regulation strategies, both adaptive ('protective') and maladaptive ('symptom promoting'): self-blame, acceptance, rumination, positive refocusing, refocusing on planning, positive reappraisal, putting into perspective, catastrophising, and blaming others. In this study, we wanted to test a relatively simple mediation model where emotion regulation ability was modelled as a mediator between attentional control and probability bias, so we summed all 36 items – reversing those intended to measure maladaptive strategies – to yield an overall cognitive emotion regulation score. Although the scale was not intended to be used in this way, the total scale showed good internal consistency (see Table 3). Please see the Supplementary Materials for basic results with the CERQ subscales.

Results

Correlations are presented in Table 3. Once again, attentional control correlated negatively with probability bias. Overall cognitive emotion regulation scores correlated positively with attentional control, and negatively with probability bias and all the psychopathology measures.

We tested a mediation model using PROCESS (Hayes, 2017) to see whether attentional control's relationship with probability bias – controlling anxiety and depression – was mediated by cognitive emotion regulation. The indirect effect was estimated using ordinary least squares, and its confidence interval was estimated by bootstrapping with 10,000 resamples. There was a significant indirect effect of attentional control on probability bias via emotion regulation, standardised β = -.04, 95% CI [-.112, -.007], but the direct effect of attentional control on probability bias was also significant, β = -.14, t (196) = -2.10, p = .04 (multicollinearity tolerances > 0.34). This means that although emotion regulation does partly explain the relationship between attentional control and probability bias, attentional control still significantly predicts probability bias even when emotion regulation, trait anxiety and depression are simultaneously controlled.

Finally, we again checked whether attentional control moderated trait anxiety or depression's relationships with probability bias. For the model with trait anxiety, adding the interaction term did not improve model fit, R^2 change = .001, F_{change} (1, 197) = 0.42, p = .52, BF_{01} = 5.93. For the model with depression, again adding the interaction term did not improve model fit, R^2 change = .006, F_{change} (1, 197) = 1.54, p = .22, BF_{01} = 2.81.

Discussion

Once again, weak attentional control was related to probability bias, and this relationship was independent of anxiety and depression. Cognitive emotion regulation partly explained this link – weaker attentional control was related to poorer emotion regulation, which was related to greater probability bias – but a direct relationship between attentional control and probability bias remained.

These results show that the relationship between attentional control and probability bias is complex. While it is true that attentional control helps regulate cognitions in negative situations and so affects risk perceptions, attentional control may also regulate risk perceptions directly. If probability bias helps to maintain anxiety and depression (Foa & Kozak, 1986) as other cognitive biases do (Browning et al., 2012; C. MacLeod et al., 2002), these results reinforce the importance of weak attentional control as a risk factor for emotional disorders.

Study 4

Study 4 sought to replicate the findings of Study 3, using a different measure of emotion regulation. The Difficulties in Emotion Regulation Scale (DERS, Gratz & Roemer, 2004) specifically measures clinically relevant emotion regulation difficulties. Again, given the relationship between attentional control and probability bias we found in Studies 1-3 and the relationship between attentional control and emotion regulation described in the literature (Hofmann et al., 2008; Koole et al., 2011), we wanted to test whether difficulties in emotion regulation mediated the relationship between attentional control and probability bias.

Method

Participants and procedure. Two hundred and thirty-nine undergraduates from the University of Kent participated for course credit. Six were excluded for reporting a current psychiatric diagnosis other than an anxiety or affective disorder, leaving a final sample of 233 (180 females, 52 males, 1 other; $M_{\text{age}} = 19.73$, $SD_{\text{age}} = 3.90$; 176 identified as British).

Measures. Participants completed the STAI-T, BAIT, ACS, and BDI; then they completed the DERS, our probability bias measure from Study 1, and the MCSD.

The Difficulties in Emotion Regulation Scale (DERS, Gratz & Roemer, 2004) consists of 36 items, intended to measure clinically relevant difficulties in emotion regulation. Participants indicate how often the items, including “When I’m upset, I have difficulty thinking about anything else” and “When I’m upset, I feel out of control”, apply to them on a 1 (“Almost never, 0-10%”) to 5 (“Almost always, 91-100%”) scale. The 36 items measure six factors: nonacceptance of emotional responses, difficulties engaging in goal-directed behaviour, impulse control difficulties, lack of emotional awareness, limited access to emotion regulation strategies, and lack of emotional clarity. As with Study 3, we summed all the items to create a total overall score, which had good internal consistency (see Table 4). See the Supplementary Materials for basic results using the individual subscales.

