Adults with dyslexia can use cues to orient and constrain attention but have a smaller and weaker attention spotlight

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Abstract

We report results from two experiments assessing distribution of attention and cue use in adults with dyslexia (AwD) and in a group of typically reading controls. Experiment 1 showed normal effects of cueing in AwD, with faster responses when probes were presented within a cued area and normal effects of eccentricity and stimulus onset asynchrony (SOA). In addition, AwD showed stronger benefits of a longer SOA when they had to move attention farther, and stronger effects of inclusion on the left, suggesting that cueing is particularly important in more difficult conditions. Experiment 2 tested the use of cues in a texture detection task involving a wider range of eccentricities and a shorter SOA. In this paradigm, focused attention at the central location is actually detrimental and cueing further reduces performance. Thus, if AwD have a more distributed attention, they should show a reduced performance drop at central locations and, if they do not use cues, they should show less negative effects of cueing. In contrast, AwD showed a larger drop and a positive effect of cueing. These results are better accounted for by a smaller and weaker spotlight of attention. Performance does not decrease at central locations because the attentional spotlight is already deployed with maximum intensity which cannot be further enhanced at central locations. Instead, use of cueing helps to focus limited resources. Cues orient attention to the right area without enhancing it to the point where this is detrimental for texture detection. Implications for reading are discussed.

KEYWORDS: visual attention; developmental dyslexia; texture segmentation; cueing; reading

An increasing body of research supports the idea that visual attention differences may play a key role in dyslexia. For example, it has been suggested that children with dyslexia (CwD) have a different distribution of attention across the visual fields (e.g. Facoetti, Paganoni & Lorusso, 2000a), that they have a narrower visual attentional window or weaker attentional spotlight (Bosse, Tainturier & Valdois, 2007; Romani, Tsouknida, di Betta, & Olson, 2011), that they have difficulty orienting to cues (e.g. Facoetti, Paganoni, Turatto, Marzola & Mascetti, 2000b) and more generally in shifting attention (e.g. sluggish attentional shifting, Hari & Renvall, 2001). People with dyslexia have also been reported to suffer to a greater extent than controls from visual crowding effects (e.g. Bouma & Legein, 1977; Martelli, Di Filippo, Spinelli & Zoccolotti, 2009; Pernet, Valdois, Celsis & Démonet, 2006) and from difficulties excluding distracting stimuli (e.g. Sperling, Lu, Manis & Seidenberg, 2005 and 2006; Moores, Cassim & Talcott, 2011; Cassim, Talcott & Moores, 2014). Still, other research – albeit on partially compensated adults with dyslexia - has suggested no attention deficit (e.g. Judge, Caravolas & Knox, 2007) or no deficit in ability to orient to cues (e.g. Moores *et al.* 2011). The purpose of the present study is to contribute to the current debate on attentional deficits in dyslexia by assessing the performance of groups of AwD in tasks where cues can be used to allocate attention to a given area, orient attention and/or restrict the focus of attention.

The distribution of attention in relation to cueing has been investigated in a series of experiments by Facoetti and colleagues. These experiments used a relatively simple paradigm in which the children had to respond (by pressing the space bar on the computer keyboard as quickly as possible) to a white dot appearing on the screen at different eccentricities subsequent to the presentation of a central circular cue. Facoetti *et al.* (2000a) incorporated two of the three possible locations of the target (and two thirds of the trials) within this circular cue. The control children responded fastest when the dot appeared at central locations, but speed decreased with increasing eccentricity. In contrast, the CwD showed a flatter profile of reaction times across the different eccentricities, suggesting a more distributed focus of attention. Facoetti and Molteni (2001a) replicated the original findings using a similar probe detection paradigm (only one of the three possible probe locations --but 70% of the trials-- fell within the cue), although the flatter profile in CwD was present only in the right visual field. On the left, CwD showed a normal profile although they were slower than the controls. Facoetti and Molteni (2001a) suggested a general inattention disorder to explain the slower responses, but a more diffuse attentional focus on the right to explain the lack of a performance gradient across eccentricities. A more diffuse attentional focus would explain the flatter gradient because it would be more hurtful at central locations than at peripheral locations where attention is diffuse anyway. However, in both experiments the factor of eccentricity was confounded with the location of the probe relative to the cue because probes at further eccentricities tended to be outside of the circular cue. Thus, results could have different explanations. One could hypothesise a difficulty in using cues rather than a more distributed focus of attention. If CwD do not use cues as efficiently as controls, having the probe outside of the cue circle (at more peripheral locations) will not be as detrimental. A flatter gradient could also have an alternative explanation and be the consequence of generally reduced attentional resources so that to cover a large enough area dyslexics have to weaken the focus at central locations.

Another set of experiments by Facoetti and colleagues specifically investigated the ability to focus attention on a cue. Facoetti, Paganoni, Turatto, Marzola & Mascetti, (2000b) used circular cues that were either large (7.5 degrees) or small (2.5 degrees). Small target probes were presented within the cued area and participants were asked to detect them as quickly as possible and press the spacebar. As expected, overall reaction times were fastest when the cued area was small and at the longest stimulus onset asynchronies (SOAs) which allowed more time to prepare. CwD differed from controls because they showed an effect of size of circle only at the shorter SOAs (while controls showed an effect at both long and short SOAs). It was suggested that this indicated a deficit in maintaining attention for longer periods. However, in a following study using a similar paradigm – except that an orientation judgement of the probe was required - Facoetti, Lorusso, Paganoni, Cattaneo, Galli & Mascetti (2003) reported an effect of cue size in CwD only at *longer* SOAs, consistent with the idea of sluggish attentional capture (Hari & Renvall, 2001). These results are susceptible to different interpretations. They could be interpreted as showing a difficulty in using cues, but the variability across experiments is also consistent with generally reduced attentional resources which allow cues to be best exploited only in certain conditions. Sometimes CwD have difficulty sustaining attention to the proper cued areas (and therefore show effects of cue-size only at short SOAs), other times they are slower in adjusting attention to the proper cued area (so that the effect is only shown at the longer SOAs). Note, however, an effect of cue-size is always demonstrated, albeit with a different time course.

In addition to evidence suggesting more diffuse attention distribution and less effective use of size cues in dyslexia, other research suggests a difficulty orienting to cues. Brannan and Williams (1987) found differences between adults and children with good or poor reading skills on Posner's spatial cueing task (Posner, 1980), but only at very rapid SOAs. Participants had to detect a target presented in either the left or the right visual field as quickly as possible. Prior to the presentation of the target, a cue appeared. The cues could be valid (i.e. correctly indicating the target location), invalid, or neutral (providing no spatial information about the target location). Valid cues should decrease and invalid cues increase reaction times, but Brannan and Williams found that poor readers showed little benefit from cues. Similarly, Facoetti *et al*. (2000b) found that CwD did not show the expected validity effect for automatic orienting of attention on a similar reaction time task, but again SOAs were very short (136ms and 238ms) so that the lack of cueing effects could derive from people with dyslexia being slower in processing the cue, having difficulties in shifting attention or - as we will argue in this study - more generally, from having reduced attentional resources. If fewer attentional resources are available to start with, depending on condition, it may take more time to use cues to focus them. Other studies, in fact, have shown no differences in the distribution of attention and/or in the ability to use cues in developmental dyslexia. Judge *et al.* (2007) found no difference between adults with dyslexia (AwD) and controls in key press latencies to stimuli presented at different eccentricities in left and right visual fields either within a cue circle (3º eccentricity) or outside of a cue circle (6º and 9º eccentricity)[1]. Moores *et al*. (2011) assessed effects of cueing on accuracy of performance in a rapidly presented visual search task in which target orientation had to be discriminated and found that AwD, not only *did* use cues, but they were more dependent on them than controls for good discrimination.

Taken together these results suggest that AwD may not have a difficulty in using cues or a different distribution of attention *per se*, but rather have a less powerful spotlight of attention so that attention must be more thinly allocated to cover a given area, with effective deployment of resources taking longer. There is evidence that attention orientation and attention focussing are independent components (e.g. Posner and Boies, 1971) and that attention can be split across different locations (e.g. Castiello and Umiltà, 1992). A weaker spotlight is able to account for difficulties in visual search tasks (e.g. Iles, Walsh & Richardson, 2000; Moores *et al.* 2011; Sireteanu, Goebel, Goertz, Werner, Nalewajko & Thiel, 2008) as well as difficulties commonly seen in tasks involving processing of serial

[1] Judge *et al.* (2007) noted that with their paradigm the effect of cueing appeared stronger than the effect of eccentricity. There were no differences in reaction times to targets presented at 6º and 9º eccentricity (both outside the cue circle), but responses were faster within the cue circle (3º).

arrays because a weaker spotlight will be more difficult to split to different locations (see e.g. Bosse, *et al.* 2007; Hawelka & Wimmer, 2005; Romani *et al*., 2011). According to this view, a lack of cueing effects in dyslexia will emerge only in special conditions and as a consequence of more general difficulties in allocating attention.

