Attentional capture by spoken language: Effects on netballers' visual task performance

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Abstract

In two experiments, participants performed visual detection, visual discrimination and decision-making tasks in which a binary (left/right) response was required. In all experimental conditions, a spoken word ("left"/"right") was presented monaurally (left or right ear) at the onset of the visual stimulus. In Experiment 1, 26 non-athletes located a target amongst an array of distracters as quickly as possible, in both the presence and absence of spoken cues. Participants performed superiorly in the presence of valid cues, relative to invalid-cue and control conditions. In Experiment 2, 42 skilled netballers completed three tasks, in randomized order: a visual detection task, a visual discrimination task and a netball decision-making task – all in the presence of spoken cues. Our data showed that spoken auditory cues affected not only target detection, but also performance on more complex decision-making tasks: cues that were either spatially or semantically invalid slowed target detection time; spatially invalid cues impaired discrimination task accuracy; and cues that were either spatially or semantically valid improved accuracy and speeded decision time in the netball task. When studying visual perception and attention in sport, the impact of concomitant auditory information should be taken into account in order to achieve a more representative task design.

Keywords***: auditory, crossmodal, decision-making, spatial attention, sport.***

1. Introduction

Athletes are able to allocate their visual attention highly effectively (Gegenfurtner, Lehtinen, & Säljö, 2011; Mann, Williams, Ward, & Janelle, 2007); and evidence suggests that this improves considerably with domain-specific practice (e.g., Castiello & Umiltà, 1992; Enns & Richards, 1997; Lum, Enns, & Pratt, 2002; Nougier, Ripoll, & Stein, 1989; Nougier & Rossi, 1999). However, attention can easily be captured by an unanticipated event in all sensory modalities, even when the event is not relevant to an ongoing primary task. Whether this is a bang, a tap on the shoulder, or a flash of light, we reflexively orient our attention to the perceived location of the event; this is referred to as *exogenous* orienting of attention (see Wright & Ward, 2008). Our attention can also be oriented voluntarily, or *endogenously*; for example, when an external cue is deemed relevant to the task at hand.

In the visual domain, the capture of attention has historically been studied using Posner's cueing paradigm (see Posner, 1980; Posner, Snyder, & Davidson, 1980), in which a cue is either predictive or non-predictive (i.e., occurring at chance probability) of a subsequent target's location. When presented with exogenous cues (e.g., a briefly presented object in the same hemifield as the ensuing target), people consistently respond more quickly and accurately to validly cued targets, even when the possible cue locations are equiprobable (Jonides, 1981; Yantis & Jonides, 1990). Posner's (1980) paradigm has been used to investigate the effect of visual cueing in sport contexts. Nougier, Ripoll, and Stein (1989) examined expert and non-expert athletes' ability to respond to cued and uncued targets presented at varying degrees of eccentricity from central fixation. Not only were the experts quicker to detect more distal targets, but their performance was less dependent on the validity of the cues – which implies an imperviousness to such exogenous attentional orienting. Cañal-Bruland and Hagemvann (2007) used a target detection task overlaid on static images of open play in soccer; participants' aim was to identify the side of the visual display in which a target black box was located. When a cue (a red ellipse) was presented to the same side as the target with a 200 ms stimulus onset synchrony (SOA), response times were significantly reduced when compared to those for invalid contralateral cues.

There is also evidence to suggest that valid/predictive visual cues may actually disrupt perceptual-cognitive performance. Using a 1-on-1 in soccer scenario, Cañal-Bruland (2009) devised an anticipation task wherein participants' attention was cued to regions of the opponent's body using red ellipses, immediately prior to presentation of still images. The participants' task was to decide whether the oncoming player was moving to the left or right. The cues failed to direct participants' attention successfully; in fact, response times in a no-cue control condition were faster. In a second, more complex task (a 3-on-2 scenario), Cañal-Bruland noted that peripheral cues speeded up response times relative to centrally-presented cues; this may reflect the reflexive, automatic nature of exogenous attentional capture (Theeuwes, Kramer, Hahn, & Irwin, 1998). In a third experiment, black boxes were superimposed on static images. Unsurprisingly, valid cues (i.e., those appearing at the target location) speeded target detection – but this did not facilitate participants' decision-making.

Although research on the exogenous capture of attention has typically focused on visual cues, the attention-capturing properties of auditory stimuli have recently come to prominence (e.g., Koelewijn, Bronkhorst, & Theeuwes, 2009a; Sosa, Clarke, & McCourt, 2011; Spence & Santangelo, 2009). Spatially non-predictive auditory cues are able to exogenously capture a person's spatial attention equally effectively as visual cues; responses to cued targets are typically faster than to those at uncued locations (Wright & Ward, 2008). However, the ability of any given cue, irrespective of modality, to capture an individual's attention is partly determined by the demands on attention required by competing stimuli. For example, Santangelo, Olivetti Belardinelli, and Spence (2007) showed that, when participants were engaged in a perceptually demanding dual-task condition that required endogenous control of attention (a rapid serial visual presentation task and an orthogonal cueing task), reflexive orienting did not occur in response to an extraneous auditory cue. This suggests that, when focusing one's attention on a perceptually demanding task, such as those encountered in many sporting contexts, the ability of exogenous cues to distract is diminished (cf. Lavie, Hirst, de Fockert, & Viding, 2004). Visual and auditory stimuli appear to compete directly with one another for our attention, in a bottom-up fashion.

Soto and Humphreys (2007) conducted two experiments in which they examined the impact of visual and verbal primes on participants' visual attention. Participants were shown shape primes 500 ms prior to conducting a visual search for a target, which was located in one of four shapes within an array. The primed shape never contained the target and so visual search was always impaired in the priming condition relative to a neutral one. The authors showed that this effect could also be replicated with primes that comprised only a verbal description of a shape; hence, they concluded that working memory (WM) of verbal information was able to bias participants' visual attention. Salverda and Altmann (2011) examined this notion further by investigating the effects of spoken cues on target detection performance. In two experiments, participants had to generate a saccade to the target, after hearing a word that referred to the target object or to a distracter. Saccade latencies were longer when spoken cues referred to distracter objects and shorter when they referred to the target, suggesting that auditory cues are also held in WM during visual task performance. In a third experiment, the authors showed that participants were quicker at detecting a subtle change in a target stimulus when that target had been verbally cued 400 ms beforehand. It is clear from these studies that both valid and invalid verbal cues directly affect visual attention processes.

