



# Asymmetries in spatial perception are more prevalent under explicit than implicit attention



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## ABSTRACT

Observers typically show systematic errors in spatial perception when asked to bisect a line. We examined whether misbisection relates to the extent by which the midpoint is scrutinized explicitly. Participants were required to position a soccer goalkeeper at the exact midpoint of the goal line, drawing explicit attention to the midpoint of the line. Subsequently, they carried out a penalty kick to score a goal, without eliciting explicit attention for the centre of the goal for choosing the side to which to kick the ball. We found that participants positioned the goalkeeper to the right of the centre, confirming the previously reported rightward bias for line bisections in extra-personal space. Although participants (erroneously) believed that the goalkeeper stood in the centre, they kicked the ball to the bigger side of the goal more often. These findings indicate that asymmetries in spatial perception are more evident with explicit than implicit attention.

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## 1. Introduction

Neurologically normal individuals err when asked to bisect a line into two halves, for instance by marking the midpoint of a line on a sheet of paper (Bowers & Heilman, 1980). Typically, people systematically misbisect lines to the left of the veridical centre. Reuter-Lorenz, Kinsbourne, and Moscovitch (1990) hypothesized that misbisection reflects the relative dominance of the right hemisphere over the left hemisphere in spatial attention (see also Heilman & van den Abell, 1980; Kinsbourne, 1993). This right hemispheric dominance in spatial attention leads to an expansion of the contralateral left visual field (cf. Fink et al., 2000; Thiebaut de Schotten et al., 2011), resulting in the left half of a line being perceived as longer than the right half (cf. Bultitude & Aimola Davies, 2006). Consequently, the explicitly perceived midpoint of a line is perceived to be somewhat to the left of the true midpoint.

Interestingly, however, the direction of misbisection depends on the individual's distance to the line: lines in near space are bisected to the left, whereas lines in far space (i.e., beyond arm reach) are bisected to the right (Covey, Small, & Ellis, 1994; Halligan & Marshall, 1991; Longo & Lourenco, 2006). It has remained somewhat obscure why misbisection is mediated

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by distance, but explanations are usually grounded in the idea that near and far spaces are differently coded and involve different cortical areas (e.g., Weiss et al., 2000). Accordingly, Nicholls, Loetscher, and Rademacher (2010) demonstrated an attentional asymmetry in goal kicking in Australian football, arguably a more representative task with respect to daily activities. In Australian football there is no goalkeeper, and hence the players typically aim for the middle of the goal. In their laboratory study, Nicholls et al. (2010) told participants to kick the ball exactly in between two goal posts in far space. They observed, however, that participants systematically kicked to the right of the goal centre, underlining that they perceived centre of the goal to the right of the true centre. Observations of Australian football matches confirmed a right side bias for kicks at the goal with more balls missing to the right of the goal than to its left.

It is obvious that the midpoint judgments in the aforementioned tasks were always deliberate or explicit; participants intentionally searched for the veridical centre and responded accordingly. This raises the question whether misbisection also occurs when participants unknowingly or implicitly search and use midpoint information. In this regard, some authors have argued that attentional asymmetries are indeed restricted to explicit perceptual judgments. Hughes, Bates, and Aimola Davies (2004, 2008) found no direction bias for grasping a wooden rod when participants were told to ascertain that the rod was evenly balanced in the hand – a task that is presumably accomplished without explicit judgment about the rod's midpoint. By contrast, the typical direction biases occurred on trials during which participants were explicitly instructed to identify the rod's midpoint (i.e., the standard line bisection during pointing). These findings suggest that the instruction biases the perceived midpoint, presumably because it manipulates the extent to which attention is explicitly directed towards searching and using information about the midpoint. Notice, however, that the participants' awareness was neither directly assessed nor controlled by anything else than instructions. Because the two tasks also had distinct functional goals, it is difficult to entirely rule out alternative explanations that – for example – misbisections relate to perception and not to action (see two-visual systems model by Milner & Goodale, 1995, 2008). As a first step to resolve this issue, we undertake to create a situation that first establishes the participants' explicit attention towards the midpoint to then scrutinize to what degree subsequent implicit interactions with the midpoint are (still) affected by the attentional asymmetry. If misbisection is a function of the degree to which attention for the midpoint is explicit, systematic errors to one side of the veridical centre are more likely to occur for explicit than for (subsequent) implicit interactions.