Different views of the attentional difficulties in dyslexia make different empirical predictions that we want to assess in the present study. A more diffuse attentional focus implies that although the total amount of attentional resources is similar in individuals with dyslexia and controls, attention is spread over an area larger than optimal in the dyslexic group so that there is an inability to restrict and concentrate attention using cues. Instead, the hypothesis of a weaker spotlight, assumes fewer attentional resources so that attention is *either* spread more thinly than optimal *and/or* covers a more restricted area. In this situation, cueing generally should be helpful - in fact, even more helpful than in controls -because it directs limited resources.

In our study, we will investigate the use of cues in AwD with two separate experiments. In the first experiment, we will investigate the ability to: a) concentrate attention to a circumscribed area (size of cued area); b) distribute attention within a cued area (eccentricity of probe within cued area); c) limit attention to the cued area (inclusion of probe inside vs. outside of cue circle). In the second experiment, we will investigate possible interactions between directing and narrowing attention using location cues. Directing attention to a location generally means a narrowing of the attentional focus. This narrowing, however, is not always beneficial. For example, a focus which is too narrow becomes detrimental when trying to detect a difference in texture (e.g. when the stimulus to be detected is at fixation; see Yeshurun & Carrasco, 1998). If AwD have a wider, more distributed focus of attention, they should be less sensitive to the possible drawbacks of a narrow attentional focus. Instead, if the dyslexic difficulties lie in a less powerful attentional spotlight, we expect them to suffer from the negative effects of a narrow focus of attention as much as the controls (worse performance at central location), but also to benefit as much, if not more, from cueing. Experiment 2 will assess these predictions using a texture detection paradigm.

1. Experiment 1

Experiment 1 adapted elements of the paradigms from Facoetti *et al.* (2000b; 2001a; 2001b; 2003) to examine AwD ability to adjust the size of attentional focus. Probe eccentricity and inclusion of a probe inside vs. outside a centrally presented circular cue were varied systematically (see Figure 1 for a schematic representation of the different conditions created by this experimental design). We assessed AwD and controls' speed to discriminate probes presented in different conditions. We investigated: (i) an effect of *size* of the cue, controlling for eccentricity; this was done by contrasting a location inside a small circle vs. the same location inside a large circle (see Figure 1 panels a & b as well as c & d); (ii) an effect of *probe eccentricity* within a cued area; this was done by contrasting probes presented at near vs. far locations within a large circle (see Figure 1 panels e & f); (iii) an effect of *inclusion of the* probe in the cue circle, controlling for eccentricity; by contrasting the location of a probe *relative* to a cueing circle - inside a large circle vs. outside of a small circle (see Figure 1 panels g & h). An effect of *size* taps the ability to limit attention within a specified area; the effect of *inclusion* provides a second measure of the ability of concentrating resources within an area, and probe *eccentricity* provides a measure of attention distribution within a specified area. For completeness, we also analysed the effect of circle size on probes falling outside of cued areas.

INSERT FIGURE 1 ABOUT HERE

1.2 Method

1.2.1. Participants. 28 controls (7 male) and 14 AwD (6 male) were included in this study[2]. A further 3 control participants were tested but omitted because of very poor accuracy on the task, suggesting chance or below chance performance. Mean psychometric data for the two groups of participants are presented in Table 1. IQ was estimated using the Wechsler Adult Intelligence Scale – Third UK edition (Wechsler, 1999a) or the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999b - for control participants). The Wechsler Individual Achievement Test-II (Wechsler, 2005) was administered to measure reading and spelling achievement. All the members of the AwD group had both a formal diagnosis of dyslexia (from an appropriately qualified psychologist) and enduring relative literacy difficulties (either WIAT-II reading or WIAT-II spelling performance significantly below their WAIS-III IQ (using the predicted difference method and norms). AwD were therefore impaired in reading relative to their IQ and not necessarily in absolute terms. In order to avoid practice effects, where a WAIS-III IQ estimate was already available (e.g. from a psychological assessment report for dyslexia) this measure was used rather than the tests being re-administered. WIAT-II reading and spelling were administered at the time of testing unless recent scores were available (less than 12 months prior to testing). Control participants reported no difficulties with reading or spelling either currently or historically and had neither spelling nor reading accuracy significantly below that predicted by their IQ. All either were or had been students at Aston University. Groups did not differ in terms of WAIS - IQ (t=.55, df=40) or age (t=.20, df=40). Groups did differ in terms of WIAT-II reading (t=3.21, df=40, $p<.01$) and spelling (t=2.52, df=40, $p<.05$).

[2]The male:female ratio is somewhat different from the more typical 3:1 ratio that you might expect in a sample of people with dyslexia. This is most likely because many were psychology students or were sources via psychology students (who in the UK tend to be predominantly female).

INSERT TABLE 1 ABOUT HERE

1**.2.2 Design and procedure**. A white fixation cross was presented in the centre of the black screen for 1000ms. This was followed by a white line circle - always presented centrally - which could either be large (35% of the time: 4º of visual angle) or small (65% of the time: 1.4º of visual angle). The circle appeared for either 100ms or 800ms (with equal probability) before being joined by a stimulus probe. The stimulus probe was either a filled white circle or a circular outline with a black centre (with equal probability) and appeared on either the left or the right hand side of the screen (with equal probability) at one of three possible eccentricities (near: 0.7º, far: 2.7º, very far: 5.7º of visual angle). Participants had to respond to the probe as quickly as possible by pressing the z key (black centre) or the m key (white centre). Participants had a maximum of 2000ms to respond before the next trial was presented. The independent variables were therefore: *group* (AwD/ control), *circle size* (small/ large), *probe eccentricity* (near/ far/ very far), *side* (left/right) and *SOA* between presentation of the circle and appearance of the probe (short: 100ms/long: 800ms). The eccentricities of the probe positions were chosen to fall half way between the fixation point and the contour of the small circle and between the contour of the small circle and that of the large circle. The combination of the probe location and circle size also created a 'dummy' variable for analysis: *inclusion* (whether the stimulus fell inside vs. outside of the circle). The probabilities of the different conditions were calculated so that (as far as possible) the appearance of a large or small circle did not provide clues as to whether the probe was more or less likely to fall inside vs. outside of it (i.e. so that roughly 70% of probes fell inside either type of circle). This meant that in a block of 124 trials, 44 of the trials would contain the large circle, with 16 near, 16 far and 12 very far probes split equally between the *side* of presentation (left/right) and *SOA* (short/long). The other 80 trials would contain the small circle (with 56 near, 12 far and 12 very far probes split as before). The very far probes were not part of planned experimental contrasts since they were always outside the cue. Rather, their purpose was to ensure that the probability of a probe falling inside the cued area was equal for both small and large cued areas. The main dependent variable of interest was the speed of response to the stimulus since we expected accuracy to be close to ceiling.

The main experiment consisted of 2 blocks of 124 trials each. A practice period of 8 trials was also conducted but not analysed. Testing time was approximately ten minutes.

1.3. Results

1.3.1 Overall analyses. Mean reaction times and percentage error rates in the different conditions are shown in Figures 2 and 3. Error rates and reaction times generally did not suggest a speed accuracy trade off, but rather both reflected increased difficulty with the task (with one exception noted below). Mean overall accuracy was 97% in controls and 93% in AwD ($t=2.53$, $p<.05$).

INSERT FIGURES 2 and 3 ABOUT HERE

First, we conducted two ANOVAs on RTs and errors to assess the effects of *group* (AwD/ control), *side* (left/right), *circle size* (large/ small), *eccentricity* (near/ far/ very far) and *SOA* (short: 100ms/ long: 800ms) on RTs to probes. A main effect of ***eccentricity*** was shown both with RTs and errors (RTs: $F_{2,80}$=83.56, $p<.001$, η^2_p =.68; errors: $F_{2,80}$ =12.43, $p<.001$, η^2_p =.24). The near probes were faster and more accurate than the far probes and the far probes were faster and more accurate than the very far probes. In addition, with accuracy there were main effects of of ***SOA*** ($F_{1,40}$=5.05, $p<.05$, η^2_p =.11), ***side*** ($F_{1,40}$=9.46, $p<.01$, η^2_p

=.19), and ***group*** ($F_{1,40}$=5.27, $p<.05$, η^2_p =.12) showing more accurate performance with longer SOAs, on the left, and in controls. There were also a number of significant interactions.