In recent years, there has been a call for more accurate representation of the real world in sport-related experimental tasks (Dicks, Davids, & Button, 2009; Pinder, Davids, Renshaw, & Araújo, 2011; Vilar, Araújo, Davids, & Renshaw, 2012). In netball (as in many team sports) auditory demands on a player's attentional resources are pervasive: players gesticulate for the attention of the team mate in possession of the ball, while simultaneously calling out – amidst a melange of shouts and gesticulations from other team mates and opponents – yet studies of visual perception and attention in sport typically examine these phenomena in a wholly unrepresentative 'auditory vacuum'. So to address this, we sought to examine the impact of spoken language on participants' visual task performance. Accordingly, two experiments were devised to assess the capacity of spoken cues that varied not only spatially (ear of presentation), but also semantically ("left" vs. "right"), to orient participants' attention and ultimately affect their decision-making.

In a pilot experiment to test the efficacy of the protocol, a group of non-athletes undertook a visual detection task, wherein a target was to be detected from an array of distractors; spoken cues were presented in all experimental trials.We hypothesized that valid cues would reduce detection times relative to control and invalid cue conditions, consistent with findings from other studies in which auditory cues were used (e.g., Salverda & Altmann, 2011). Despite skilled team sport players' ability to allocate visual attention highly effectively (Enns & Richards, 1997; Nougier, et al., 1989), we predicted that skilled netballers would be prone to auditory attentional capture effects – consistent with the notion that skilled team sport athletes do not differ from non-athletes on fundamental measures of perception and attention (Abernethy, Neal, & Koning, 1994; Hughes, Blundell, & Walters, 1993; Ward, Williams, & Loran, 2000; Williams & Grant, 1999).

For a perceptually demanding visual discrimination task, in which judgments of horizontal separation were required, we hypothesized that the task demands would attenuate auditory cueing effects (cf. Koelewijn, et al., 2009b; Santangelo, et al., 2007). However, because decision uncertainty was also likely to be high for this task (see Methods), we hypothesized that participants would be less accurate when a semantically invalid cue was presented, because the word (e.g., "left") would increase attention to the cued side (cf. Soto & Humphreys, 2007). Finally, skilled netballers undertook a netball decision-making task comprising still images taken from scenarios during a competitive netball training session. We predicted that both spatially invalid and semantically invalid cues would increase decision-making times, but that this effect would be greatest for spatial cues, whose effects unfold rapidly (Berger, Henik, & Rafal, 2005; Theeuwes, et al., 1998).

2. Ethics Statement

Prior to their participation, participants were informed, in writing and verbally, as to what was required of them; they then gave their informed consent. All experimental procedures were conducted pursuant to institutional ethics committee approval.

3.Experiment 1: Pilot Study

3.1. Methods

This pilot study was run to establish whether monaurally-presented valid and invalid spoken cues had an effect on visual task performance, relative to a control condition in which auditory cues were absent.

3.1.1. Participants.

Twenty-six non-netballers aged 24 to 47 years (*M* = 37.5 yrs; *SD* = 5.4 yrs) were invited to take part in this pilot study. All participants had normal or corrected-to-normal vision and normal hearing. All but three of the participants were right-handed.

3.1.2. Materials.

The experiment was administered on a Windows laptop computer running the E-Prime software program (Psychology Software Tools, Sharpsburg, PA). The images were displayed on a 15-in. display (60 Hz refresh rate). Screen resolution was set to 1024 x 768 pixels, such that the images filled the screen. Participants were seated approximately 0.3 m from the laptop screen; the laptop was elevated such that the centre of the screen was in line with the participant's eye level. Responses were made via two keys (numbers 3 [left] and 6 [right]) on a standard USB numeric keypad, using the index and middle fingers of the right hand, respectively. The keypad was positioned such that the two keys retained their original orientation - aligned in the sagittal plane – to mitigate stimulus response compatibility effects (i.e., the Simon Effect; Simon & Rudell, 1967; Simon & Wolf, 1963); in other words, the responses were neither left- nor right-located, and so could not be described as being compatible or incompatible with the target.

***3.1.2.1. Visual stimuli*.**

Participants' aim was to identify the hemifield location of a target amongst an array of distracters; Figure 1 shows a typical array (target in right hemifield; row 3, column 5). There were 216 stimuli in total. All displays contained vertical black bars (no pixels lit) presented on a medium grey background (one out of two pixels lit) presented on a

medium grey background (one out of two pixels lit). For each trial, the target item was located in each of 24 possible array positions for 3 trials, totalling 72 trials in each block. The distance between items was approximately 6.8° of visual angle. For every display type, the target item was a vertical black bar spanning approximately 0.6° x 4.4°. The characteristic that differentiated the target from the distracter items was its length: distracters were two-thirds of the length of the target (2.93° approx.). Target and distracter items were jittered (deliberately misaligned) across rows and columns so that the larger target did not 'pop out' of the array.

***3.1.2.2. Auditory stimuli*.**

In the two experimental conditions, participants heard a brief abrupt-onset auditory cue – a call of either "left" or "right" – that was presented in the corresponding ear at approximately 85 dBA in synchrony with the onset of the visual stimulus (Stimulus Onset Asynchrony [SOA] of 0 ms). For all experimental trials, there was an equal number of trials (*n* = 72) for which (a) both the semantic and spatial components of the cues were valid (i.e., both aimed at orienting attention to the half of the display containing the target; valid–valid) and (b) both components were invalid (*invalid-invalid*); in this regard, they were non-predictive (NB: participants were unaware of the predictive validity of the cues). Control trials (*n* = 72) were not accompanied by an auditory cue.

3.1.3. Procedure.

Participants performed ten familiarisation trials; all participants reported that they understood the requirements of the task. They subsequently performed a total of 216 randomized experimental trials, in two blocks (*n* trials = 72). Participants were required to wear earphones throughout the entire protocol. They were verbally informed that each trial would commence as soon as the stimulus appeared and that the auditory cue may or may not relate to the correct response; on-screen instructions reaffirmed this. Each trial was preceded by a fixation cross in the centre of the screen for 500 ms. Displays remained visible until participants made a key press response. No feedback was given in between trials. All trials were randomized.

3.1.4. Data analysis.

All data were analysed using PASW Statistics (v 18.0, SPSS Inc., Chicago, IL). A one-way MANOVA (*Conditions*: invalid, valid, control) was performed; the dependent measures were accuracy and response time.

