Altering attentional control settings causes persistent biases of visual attention

Short Title: Attentional Bias Development

Helen C. Knight [a]*, Daniel T. Smith [b], David C. Knight [b] & Amanda Ellison [b]

[b] Department of Psychology, University of Sunderland, St. Peter's Way, Sunderland, SR6 0DD, United Kingdom

[a] Department of Psychology, Durham University, Queen's Campus, University Boulevard, Stockton-on-Tees, TS17 6BH, United Kingdom

* Correspondence to helen.knight@sunderland.ac.uk Tel: +44 (0)191 5152571 Fax: +44 (0)191 5153405

daniel.smith2@durham.ac.uk Tel: +44 (0)191 3340436

dave.knight@dunelm.org.uk Tel: +44 (0)191 3340105

amanda.ellison@durham.ac.uk Tel: +44 (0)191 3340430

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Abstract

Attentional control settings have an important role in guiding visual behaviour. Previous work within cognitive psychology has found the deployment of general attentional control settings can be modulated by training. However, research has not yet established whether long-term modifications of one particular type of attentional control setting can be induced. To address this, we investigated persistent alterations to Feature Search Mode, also known as an attentional bias, towards an arbitrary stimulus in healthy participants. Subjects were biased towards the colour green by an information sheet. Attentional bias was assessed using a change detection task. After an interval of either 1 or 2 weeks participants were then either re-tested on the same change detection task, tested on a different change detection task where colour was irrelevant, or were biased towards an alternative colour. One experiment included trials in which the distracter stimuli (but never the target stimuli) were green. The key finding was that green stimuli in the second task attracted attention, despite this impairing task performance. Furthermore, inducing a second attentional bias did not override the initial bias toward green objects. The attentional bias also persisted for at least two weeks. It is argued that this persistent attentional bias is mediated by a chronic change to participants attentional control settings, which is aided by long-term representations involving contextual cuing. We speculate that similar changes to attentional control settings and continuous cuing may relate to attentional biases observed in psychopathologies. Targeting these biases may be a productive approach to treatment.

Key Words

Attentional Bias, Cognitive Bias, Attention, Visual Attention, Attentional Set

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Attentional bias is a phenomenon wherein certain items are preferentially processed at the cost of other items in a visual field (MacLeod, Matthews & Tata, 1896; Field & Cox, 2008). It plays an important role in guiding visual behaviour, yet has almost only exclusively been studied within abnormal psychology. Individuals with issues such as anxiety (Rinck, Becker, Kellermann & Roth, 2003; Mogg & Bradley, 2005), eating disorders (Smeets, Roefs, van Furth & Jansen, 2008), depression (Gotlib, Krasnoperova, Yue & Joormann, 2004), chronic pain (Schoth, Nunes & Liossi, 2012), specific phobias (Constantine, McNally & Hornig, 2001) and addiction (Yaxely & Zwaan, 2005; Jones, Bruce, Livingstone & Reed, 2006) all appear to preferentially process items relating to their concerns. The consistent finding across all fields is that the more severe the psychopathology, the more prominent the attentional bias. One issue is that within these populations, affected individuals attend to pathology-related items whether they wish to do so, or not (Sharma, Albery & Cook, 2001). This feeds into a circular problem, since attending to and then processing pathology-related items can cause the pathology itself to worsen (Field & Eastwood, 2005), which in turn intensifies the attentional bias (Bearre, Sturt, Bruce & Jones, 2007). Investigating the possible development of these biases may then go some way in explaining the non-volitional persistence that underpins attentional bias. However, despite the strong links between behaviours such as addiction and cognitive processes such as attention, there is currently very little overlap in the literature. Consequently, the purely cognitive mechanism that may underpin attentional bias has not yet been explored.

Within the cognitive literature, attentional biases can be thought of as synonymous to an attentional setting, which is a top-down controlled state that allows for the prioritisation of certain stimuli, based on particular visual features (Folk, Remington & Johnston, 1992; Leber & Egeth, 2006). Although there has been great debate on how visual stimuli are selected for further processing (Theeuwes, 1991; 1992; Belopolsky & Theeuwes, 2010; Folk et al., 1992; Bacon & Egeth, 1994), one generally accepted proposal is that observers can activate one of two distinctive attentional sets:

Singleton Detection Mode or Feature Search Mode (Bacon & Egeth, 1994; Leber & Egeth, 2006b). Singleton Detection Mode is based purely on the physical salience of an item, allowing the most salient item in a visual field – such as a feature singleton (a red item amongst greyscale items) – to capture attention. Alternatively, Feature Search Mode relies on a defining target feature – such as a particular colour – and is a much narrower attentional set that results in a reduction of interference from salient objects that do not share the defining target feature. Of the two search modes, Singleton Detection Mode appears to be the default setting (Bacon & Egeth, 1994; Kawahara, 2010). Persistently engaging Feature Search Mode for a specific stimulus characteristic can be thought of as tantamount to an attentional bias towards that characteristic. In other words, an attentional bias towards a specific stimulus or stimuli characteristic is akin to an individual's attention system being uncontrollably and chronically set to a specific type of Feature Search Mode, prioritising corresponding items for further processing and thus ensuring that they capture attention over other available items. However, due to the poor integration between the abnormal and cognitive literatures on this topic, it remains unknown how or even if changes to attentional settings resulting in the prioritisation of a visual feature corresponds to the seemingly identical way with which those with pathological attentional biases prioritise certain information.

Leber and Egeth (2006) have found that past experience can determine the attentional set chosen by observers in subsequent tasks, suggesting that individual experiences can influence chosen attentional sets. Regarding psychopathological attentional biases, these findings suggest that the past experiences an individual has with pathology-related stimuli will have an effect on their attentional control settings, altering the extent to which pathology-related items capture attention. However, though Leber and Egeth's findings do offer some explanations on how attentional biases may develop; the study was focused on the general selection of either Singleton Detection Mode or Feature Search Mode rather than a specific persistent type of Feature Search Mode, which is what pathological attentional biases are concerned with. Moreover, how these attentional control settings are initially altered and what factors may aid or hinder these changes remain unknown.

More recently, Leber, Kawahara and Gabari (2009) investigated the role of past experience on the selection of attentional settings in more detail by studying how the selection manifested in a more long-term setting. They firstly discovered that using a particular type of search mode was not due to a perseverance in being biased towards one type of visual selection (i.e., towards one particular feature), but were due to more long-term abstract learning to use a particular general type of search mode, which lasted at least one week. Secondly, it was discovered that learning via the training session was not specific to a particular feature, but was a more abstract learning of using a general search mode for a particular task. While these findings suggest that selection of a particular search mode reflects long-term learning of an abstract attentional set, these findings are more difficult to generalise to traditionally studied attentional biases. Leber and colleagues found that training specifically to identify red objects did not mean that only red objects were attended in later sessions – it was a general learning of overall search mode rather than a persistent bias for one specific type of stimulus. Thus, while learning to implement a more abstract general search mode can be lasting, it is unclear how learning to persistently select only one specific type of visual feature develops; and if learned, how long these selection biases persist.

The research outlined so far has relied more on instructing and training participants to use a particular search mode. However, attentional biases most often develop implicitly (Sharma et al., 2001; Rooke, Hine & Thorsteinsson, 2008). Although it has been found that general search modes can be trained without explicit instructions but via online feedback within training sessions (Kawahara, 2010), implicit alterations of attentional control settings may be instead due to such issues as emotions and/or memories that may be triggered by bias-related items (i.e., feelings of relief when spotting a café at lunch time). In other words, it is possible that training will only cause individuals to adopt a general attentional setting when using non-emotive stimuli, whereas with emotive stimuli the additional neural processing that occurs alongside can implicitly cause a bias towards particular features within an attentional set. Thus, the persistent selection of a specific type

of Feature Search Mode – or an attentional bias towards certain information – may be related to the additional neural processing that occurs to process potential emotive aspects of the stimuli.