In terms of RTs, there were two significant interactions (see Figure 2): 1. ***circle size x eccentricity*** ($F_{2,80}$=9.12, $p<.001$, η^2_p =.19; see Figure 2a and b), showing that whereas the smaller circle produced faster RTs for near probes, the larger circle produced a flatter profile with less peaked effects of eccentricity. This is partly an inclusion effect (explored more below) since the small circle only included the probe at the near location, thus enhancing the eccentricity effect. 2. ***side x eccentricity x group*** ($F_{2,80}$=3.74, $p<.05$ η^2_p =.09: see Figure 2) because at very far eccentricities AwD were similar to controls on the right, but slower on the left (but note opposite effects in terms of accuracy) – these effects are explored further below. In terms of accuracy, there was one significant interaction: ***side x circle size x group*** ($F_{1,40}$=5.36, $p<.05$, η^2_p =.12; see Figure 2a and 2b) because with the small circle AwD made more errors on the left, while with the larger circle they made more errors on the right. This may be due to the fact that AwD restrict attention well within a small cue - increasing extant difficulties on the left. In contrast, with the large circle attention cannot be properly distributed across the whole circle area. We speculate that this may make detection on the right more difficult, because a left to right scanning strategy focuses attention more on the left than on the right.

We carried out further more restricted ANOVAs to more directly assess the effects of our experimental variables and interactions found in the larger ANOVAs 1. size of cued area (large vs. small circle), 2. eccentricity within cued area (near vs. far from centre) and 3. inclusion in cued area (inside vs. outside of circle) and possible interactions with *group*, *SOA* and *side*.

1.3.2. Size of cued area - narrowing attention. We carried out an ANOVA assessing effects of *circle size* on the near eccentricity probe only, since only at these locations the probe was always inside the circle, thus allowing comparison of circle size in identical inclusion and eccentricity conditions (see Figure 1a & 1b). With RTs, there was a main effect of *circle size* ($F_{1,40}$=22.92, p<.001, η^2_p =.36; see Figure 2a and 2b) with faster RTs for the small circle, but there was a speed-accuracy trade off and accuracy was better for the large circle ($F_{1,40}$=9.58, $p<.05$, η^2_p =.19: 96.5% vs. 95.2%). With accuracy, there was also a ***circle size x SOA x side*** interaction ($F_{1,40}$=10.42, $p<.01$, η^2_p =.21), but the significance of this is unclear. There were no other main effects or interactions involving circle size.[3] With a further ANOVA, we analysed the effect of *circle size* for the very far eccentricity probes, where the probe was always outside the circle (Figure 1c & 1d). There were no effects involving circle size.[4]

Conclusion: There are no consistent effects of circle size in the controlled comparisons. In the general ANOVA there was a ***circle size x eccentricity*** interaction for RT. As discussed, this is due to the fact that the small circle enhances eccentricity effects because it only contains the probe at the near locations. However, in the general ANOVA there was also a ***side x circle size x group*** interaction for accuracy, because AwD showed worse performance with the large circle on the right. This suggests that circle size has some effects in modulating attention in the AwD.

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[3] Another significant effect at the near eccentricities with accuracy was an ***SOA x group*** interaction ($F_{1,40}$=4.92, $p<.05$, η^2_p =.11) because groups performed similarly at longer SOAs but the AwD were less accurate at short SOAs (see Figure 2c & 2d).

[4] Other significant effects at the very far eccentricities were; 1. With RTs, a marginal ***side x group*** interaction ($F_{1,40}$=4.02, p=.052, η^2_p =.09) because whereas controls were faster on the left compared to the right, AwD were slower - as already discussed; 2. with accuracy, a main effect of ***group*** ($F_{1,40}$=5.36, $p<.05$, η^2_p =.12) and marginal effect of ***SOA*** ($F_{1,40}$=4.06, $p=.051$, η^2_p =.09).

1.3.3. Eccentricity - distribution of attention. We carried out an ANOVA assessing the effect of *eccentricity* just on probes falling *inside* the large circle, again to control for inclusion condition (see Figure 1e & 1f and for results Figure 3a & 3b). There was a significant main effect of *eccentricity* both for RTs and errors (RTs: $F_{1,40}$=24.27, $p<.001$, η^2_p =.38; errors: $F_{1,40}$=15.46, $p<.001$, η^2_p =.28), with faster and more accurate responses to near than far probes. There was also a significant ***eccentricity x SOA x group*** interaction for RTs ($F_{1,40}$=4.38, $p<.05$, η^2_p =.10). This is because AwD were slower than the controls at further locations with the shorter SOA, but not the long SOA. With accuracy, a significant ***eccentricity x side x group*** interaction also emerged ($F_{1,40}$=4.31, $p<.05$, η^2_p =.10); showing the largest divergence of group at far right locations. There were no other significant effects involving eccentricity.[5]

Conclusion. Our results show similar effects of eccentricity in AwD and controls. The task was harder at far eccentricities for both groups. Presenting the probe at far eccentricities allows effects of group to emerge in terms of SOA and side. This is not surprising. The task is more difficult at far eccentricities, short SOA and on the right, and these are the conditions where AwD differ from controls. However, the overall profile of the distribution of attention is strikingly similar in the two groups.

1.3.4. Inclusion – effect of cueing area. We carried out an ANOVA assessing effects of *inclusion,* on the far eccentricity probes only, by comparing a condition with the probe outside a small circle vs. a condition with the probe inside a large circle, with both conditions at the same distance from central fixation (far eccentricity; see Figure 1g & 1h and for results

[5] Considering only the large circle, RTs showed a significant ***side x group*** effect ($F_{1,40}$=4.14, $p<.05$, η^2_p =.09) with similar performance of groups on the left, but AwD slower on the right; accuracy showed significant effects of ***side*** ($F_{1,40}$=8.88, $p<.01$, η^2_p =.18), with more accurate performance on the left and ***side x group*** ($F_{1,40}$=9.34, $p<.01$, η^2_p =.19) with controls being equally accurate across visual fields, but AwD less accurate on the right. These patterns have already been noted in the general ANOVAs.

Figure 3). There was a significant main effect of ***inclusion*** ($F_{1,40}$=7.36, $p<.01$, η^2_p =.16), with faster RTs to probes included in the circle. There were also significant interactions ***inclusion x side*** for RTs ($F_{1,40}$=8.74, $p<.01$, η^2_p =.18) -- inclusion had a positive effect on the left but not on the right —and ***inclusion x side x group*** for both RTs and errors which, however, went in opposite directions (RTs: $F_{1,40}$=6.07, $p<.05$, η^2_p =.13; Errors: $F_{1,40}$=10.10, p<.01, η^2_p =.20). With RTs, inclusion was most beneficial on the left and that this effect was largest in AwD. With errors, the AwD showed no interaction, while the controls showed the opposite effect with better accuracy with *excluded* probes on the left ($F_{1,27}$=8.76, p<.01, η^2_p =.25).[6]

Conclusion. Our results show an overall effect of inclusion which is stronger on the left in the AwD, but not clearly modulated by side in the controls where there are speed-accuracy trade-offs. It is possible that AwD show stronger effects of cues on the left because it is on the left that allocation of attention is more difficult. This interpretation, however, is weakened by no overall effect of side in AwD. Besides these interactions with side (the explanation for which is not totally clear) these results show clear effects of cueing in terms of probe inclusion in both AwD and controls.

1.4 Discussion

Experiment 1 showed that: (i) AwD were less accurate overall; but (ii) AwD and controls had similar RTs; (iii) our experimental manipulations were generally effective with significant effects of *SOA*, *eccentricity*, and *inclusion* of probe in cued area; (iv) AwD and controls showed a similar advantage when they had more time to use the cue information (similar effects of SOA); (v) AwD and controls distributed attention similarly (similar effect of eccentricity) and (vi) benefitted similarly from using the cue to restrict attention (similar effects of inclusion). Interactions between group and side were inconsistent across

[6] There was also a significant effects of ***group*** ($F_{1,40}$=4.06, p<.05, η^2_p =.09) with controls being more accurate than AwD.

conditions, but there was an indication that a longer SOA was more important for the AwD at far eccentricities when they needed more time to focus attention and that effects of inclusion were stronger on the left in the AwD.