3.2. Results

There was a main effect of Condition, $F(3,23) = 11.16$, $P < 0.001$, Pillai's Trace = 0.59, η2p = 0.59. Univariate tests revealed that task accuracy was unaffected ($P > 0.05$), but there was an effect on response time, $F(2,50) = 24.12$, $P < 0.001$, η2p = 0.49. Bonferroni-corrected pairwise comparisons showed that the valid cue combination ($\bar{x}$ = 902.79 ms, s = 299.70 ms) elicited faster response times than did both invalid cues ($\bar{x}$ = 949.40 ms, s = 307.05 ms), $P < 0.001$, 95% CI of the difference = 22.64–70.60 ms, and the control condition ($\bar{x}$ = 927.62 ms, s = 302.32 ms), $P = 0.001$, 95% CI of the difference = 13.02–36.66 ms. Invalid cues also elicited slower response times than did the control condition, $P = 0.001$, 95% CI of the difference = 8.51–35.05 ms.

4. Experiment 2

4.1. Methods

4.1.1. Participants.

Forty-two female netball players aged 18 to 29 years (*M* = 21.2 yrs; *SD* = 3.2 yrs) were recruited to take part. Their competitive experience ranged from 4 to 15 years (*M* = 10.5 yrs; *SD* = 3.2 yrs); competitive standard ranged from university to international level. Participants were recruited from UK university netball teams and an international netball squad. All participants had normal or corrected-to-normal vision and normal hearing. All but one of the participants were right-handed.

4.1.2. Materials.

All tasks were administered on a Windows computer running the E-Prime software program (Psychology Software Tools, Sharpsburg, PA). The images were displayed on a 21-in. display CRT monitor (75 Hz). Screen resolution was set to 1024 x 768 pixels, such that the images filled the screen. Viewing distance was approximately 0.5 m. Responses were made via two keys (numbers 3 and 6) on the numeric keypad of a standard keyboard, using the index and middle fingers of the right hand respectively, such that the two keys were aligned in the sagittal plane.

4.1.2.1. Visual detection task stimuli. Participants completed a visual task identical to that undertaken in Experiment 1.

4.1.2.2. Visual discrimination task stimuli. The main aim of netball is to score more goals than one's opponents. This is typically achieved by passing the ball between team mates, finally passing to a designated shooter whose aim it is to land the ball in the opponent's hoop. The outcome of any given pass may be determined, in part, by the proximity of an opponent to one's teammates, because closeness increases the likelihood that the opponent will make a successful interception; hence, the perceived distance between team mates and opponents is a consideration for the passer – be it an implicit or explicit one. Accordingly, in an artificial and simplified version of this real-world perceptual requirement, participants were required to judge the best passing option of two 'teammates' (light grey tunics in Figure 2) according to their lateral distance from the vertical meridian – and therefore perceived distance from the passer/participant; one of the two 'team mates' was always nearer to the vertical meridian than the other. The relations between the team mates and the marking opponents (darker tunics) did not vary from one stimulus to the next and so the best passing option could only be distinguished by lateral distance alone. Distance from the vertical meridian was manipulated pre-experimentally such that participants would typically be able to identify the best passing option at above-chance levels, but without high levels of confidence in their decision: These distances were derived according to the ratios used by Masters, van der Kamp, and Jackson (2007) in their examination of judgments in soccer penalty-taking, so as to maximise the perceptual challenge of the task. Figure 2 shows two stimuli (vertical meridian is drawn only for reference purposes): image A depicts a scenario in which the best (closest) passing option is the team mate on the left of the meridian; image B depicts the reverse. There were 48 images in total, each presented once; presentation of stimuli was balanced such that the best passing option was equally represented in both left and right hemifields.

4.1.2.3. Netball decision-making task stimuli. Thirty-two still images, which had been taken from a pool of 60 first-person perspective shots of competitive netball scenarios, were used; Figure 3 shows one of the images. It was explained to participants that the players in dark grey tops (no bibs) were team mates and that the aim of the task was to identify the best passing option – as previously judged by two international netball coaches and an international netball performance analyst ($\bar{x}$ international experience = 15.3 yrs; *SD* = 4.8 yrs). All images were flipped to form an equivalent set of mirror images, such that each scenario was associated with both a left-located and a right-located best passing option, yielding a total of 64 experimental trials.

4.1.2.4. Auditory stimuli. As for Experiment 1, participants heard an auditory cue varying both semantically and spatially, at an SOA of 0 ms. For each task, there was an equal number of trials for which (a) both spatial and semantic components of the cue were valid (i.e., both were designed to orient attention to the correct side; *valid-valid*; e.g., a call of "right" in the right ear, when the target was located in the right side of the display); (b) only the spatial component was valid (valid–invalid; e.g., a call of "right" in the left ear, when the target was located in the left side of the display); (c) only the semantic component was valid (invalid–valid; e.g., a call of "right" in the left ear, when the target was located on the right side of the display); and (d) both components were invalid (invalid–invalid; e.g., a call of "right" in the right ear, when the target was located on the left side of the display); hence, the cues were entirely non-predictive, occurring congruently with the target at chance frequency (NB: participants were unaware of the predictive validity of the cues).

4.1.3. Procedure.

Participants were required to wear earphones throughout the entire protocol. They were verbally informed that each trial would commence as soon as the stimulus appeared and that the auditory cue may or may not relate to the correct response; on-screen instructions reaffirmed this. Each trial was preceded by a fixation cross in the centre of the screen for 500 ms. Displays remained visible until participants made a key press response. No feedback was given in between trials. The order of all trials was randomized. In each experiment, participants performed ten familiarisation trials. They proceeded to the experimental trials after reporting that they understood the task requirements.

4.1.4. Data analysis – all tasks.

All data were analysed using PASW Statistics (v 18.0, SPSS Inc., Chicago, IL). A two-way MANOVA (semantic component validity x spatial component validity) was conducted; the dependent measures were accuracy and response time.