Such a possibility has been observed in the addiction literature. Janes et al. (2010) used a smoking-related Stroop paradigm along with smokers and non-smokers, while examining their neural activity via fMRI. They found that when presented with smoking-related items, smokers showed an increase of activation in areas of the medial temporal lobe associated with the storage and recall of long term memories (Scoville & Milner, 1957; Squire & Zola-Morgan, 1991; Aggleton & Brown, 1999; 2006; Brown & Aggleton, 2001). There was also an increase in activity of the left amygdala and bilateral insula – areas associated with emotional saliency (Phillips, Drevets, Rauch & Lane, 2003; Phelps, 2004). It is very possible that the emotionally charged, smoking-related words used triggered the recall of emotions and emotional memories associated with smoking (or attempts to quit), and it is these emotions and the heightening of cortical activity relating to them that is causing attentional control settings to be persistently set to prioritise pathology-related information.

Alternatively, it is possible that the emotional connections towards pathology-related items (due to motivations to approach stimuli with addictions or vigilance to avoid stimuli for anxiety) cause internal representations of pathology-related stimuli to remain active –at low levels – even when pathology-related stimuli are not physically present. This would bias activity in the system, such that incoming sensory information from bias-related stimuli is processed more rapidly. In other words, it is as if patients are permanently primed to process bias-related stimuli. However, due to the separation between traditional investigations of attentional biases and cognitive investigations of altered attentional control settings, there is need for clarification. It remains unknown if long-term alterations favouring a specific type of Feature Search Mode can develop, rather than the learning of a general search mode. If so, the development of such specific biases in the absence of emotion would also suggest that there is a possible cognitive foundation of pathological attentional biases which are then strengthened by emotional feedback.

The following experiments aim to explore this by investigating how persistent alterations of a specific type of Feature Search Mode, rather than just Feature Search Mode in general, can occur. If so, the persistence of these alterations when task demands require an alternative strategy for optimal performance will be examined. Here, we manipulated the goals of observers by initially informing participants that the experiment related to the perception of the colour green (i.e. source bias) in a change detection task. The behavioural relevance of stimuli was manipulated during a second experimental session in which the same participants were either retested on the same task, but with the instruction that green was no longer important (Experiment 1), or tested on a different task in which colour was irrelevant and probes never appeared as green items, thus making green behaviourally irrelevant (Experiment 2). The strength of the initial source bias was then further investigated by inducing an additional bias towards a second arbitrary stimulus (the colour blue) in the second experimental session, and examining the extent to which items relating to the first course bias influenced behaviour (Experiment 3), allowing us to ascertain if results reflect simple switches of attentional control settings, or if – like with the psychopathological bias literature – participants attend to biased stimuli whether they want to or not. Using an arbitrary stimulus, i.e. the colour green, also removed rewards associated with addiction-related attentional bias, enabling us to ascertain if associations between stimulus and reward are a requirement for the development and sustainability of attentional biases. Attentional bias was measured using a one-shot change detection task (e.g., Beck, Muggleton, Walsh & Lavie, 2006) in which a mask interposed between subtly different stimulus arrays is used to induce change blindness (Rensink, O'Regan & Clark, 1997). This type of paradigm has been shown to be highly sensitive to the locus of attention (Cole, Kentridge, & Heywood, 2004; Smith & Schenk, 2008).

There were four questions addressed in the experiments: a) Can an attentional bias be established towards an arbitrary stimulus in healthy participants? b) Is this bias robust? c) Does this attentional bias transfer to other tasks in which attending to the biased feature is incompatible with successfully

performing the task? d) Do the observed effects reflect a persistent attentional bias towards specific objects or more simple carry-over effects of an attentional set?

Experiment 1

Method

Participants

Thirty (12 male) undergraduate Psychology students aged 18 to 30 (M: 19.97, SD: 2.44) studying at Durham University participated. All had normal or corrected to normal vision, no colour blindness (assessed via self-report), and gave informed consent with the approval of Durham University Ethics Advisory Committee. Participants were compensated for their time in the form of course credits.

Stimuli & Apparatus

All experimental stimuli were programmed in C++ using Borland C++ builder and produced via a VSG ViSaGe box and custom graphics card (Cambridge Research Systems, Rochester, England). They were displayed using a 19“ Sony Trinitron monitor with a resolution of 1024x768 and a refresh rate of 100Hz. Responses were collected via a custom-made two-button button box. Information and consent forms were also used, of which there was a different version for each condition (test or re-test). The biasing test information sheet informed participants that they were carrying out an experiment investigating how the human visual system perceives and processes the colour green, and used the word *green* several times. The neutral re-test sheet informed participants that they were carrying out an experiment investigating how human visual system perceives and processes colour, thus substituting the word *green* for *colour*.

A white fixation cross situated in the centre of a black screen (0.704 x 0.704° visual angle) preceded the test array consisting of a circular (radius 5.1cm) composition of six circles (2.5° x 2.5° visual angle) each of which was one of 8 different equiluminescent colours (green, red, blue, pink, purple, grey, mustard or orange, all 34 cd/m^2). The mask was a black screen.

Design

Participants were assigned to one of 3 groups. All groups received the same information at the start of the experiment and completed the change detection task. Group 1 was then immediately presented with the 2nd, neutral information sheet and asked to complete a second experimental session. Group 2 were invited to return in 1 week. In the 2nd session they were presented with the neutral information sheet then asked to complete the change detection task. Group 3 were invited to return in 2 weeks. In the 2nd session this group were also presented with a neutral information sheet and asked to complete a change detection task. The experiment therefore had a mixed design. There was a within-subjects factor of experimental session (Session 1 v Session 2) and a between subjects factors of Inter Session Interval (0 weeks vs 1 week vs 2 weeks)

Procedure

Testing occurred in a darkened room. Participants read the biasing information sheet, and were seated 57cm away from the screen with their heads in a chin rest. Participants were presented with the one-shot change-detection task, where they were informed that their goal was to detect any changes between two sequentially presented arrays. A change was defined as one coloured stimuli changing into a different colour not already present in the array.

The experiment began with the presentation of a fixation cross for 1000ms followed by the stimulus array for 1500ms. The array was then masked for 100ms, after which the stimulus array re-appeared. Stimuli remained present until a response was made. On 25% (45 trials) of trials a green item was present and changed colour (Congruent Change Trials), on 25% of trials a green item was present in the display but a different item changed colour (Incongruent Change Trials), on 25% of trials no green item was present and one of the other objects changed colour (Neutral Change Trials) and on 25% of trials a green item was present but no change occurred (No Change Trials). The position of the coloured items was varied randomly across trials.

Participants were advised that a change could occur to any of the presented stimuli in any position in the array. See Figure 1 for paradigm used in experiment 1. Participants were asked to respond as

quickly, but as accurately as possible via the button box if they saw a change (right press) or not (left press). Participants completed 3 blocks of 60 trials with a 5 minute break between each block.

(Figure 1 here)

Results Questions 1 & 2: Can an attentional bias be induced? Is the effect robust?

Outliers with a reaction time above or below 2 standard deviations from the mean were excluded from analyses, resulting in the loss of 0.28% of trials.

d'

Participants sensitivity to changes was calculated using d'. This was entered into a 3 (Inter session Interval: 0 /1 week/2 week) x 3 (Trial Type: Congruent Change/Incongruent Change/Neutral Change) x 2 (Experimental Session: Session 1/Session 2) Mixed Factor ANOVA. Trial and Session were within-subjects factors; Inter Session Interval was between-subjects.

There was a significant main effect of Trial Type: $F(2,54) = 9.979$, $MSE = 1.802$, $p < .001$. d' scores for Congruent Change trials were significantly higher (M: 3.671) than d' scores for Neutral Change trials (M: 2.914, $p = .033$, $r = .466$) and Incongruent Change trials (M: 2.608, $p<.001$, $r = .847$) – see Table 1 for accuracy. There was also a significant main effect of Session: $F(1,27) = 6.824$, $MSE = 2.389$, $p = .015$. d' scores in the re-test condition were higher by an average of .602 ($r = .428$). Since participants all received this condition after initial testing, this could be evidence of an overall practice effect. No Trial x Session interaction was observed: $F(2,54) = .035$, $MSE = 1.074$, $p = .966$.