Overall, our results are consistent with the hypothesis that AwD are slower in deploying and focusing attention. General difficulties with choice reaction times may partially account for the overall effect of shorter reaction times in people with dyslexia (see e.g. Nicolson and Fawcett, 1994), but attentional difficulties are more likely to explain interactions with SOA and probe inclusion. Crucially for our purposes, however, AwD showed a very similar use of cues to the control participants, with better performance when the probe was inside the cue.

Our eccentricity findings contrast with those of Facoetti and colleagues (Facoetti & Molteni, 2001a). They found that in dyslexic children, eccentricity effects were only present on the left, with a flatter gradient on the right. In contrast, we found equally strong effects of eccentricities in both visual fields and in both groups. However, we did observe decreased inclusion effects and slower overall performance on the right in AwD (see 1.3.4). It is possible, therefore, that these discrepant results can be accounted for in terms of cue use. In Facoetti and Molteni (2001a), the further probe fell outside the cue area, so the flatter gradient on the right could reflect decreased use of cues in this field. Interpretation of these results is not straightforward, but it is possible that weaker attentional resources on the left allow more scope for benefits of cueing (see also Hari, Renvall & Tanskanen, 2001; Facoetti, *et al.*, 2001a; Waldie & Hausmann, 2010, Sireteanu, Goertz, Bachert & Wandert, 2005). It should also be noted that Facoetti and colleagues conducted experiments on Italian CwD, whereas our study was conducted on English AwD. Italian is a very 'transparent' language with consistent grapheme-to-phoneme mapping, whereas English is very 'opaque'. Thus, age differences and/or differences in severity and type of dyslexia may also account for some differences in results.

In Experiment 1, probes were only presented at three different eccentricities with the furthest location within a cued area at 2.7º eccentricity and with an SOA of 100ms in the short condition. These manipulations were strong enough to produce significant effects both in AwD and control participants. It is difficult, therefore, to argue that the lack of interactions is due to lack of sensitivity and that probes were not presented far enough or quickly enough to reveal differences. Nevertheless, Experiment 2 further investigated the distribution of attention in five different locations across the visual field with up to 10º eccentricity. It also investigated whether AwD were able to orient attention to the different locations using cues presented at an even shorter SOA (60ms). Finally, Experiment 2 targeted a group of AwD more severely impaired in reading and spelling than that used in Experiment 1, with the criterion of performance on spelling of words or nonwords of at least two standard deviations below the control mean. This allowed us to establish whether cues are also used by a more impaired group.

2. Experiment 2

Experiment 2 adapted a paradigm used by Yeshurun and Carrasco (1998) which illustrates that attention does not always improve performance on visual tasks. In a texture detection task, attention can either improve or impair visual performance by enhancing spatial resolution. Two stimulus displays consisting of small tilted lines are presented sequentially and rapidly. One of the two displays contains a target texture patch consisting of a smaller area of lines tilted in the opposite direction --in the other the lines are all in the same direction. Observers are asked to indicate (using a forced choice method) which display contained the target texture. Studies using this technique (e.g. Yeshurun and Carrasco, 1998;

2000) have shown that performance may be lower when targets are presented at central rather than at peripheral locations, but that this is dependent on the scale of the texture so that performance at central locations can be improved by either decreasing the scale of the texture or increasing the viewing distance. Furthermore, Yeshurun and Carrasco (1998) showed that cueing attention to the location of the target produced further detriments to performance at central locations, but improved performance in the periphery.

The texture detection paradigm offers the opportunity to explore the interactions between the ability to direct and focus visual attention using cues in AwD. In this paradigm, the effect of cues depends on the balance between the benefits of directing attention to the right visual area and the effects of focusing attention which could be either positive or negative depending on location: positive in the periphery, where focus is wide, but negative at the central location where the focus is narrow. The hypothesis that people with dyslexia have a wider, more diffuse focus of attention predicts that their accuracy would be higher than controls at central locations where a more distributed focus should be beneficial with or without cues. The hypothesis that they cannot use cues predicts less effect of cueing across locations. Finally, the hypothesis of a weaker attentional spotlight predicts the same profile shown by the controls (with reduced accuracy at central locations) but, possibly, enhanced effects of cueing because cues allow limited attentional resources to be directed to the right.

2.1 Method

2.1.1 Participants. Experiment 2 was conducted as part of a larger study, so different psychometric tests from Experiment 1 were used for participant selection. Table 2 shows a selection of the mean psychometric data for the two groups of participants. Nineteen dyslexic (6 male) students were selected from a larger set of adults referred to us by the Disability and Additional Needs Unit of Aston University, the Student Counselling Centre of the University of Birmingham and the Birmingham Adult Dyslexia Group. They had either a diagnosis of dyslexia at some point in their school history or a suspicion of dyslexia confirmed at time of testing. All had English as a native language, at least average (>90) IQ level on the Wechsler Adult Intelligence Scale and performance on spelling of words or nonwords of at least two standard deviations below the control mean. There was no history of auditory or visual problems and no neurological, motor or psychological problems. They received payment or a detailed psychological assessment report by a chartered psychologist, which explained what the tasks measured, reported their performance and included recommendations.

INSERT TABLE 2 ABOUT HERE*

Eighteen control (2 male) students were recruited through the Research Participation Scheme of the Psychology programme of Aston University, posters at Aston University and by word of mouth. They all had English as a native language, at least average IQ level (>90) on the Wechsler Adult Intelligence Scale or the Wechsler Abbreviated Scale of Intelligence, no family history of spelling/reading difficulties, no history of auditory or visual problems and no neurological, motor or psychological problems. They received course credits or payment for their participation. Informed consent was obtained prior start of the experiment.

Groups did not differ in terms of WAIS - IQ (t=1.32, df=35) or age (t=1.67, df=35), but differed in terms of number of errors made on the PALPA: Psycholinguistic Assessments of Language Processing in Aphasia (Kay, Lesser and Coltheart, 1992) word reading (t=4.11, df=35, p<.001) and on Schonell regular word (t=4.89, df=33, p<.001) and irregular word spelling (t=5.02, df=33, p<.001) tests (Schonell, 1985). Control data for the Schonell tests were missing for two control participants. A non-word reading test was also created by changing one or two letters in the words from the PALPA test; groups also differed in the number of errors made on this test (t=5.59, df=35, p<.001).

2.1.2 Stimuli. The stimuli were made using Matlab software. When displayed, the main background texture consisted of 210 lines (7 rows x 30 columns) arranged within a 8cm x 40cm display (see Figure 4). Each line was approximately 10mm long x 1mm wide (1º x 0.1º). A random (up/down/left/ right) 4mm jitter was applied to each line to avoid the texture being in a precise grid format. The lines could either all be at a 45º angle or a 135º angle. The target was made according to the same specifications, but consisted only of a 3 row x 3 column grid. Target lines were orthogonal to the background lines. The mask consisted of crossed (±45º) line elements (see Figure 4b).

INSERT FIGURE 4 ABOUT HERE

2.1.3 Design and procedure. The design closely followed that of Yeshurun and Carrasco (1998), except that it used a more limited range of target eccentricities in order to reduce testing time. The experiment was programmed using E-prime software, which was used to present the stimuli and to record data. A schematic representation of the display sequence is shown in Figure 5. A fixation point (+) was presented in the centre of the screen for 1000ms. This was followed by a cue lasting 54ms which could be either neutral, valid-present or valid-absent with equal probability. Neutral cues consisted of a long green line which spanned the whole display and which was positioned either just above or just below the entire background texture. Valid-present cues consisted of a short green line positioned either just above or just below where the target texture patch was to be presented. Valid-absent cues consisted of short green line (the same as valid-present cues) which corresponded to a position where there was no patch (and no patch was present in any other location).

There were no invalid cues. After a blank inter-stimulus interval (ISI) lasting for 60ms, the first texture display was presented with variable duration. This was then masked for 300ms before a second sequence of fixation point (1000ms), cue (54ms), ISI (60ms), texture display (variable) and mask (300ms) were presented. A valid or neutral cue for the first display could be paired either with a valid or a neutral cue in the second display. The target patch with different texture was present in either the first or the second texture display with equal probability. The final screen then asked participants to judge which of the two displays contained the patch by pressing the '1' or '2' number keys on the keyboard.

INSERT FIGURE 5 ABOUT HERE*

The duration of the texture displays was set individually in order to keep overall performance across conditions between 70% and 90% correct and could vary in steps of 11ms (the approximate refresh rate of the screen used). This allowed allocation of attention to be investigated independently from any major differences in the speed of processing (see e.g. Skottun & Skoyles, 2007a and 2007b for a critique that has been leveled at some research in this area). Yeshurun and Carrasco (1998) varied their display durations between 15ms and 50ms, but we allowed a wider range (between 11ms and 176ms) in an attempt to match overall accuracy between the groups.