4.2. Results

4.2.1. Visual detection task.

There was no significant interaction effect. There were main effects of both the semantic component, *F* (2,40) = 3.99, *p* = .030, Pillai's Trace = .17, η_p^2 = .17, and of the spatial component, *F* (2,40) = 8.62, *p* = .001, Pillai's Trace = .30, η_p^2 = .30,. Univariate tests revealed that semantically invalid cues ($\bar{x}$ = 894.83 ms; *SD* = 302.71 ms) elicited slower responses than did valid ones, ($\bar{x}$ = 874.18 ms; *SD* = 278.54 ms), *F*(1,41) = 6.98, *p* = .010, η_p^2 = .15, 95% CI = 4.86–36.43 ms; as did spatially invalid cues ($\bar{x}$ = 898.13 ms; *SD* = 296.42 ms) relative to valid ones ($\bar{x}$ = 870.89 ms; *SD* = 284.83 ms), *F*(1,41) = 17.07, *p* < .001, η_p^2 = .29, 95% CI = 13.92–40.55 ms (see Fig. 4(A)).

4.2.2. Visual discrimination task.

There was a significant interaction effect of the two cue components, *F*(2,40) = 5.33, *p* = .009, Pillai's Trace = .21. Univariate tests showed that there was an effect on accuracy, *F*(1,41) = 6.40, *p* = .015, η_p^2 = .14; follow-up tests showed that doubly valid cues ($\bar{x}$ = 76.63%; *SD* = 16.19%) elicited more accurate responses than did a cue that was spatially invalid but semantically valid ($\bar{x}$ =71.33%; *SD* = 20.53%), *p* = .002. This disordinal interaction is depicted in Figure 5(A).

There was a main effect of the spatial component, *F* (2,40) = 5.29, *p* = .009, Pillai's Trace = .21, η_p^2 = .21. Univariate tests revealed that spatially valid cues ($\bar{x}$ = 74.73%, *SD* = 17.16%) led to greater accuracy than did those that were invalid ($\bar{x}$ = 71.85%, *SD* = 20.83%), *F* (1,41) = 5.60, *p* = .023, η_p^2 = .12, 95% CI = 0.40–5.30% (see Fig. 4B). There was no effect of the semantic component.

4.2.3. Netball task.

There was a significant interaction effect of cue components, $F(2,40) = 3.67$, $p = .034$, Pillai's Trace = .16, $\eta_p^2 = .16$. Univariate tests showed that there was an effect on accuracy, $F(1,41) = 6.88$, $p = .012$, $\eta_p^2 = .15$; follow-up tests revealed that doubly valid cues (*M* = 75.21%; *SD* = 13.84%) elicited more accurate responses than did both conditions in which the cue was spatially invalid (semantically invalid cue, $\bar{x}$ = 63.69%; *SD* = 12.86%; semantically valid cue, $\bar{x}$ = 69.79%; *SD* = 12.73%), $p < .002$. This ordinal interaction is depicted in Figure 5(B).

There were main effects of both the semantic component, $F(2,40) = 14.27$, $p < .001$, Pillai's Trace = .16, $\eta_p^2 = .16$, and the spatial component, $F(2,40) = 25.66$, $p < .001$, Pillai's Trace = .56, $\eta_p^2 = .56$,. Univariate tests revealed that semantically invalid cues reduced accuracy ($\bar{x}$ = 69.25%; *SD* = 12.22%) relative to valid ones ($\bar{x}$ = 72.50%; *SD* = 13.28%), $F(1,41) = 5.04$, $p = .030$, $\eta_p^2 = .11$, 95% CI = 0.30%–6.20%; they also increased response times ($\bar{x}$ = 1544.92 ms; *SD* = 593.07 ms *vs.* $\bar{x}$ = 1437.04 ms; *SD* = 489.30 ms, respectively), $F(1,41) = 16.58$, $p < .001$, $\eta_p^2 = .29$. Spatially invalid cues (*M* = 66.74%; *SD* = 12.80%) also decreased accuracy, $F(1,41) = 37.12$, $p < .001$, $\eta_p^2 = .48$, 95% CI = 5.50–11.0%; and increased response times (*M* = 1532.79 ms; *SD* = 560.57 ms *vs.* $\bar{x}$ = 1449.17 ms; *SD* = 521.79 ms), $F(1,41) = 12.93$, $p = .001$, $\eta_p^2 = .24$, 95% CI = 36.35–136.59 ms (see Figs. 4(C) & 4(D)).

5. Discussion

We conducted two experiments designed to illustrate the impact of spoken cues on participants' visual attention and decision-making. The findings provide considerable support for our hypotheses, together with some unexpected findings. In Experiment 1, the experimental manipulation was effective and mirrors Salverda and Altmann's (2011) findings: valid and invalid auditory spoken cues speeded and slowed detection time relative to a control condition, through a shifting of attention. In Experiment 2 we sought to explore this orienting effect in a group of skilled netballers and to examine the effect of its interaction with task demands on decision-making. In a visual detection task, cues that were both semantically and spatially valid speeded target detection – consistent with our predictions and the extant literature (see Wright & Ward, 2008). A wholly unexpected finding was that spatial cues affected participants’ accuracy in the visual discrimination task; and doubly valid cues appeared to be particularly effective in improving performance on this task. In the netball-specific task, both cue types improved the accuracy of decisions made and reduced the time taken to make them, relative to invalid cues; again, whilst the effect on response times was predicted, the effect on accuracy was not. These findings are discussed in more detail below.

The pilot study data clearly show that spoken cues affected non-athletes’ target detection speed; notably it deteriorated in the presence of invalid cues and improved in the presence of valid ones. Hence, our chosen manipulation was effective. Given the superior ability of skilled performers to selectively attend to pertinent visual information (Gegenfurtner, et al., 2011; Mann, et al., 2007), the extent to which spoken cues would affect their performance was deemed worthy of examination, to address an existing gap in the sport literature (e.g., Canal-Bruland & Hagemann, 2007; Castiello & Umiltà, 1992; Enns & Richards, 1997; Hagemann, Strauss, & Cañal-Bruland, 2006). The present findings suggest that, contrary to Nougier et al.’s (1989) findings with visual stimuli, the skilled netballers were equally affected by auditory cues in the visual detection task: the effect sizes of the differences in response times between the doubly valid and doubly invalid conditions, for both the non-netballers (Experiment 1) and the skilled netballers (Experiment 2), were identical (Cohen's d = 0.16). Eye movement data would establish whether this orienting of attention was overt or covert.