There was also a main effect of Inter Session Interval: $F(2,27) = 5.852$, $MSE = .927$, $p = .008$, however, this did not interact with any other variable (Session: $F(2,27) = 1.730$, $MSE = 2.389$, $p = .196$; Trial: $F(4,54) = 1.012$, $MSE = 1.802$, $p = .409$; Session x Trial: $F(4,54) = .191$, $MSE = 1.074$, $p = .942$). Pairwise comparisons revealed that mean d' scores for week 1 were significantly higher than week 3 (mean difference: 1.472, $p = .006$, $r = .422$).

To examine if time was the intervening factor in the persistence of the bias effect rather than experience with the task, an additional analysis was undertaken examining d' scores of session 2 only for each type of trial in a block-by-block analysis. Thus, d' scores in Session 2 were entered into a 3

(Trial Type: Congruent Change/Incongruent Change/Neutral Change) x 3 (Experimental Block: Block 1/Block 2/Block 3) Within Factor ANOVA. As expected, there was a significant main effect of Trial Type: $F(2,58) = 35.851$, $MSE = .787$, $p < .001$. d' scores for Congruent Change trials were significantly higher (M: 3.620) than d' scores for Neutral Change trials (M: 2.753, $p < .001$, $r = .742$) and Incongruent Change trials (M: 2.572, $p < .001$, $r = .783$). There was no main effect of Experimental Block ($F(2, 58) = 1.350$, $MSE = 1.849$, $p = .267$) and no Trial Type x Experimental Block interaction ($F(4, 116) = .391$, $MSE = .377$, $p = .814$).

(Table 1 here)

(Figure 2 here)

Discussion

It was predicted that biasing participants towards the colour green would improve change detection performance on trials where the green object changed and impair performance on trials where a green object was present, but the change occurred at a different location. Furthermore, that this bias persisted for at least two weeks. On first inspection these results appear to offer support for the view that it is possible to induce a non-emotional attentional bias in healthy participants. It should be noted that while our results do suggest a successful inducement of an attentional bias towards green items, data supporting our second hypothesis of impaired performance on Incongruent Change trials is inconsistent. Effect sizes do suggest greater sensitivity in Congruent compared to Incongruent trials than Congruent compared to Neutral trials. However, sensitivity in Incongruent Change trials was not significantly more impaired than Neutral Change trials, thus our findings do not conclusively support our second hypothesis.

A further possibility is that since no change trials always include a green item, a search strategy could have been adopted to aid wherein participants scan the initial array and if no green item was present, know it was going to be a change trial and answer accordingly. However, we feel that such a possibility is unlikely since if such a strategy was utilised, accuracy of Neutral Trials would be at or near ceiling. However, Table 1 shows that the overall accuracy of Neutral Change trials in Experiment

1 is 72.65%. This is lower than the accuracy of Congruent Change trials (87.09%); a pattern reflected in d' scores. Furthermore, the block-by-block analysis showed no interaction between experimental block and trial type, thus participants' sensitivity at detecting Neutral Change trials did not improve as the experiment progressed. Consequently, the adoption of a search strategy is not supported. Nevertheless, the data need to be analysed with caution for the following reasons. Although participants were told that colour was irrelevant in the 2nd session they may still have consciously implemented a 'select green' strategy because it had been successful in the 1st session. Indeed, there is evidence that participants in experiments have a tendency to persist with previously successful problem-solving strategies even when they are no longer effective (Crone, Bunge, Van Der Molen & Ridderinkhof, 2006). Furthermore, the change was likely to occur on the green item on 25% of trials, but there were seven other items so the probability of the change occurring at a non-green item was only 11%. In other words, changes were twice as likely to occur at a green item than any other item. It therefore makes sense for the participant to attend the location where there is the highest probability of a change occurring. In this case, it is difficult to know whether the improved performance for green items during the second session was due to an unconscious attentional bias or a conscious decision to attend to the colour green.

Additionally, a robust induced bias effect would be determined by little or no difference in behaviour between the three differences in inter-test interval between the biasing and neutral testing sessions. The d' analysis revealed that participants who were tested and re-tested in the same week had a higher d' than those who had a two-week gap in between. Generalised practice effects could explain this difference, since having all six blocks of trials in the same session could allow participants to become better at the task than those with a one- or two-week gap in between. The fact that no difference between inter-test interval and condition was present suggests a robustness of the biasing effect. Moreover, the fact that d' scores in Session 2 did not wane across the three blocks of trials suggests that task experience is not having an effect on the induced attentional bias towards green objects.

In order to rule out the explanation that participants volitionally attended to the green item a second experiment was conducted in which attentional bias was tested under conditions where the change never occurred at the green item. In this case, attending to green would never lead to successful change detection.

Experiment 2

Method

Participants

Participants were 30 (10 male) undergraduate Psychology students aged 18 to 56, (M: 25, SD: 8.08) studying at Durham University. All had normal or corrected to normal vision, no colour blindness, gave informed consent with the approval of Durham University Ethics Advisory Committee and were compensated for their time via course credits.

Stimuli & Apparatus

Stimuli production and presentation apparatus was identical to experiment 1, as were the biasing information and consent forms. Thus, the biasing test information sheet for session 1 informed participants that they were carrying out an experiment investigating how the human visual system perceives and processes the colour green, and used the word *green* several times. The shape task information and consent forms substituted the word *colours* for *shapes* and *green* for *shape,* informing participants that they were carrying out an experiment investigating how human visual system perceives and processes shape. There was also an additional paragraph stressing the focus on shape changes and emphasising that colour was irrelevant to the task. The sheet did not mention the word *green*.

Stimuli in session 1 were identical to those used in experiment 1. For the shape task, the array (radius 5.1cm) comprised four different shapes (square, circle, triangle, pentagon or trapezium: visual angle: 2.5° x 2.5°), all of a different equiluminescent colour (34 cd/m^2). The mask was a completely blank screen.

Design

Participants were again assigned to one of 3 groups. All groups received the same information at the start of the experiment and completed the change detection task. Group 1 was then immediately presented with the 2nd session – the shape information sheet – and asked to complete a different experiment on the perception of shapes. It was stressed that colour was irrelevant to the task. Group 2 were invited to return in 1 week. In the 2nd session they were presented with the shape information sheet then asked to complete the shape change detection task. Group 3 were invited to return in 2 weeks. In the 2nd session this group were also presented with the shape information sheet and asked to complete the shape change detection task. The experiment therefore had a mixed design. There was a within-subjects factor of experimental session (Session 1 v Session 2) and a between subjects factors of Inter Session Interval (0 weeks vs 1 week vs after 2 weeks)

Procedure

Procedure for session 1 was identical to that used in experiment 1, in that participants were presented with the biasing information sheet and asked to complete the six-circle experimental task. In session 2, participants were again asked to detect changes between two sequentially presented arrays of stimuli, separated by a mask. Here, changes were defined as a shape in the array changing into a different shape, with the colour of shape never changing. The shape experiment began with the presentation of a fixation cross for 1000ms followed by the stimulus array for 750ms. The array was then masked for 100ms, after which the stimulus array re-appeared. Stimuli remained present until a response was made. On 25% (120 trials) of trials a green shape was present, but a different shape changed shape, (Green Present Change Trials), on 25% of trials a green item was present but no change occurred (Green Present No-Change Trials), on 25% of trials no green item was present and one of the shapes changed shape (Green Absent Change Trials) and on 25% of trials no green item was present and no change occurred (Green Absent No Change Trials). The position of the coloured items was varied randomly across trials.

Participants were advised that a change could occur to any of the presented shapes in any position in the array. See Figure 3 for paradigm used in the shape change detection task. Participants were asked to respond as quickly, but as accurately as possible via the button box if they saw a change (right press) or not (left press). Participants completed 6 blocks of 80 trials with a 5 minute break between each block.

(Figure 3 here)

Results Question 3: Does the bias generalise to a different experimental paradigm?