The target texture patch could occur in five fundamental positions: left far, left near, centre, right near and right far, representing approximately -10º, -5º, 0º, +5º and +10º visual angle eccentricity respectively. These positions were used randomly and were selected from the larger range of those used by Yeshurun and Carrasco (1998) as those most likely to elicit differences. However, in order to add variation and avoid location predictability, the fundamental positions were also randomly ‘jittered’ by either plus 0.6º or minus 0.6º or 0º of visual angle eccentricity.

Only accuracy (not reaction time) was measured. Speed in different conditions was a less meaningful variable since stimulus duration was individually varied for the different participants precisely to account for differences in speed. Still we will compare the average duration of the displays between groups as a general measure of difficulty with the task.

The main experiment consisted of 8 blocks of 36 trials each (288 trials in total). At the end of each block, performance was assessed automatically by the program and the duration of the displays adjusted by +/-11ms to either increase or decrease accuracy as necessary. A practice period consisting of shorter blocks of 12 trials served to ensure that participants’ accuracy was in the correct range before starting the main experiment and as many blocks as necessary to achieve this aim were run. The duration of the texture display in the practice session was started at 110ms.

The independent variables in this experiment were group, cue condition (cued/ neutral) and target position (left far, left near, centre, right near and right far). The dependent variable was accuracy (proportion of correct trials). Participants sat at a distance of 57cm from the computer screen and used a chin rest in order to keep their head in the centre of the screen. The length of the experiment varied slightly for each participant, but took roughly 30 minutes.

2.2 Results

The mean display durations used for the control participants in order to keep accuracy within the 70% - 90% range ranged from 37ms to 115ms (overall mean=85ms; SD=19ms). This was significantly different from that of the AwD whose mean display durations ranged from 49ms to 124ms (overall mean= 103ms; SD=18ms; t=2.95, df=35, p<.01, Cohen’s d=1.00). The AwD, therefore, found the task more difficult as the displays had to be presented for longer to achieve accuracy levels in the requisite range. The number of practice blocks to reach the required level of performance varied between participants but did not differ significantly between groups (3.3 blocks for control participants vs. 2.9 blocks for AwD: $F<1$).

Figure 6 shows AwD and control group's performance in both cued and uncued conditions. It can be seen that both groups showed a central performance drop in both conditions. However, the control group showed a further performance drop at the central location when the target location was cued, whereas the AwD found the cue beneficial at most target locations including the central location. Performance for both groups in both conditions was higher on the right than on the left.

INSERT FIGURE 6 ABOUT HERE

2.2.1 Distribution of attention and use of cues. A 3 factor ANOVA examined effects of *group, cue* (cued/ neutral) and *target position* (left far, left near, centre, right near and right far) on accuracy to detect the target. There was no main effect of *cue* ($F_{1,35}$=2.11), but a main effect of *target position* ($F_{4,140}$=25.44, $p<.001$, η^2_p =.42), with central targets producing the lowest accuracy (77.0%) and right near targets the highest accuracy (91.2%). There was also a main effect of *group* ($F_{1,35}$=4.88, $p<.05$, η^2_p =.12), indicating that despite efforts to keep accuracy at similar levels, AwD performed at a lower level than controls (82.5% vs. 87.7%). The *cue x group* interaction narrowly failed to reach significance ($F_{1,35}$=3.79, p=.06, η^2_p =.10), but there was a significant three way interaction for *cue x group x target position* ($F_{4,140}$=3.29, $p<.05$, η^2_p =.09). Post hoc paired-sample t-tests conducted for the control and AwD separately, showed that whereas cueing significantly helped AwD at two of the target locations --central (*t*=-2.56, *df*=18, $p<.05$) and right far (*t*=-2.46, *df*=18, $p<.05$) --it did not help the controls at any location, but, instead, hindered performance at the central target location (*t*=2.53, *df*=17, $p<.05$). There was no *target position x group* or *target position x cue* interaction (both Fs<1).

2.2.2 Comparison of left vs. right visual fields. In order to investigate whether there were any differences between left and right visual fields, data from central target positions were omitted and a 4 factor ANOVA was conducted on the remaining data using the factors of group, cue, target side and eccentricity (near/ far). There were significant main effects of *side* ($F_{1,35}$=24.71, $p<.001$, η^2_p =.41), with higher accuracy on the right, *eccentricity* ($F_{1,35}$=10.60, $p<.01$, η^2_p =.23), with better performance on near targets and *group* with lower performance in AwD ($F_{1,35}$=4.72, $p<.05$, η^2_p =.12) and a trend towards an effect of *cue* with better performance in cued than uncued conditions ($F_{1,35}$=3.25, p=.08, η^2_p =.09). No other main effects or interactions were significant or approached significance.

2.3. Discussion

Experiment 2 had three main results. The first is that, contrary to the prediction of a more diffuse focus of attention (e.g. Facoetti *et al.* 2000a; Facoetti & Molteni, 2001a), AwD did not show better performance at central locations relative to control participants. The profile of the results was very similar in the two groups with lower performance at central locations. In fact, a post-hoc analysis investigating the extent of the drop relative to the mean of the two near position targets, showed this drop to be significantly larger in AwD than controls (14% vs. 7% accuracy drop: $F_{1,35}$=4.40, p<.05, η^2_p =.11). Consistent with Experiment 1, this result therefore directly contradicts the idea of more diffuse attention in AwD - even in a more severely impaired group of AwD than used in Experiment 1 - suggesting instead a more restricted attention focus.

The second result is that AwD are helped by cues across conditions. This result is consistent with that of Experiment 1 in showing that even more severely impaired AwD are able to use cues to focus attention. This contradicts previous research arguing that people with dyslexia do not make as good use of cues to rapidly orient attention, particularly in the periphery (see e.g. Brannan & Williams, 1987; Facoetti *et al.*, 2000b; Roach & Hogben, 2004).

The third – somewhat unexpected - result is that AwD benefit from cues even at central locations, in contrast with control participants. According to earlier research (e.g. Yeshurun & Carrasco, 1998; Gurnsey, Pearson & Day, 1996), cues at central locations should impair performance because cueing increases the focus of attention and a focus which is too narrow prevents the detection of differences in texture. A (post-hoc) two factor ANOVA analysis on the central location data showed no significant main effects of either *group* ($F_{1,35}$=2.07) or *cue* (F<1), but a significant interaction between the two ($F_{1,35}$=12.95, p<.001, η^2_p =.27). The controls showed worse performance with cues, whilst the AwD showed an improvement. In fact, whereas eleven out of eighteen of the control participants (61%) showed the expected central performance drop with cueing (the others showing little difference between conditions), only five out of nineteen of the AwD (26%) did. There are three possible explanations for this pattern of results, which we will consider in turn.

i) Difficulty with noise exclusion/ signal enhancement: We will assume that cues can have a general positive effect on performance by directing attention to the right area of the display where the patch may appear. What we have to explain is why, at a central location, cues have negative effects for the controls and positive effects for the AwD. One hypothesis is that cues focus attention by reducing noise/enhancing the signal and this is detrimental at central locations. If AwD could use cues to orient attention but not exclude noise, this would explain why they show an overall positive effect of cueing in this paradigm. Consistent with this explanation, Roach and Hogben (2007) reported that AwD, in a visual search task, were not helped by cues to ignore distractors (see also Sperling *et al*., 2005; 2006). However, Moores *et al.* (2011), using a similar task, showed that AwD are strongly dependent on cues, and relied on them to mitigate stronger effects of number and proximity of distractors. Moreover, while there is evidence that moving attention and focusing attention are separate components (e.g. Posner & Boies, 1971), there is no reason to assume that focusing of attention is *independent* from noise exclusion/signal enhancement. In fact, one could argue that this is exactly what focusing attention means. Therefore, a more general interpretation of our finding may refer to a weaker attentional spotlight in the AwD without any need to assume an independent impairment to exclude noise. According to this hypothesis, AwD benefit from cueing at central locations because cueing directs attention, but they will not suffer the consequences of a narrowing of attention because this is already as focused as possible given limited resources with no power for further enhancement.