The high perceptual demands of the visual discrimination task (cf. Santangelo, et al., 2007) appeared to compete effectively with the semantic component for participants' attention, such that this component did not affect task performance; but the fact that visual detection task performance *was* affected suggests that they were not simply being ignored. So, whilst the word itself might have increased attention to the cued side, it did not affect the decisions made, nor the time taken to make them. The same cannot be said for the spatial component: when this was valid, participants made more accurate judgements than when they were invalid, which was an entirely unpredicted – and serendipitous – finding. Although we might expect that exogenous cues exert more potent effects on attention (Berger, et al., 2005; Jonides, 1981; Yantis & Jonides, 1990), the notion that they might affect subsequent decision-making is very novel – even though comparable effects of auditory cues on visual discrimination judgements have been demonstrated for a line bisection task (Sosa, Clarke, & McCourt, 2011). However, it is noteworthy that, even though participants reported that they had guessed much of the time (cf. Masters, et al., 2007), the percentage of correct responses across all trials ($\bar{x}$ = 73.29%) was considerably above the chance level. Therefore, it seems as though the perceptual demands of the task might have interacted with the spatial cues in such a way that the effects of invalid, not valid, cues were typically attenuated; this suggests that bottom-up capture by auditory cues can be suppressed by top-down attentional control – but in a way that is explicitly dependent on the perceived veracity of the visual information (cf. Koelewijn, Bronkhorst, & Theeuwes, 2009).

In the netball task, a semantically valid cue (e.g., a call of "left" when the correct passing option was located on the left) improved participants' accuracy and response times relative to an invalid one (see Figures 4(C) & (D)), consistent with Hagemann et al's (2006) findings, but in contrast to those of Cañal-Bruland (2009). This may be attributed to the 'priming' effect (Soto & Humphreys, 2007) of the words: they were readily accessible at the point of making the decision (cf. Tversky & Kahneman, 1973). Nonetheless, it is important to note that this is still a surprising finding, when considering that the cues were entirely non-predictive – i.e., they were valid for only 50% of trials. The link between exogenous orienting of attention and netball task decision accuracy is not only highly novel, but also challenging to explain. However, a comparable effect was observed by Shimojo, Simion, Shimojo, & Scheier (2003), who exogenously manipulated the duration of participants' gaze at on-screen faces by increasing the duration for which the faces were presented. Longer durations promoted greater overt attention – and ultimately preferences. Hence, it is possible that, in the present data, the reflexive cueing effect of the exogenous cues promoted an increased gaze duration for the cued side, which engendered a preference for one team mate/passing option over another. Again, eye movement data collection would enable us to determine this unequivocally.

The varied effects across the discrimination and netball tasks may be interpreted in light of Lavie et al.'s (2004) Load Theory, which was put forward to resolve the early-versus-late selection debate in attention research. Using a series of experiments, Lavie et al. proposed a hybrid of the two approaches, for which two discrete mechanisms exist: when an ongoing task is perceptually demanding, a passive selection mechanism operates to exclude distracters from perceptual processing; and when cognitive load is high (e.g., when WM is under great demand), a more active system seeks to minimise disruptive intrusions, so as to maintain ongoing task performance. However, the 'monitoring function' of this system ironically renders it vulnerable to irrelevant distracters. This seems to have occurred in the present study: although the netball task was arguably more cognitively demanding than the discrimination task – participants were required to anticipate, inter alia, implied player movements, potential interceptions, etc. – it did not present the same perceptual challenge and so performance on this task was more prone to auditory cueing effects. Although Load Theory was developed using visual stimuli, it has since been successfully used as a framework for examining the effects of verbal auditory load on selective attention (Dittrich & Stahl, 2012), and so may provide a useful scaffold for further investigations of crossmodal cueing effects in sport.

In contradiction to Load Theory (Lavie, et al., 2004), combined visual and auditory cues successfully capture attention under high perceptual loads (Spence & Santangelo, 2009); hence, a fruitful line of enquiry would be to examine the effects of multimodal cueing (i.e., doubly valid visual and auditory cues in combination) on attention and consequent decision-making. To use such cues would more closely replicate the actuality – the bombardment of the senses that occurs in many sporting contexts; investigations in cognitive psychology have largely been confined to examining the impact of cues in one modality on performance in another, most notably the impact of auditory cues on visual task performance (e.g., Koelewijn, et al., 2009). If an arm-waving, hollering team mate was also the 'best' passing option, then such a combination of visual and auditory cues would be doubly valid. Research suggests that effects are most pronounced when the two types are matched along one or more dimensions (e.g., low spatial position and low pitch; Ben-Artzi & Marks, 1995) and so the use of auditory tones played at pitches that correspond to visual cue locations should accelerate attention to, and consequently learning from, previously-identified information-rich regions of the visual display (e.g., Hagemann, et al., 2006). The paradigms employed by Hagemann et al. (2006) and Cañal-Bruland (2009) could easily be adapted to comprise multimodal cues.

5.1. Conclusions

Our data show that not only did auditory capture of attention occur when performing visual detection tasks, but that decision-making in more complex visual tasks was also affected – often to the extent that decision accuracy improved with cue validity. The most notable and novel finding from the present study was the power of spatial cues to exert this effect; to our knowledge, this has not hitherto been demonstrated in a sport setting. In accordance with previous findings and extant theory (Lavie, et al., 2004), it is apparent that a visual task with high perceptual demands may attenuate the effects of spoken cues – a notion which warrants further consideration, given the inherently multimodal and perceptually demanding nature of many team sports.

We have established a profound effect of concurrently presented auditory information on visual detection, visual discrimination and decision-making task performance. Given the evidence for the sharing of neural pathways by both visual and auditory attention (Brown, Clarke, & Barry, 2007; Donohue, Roberts, Grent-'t-Jong, & Woldorff, 2011), this is a necessary and timely consideration. Recent discussion of representative task design has centred on the extent to which perception and action are coupled (Dicks, et al., 2009; Kingsley, Russell, & Benton, 2012; Pinder, et al., 2011; Vilar, et al., 2012). However, auditory information is undeniably a ubiquitous environmental constraint in many sporting contexts – moreover, a demonstrably impactful one – and so warrants greater consideration in future investigations of visual perception and attention in sport, in order to strive for greater task representativeness.