Session 1

d' scores from Session 1 (the initial colour experiment following the presentation of the biasing information sheets) were entered into a 3 (Inter Session Interval Group: 0 /1 week/2 week) x 3 (Trial Type: Congruent Change/Incongruent Change/Neutral Change) Mixed Factor ANOVA. Trial was a within-subjects factor; Inter Session Interval Group was between-subjects. The results show a significant main effect of Trial Type: $F(2, 54) = 40.140$, MSE = .257, $p < .001$. d' Scores of Congruent Change trials were significantly higher (M: 2.624) than d' scores of Incongruent (M: 1.633, $p < .001$, $r = .806$) and Neutral Change (M: 1.725, $p < .001$, $r = .812$) trials. There was no effect of Inter Session Interval Group: $F(2, 27) = .128$, MSE = .565, $p = .880$, and no Trial Type x Inter Session Interval Group interaction: $F(4, 54) = .279$, $p = .890$. Thus, we can conclude that we were successful in initially inducing an attentional bias towards green items in all groups in Experiment 2.

Session 2

Trials with a reaction time above or below 2 standard deviations from the mean were deemed outliers and were excluded from analyses, resulting in the loss of 0.35% of trials.

d'

Calculated d' scores were entered into a 3 (Inter Session Interval: 0 /1 week/2 week) x 2 (Bias: Green Present /Green Absent) Mixed Factor ANOVA. Trial was within-subjects; Inter Session Interval was between-subjects. Mean d' scores when a bias shape was present was 1.5407, as opposed to 1.7214 with no bias shape present. The ANOVA revealed that this difference was significant: $F(1, 27) = 4.667$,

p = .04, r = .383. Figure 4 displays this effect, while Table 2 displays the mean accuracy. There was no main effect of Inter Session Interval: F(2,27) = .638, MSE = .266, p = .536, or a Bias x Inter Session Interval interaction: F(2,27) = .397, MSE = .105, p = .676.

Again, to examine if time was the intervening factor in the persistence of the bias effect, a block-by-block analysis was carried out by entering mean d' scores into a 2 (Bias: Green Present/Green Absent) x 2 (Trial Type: Change/No Change) x 6 (Experimental Block: Block 1/Block 2/Block 3/Block 4/Block 5/Block 6) Within Factor ANOVA. The main effect of Bias remained: F(1, 29) = 9.144, MSE = .551, p = .005, with d' scores of Bias Present trials significantly lower than Bias Absent trials by an average of .236. The ANOVA revealed no main effect of Experimental Block: F(5, 145) = 1.781, MSE = .374, p = .120 and no interaction between Bias and Experimental Block: F(5, 145) = 1.485, MSE = .267, p = .198, suggesting that the effect of the presence of a green shape on sensitivity to detect changes did not wane across experimental blocks.

(Table 2 here)

(Figure 4 here)

Discussion

Our evidence indicated the induced attentional bias had extended beyond the immediate experimental situation, despite colour now being explicitly irrelevant. This result argues against the suggestion that participants were simply choosing to attend to the green item. Reaction times were substantially slower in trials with a green shape present, and accuracy was impaired when a shape in the array changed, but green was also present. Accuracy was improved in no change trials when a green shape was present, probably because attention was biased towards the green shape. These differences in behaviour would seem to be due to the induced attentional bias decreasing participants' sensitivity to detect change when a green shape is present, as evidenced by d'. This is because the green item when presented captures attention, thus diverting attention away from the visual transient. This manifests in lowered accuracy to green-present change trials and slower overall reaction times when a green shape is present. While participants in the Same Week condition may

have still been using an ‘attend green’ strategy, since this would have been beneficial in their previous experimental block (the initial six-circle task), the length of time between biasing and subsequent re-testing had no significant effect on reaction time or sensitivity to detect change. This suggests that all three experimental groups would have been using the same strategy when completing the shape task in the second session. With two weeks between Session 1 and Session 2 for some participants, it seems unlikely that participants here were still using a ‘select green’ strategy, suggesting a less transient effect is taking place. Additionally, the lowered sensitivity to detect changes did not dissipate across experimental blocks, suggesting that task experience was not an influencing factor in the persistence of the biasing effect. Even more, the fact that the induced bias generalises from one experimental paradigm to another, suggests that the induced bias is also robust.

Nevertheless despite these promising findings, it is possible that the ratio of Congruent Change trials in session 1 wherein participants read the biasing information sheet before carrying out the task may have also played a role in the establishment of an attentional control setting to favour the processing of green items. It is possible that participants implicitly learn to attend to green items in session 1 because this gives a behavioural advantage, and that the success of this adopted strategy simply carries over to the shape task. Thus, the altered attentional control settings may have little to do with the biasing information sheet and may simply be related to a probability-based learning mechanism. In order to establish if this probability based learning can occur independently of the initial information sheet, an additional control experiment was carried out. Here, participants receive the identical change-detection task used in session 1 of experiments 1 and 2; however they only receive a neutral instruction sheet.

Control Experiment

Method

Participants

Participants were 10 (3 male) undergraduate Psychology students aged 18 to 27, (M: 20.4, SD: 3.134) studying at Durham University. All had normal or corrected to normal vision, no colour blindness, gave informed consent with the approval of Durham University Ethics Advisory Committee and were compensated for their time via course credits.

Stimuli, Apparatus, Design & Procedure

Stimuli production and presentation apparatus was identical to session 1 of experiments 1 and 2; however information and consent forms were neutral. The information sheet for this experiment therefore only informed participants that they were carrying out a change-detection experiment investigating how the human visual system processes colour; there was no mention of the word *green*. Stimuli were identical to those used in both session of experiment 1, and session 1 of experiment 2.

All participants received the same information at the start of the experiment and completed the single change detection task. The experiment therefore had a within subjects design. There was a single factor of Trial (Congruent Change v Incongruent Change v Neutral Change v No Change). The procedure was identical to that used in experiment 1 and session 1 of experiment 2, with the only alteration being the information and consent forms presented to participants. Here, participants were presented with a neutral information sheet and asked to complete the six-circle experimental task. The number of blocks, trials per block and ratio of each type of trial was kept the same.

Results: Is the adoption of an attentional setting favouring green a result is implicit probability-based training?

Trials with a reaction time above or below 2 standard deviations from the mean were deemed outliers and were excluded from analyses, resulting in the loss of 0.32% of trials

d'

Calculated d' scores using No Change trials to assess hit and false alarm rates were entered into a one-way ANOVA with a single within subjects' factor of Trial Type (Congruent Change/Incongruent Change/Neutral Change). The ANOVA revealed no significant main effect of Trial Type: $F(2, 18) = .969$, $MSE = .093$, $p = .399$, $r = .226$. The mean d' score for Congruent Change trials was 2.033 (SD: 0.595), for Incongruent Change trials this was 2.082 (SD: .0498), and Neutral Change trials had a mean d' score of 2.215 (SD: 0.477). Furthermore, the effect sizes of the comparison of each Trial Type with each other suggests that participants were not adopting any sort of strategy or were implicitly biased towards detecting green changes via a probability-based learning mechanism. Comparing Congruent Change trials against Incongruent Change trials, the effect size was $r = .240$ ($p = .478$); comparing Congruent Change trials against Neutral Change trials the effect size was $r = .340$ ($p = .307$). Finally comparing Incongruent Change trials against Neutral Change trials, the effect size was $r = .284$ ($p = .397$).

(Table 3 here)

(Figure 5 here)

Discussion

The results from this control experiment offer strong evidence that no bias towards any colour exists if participants are given a neutral information sheet before the change detection task. As such, the carry-over effects from the initial biasing session to the shape session in experiment 2 is due to the word prime on the information sheet and not due to probability-based implicit learning. Consequently, this control experiment provides ample evidence that the biasing information sheet is at the root of the behavioural changes observed in experiments 1 and 2, and thus is the cause of the attentional bias towards selecting green items for further processing. Furthermore, while it is impossible to control for the qualia of individual colour experiences between participants, this experiment strongly suggests that no natural bias towards green exists. Therefore our stringent controls involving the size, visual angle and luminance of stimuli was successful meaning that the

results observed in experiments 1 and 2 were not due to green items simply standing out more over other items in the arrays.