Results

Correlations are presented in Table 4. Once again, attentional control correlated negatively with probability bias, and with all the psychopathology measures including difficulties in emotion regulation. Difficulties in emotion regulation showed strong positive correlations with all the psychopathology measures.

As with Study 3, we tested a mediation model to see whether attentional control's relationship with probability bias was mediated by difficulties in emotion regulation, controlling for trait anxiety and depression. There was a significant indirect effect of attentional control on probability bias via difficulties in emotion regulation, standardised β = -.03, 95% CI [-.069, -.003], but the direct effect of attentional control on probability bias was also significant, β = -.14, t (228) = -2.19, p = .03 (multicollinearity tolerances > 0.39). This replicates Study 3's finding that although difficulties in emotion regulation do partly explain the relationship between attentional control and probability bias, attentional control still significantly predicts probability bias even when emotion regulation, trait anxiety and depression are simultaneously controlled.

Finally, we again checked whether attentional control moderated trait anxiety or depression's relationships with probability bias. For the model with trait anxiety, adding the interaction term did not improve model fit, R^2 change = .001, F_{change} (1, 229) = 0.22, p = .64, BF_{01} = 6.25. For the model with depression, again adding the interaction term did not improve model fit, R^2 change = .001, F_{change} (1, 229) = 0.29, p = .59, BF_{01} = 5.56.

Discussion

Study 4 replicated the results of Study 3 very closely. Attentional control again predicted probability bias independently of anxiety and depression, and this relationship was partly mediated by difficulties in emotion regulation. Indeed, the βs for the indirect and direct effects were very similar for the two studies, despite the fact that they used different measures of emotion regulation. This reinforces our conclusion that attentional control's relationship with probability bias is real, and partly results from attentional control's role in emotion regulation; it also supports the broader hypothesis that weak attentional control might increase risk of emotional disorder.

General Discussion

In four studies, weak attentional control was consistently related to probability bias. While the literature suggests attentional control tends to moderate negative affect's relationship with attentional bias, we have found that attentional control has its own independent relationship with probability bias. This relationship is partly explained by the fact that people with weaker attentional control also have less effective emotion regulation, but we also found a direct relationship independent of emotion regulation. Since cognitive biases help to cause or maintain high negative affect, anything which makes one more likely to show cognitive biases also makes one's negative affect more likely to grow out of control. Together with the relevance of probability bias to worry, this reinforces the idea that weak attentional control is a risk factor for high negative affect and emotional disorders.

Relationship Between Attentional Control and Probability Bias

Across all studies we found a negative correlation between attentional control and probability bias, ranging from r = -.33 to -.46, meta-correlation = -.38, 95% CI [-.44, -.32]. When trait anxiety and depression were controlled, this relationship remained significant ranging from β = -.13 to -.24. Attentional control positively predicted the perceived probability of positive events, and negatively predicted the probability of negative events; these two correlations were very similar in size. Although attentional control's relationship with probability bias is not as strong as trait anxiety's relationship with probability bias, it is strong enough to be clinically relevant (see also Supplementary Materials).

One limitation of these studies is our use of a self-report measure of attentional control. Most studies on attentional control and attentional bias have used the ACS, so we used the same scale to ensure our results would be comparable. However, there is mixed evidence concerning the validity of the ACS (Judah, Grant, Mills, & Lechner, 2014; Reinholdt-Dunne, Mogg, & Bradley, 2013). Quigley, Wright, Dobson, and Sears (2017) recently claimed that this scale measures subjective beliefs about attentional control ability, more than the ability itself; more generally, people high in negative affect might tend to respond negatively to any question about themselves or their abilities, which would yield negative correlations between negative affect and attentional control, and between attentional control and probability bias. This cannot account for our results, because we consistently found that attentional control predicted probability bias when trait anxiety and depression were controlled (adding social desirability as a further control variable also did not change this relationship). This means attentional control's relationship with probability bias is independent of any general response bias, other common-method biases (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003), and any influence of general affect. Since the ACS has shown some relationship with behavioural measures of attentional control (Judah et al., 2014), the most parsimonious conclusion is that weak attentional control is linked to probability bias. This conclusion could be further strengthened by a replication of these findings with the ACS presented first, to prevent its being biased by the affect scales. Of course, replications using behavioural measures of attentional control would be extremely valuable. Furthermore, experimental studies manipulating available attentional control resources would help to confirm whether weak attentional control directly causes a more negative probability bias.