A weaker attention spotlight explains difficulties with noise exclusion and can also account for reports of more diffuse attention in people with dyslexia (e.g., Facoetti & Molteni, 2001a). More limited resources will produce less difference in resource allocation between attended and unattended areas. A weaker attentional spotlight would also account for the general difficulty showed by AwD in our two experiments (with lower accuracy or a longer required display duration across conditions), and for their over-reliance on cues. It would also explain the worse performance of AwD at the central location in uncued conditions because more limited attentional resources will result in an even narrower focus of attention.

ii) *Sluggish Attentional Shifting (SAS; Hari and Renvall, 2001)*. This hypothesis would be able to account for some cueing effects (i.e. spreading of attention) emerging only at longer SOAs in AwD. However, in Experiment 2, SAS is contradicted by the benefit shown by AwD with cues presented very briefly and at very short SOAs. Instead, such effects can be explained a weaker/narrower attentional spotlight which benefit from being directed to the right location and which requires more time to be modulated than a stronger spotlight would.

iii) Different spatial resolution of filters. Finally, we should consider the possibility that AwD have visual filters with a different spatial resolution. Yeshurun and Carrasco (1998) suggest that in their task *"performance is worse at the fovea because its spatial filters are too small and have too high a resolution for the scale of the texture"* (p73). Cueing at the fovea would further reduce performance by increasing reliance on a neural population with already smaller receptive fields. It is possible that the hypothesis of smaller receptive fields/too small filters and the hypothesis of weaker spotlight are to a certain extent equivalent. However, we prefer the spotlight interpretation because it is less tied to a particular neural mechanism, and because it allows trade-offs depending on resource allocations and task demands.

3. Conclusions

We have investigated effects of cueing in AwD using two tasks where effects were expected to beneficial (Experiment 1) or detrimental (Experiment 2). In Experiment 1, AwD showed normal effects of cueing in a probe detection task. Like controls they benefitted from using a cue circle to orient and distribute attention. Like controls, they performed better when the probe was included in the circle, showed effects of eccentricity - performing best with probes at central locations and increasingly worse with probes at farther locations, and showed effects of SOA - performing best when the cueing circle was shown earlier, thus allowing more time to prepare. In addition, AwD showed a stronger effects of SOA at far eccentricities when more time was needed to move attention and stronger effects of cues on the left, possibly because here attention was weaker. These results show that AwD are perfectly able to use cue to direct and distribute attention (see also Moores *et al.*, 2011;

Cassim *et al*., 2014). In Experiment 2, AwD, in fact, showed stronger effects of cueing than controls. In a texture detection task, they benefitted from cues even at central locations where restricting the focus of attention should have actually hindered performance. We believe that both sets of results are best interpreted by assuming that AwD suffer from weaker attentional resources or a weaker spotlight of attention. According to this hypothesis, AwD would have no difficulties to orient or focus attention using cues, consistent with the results of Experiment 1. Instead, difficulties will arise when there are not enough attentional resources to split attention to different locations or when attention cannot be further restricted (e.g., see Romani *et al*., 2011). This limitation in restoring the focus of attention would result in net positive effects of cueing in Experiment 2: cues orient attention to the right area, but attention is not restricted to the point where this is detrimental for texture detection.

More broadly, our results are consistent with theories which see attentional limitations as an important source of difficulties in developmental dyslexia. Since neither letters nor complex stimuli were used in these experiments, phonological difficulties in AwD are unable to account for the results. One may note that we have investigated partially compensated adults with dyslexia rather than children. Our results and interpretations, however, are broadly consistent with a number of findings from the literature, both on children (e.g. Bosse *et al*., 2007; Valdois, Bosse & Tainturier, 2004; Lassus-Sangosse, N'Guyen-Morel & Valdois, 2008; Lobier, Zoubrinetsky & Valdois, 2012) and AwD (Judge *et al*., 2007; Moores *et al.,* 2011; Romani *et al.*, 2011; Judge, Knox & Caravolas, 2013, Cassim *et al.*, 2014). A number of studies have reported impaired performance in processing multi-element arrays in dyslexic children (Hawelka & Wimmer, 2005) or AwD (e.g. Hawelka, Huber & Wimmer, 2006; Romani, Tsouknida & Olson, 2015). Bosse *et al*. (2007) argued there is a narrow attentional window in dyslexia in terms of the amount of information that can be processed at once from a briefly presented display. Romani *et al.* (2011) have shown that AwD have a reduced capacity to split attention in a number of distinct spotlights.

The idea that AwD might have a weaker attention spotlight has important implications for reading. Rayner, Murphy, Henderson and Pollatsek (1989) reported a case study of an adult with developmental dyslexia who read more successfully when letters outside of a small centrally fixated window were replaced with Xs (see also McConkie & Rayner, 1975). Spinelli, DeLuca, Judica and Zoccolotti (2002) asked CwD and controls to say whether two words presented sequentially on a screen were the same or different and measured vocal reaction times. They showed that CwD were more detrimentally affected than controls by surrounding 'crowding' stimuli. A second experiment showed an improvement in word reading with increased inter-letter spacing. Benefits of increased letter spacing were also shown in young readers and CwD by Perea, Panadero, Moret-Tatay and Gómez (2012) and Zorzi *et al.*, (2012). Similarly, people with dyslexia find easier to read text when words are displayed one at a time or one line at a time (e.g. Hill & Lovegrove, 1993; Lovegrove & MacFarlane, 1990; Schneps, Thomson, Chen, Sonnert & Pomplun, 2013a; Schneps *et al.*, 2013b). Franceschini, Gori, Ruffino, Pedrolli and Facoetti (2012) showed how performance on visual attention tasks in pre-school age Italian children can be used to predict reading acquisition two and three years later. All of these studies are consistent in pointing to a visuo-attentional impairment in dyslexia. Solutions, however, are more difficult to devise. Crutch and Warrington (2009) reported two cases of acquired dyslexia caused by posterior cortical atrophy that showed large negative effects of flanking and positive effects of spacing in letter identification tasks. However, increasing letter spacing within words had only limited benefits for reading because although individual letter identification was improved, whole word reading was negatively affected. This exemplifies the difficulty of finding solutions for a weaker attentional spotlight and increased crowding effects in dyslexia.

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*Table 1. Mean psychometric data for the two groups of participants used in Experiment 1 (standard deviation shown in parentheses) * for p<.05, ** for p<.01*

	AwD Mean (SD) n=14	Controls Mean (SD) n=28	*p*	*Cohen's d*
Age (years)	23.1 (4.2)	22.8 (5.4)	n.s.	
IQ (standard score)	117.4 (7.4)	119.0 (9.3)	n.s.	
WIAT-II Reading (standard score)	102.3 (11.1)	111.0 (6.4)	p<.01**	0.99
WIAT-II Spelling (standard score)	105.1 (11.3)	113.9 (10.3)	p<.05*	0.82

Table 2. Mean psychometric data for the two groups of participants used in Experiment 2 (standard deviation shown in parentheses)

	AwD Mean (SD)	Controls Mean (SD)	*p*	Cohen's d
Age (years)	22.3 (4.3)	19.9 (4.2)	*ns*	
IQ (standard score)	109.9 (12.7)	115.2 (11.8)	*ns*	
PALPA Word Reading errors (out of 80)	3.68 (2.94)	0.72 (0.83)	<*.001*	1.39
PALPA Non-Word Reading errors (out of 80)	19.95 (8.12)	7.23 (5.27)	<*.001*	1.89
Schonell regular word spelling errors (out of 60)*	4.79 (2.86)	0.94 (1.44)	<*.001*	1.70
Schonell irregular word spelling errors(out of 60)*	10.05 (6.22)	1.94 (1.88)	<*.001*	1.75

*Control data missing for 2 participants on these tasks

Figure 1. Schematic representation of possible conditions in Experiment 1.