6. References

Abernethy, B., Neal, R. J., & Koning, P. (1994). Visual-Perceptual and Cognitive Differences Between Expert, Intermediate, and Novice Snooker Players. *Applied Cognitive Psychology*, *8*, 185-211. doi: 10.1002/acp.2350080302

Ben-Artzi, E., & Marks, L. E. (1995). Visual-auditory interaction in speeded classification: Role of stimulus difference. *Perception & Psychophysics*, *57*, 1151-1162. doi: 10.3758/BF03208371

Berger, A., Henik, A., & Rafal, R. (2005). Competition Between Endogenous and Exogenous Orienting of Visual Attention. *Journal of Experimental Psychology: General, 134*, 207-221. doi: 10.1037/0096-3445.134.2.207

Cañal-Bruland, R. (2009). Visual cueing in sport-specific decision-making. *International Journal of Sport & Exercise Psychology, 7*(4), 450-464. doi: 10.1080/1612197X.2009.9671919

Canal-Bruland, R., & Hagemann, N. (2007). Posner's cueing paradigm with sport-specific stimuli. *Journal of Sport & Exercise Psychology, 29*, S58-S59. doi: 10.1080/1612197X.2009.9671919

Castiello, U., & Umiltà, C. (1992). Orienting of attention in volleyball players. *International Journal of Sport Psychology, 23*, 301-310.

Dicks, M., Davids, K., & Button, C. (2009). Representative task designs for the study of perception and action in sport. *International Journal of Sport Psychology, 40*(4), 506-524.

Dittrich, K., & Stahl, C. (2012). Selective impairment of auditory selective attention under concurrent cognitive load. *Journal of Experimental Psychology: Human Perception and Performance, 38*, 618-627. doi: 10.1037/a0024978

Enns, J. T., & Richards, J. C. (1997). Visual attentional orienting in developing hockey players. *Journal of Experimental Child Psychology, 64,* 255-275. doi: 10.1006/jecp.1996.2348

Gegenfurtner, A., Lehtinen, E., & Säljö, R. (2011). Expertise Differences in the Comprehension of Visualizations: a Meta-Analysis of Eye-Tracking Research in Professional Domains. *Educational Psychology Review, 23*, 523-552. doi: 10.1007/s10648-011-9174-7

Hagemann, N., Strauss, B., & Cañal-Bruland, R. (2006). Training Perceptual Skill by Orienting Visual Attention. *Journal of Sport & Exercise Psychology, 28*, 143-158.

Hughes, P. K., Blundell, N. L., & Walters, J. M. (1993). Visual and psychomotor performance of elite, intermediate and novice table tennis competitors. *Clinical & Experimental Optometry, 76*, 51-60. doi: 10.1111/j.1444-0938.1993.tb05090.x

Jonides, J. (1981). Voluntary vs. automatic control over the mind's eye in movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and Performance IX*. Hillsdale, NJ: Erlbaum.

Kingsley, M., Russell, M., & Benton, D. (2012). Authors' response to letter to the Editor: "The need for 'representative task design' in evaluating efficacy of skills tests in sport: A comment on Russell, Benton and Kingsley (2010)". *Journal Of Sports Sciences, 30*(16), 1731-1733.

Koelewijn, T., Bronkhorst, A., & Theeuwes, J. (2009). Auditory and visual capture during focused visual attention. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 1303-1315. doi: 10.1037/a0013901

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load Theory of Selective Attention and Cognitive Control. *Journal of Experimental Psychology: General*, *133*, 339-354. doi: 10.1037/0096-3445.133.3.339

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-Cognitive Expertise in Sport: A Meta-Analysis. *Journal of Sport & Exercise Psychology, 29*, 457-478.

Masters, R. S. W., van der Kamp, J., & Jackson, R. C. (2007). Imperceptibly Off-Center Goalkeepers Influence Penalty-Kick Direction in Soccer. *Psychological Science*, *18*, 222-223. doi: 10.1111/j.1467-9280.2007.01878.x

Nougier, V., Ripoll, H., & Stein, J. F. (1989). Orienting of attention with highly skilled athletes. *International Journal of Sport Psychology*, *20*, 205-223.

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative Learning Design and Functionality of Research and Practice in Sport. *Journal of Sport & Exercise Psychology, 33*(1), 146-155.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25. doi: 10.1080/00335558008248231

Posner, M. I., Snyder, C. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General*, *109*(2), 160-174. doi: 10.1037/0096-3445.109.2.160

Salverda, A. P., & Altmann, G. T. M. (2011). Attentional capture of objects referred to by spoken language. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 1122-1133.

Santangelo, V., Olivetti Belardinelli, M., & Spence, C. (2007). The suppression of reflexive visual and auditory orienting when attention is otherwise engaged. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 137-148. doi: 10.1037/0096-1523.33.1.137

Shimojo, S., Simion, C., Shimojo, E., & Scheier, C. (2003). Gaze bias both reflects and influences preference. *Nature Neuroscience, 6*, 1317-1322. doi: 10.1038/nn1150

Sosa, Y., Clarke, A. M., & McCourt, M. E. (2011). Hemifield asymmetry in the potency of exogenous auditory and visual cues. *Vision Research, 51*, 1207-1215. doi: 10.1016/j.visres.2011.03.012

Soto, D., & Humphreys, G. W. (2007). Automatic guidance of visual attention from verbal working memory. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 730-737. doi: 10.1037/0096-1523.33.3.730

Spence, C. (2001). Crossmodal attentional capture: a controversy resolved? In C. Folk & B. Gibson (Eds.), *Attention, distraction and action: multiple perspectives on attentional capture* (pp. 231-262). Amsterdam: Elsevier Science BV.

Spence, C., & Santangelo, V. (2009). Capturing spatial attention with multisensory cues: A review. *Hearing Research, 258*, 134-142. doi: 10.1016/j.heares.2009.04.015

Theeuwes, J., Kramer, A. F., Hahn, S., & Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science, 9*(5), 379-385. doi: 10.1111/1467-9280.00071

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5*, 207-232. doi: 10.1016/0010-0285(73)90033-9

Vilar, L., Araújo, D., Davids, K., & Renshaw, I. (2012). The need for 'representative task design' in evaluating efficacy of skills tests in sport: A comment on Russell, Benton and Kingsley (2010). *Journal Of Sports Sciences, 30*(16), 1727-1730.

Ward, P., Williams, A. M., & Loran, D. F. C. (2000). The development of visual function in elite and sub-elite soccer players. *International Journal of Sports Vision, 6*, 1-11.

Williams, A. M., & Grant, A. (1999). Training perceptual skill in sport. *International Journal of Sport Psychology, 30*, 194-220.