Experiment 3

Experiment 3 was designed to examine the strength of the induced attentional bias. Since a key aspect of attentional bias lies in an individual's inability to overcome the bias (Cox, Hogan, Kristian & Race, 2002; Field & Cox, 2008), experiment 3 aimed to induce the primary attentional bias towards the colour green in session 1, and then induce a second attentional bias towards a different colour (in this case, towards the colour blue) in session 2. A bias towards blue over red was chosen to avoid any possible confounds resulting from conflicting colour opponency (Hurvich & Jameson, 1957; Park, An & Lee, 2002). This enabled us to investigate if the second attentional bias towards blue objects obliterated the attentional bias towards green objects, or if the primary attentional bias towards green objects still persisted. Experiment 3 therefore allowed us to distinguish between a persistent attentional bias towards specific objects or if our results reflected more simple carry-over effects of an attentional set (Leber & Egeth, 2006). However, since no effect of the duration between sessions 1 and 2 has been observed, sessions 1 and 2 in experiment 3 were either undertaken on the same day, or with a one-week gap in between.

Method

Participants

Participants were 40 (9 male) undergraduate Psychology students aged 18-21 (M: 19.05, SD: 0.955) studying at Durham University. All had normal or corrected to normal vision, no colour blindness, gave informed consent with the approval of Durham University Ethics Advisory Committee and were compensated for their time via course credits.

Stimuli & Apparatus

Stimuli production and presentation apparatus was identical to experiments 1 and 2, as were the biasing information and consent forms. The blue task information and consent forms substituted the

word *green* for *blue*. Stimuli in both sessions were identical to those used in experiment 1. The mask was a completely blank screen.

Design

Participants were assigned to one of 2 groups. All groups received the same green-biasing information sheet at the start of the experiment and completed the change detection task. Group 1 was then immediately presented with the 2nd session – the blue information sheet – and asked to complete an additional change detection task. Group 2 were invited to return in 1 week. In the 2nd session they were presented with the blue information sheet then asked to complete the change detection task. The experiment therefore had a mixed design. There was a within-subjects factor of experimental session (Session 1 v Session 2) and a between subjects factors of Inter Session Interval (0 weeks vs 1 week)

Procedure

As with experiment 1, testing occurred in a darkened room. Participants read the biasing information sheet, and were seated 57cm away from the screen with their heads in a chin rest. Participants were presented with the one-shot change-detection task, where they were informed that their goal was to detect any changes between two sequentially presented arrays. A change was defined as one coloured stimuli changing into a different colour not already present in the array.

Procedure for session 1 was identical to that used in experiment 1. In session 2, Participants were presented with the blue information sheet and again asked to detect changes between two sequentially presented arrays of stimuli, separated by a mask. The procedure for each presented trial was identical to that used in session 1; however the quantity and type of trials differed. Here, on 15% (45 trials) of trials a blue item was present and changed colour (Blue Congruent Change Trials), on 15% of trials a blue item was present in the display but a different item changed colour (Blue Incongruent Change Trials), On 15% of trials a green item was present and changed colour (Green Congruent Change Trials), on 15% of trials a green item was present in the display but a different item changed colour (Green Incongruent Change Trials), on 15% of trials both blue and green item

were present but a different item changed colour (Both Incongruent Change Trial), on 15% of trials no blue or green item was present and one of the other objects changed colour (Neutral Change Trials) and on 10% of trials a blue and green item was present but no change occurred (No Change Trials). The position of the coloured items was varied randomly across trials.

Participants were advised that a change could occur to any of the presented stimuli in any position in the array. Participants were asked to respond as quickly, but as accurately as possible via the button box if they saw a change or not. Participants completed 5 blocks of 60 trials with a 5 minute break between each block.

Results: Do results reflect a persistent attentional bias towards specific objects or carry-over effects of an attentional set?

Trials with a reaction time above or below 2 standard deviations from the mean were deemed outliers and were excluded from analyses, resulting in the loss of 0.41% of trials.

d'

Participants sensitivity to change was calculated using d'. This was entered into a 3 (Inter Session Interval: 0 /1 week) x 6 (Trial Type: Blue Congruent/Green Congruent/Blue Incongruent/ Green Incongruent/ Both Incongruent/ Neutral Change) Mixed Factor ANOVA. There was a main effect of Trial Type: $F(5, 190) = 37.117$, $MSE = 1.480$, $p < .001$. Bonferroni corrected pairwise comparisons revealed that d' scores of Blue Congruent trials were significantly higher than Blue Incongruent (mean difference: .697, $p<.001$, $r = .716$), Green Incongruent (mean difference: .734, $p<.001$, $r = .707$) and Both Incongruent (mean difference: 1.225, $p<.001$, $r = .838$). Calculated d' scores of Green Congruent trials were also significantly higher than Blue Incongruent (mean difference: .594, $p<.001$, $r = .726$), Green Incongruent (mean difference: .631, $p<.001$, $r = .713$) and Both Incongruent trials (mean difference: 1.122, $p<.001$, $r = .861$). Participants' d' scores of Blue Congruent and Green Congruent trials did not differ ($p = .278$), nor did d' scores of Blue Incongruent and Green Incongruent trials ($p = .469$). However, d' scores of Neutral Change trials were significantly higher than both Blue Incongruent (mean difference: 1.405, $p<.001$, $r = .698$) and Green Incongruent trials (mean

difference: 1.502, p<.001, r = .707). Interestingly, while d' scores of Neutral Change trials did not differ from Blue Congruent trials, they were significantly higher than Green Congruent trials (mean difference: .871, p = .012, r = 496) – see Table 3 for accuracy.

Furthermore, in addition to d' scores of Both Incongruent trials being lower than Blue Congruent and Green congruent trials, d' scores of Both Incongruent trials were also significantly lower than Blue Incongruent (mean difference: .594, p<.001, r = .837), Green Incongruent (mean difference: .631, p<.001, r = .758) and Neutral Change trials (mean difference: 1.122, p<.001, r = .786). There was no main effect of Inter-Session Interval: F(1, 38) = .017, p = .896), nor did Inter-Session Interval interact with Trial Type: F(5, 190) = .038, p = .951. Finally, a block by block analysis of d' scores across all trials yielded no significant main effect of Block: F(4, 152) = 1.270, MSE = .534, p = .284, and no Trial x Block interaction: F(20, 760) = 1.285, MSE = .925, p = .263.

(Table 4 Here)

(Figure 6 Here)

Discussion

Our findings suggest that an attentional bias towards green objects was still present after participants were also biased towards blue objects, thus suggesting a persistent bias towards specific objects, rather than just carry-over effects of an attentional set (Leber & Egeth, 2006). Interestingly, however, rather than participants remaining more sensitive to detecting green (or blue) changes – since participants were actually more sensitive at detecting neutral changes than green changes, and there was no difference in sensitivity between blue and neutral changes – the bias presented more in terms of participants having lower sensitivity to detect changes when green objects were present but did not change. This suggests that green and blue objects captured attention when present, reducing sensitivity when a different object changed colour. The results also show that when both a green and blue object were present, participants' sensitivity to detect other changes dropped yet further – suggesting that the distractions caused by biased stimuli when present was amplified when multiple biased stimuli were present: further signifying that attentional biases towards both blue and green

items was present. Since a key aspect of attentional bias lies in an individual's inability to overcome the bias (Field & Cox, 2008), these results show that information sheets are sufficient to induce persistent attentional biases that are difficult to interfere with.

General Discussion

The current experiments have found that causing a persistent alteration to an attentional setting – specifically within Feature Search Mode – towards a non-emotional and arbitrary stimulus can be easily induced in healthy participants using just a single information sheet. This is synonymous with creating an attentional bias towards the stimulus in question. The altered attentional set, or attentional bias, is long-lasting – persisting for at least two weeks – and robust, such that it interferes with processing in other tasks when colour is made both explicitly and implicitly irrelevant, and is still present when a second arbitrary bias is induced. The bias was found to alter participants' sensitivity to detect bias-related stimuli. Importantly, this top-down modulation cannot be due to the current goals of participants, since attending to colour in the shape task went against the behavioural goal to detect changes to shapes. Furthermore, it does not reflect a simple switch of attentional control settings, since inducing a second attentional bias towards a different arbitrary stimulus did not override the first bias.