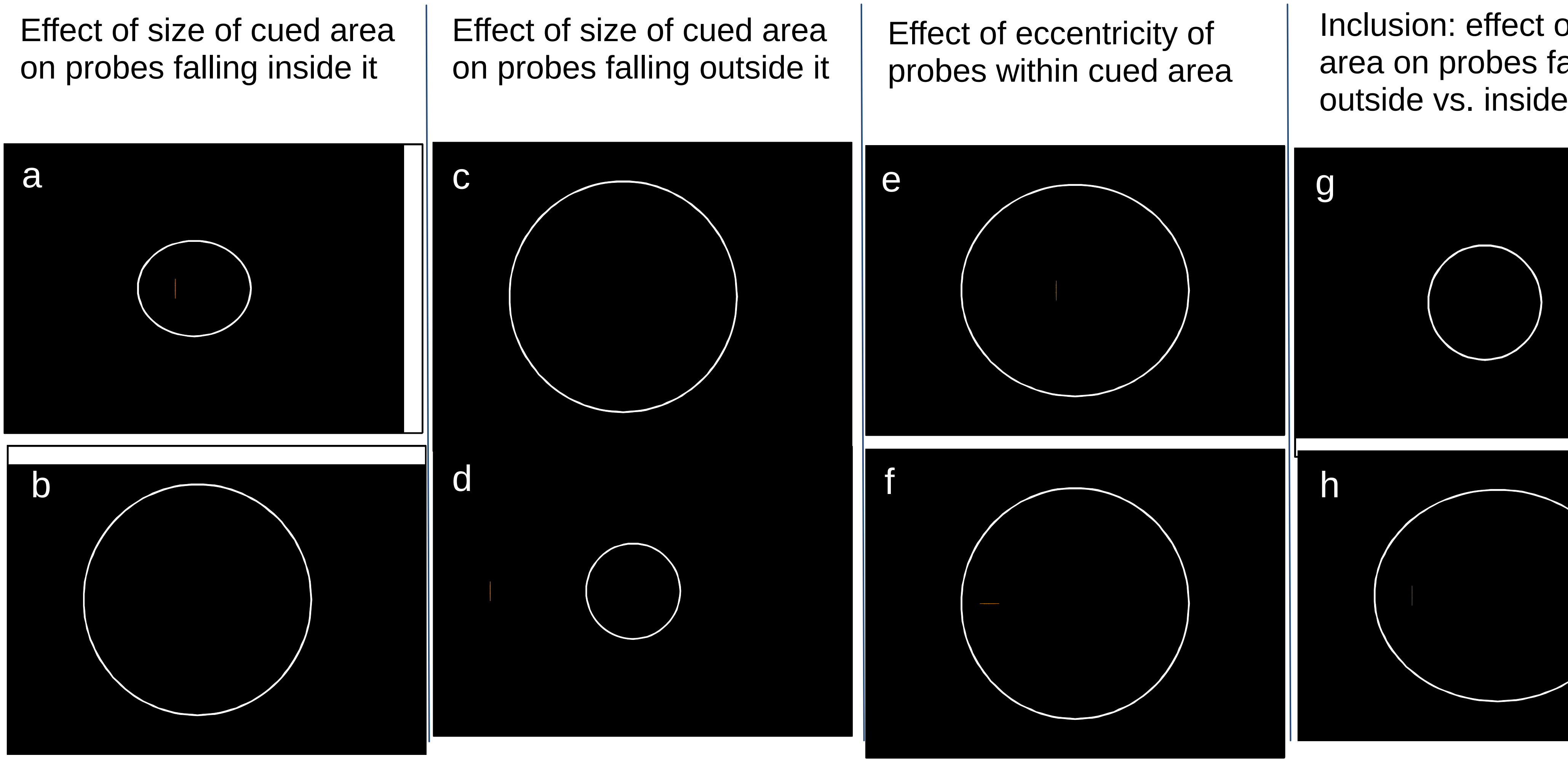


Figure 2. *Mean reaction time (ms) of responses to probes by control participants (dotted lines) and AwD (solid lines) for small vs. large cue circles (averaged across SOA) or for short vs. long SOA (averaged across circle size). Percentage errors are also shown on the right axis(lower lines).*

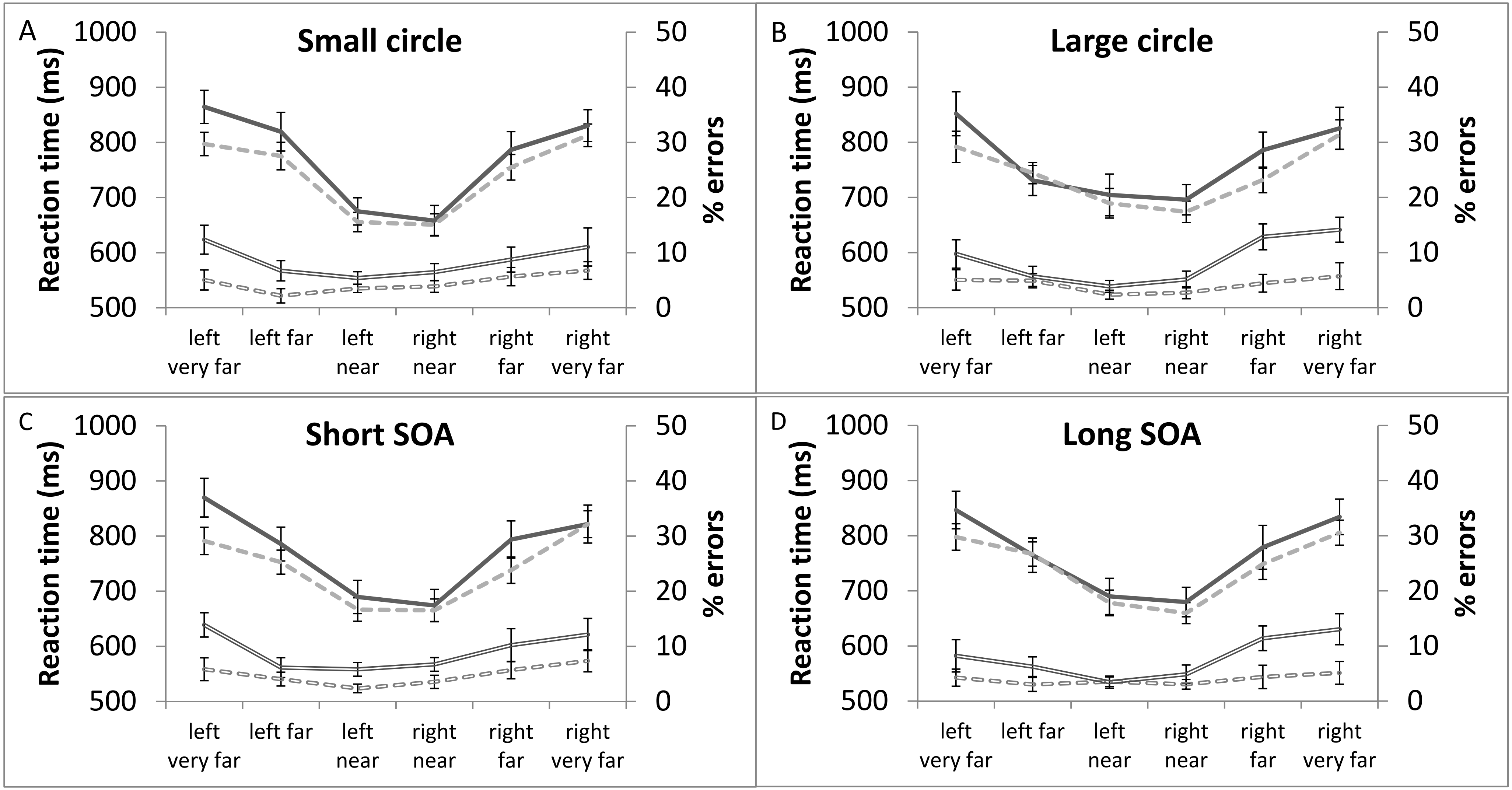


Figure 3. Mean reaction time (ms) of responses to probes by control participants (dotted lines) and AwD (solid lines)according to short vs long SOA when eccentricity and inclusion are controlled . Percentage errors are also shown on the right axis(lower lines).