Wright, R. D., & Ward, L. M. (2008). *Orienting of attention*. Oxford: Oxford University Press.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance, 16*, 121-134. doi: 10.1037/0096-1523.16.1.121

7. Figures

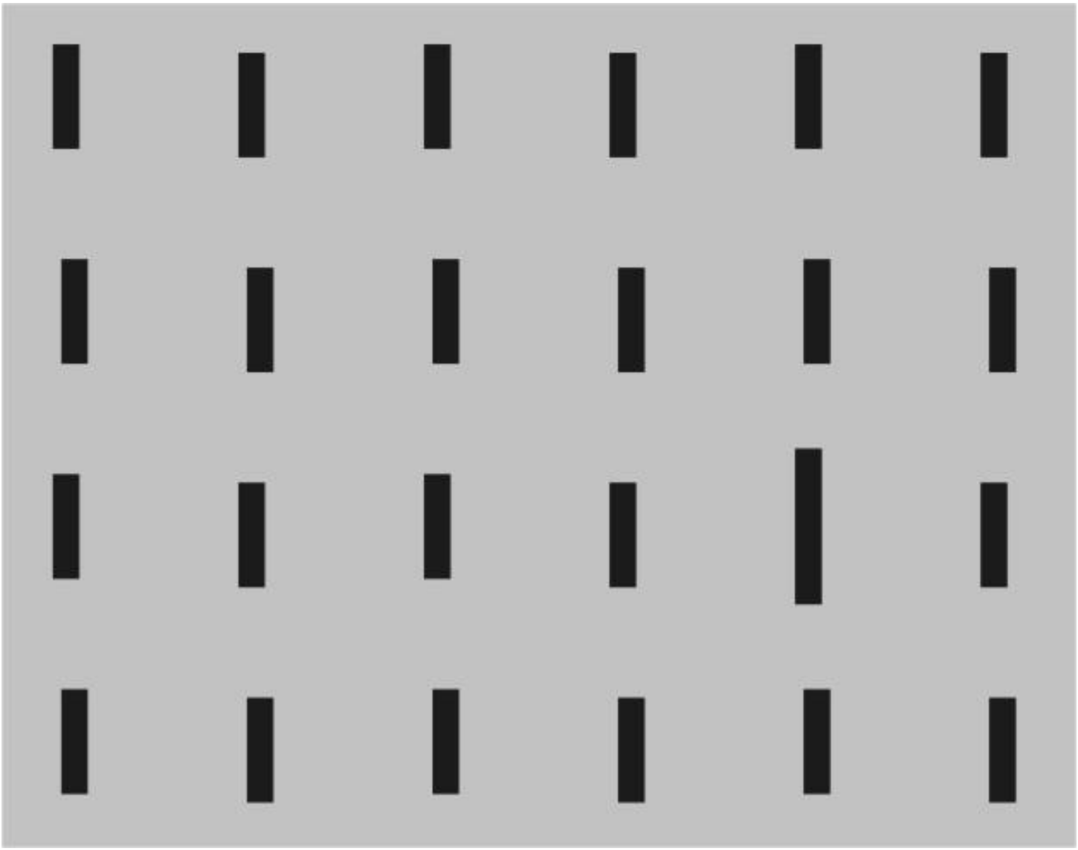

Figure 1. Visual detection task – sample stimulus

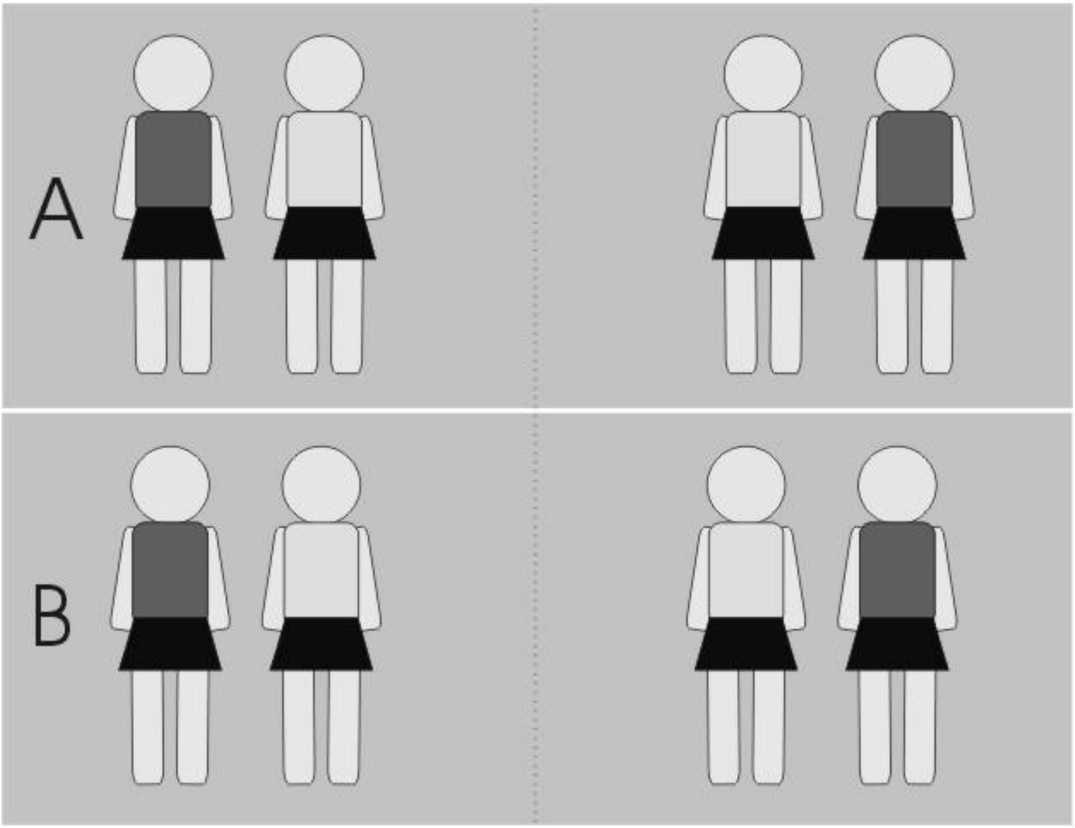

Figure 2. Visual discrimination task – two sample stimuli

Figure 3. Netball task – sample stimulus

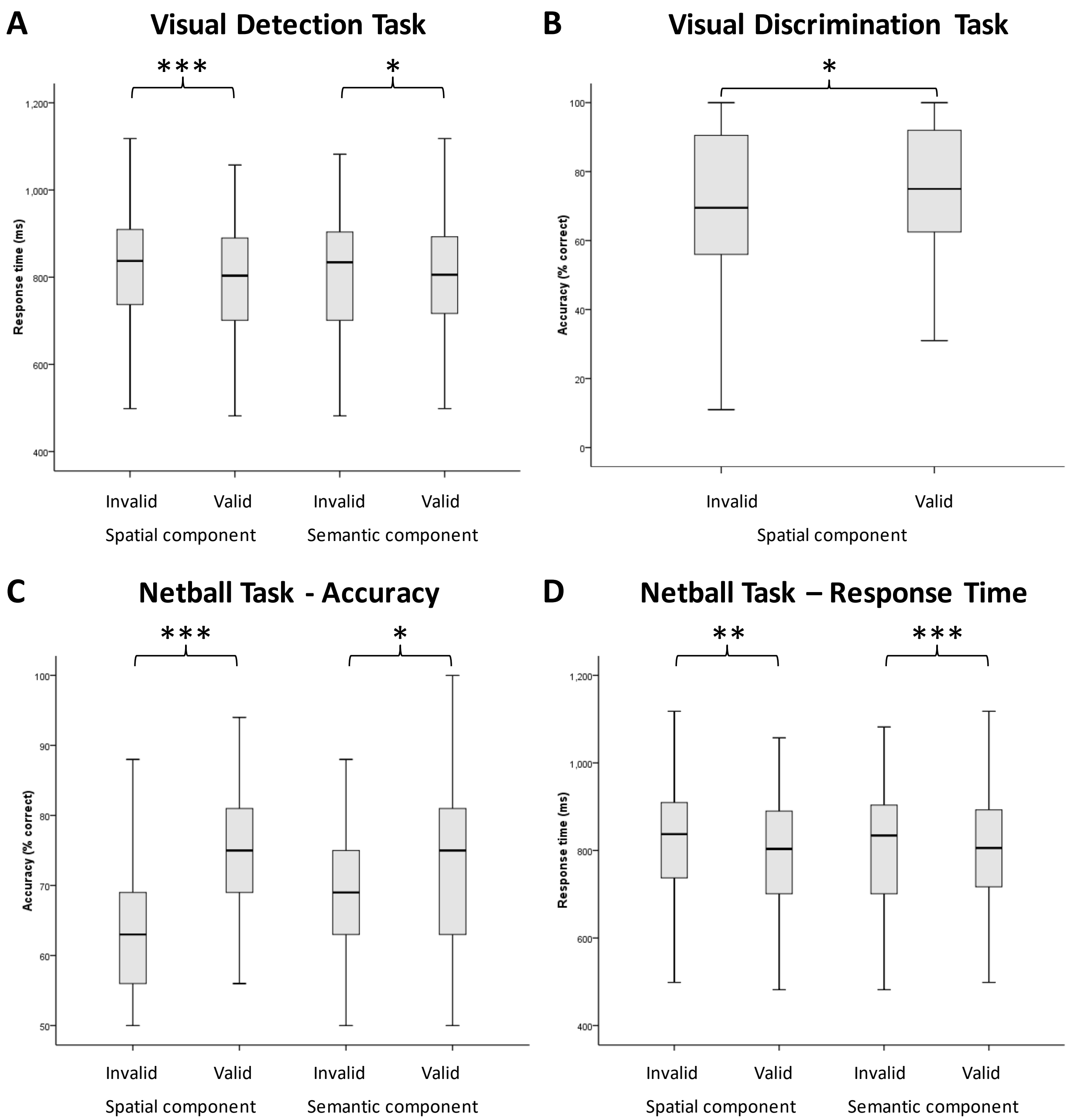