It should also be acknowledged that our samples included relatively few males. Of course this is not unusual for psychology student samples, and the literature on probability biases has not revealed sex differences, but it would be useful to investigate these issues in samples of males, who tend to have lower negative affect.

Mechanisms

Why is weak attentional control related to probability bias? We suggested above that attentional control is important for emotion generation and regulation, and so may help to control estimates of, and responses to, potential risk. This is complicated by the fact that people, on average, tend to think that positive events are more likely to occur than negative events. To shed more light on this issue, we tertile-split our four samples by ACS score, and examined the probability bias scores of the highest and lowest tertiles. For the four studies, the mean probability bias for the high-attentional control tertiles were -19.70 (SD = 27.38), -18.14 (SD = 26.98), -21.80 (SD = 28.04), and -28.29 (SD = 31.50), meta-estimate of the mean = -21.67, 95% CI [-24.69, -18.66]; whereas the means for the low-attentional control tertiles were 0.80 (SD = 27.38), 8.46 (SD = 22.18), 1.51 (SD = 25.20), and -3.35 (SD = 31.52), meta-estimate of the mean = 2.54, 95% CI [-0.44, 5.53]. In other words, the high-attentional control tertiles thought that positive events were more likely, whereas the low-attentional control tertiles thought that positive and negative events were roughly equally likely. This might suggest that the above-mentioned positive bias is not automatic, and requires attentional control. Future research must investigate whether the 'default setting' of healthy individuals is to perceive negative and positive events as being equally likely.

Studies 3 and 4 found weak attentional control relates to probability bias partly because attentional control contributes to emotion regulation. This was expected, given that attentional control has been implicated in avoiding distraction by emotional stimuli (Grimshaw, Kranz, Carmel, Moody, & Devue, 2018), restraining emotional expressions (Schmeichel et al., 2008), and positive reappraisal (Pe, Raes, & Kuppens, 2013). On the other hand, a relatively strong direct effect of weak attentional control on probability bias, independent of emotion regulation, was also found. Probability bias may occur when it is easier to think of reasons why negative events would happen relative to positive events (A. K. MacLeod et al., 1991); attentional control assists with memory search (Dalgleish et al., 2007), so perhaps higher-attentional control people are more able to bias their searches of episodic and semantic memory to generate more reasons for positive events. Furthermore, the CERQ and DERS both focus on negative emotions, but regulation of positive emotions is also important for emotional disorders (Carl, Soskin, Kerns, & Barlow, 2013) and, as discussed above, probability bias may be a more positive irrationality in healthy people. Also, both scales concentrate on ‘response-focused’ regulation strategies (Gross, 1998), whereas more ‘antecedent-focused’ regulation strategies, which are deployed proactively to protect from negative emotions, may be just as important for probability bias. Studies with more comprehensive assessments of emotion regulation ability are needed to investigate this topic.

Why No Interaction Between Attentional Control and Negative Affect?

These studies found that attentional control and negative affect have independent relationships with probability bias; previous studies found that weak attentional control moderates the relationship between negative affect and attentional bias. We suspect that attentional control may also independently predict attentional bias, but that this has been obscured in previous studies by the moderation effect. The moderation may occur because attentional bias reflects a failure of selective attention (Eysenck et al., 2007), and weak attentional control necessarily exaggerates any such failure. This does not happen with probability bias because it does not rely so much on attention. Also, commonly-used attentional bias tasks are unreliable (Chapman, Devue, & Grimshaw, 2017; Waechter & Stolz, 2015; Zvielli, Bernstein, & Koster, 2015), which may obscure their relationships with attentional control.

Conclusions

Based on these studies, we conclude that attentional control’s role in cognitive biases is more complex, fundamental, and important than the existing literature would suggest. Poor attentional control does not simply exaggerate biases related to negative affect, but can be independently related to them, and may well be a risk factor for emotional disorders. Unfortunately, attentional control is not particularly amenable to improvement by training, but we hope that better understanding its role in cognitive biases and negative affect can inform future efforts to predict, assess, and treat emotional disorders.