It would seem that the alteration of internal state caused by our manipulation of the attentional control settings (Folk et al., 1992; Bacon & Egeth, 1994) has affected top-down influences on the priority map which selects items for preferential processing (Fecteau & Munoz, 2006; Awh, Belopolsky & Theeuwes, 2012). In the current experiments, it appears as if participants adopt an attentional control setting specifically within Feature Search Mode in response to the first information sheet (about the colour green). This resulted in green items being preferentially passed through the attentional filter and effortlessly capturing attention.

Crucially, a feature-specific long-term alteration of Feature Search Mode has occurred, rather than a general preference for a type of search mode (Leber & Egeth, 2006). Previous findings have resulted from training subjects then placing them in ambiguous settings wherein either search mode could be

effectively used (Leber & Egeth 2006; 2006b; Leber et al., 2009; Kawahara, 2010). These studies have found that long-term alterations favouring a particular attentional set must be learned over a sufficiently long training phase (Leber & Egeth, 2006). Moreover, they do not reflect stimulus-specific learning, but a more abstract learning of choice of either Singleton Detection or Feature Search Mode (Leber et al., 2009). However, we have found that a long-term stimulus-specific form of Feature Search Mode can be easily adopted, even with non-emotive stimuli. It is possible that these novel findings are due to participants receiving an explicit information sheet, rather than a bias being implicitly formed from sitting in a green room or via online trial-by-trial accuracy feedback (Kawahara, 2010).

Our results are therefore more aligned with the behaviours observed within psychopathological research areas, wherein patients are unable to favour attentional control settings towards items not related to their pathology (Schoenmakers, Wiers, Jones, Bruce & Jansen, 2007). This is particularly evident in Experiment 3, wherein participants were unable to remove their attentional control settings towards green items after being informed that they should now be favouring blue items. The fact that the initial green bias persists after the second competing blue bias has been induced speaks to the strength of the initial altered settings. However, since we do not directly analyse any psychopathological sub-groups, these links are currently only speculative. Future studies could investigate this further, as this goes beyond the scope of the current series of experiments.

Our control experiment wherein participants were provided with only a neutral information sheet before carrying out the initial change detection task provides further insight. In Session 1 of all experiments, participants are biased via an information sheet, and then the usefulness of attending to green items is reinforced due to the ratio of Congruent Change trials. It could be argued that the persistence of the bias stems from a combination of the information sheet and the effectiveness of attending to green. However, just a utility of attending to green items is not sufficient to alter attentional control settings – a biasing information sheet is also required in order for an attentional bias to form. Thus, an attentional bias towards green was not implicitly formed via a probability-

based training mechanism or from participants learning that attending to green items in Session 1 gives them an advantage in the task. Moreover, in Experiment 3 an attentional bias towards blue items is not implicitly reinforced via the ratio of Blue Congruent Change trials, and yet participants display an immediate alteration of attentional control settings favouring blue items which does not diminish across five blocks of experimental trials. It is also unlikely that our findings are due to participants holding green (or indeed blue) items in working memory, since biasing effects for both the colour and shape tasks were still present two weeks after initial biasing, whereas in order for working memory to have an effect on attention, the active maintenance of stimuli is necessary (Downing & Dodds, 2004; Soto and Humphreys 2006) which is not a requirement of the current experiments.

While working memory representations are unlikely to account for our findings, it is possible that participants' attentional control settings were cued by the context in which they received the initial task instructions, and then reactivated when they returned for their second experimental session. Support from this view stems from a study in which participants were trained to use either Singleton Detection or Feature Search Mode within one training session, but in separate blocks on separate, irrelevant contextual backgrounds. In the test phase it was found that the search mode employed in ambiguous blocks (wherein either mode could be used) was determined by the irrelevant background on which the trails were presented (Cosman and Vecera 2013). This suggests that automatic responses to a task may depend on long-term memory representations (Carlisle et al., 2011) that are cued by the initial context in which a task takes place.

In our experiments, participants returned to the same lab for their second experimental session. This may have acted as a cue, which reactivated the attentional control settings favouring green items. If so, this builds upon Cosman & Vecera's initial findings and suggests that contextual long-term memory cues can also aid in feature-specific adoptions of Feature Search Mode. This is particularly evident in Experiment 3 where participants were given explicit instructions to adopt a new Feature Search Mode for blue objects within the same experimental context. This should have resulted in a

switching of Feature Search Mode from favouring green to blue objects, with representations of blue objects also present in working memory (Logan, 2002). Instead, we found that attention was biased towards both irrelevant green and blue items, with both distracting when present in isolation and even more so when present simultaneously. This suggests that active working memory representations cannot fully override long-term alterations of the attentional set when a feature-specific form of Feature Search Mode has been adopted. This also offers as explanation of the sustainability of attentional biases in the addiction literature (Schoenmakers et al., 2007; Field et al., 2007). Addicts may be trapped in a situation where their attentional control settings are permanently cued towards a feature-specific Feature Search Mode that selects items via long-term memory representations (Janes et al., 2010). However again, this link to the abnormal literature is only tenuous and needs to be substantiated by formal investigation.

It must be noted that reward may play a role in the current experiments. Additional processing involving the mesolimbic dopamine reward system is thought to play an integral role in addiction-related attentional biases (Robinson & Berridge, 1993; Franken, 2003; Franken, Booij & van den Brink, 2005). Similarly, it has been found that previously rewarding stimuli can reflexively capture attention when contextually irrelevant to a task (Anderson, Laurent & Yantis, 2011a;b), and that attentional capture by rewarding stimuli results in altered electrophysiological signatures of attentional selection (Kiss, Driver & Eimer, 2009). This value-driven capture may develop via associative learning and has been likened to the way that irrelevant drug-related stimuli bias the attention of addicts (Anderson, Laurent & Yantis, 2011a). In Session 1 of all experiments in the current study, participants could have been arbitrarily rewarded via improved accuracy in Congruent Change trials – especially considering the ratio of trial types. This subjective 'reward' may have reinforced the relevance of green items causing them to continuously capture attention when task-irrelevant. However, value-driven capture is extinguished over many trials when consistently task-irrelevant (Anderson, Laurent & Yantis, 2011b). This, combined with our findings on the sustainability

and persistence of the green bias suggest that reward-based training has not occurred. Nevertheless, the importance of reward in addiction-related attentional biases warrants further investigation.

What is unclear in the current study is the extent to which an induced attentional bias can transfer to other tasks. An attentional bias towards a colour assessed in a change detection task was found to transfer to other stimulus properties; however this was only examined using additional change detection tasks. Thus, induced attentional biases are robust, but it is unknown if they transfer to non-change-detection tasks. It would therefore be of great interest to examine if an induced attentional bias initially examined via a change detection task can transfer to tasks such as a feature visual search, or can alter inhibition of return.

In summary, a single information sheet was found to induce a stimulus-specific Feature Search Mode for the colour green in healthy participants. This is synonymous with inducing a robust attentional bias towards green items. The bias was found to affect early perceptual sensitivity, which effected accuracy. This induced attentional bias was also found to persist outside the immediate testing situation – even when explicitly task-irrelevant – and did not diminish when a second competing bias was induced. To the authors' knowledge, this is the first time that such an immediate adoption of a robust bias that effects behaviour in different settings a further two weeks later has occurred. We posit that this induced attentional bias is mediated by a chronic change to attentional control settings, involving long-term contextual learning. Similar changes to attentional control settings may be a common factor in attentional biases observed in psychopathologies. Targeting these settings may therefore be a productive approach to treatment.