Figure 4. Experiment 2: Main effects – all tasks

Note. *** $p < .001$; ** $p < .005$; * $p < .05$; (A): visual detection task – main effects of spatial and semantic components on response time; (B): visual discrimination task – main effect of the spatial component on accuracy; (C) and (D): Netball Task – main effects of spatial and semantic components on accuracy (C) and response time (D).

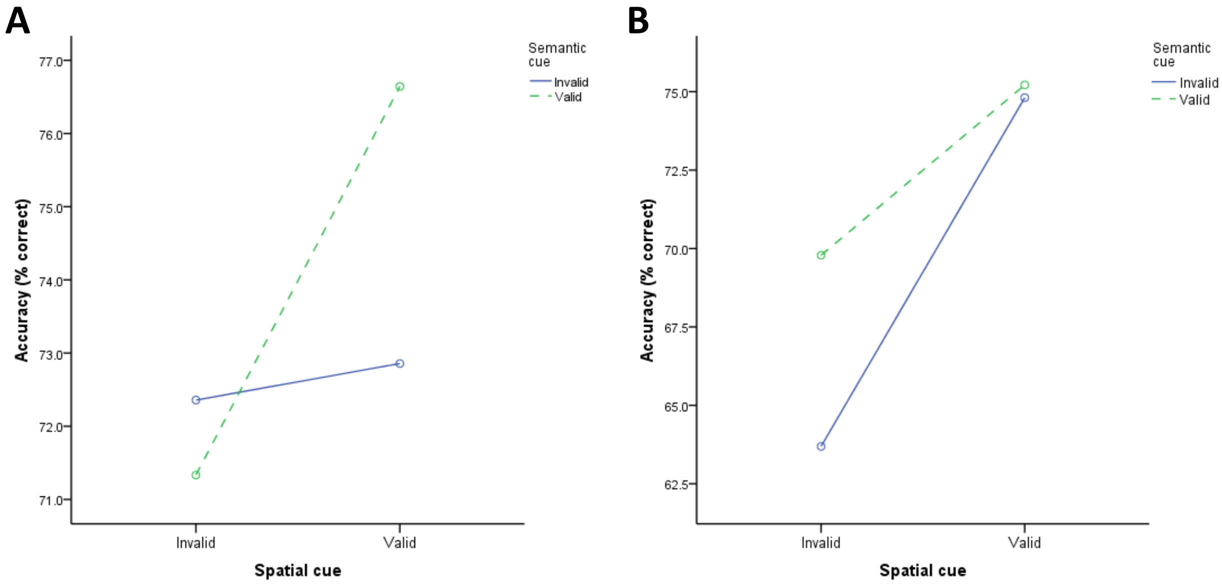

Figure 5. Significant interactions – visual discrimination (A) and netball (B) tasks