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Table 1

Bivariate Correlations, Descriptive Statistics and Cronbach's Alphas for Study 1.

	2	3	4	5	6	7	8	9	10	*M*	*SD*	α
1 – STAI-S	.73***[.67, .78]	.54***[.44, .62]	.62***[.54, .69]	-.28***[-.39, -.16]	-.28***[-.39, -.16]	-.35***[-.46, -.23]	.29***[.17, .40]	.39***[.28, .49]	.11 [-.02, .23]	40.07	11.40	.93
2 – STAI-T		.59***[.50, .67]	.71***[.64, .77]	-.35***[-.46, -.23]	-.38***[-.48, -.27]	-.52***[-.61, -.42]	.41***[.30, .51]	.57***[.48, .65]	.09 [-.04, .22]	46.31	9.43	.89
3 – BAIT			.60***[.51, .68]	-.32***[-.43, -.20]	-.23***[-.35, -.11]	-.32***[-.43, -.20]	.31***[.19, .42]	.39***[.28, .49]	.15*[.02, .27]	13.72	10.50	.93
4 – BDI				-.38***[.27, .48]	-.31***[-.42, -.19]	-.39***[-.49, -.28]	.43***[.32, .53]	.49***[.39, .58]	.13 [.00, .25]	15.68	11.66	.91
5 – ACS					.31***[.19, .42]	.26***[.14, .38]	-.28***[-.39, -.16]	-.33***[.21, .44]	-.03 [-.16, .10]	48.35	8.17	.84
6 – MCSD						.23***[.11, .35]	-.23***[-.35, -.11]	-.28***[-.39, -.16]	-.13 [-.25, -.00]	49.46	4.76	.71
7 – Probability (positive events)							-.34***[-.45, -.22]	-.86***[-.89, -.82]	-.07 [-.20, .06]	85.91	19.05	.93
8 – Probability (negative events)								.78***[.73, .83]	.15*[.02, .27]	75.81	15.72	.89
9 – Probability bias									.13*[.00, .25]	-10.10	28.57	-
10 – Cost bias										-2.33	9.98	-

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 238$. STAI-S, State-Trait Anxiety Inventory, state subscale; STAI-T, State-Trait Anxiety Inventory, trait subscale; BAIT, Beck Anxiety Inventory, trait version; BDI, Beck Depression Inventory; ACS, Attentional Control Scale; MCSD, Marlow-Crowne Social Desirability. The scores are not unusual for student samples, and suggest the sample was mildly anxious and depressed on average. Square brackets show 95% confidence intervals.

Table 2

Bivariate Correlations, Descriptive Statistics and Cronbach's Alphas for Study 2.