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Tables

Table 1

Mean hit rate in Experiment 1 across all types of trial and mean correct rejection/false-alarm rates for no-change trial when a green stimulus was either present or absent

Trial Type	*Hit Rate*	*Correct rejection*	*False-alarm*

		rate	*rate*
Congruent Change	87.09	90.72	9.28
Incongruent Change	66.22	90.72	9.28
Neutral Change	72.65	93.30	6.70

Table 2

Mean hit rate in Experiment 2 across both types of change trial and mean correct rejection/false-alarm rates for no-change trial when a green stimulus was either present or absent

Bias Type	*Hit Rate*	*Correct rejection*	*False-alarm*

		rate	*rate*
Green Present	59.29	88.32	11.68
Green Absent	72.54	84.46	15.54

Table 3

Mean hit rate in the Control Experiment across all types of trial and mean correct rejection/false-alarm rates for no-change trial when a green stimulus was either present or absent

Trial Type	*Hit Rate*	*Correct rejection rate*	*False-alarm rate*
Congruent Change	71.56	91.33	8.67
Incongruent Change	70.44	91.33	8.67
Neutral Change	73.77	93.54	6.46

Table 4

Mean hit rate in Experiment 3 across all types of trial and mean correct rejection/false-alarm rates for no-change trial when a blue and/or green stimulus was either present or absent

Trial Type	*Hit Rate*	*Correct rejection rate*	*False-alarm rate*
Blue Congruent Change	86.7	89.48	10.52
Green Congruent Change	86.08	88.82	11.18
Blue Incongruent Change	73.68	89.48	10.52
Green Incongruent Change	72.33	88.82	11.18
Both Incongruent Change	56.48	93.26	6.74
Neutral Change	88.73	91.71	8.29

Figure Captions

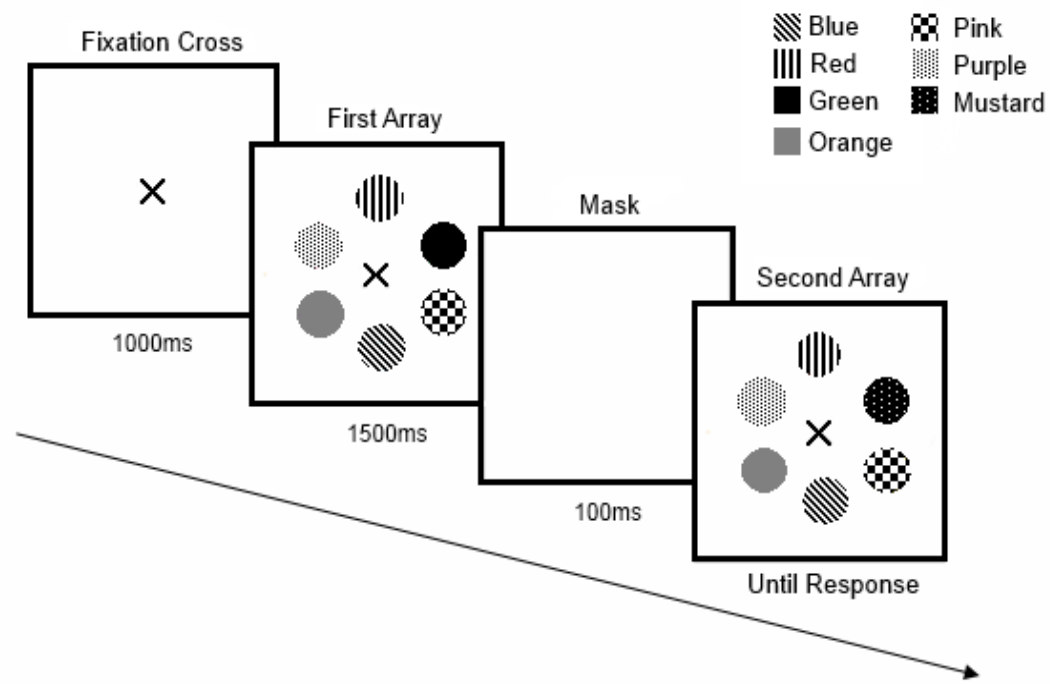

Fig 1: Procedure of Experiment 1. A fixation cross was presented for 1000ms, followed the first array for 1500ms. This was then masked for 100ms before reappearing, where participants had to make their response using the index finger of each hand.

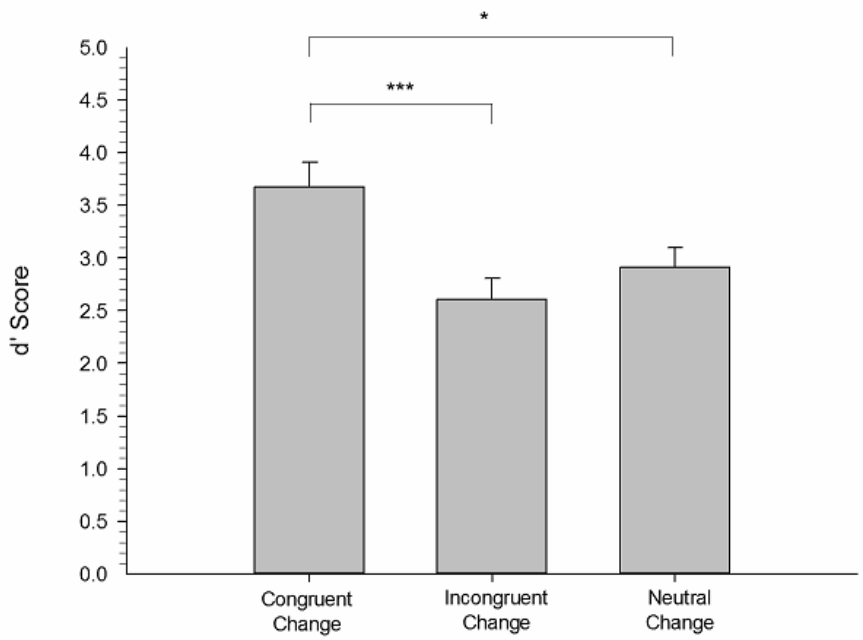

Fig. 2: Effect of induced attentional bias on d' in a change detection task. Higher d' indicates greater sensitivity to change. Sensitivity is higher in Congruent Change trials than both Incongruent and Neutral change trials. This difference is larger in Congruent compared to Incongruent Change trials, thus attention is captured by a biased stimulus, and it also distracts from detecting other changes. Error bars show standard error of the mean. *Note:* * p<.05, *** p<.001

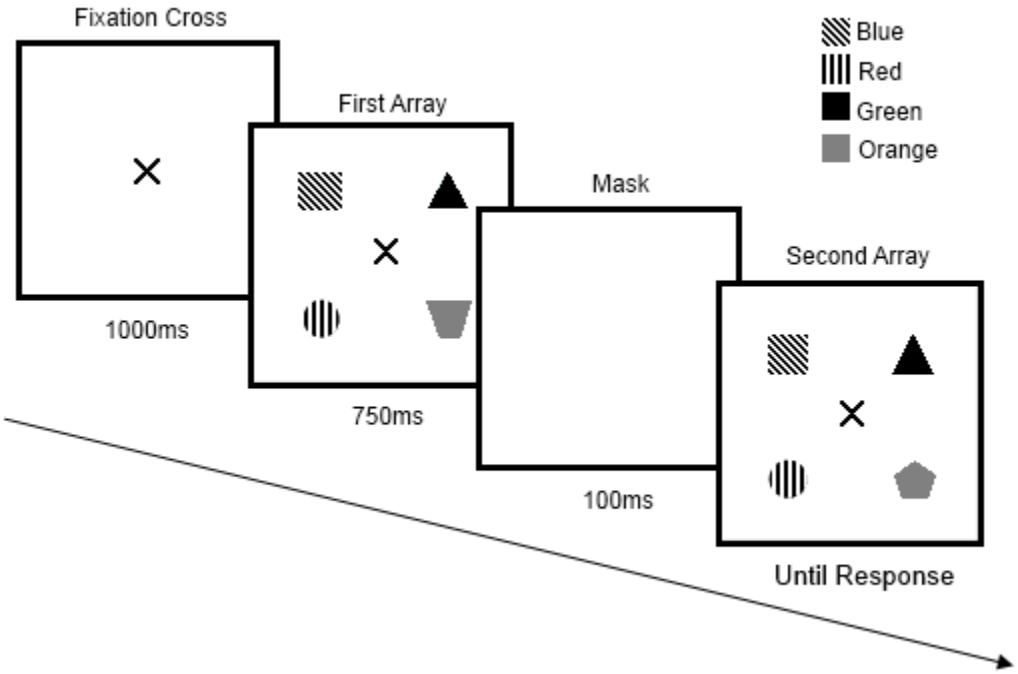

Fig. 3: Procedure of Experiment 2. A fixation cross was presented for 1000ms, followed the first array for 750ms. This was then masked for 100ms before reappearing, where participants had to make their response, using the index finger of each hand.