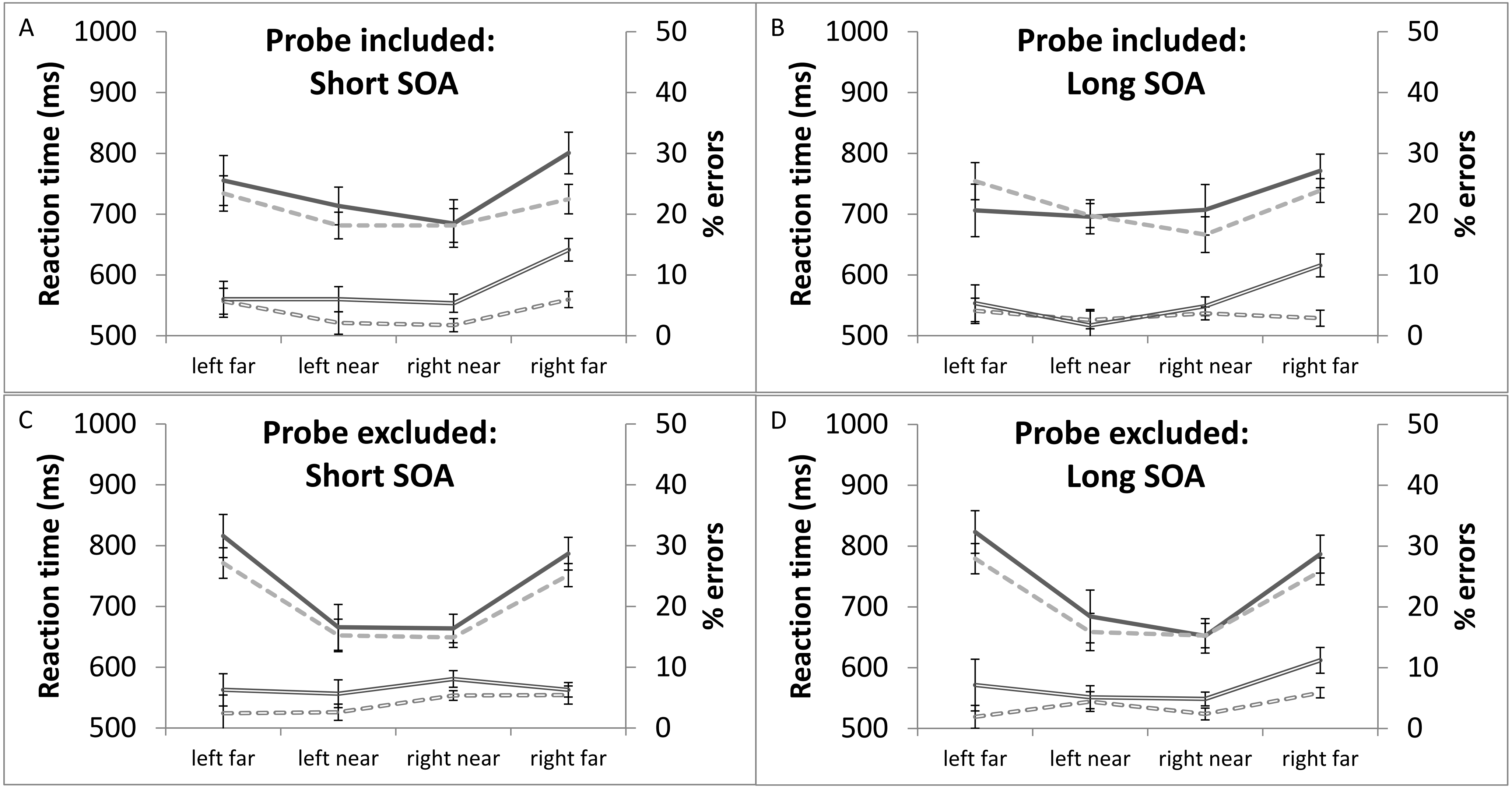
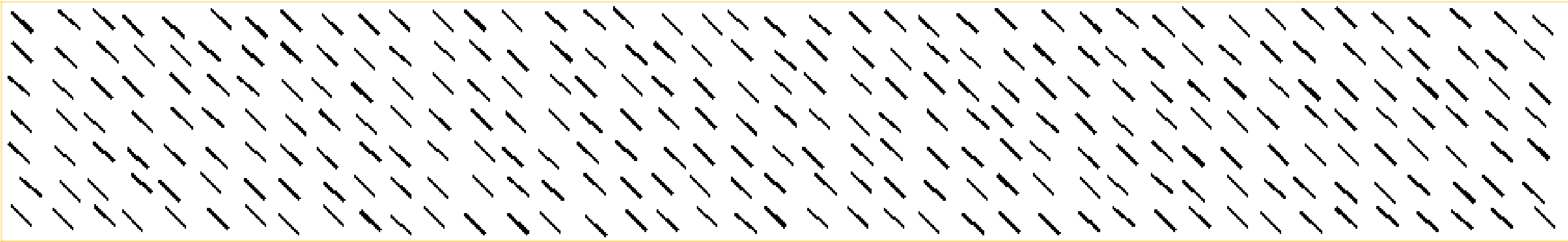


Figure 4. The background and mask textures in Experiment 2.

a. Background Texture



b. Mask Texture

c. Background Texture with target present

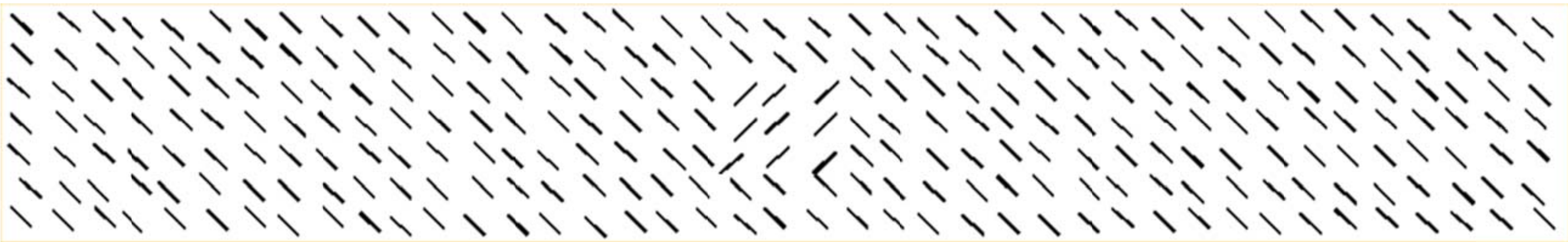


Figure 5. Schematic representation of Experiment 2

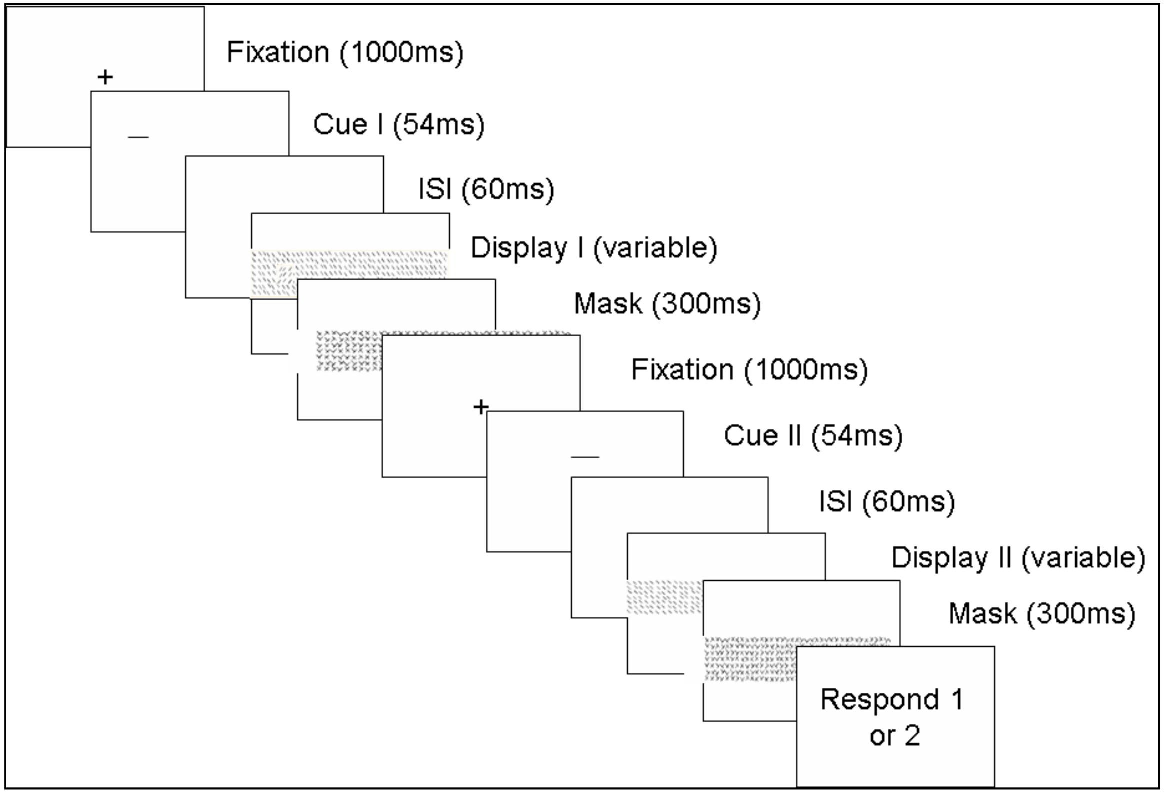


Figure 6. Performance of the groups in cued (solid line) and uncued (broken line) conditions. Standard error bars shown.

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