	2	3	4	5	6	7	8	9	10	11	12	13	14	*M*	*SD*	α
1 – STAI-S	.70*** [.62, .77]	.60*** [.50, .69]	.62*** [.52, .70]	-.41*** [-.52, -.28]	-.31*** [-.44, -.17]	-.39*** [-.51, -.26]	.35*** [.22, .47]	.42*** [.29, .53]	.14 [-.00, .28]	.04 [-.11, .18]	.01 [-.13, .15]	-.02 [-.16, .13]	-.02 [-.16, .13]	39.77	11.95	.94
2 – STAI-T		.71*** [.63, .78]	.73*** [.66, .79]	-.46*** [.34, .57]	-.37*** [-.49, -.24]	-.48*** [-.58, -.36]	.44*** [.32, .55]	.53*** [.42, .63]	.05 [-.10, .19]	.07 [-.08, .21]	.01 [-.13, .15]	-.04 [-.18, .11]	.03 [-.12, .17]	46.20	9.66	.88
3 – BAIT			.69*** [.61, .76]	-.29*** [-.42, -.15]	-.33*** [-.45, -.20]	-.39*** [-.51, -.26]	.47*** [.35, .58]	.49*** [.37, .59]	.13 [-.02, .27]	.05 [-.10, .19]	.02 [-.13, .16]	-.02 [-.16, .13]	.05 [-.10, .19]	14.54	10.03	.92
4 – BDI				-.41*** [-.52, -.28]	-.36*** [-.48, -.23]	-.52*** [-.62, -.41]	.44*** [.32, .55]	.55*** [.44, .64]	.07 [-.08, .21]	-.03 [-.17, .12]	.01 [-.13, .15]	.03 [-.12, .17]	.10 [-.05, .24]	16.40	12.49	.92
5 – ACS					.31*** [.17, .44]	.40*** [.27, .52]	-.41*** [-.52, -.28]	-.46*** [-.57, -.34]	-.19** [-.33, -.05]	-.10 [-.24, .05]	-.01 [-.15, .13]	.06 [-.09, .20]	-.05 [-.19, .10]	48.79	8.93	.86
6 – MCSD						.22** [.08, .35]	-.27*** [-.40, -.13]	-.28*** [-.41, -.14]	-.13 [-.27, .02]	.07 [-.08, .21]	-.03 [-.17, .12]	-.07 [-.21, .08]	-.13 [-.27, .02]	49.68	4.84	.73
7 – Probability (positive, self)							-.54*** [-.64, -.43]	-.90*** [-.92, -.87]	-.20** [-.34, -.06]	.09 [-.06, .23]	.08 [-.07, .22]	-.02 [-.16, .13]	-.04 [-.18, .11]	84.17	16.13	.89
8 – Probability (Negative, self)								.86*** [.82, .89]	.20** [.06, -.34]	.16* [.02, .30]	.27*** [.13, .40]	.05 [-.10, .19]	.01 [-.13, .15]	77.02	14.17	.85
9 – Probability bias (self)									.23** [.09, .36]	.03 [-.12, .17]	.10 [-.05, .24]	.04 [-.11, .18]	.03 [-.12, .17]	-7.15	26.64	-
10 – Cost bias (self)										-.07 [-.21, .08]	.05 [-.10, .19]	.08 [-.07, .22]	.42*** [.29, .53]	-0.53	9.56	-
11 – Probability (positive, peer)											-.21** [-.34, -.07]	-.81*** [-.85, -.75]	-.38*** [-.50, -.25]	92.62	12.93	.91
12 – Probability (negative, peer)												.74*** [.67, .80]	.17* [.03, .31]	74.15	11.18	.85
13 – Probability bias (peer)													.36*** [.23, .48]	-18.47	18.75	-
14 – Cost bias (peer)														-0.79	8.25	-

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 185$. STAI-S, State-Trait Anxiety Inventory, state subscale; STAI-T, State-Trait Anxiety Inventory, trait subscale; BAIT, Beck Anxiety Inventory, trait version; BDI, Beck Depression Inventory; ACS, Attentional Control Scale; MCSD, Marlow-Crowne Social Desirability. The scores suggest the sample was mildly anxious and depressed on average. Square brackets show 95% confidence intervals.

Table 3

Bivariate Correlations and Descriptive Statistics for Study 3.

	2	3	4	5	6	7	8	9	*M*	*SD*	α
1 – STAI-T	.66*** [.57, .73]	.76*** [.70, .81]	-.47*** [-.57, -.36]	-.31*** [-.43, -.18]	-.62*** [-.70, -.53]	-.53*** [-.62, -.42]	.49*** [.38, .59]	.58*** [.48, .67]	46.81	8.84	.88
2 – BAIT		.61*** [.52, .69]	-.33*** [-.45, -.20]	-.22** [-.35, -.08]	-.37*** [-.48, -.24]	-.26*** [-.39, -.13]	.37*** [.24, .48]	.35*** [.22, .47]	13.28	9.88	.92
3 – BDI			-.37*** [-.48, -.24]	-.21** [-.34, -.07]	-.56*** [-.65, -.46]	-.35*** [-.47, -.22]	.36*** [.23, .48]	.40*** [.28, .51]	16.09	11.63	.90
4 – ACS				.36*** [.23, .48]	.47*** [.36, .57]	.34*** [.21, .46]	-.38*** [-.49, -.26]	-.41*** [-.52, -.29]	47.85	8.09	.83
5 – MCSD					.33*** [.20, .45]	.35*** [.22, .47]	-.24*** [-.37, -.11]	-.34*** [-.46, -.21]	48.49	4.60	.71
6 – CERQ						.44*** [.32, .55]	-.41*** [-.52, -.29]	-.48*** [-.58, -.37]	114.18	14.85	.84
7 – Probability (positive events)							-.54*** [-.63, -.43]	-.90*** [-.92, -.87]	84.03	17.25	.91
8 – Probability (negative events)								.85*** [.81, .88]	73.43	13.81	.84
9 – Probability bias									-10.61	27.29	-

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 201$. STAI-T, State-Trait Anxiety Inventory, trait subscale; BAIT, Beck Anxiety Inventory, trait version; BDI, Beck Depression Inventory; ACS, Attentional Control Scale; MCSD, Marlow-Crowne Social Desirability; CERQ, Cognitive Emotion Regulation Questionnaire. The scores suggest the sample was mildly anxious and depressed on average. Square brackets show 95% confidence intervals.