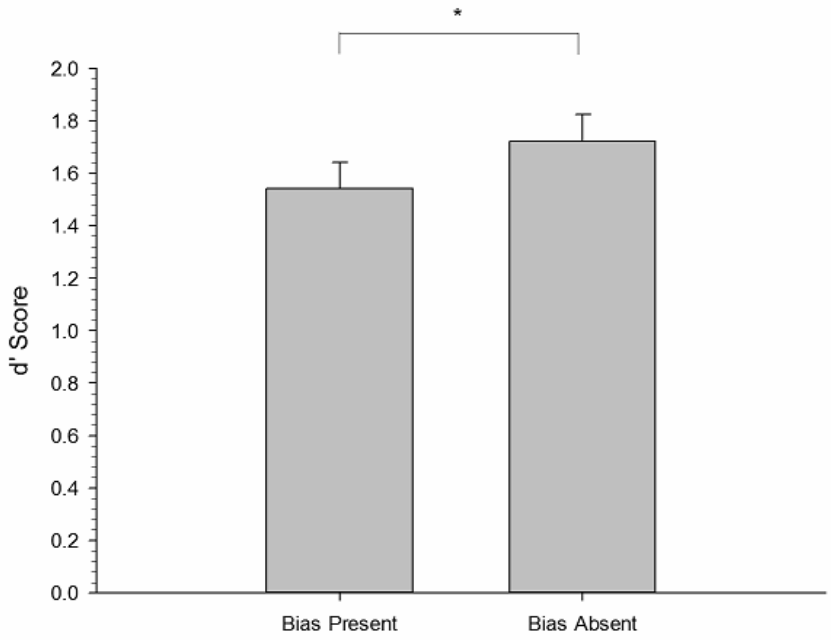

Fig. 4: Effect of the presence of a biased stimulus (a green shape) on d' when colour is task-irrelevant. Higher d' indicates greater sensitivity to change. Participants are distracted from detecting other changes when a green stimulus is also present. Error bars show standard error of the mean. *Note:* * p<.05

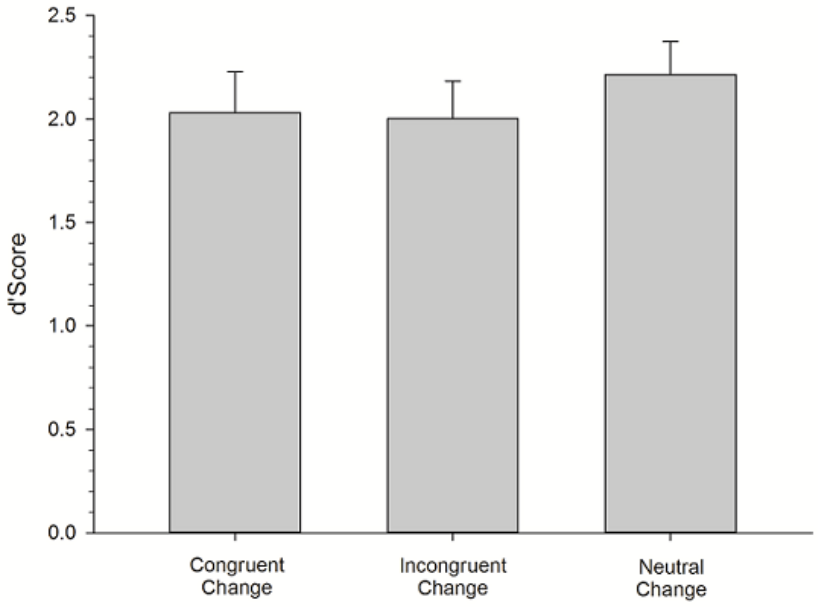

Fig. 5: Effect of the presence of a green stimulus on d' when no biasing information sheet has been presented to participants before the experiment.

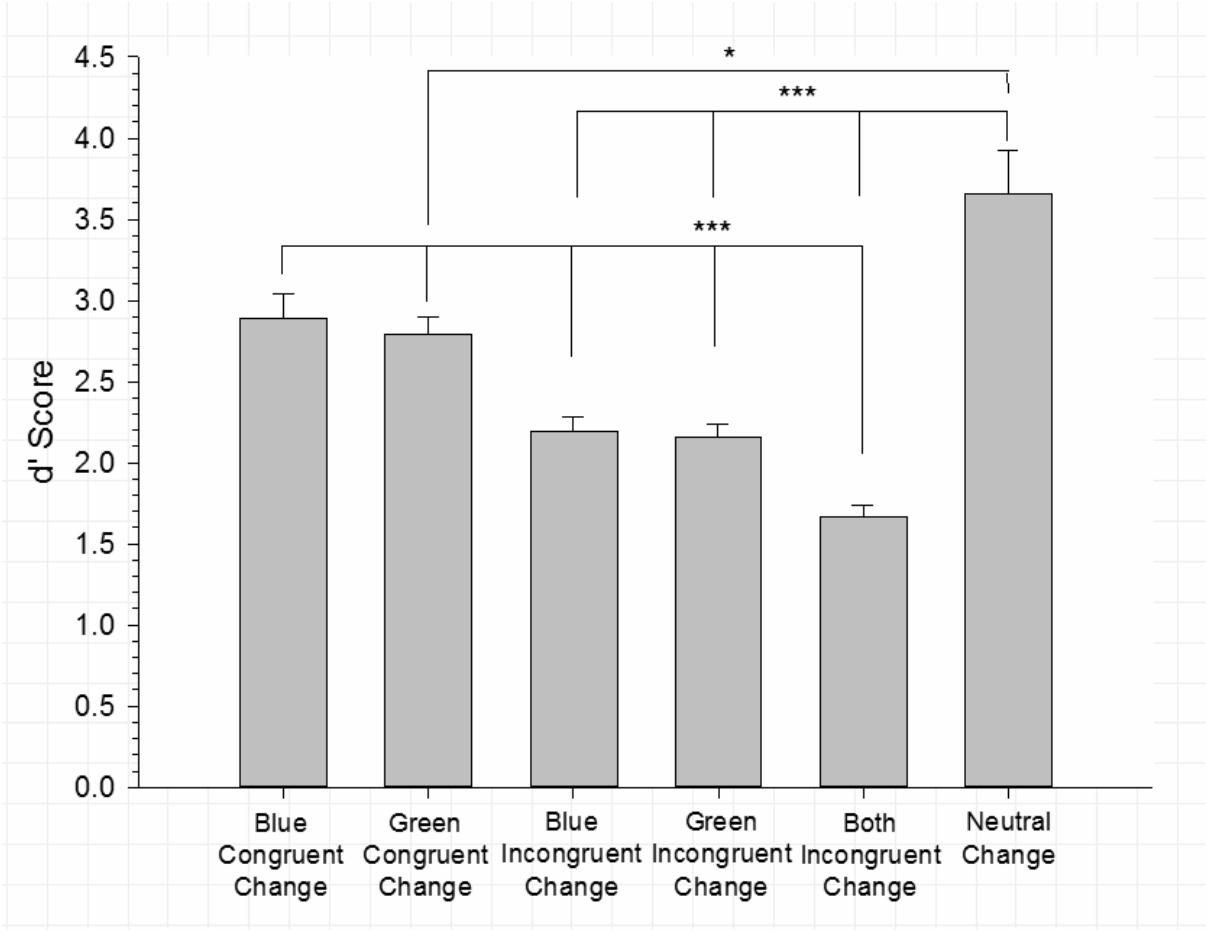

Fig. 6: Effect of the presence of a single blue, single green, or both blue and green stimulus on d' following an initial attentional bias towards green and a secondary attentional bias towards blue. Higher d' indicates greater sensitivity to change. Participants are distracted from detecting other changes when a blue or green stimulus is also present. This pattern is more extreme when both a blue and green stimulus are present. Error bars show standard error of the mean. *Note:* * p<.05, *** p<.001