Table 4

Bivariate Correlations and Descriptive Statistics for Study 4.

	2	3	4	5	6	7	8	9	*M*	*SD*	α
1 – STAI-T	.62*** [.53, .69]	.71***[.64, .77]	-.37***[-.48, -.25]	-.21**[-.33, -.08]	.70***[.63, .76]	-.50***[-.59, -.40]	.43***[.32, .53]	.52***[.42, .61]	46.95	8.17	.85
2 – BAIT		.67***[.59, .74]	-.27***[-.39, -.15]	-.05 [-.18, .08]	.61***[.52, .69]	-.26***[-.38, -.14]	.39***[.28, .49]	.35***[.23, .46]	12.97	10.36	.93
3 – BDI			-.37***[-.48, -.25]	-.17**[-.29, -.04]	.65***[.57, .72]	-.42***[-.52, -.31]	.42***[.31, .52]	.46***[.35, .56]	16.70	12.75	.92
4 – ACS				.35***[.23, .48]	-.45***[-.55, -.34]	.36***[.24, .47]	-.26***[-.38, -.14]	-.35***[-.48, -.23]	48.14	8.36	.83
5 – MCSD					-.28***[-.39, -.16]	.22**[.09, .34]	-.15*[-.27, -.02]	-.20**[-.32, -.07]	49.11	4.72	.73
6 – DERS						-.46***[-.56, -.35]	.42***[.31, .52]	.48***[.38, .57]	94.39	23.09	.94
7 – Probability (positive events)							-.65***[-.72, -.57]	-.93***[-.95, -.91]	86.70	19.43	.93
8 – Probability (negative events)								.89**[.86, .91]	70.43	15.60	.87
9 – Probability bias									-16.27	31.82	-

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 233$. STAI-T, State-Trait Anxiety Inventory, trait subscale; BAIT, Beck Anxiety Inventory, trait version; BDI, Beck Depression Inventory; ACS, Attentional Control Scale; MCSD, Marlow-Crowne Social Desirability; DERS, Difficulties in Emotion Regulation Scale. The scores suggest the sample was mildly anxious and depressed on average. Square brackets show 95% confidence intervals.

Appendix: Items Used to Assess Probability Bias

The probability bias measure used in all studies presented 20 positive and 20 negative events in a random order. These events are listed below. These events were tailored for UK students. Some are adapted from previous studies, including those of Butler & Mathews (1987) and Stöber (1997); others were created by us.

The next exam you sit will be unusually hard

Your best friend will grow bored of you, and begin spending more time with other friends

You will be diagnosed with cancer in your lifetime

You will lose or seriously damage your mobile phone in the next year

You will become well-known for an outstanding accomplishment

You will fail a course this year

You will be happily married

You will become very wealthy

You will graduate in the top 30% of your year-group

You will embarrass yourself at your next social event

You will have a serious argument with your family in the next month

You will be able to succeed in your next venture or goal

You will lose someone you love in the next year

You will be the victim of a violent crime

You will be perceived well at the next party or social event you attend

During your next exam, you will fail to read one of the questions carefully enough

At some time in your life, you will spend many years alone

You would win the lottery if you played regularly

You will get a first in all your courses for a term

You will become very well-known in your industry

You will have an exceptionally gifted child

You will find “true love”

You will be alive and healthy into old age

You will be completely satisfied with your life

You will be fired from your first job out of university

You will greatly enjoy your next holiday

You will find the perfect job right out of university

You will become homeless

You could get into any masters programme you wanted

You will be seriously injured in a natural disaster

Your friends would be there to support you if you had some crisis

You will do much better than expected in your next exam

Your family will always be very proud of you

You will have a child with a severe birth defect

You will be in a serious car accident in the next 5 years

Tomorrow will be a wonderful day for you

You will die before age 50

You will fail an exam this term

You will be mistreated by a lecturer or seminar leader

If you borrowed a friend’s laptop, you would damage it accidentally