To analyse this in more detail, we adopted the penalty kick in association football (i.e., soccer), which contrary to Australian football does involve a goalkeeper, and combined typical line bisection procedures (for an overview see Jewell & McCourt, 2000) with the recently developed off-centre paradigm (Masters, van der Kamp, & Jackson, 2007). In soccer penalty kicking, the position of the goalkeeper on the goal line relative to its centre influences a player's decision to which side to kick the ball with a systematic preference for the goal side with greater space. In the off-centre paradigm, it is found that this is true even when goalkeepers stand only marginally (i.e., between 5 and 10 cm) to the left or right side of the veridical centre and the player is not aware that the goalkeeper is positioned off-centre (Masters et al., 2007; Weigelt & Memmert, 2012; Weigelt, Memmert, & Schack, 2012). In-depth investigations are currently lacking, but it is argued that the systematic decisions to direct the ball to the side with greater space reflect an implicit judgment (or comparison of the spaces on both sides of goalkeeper). Yet, the player erroneously believes that the goalkeeper stands in the middle of the goal. It has not been tested directly, however, whether this off-centre effect is indeed biased by (or arises from) explicit misperceptions of the goal's centre.

In the current study, we asked penalty takers to (verbally) direct/guide the goalkeeper to the centre of the goal (i.e., line bisection at a distance) and once they believed that the goalkeeper stood in the exact middle, to kick the ball to score a goal (i.e., off-centre paradigm). Crucially, by doing so, we first drew the participants' explicit attention to the midpoint and then examined to what degree this mediates implicit interactions with the same midpoint (i.e., participants were instructed to score a goal without any hinting to side or goalkeeper position). Accordingly, when they kicked the ball, the participants believed that the goalkeeper was in the exact middle, even in those cases in which they made misbisection errors. Consequently, any bias to kick the ball to one goal side must then stem from implicit attention to the goalkeeper's location relative to the centre of the goal (or comparisons of the space of the two halves of the goal). If so, this would indicate that misbisection errors are related to explicit attention towards the midpoint. Specifically, we expected that the participants' explicit judgement of the goal's centre would be systematically biased to the right side and hence participants would place the goalkeeper to right of the true centre of the goal, similar to the right side bias observed in previous distant line bisection studies (Nicholls et al., 2010). In cases that the goalkeeper would indeed not be placed in the veridical centre of the goal – unbeknownst to the participants (!) –, we anticipated that participants would kick to the goal side with greater space more often, as was observed in previous off-centre studies (Masters et al., 2007). In other words, we expected that the performance in the positioning task was less accurate and more prone to attentional asymmetries than performance in the kicking task.

## 2. Methods

### 2.1. Participants

Seventy-six intermediate soccer players (69 male, 7 female) with an average age of 22.6 (SD = 4.2) took part in this experiment. All participants played amateur soccer or soccer for recreational purpose on a regular basis for a minimum of ten years. Sixty-nine participants were right-footed and seven left-footed, all participants were right-handed. Four different

goalkeepers (mean age: 24.5; SD = 6.3) functioned as a goalkeeper throughout the experiment, and were naïve to the purpose of the experiment. All participants provided written consent prior to the experiment, and were treated in accordance with the local institution's ethical guidelines. The local ethics committee approved the study before it was carried out.

## 2.2. Apparatus

The experiment took place on an adult-sized soccer field. The goal's dimensions (7.32 m × 2.44 m) and the distance between the penalty mark and goal centre (11 m) were in accordance with FIFA rules. Throughout the whole experiment, "FIFA approved" balls (size 5) were kicked towards a goal in front of a background with minimum visual texture. A measuring tape was placed on the goal line in between both posts to delineate the goalkeeper's position relative to the centre of the goal (in cm) after the first task of the experiment.

The paper line bisection task consisted of eight horizontal lines on a white paper sheet that was attached vertically to a flipchart. Line length was on average 10.25 cm and ranged from 5 to 16 cm. The lines were arranged in a way that none of the veridical centres of the lines were at the same horizontal position. Participants used a fine pencil to bisect lines.

## 2.3. Procedure

After providing informed consent, half of the participants started with the paper line bisection task, while the other half performed this after the main experiment. For the paper line bisection task, the participants were instructed to bisect the eight lines as accurate as possible using their dominant hand. There were no time restrictions.

For the main experiment, the participants took ten penalty kicks. Prior to each penalty kick, they verbally guided the goalkeeper to the exact centre of the goal (positioning task). To this end, the goalkeeper positioned himself to the inside of the left or right goalpost (in alternating order). The goalkeeper waited for the penalty takers' go signal to start displacing himself on the goal line towards the other post (It was emphasized to the goalkeeper to make very small steps and to move at low speed). Participants, who were standing one step behind the ball (i.e., approx. 12 m from the goal line), verbally indicated the keeper to stop, when they perceived the goalkeeper's body midline to coincide with the exact centre of the goal. If they believed that the goalkeeper had stopped at the incorrect position, the participants were allowed to alter the goalkeeper's position. It was stressed that accuracy was of utmost importance. In addition, once they had positioned the goalkeeper, the participants looked at their feet until they received permission to kick the ball. In the meantime, the goalkeeper identified his position relative to the goal's true centre referring to the measuring tape. That is, goalkeepers stood, feet together, on the measuring tape and identified their position by reading the value at the point where the feet contacted each other. After reading the value, they used their hands to communicate this to a research assistant who was naïve to the purpose of the experiment. This procedure was practiced before the experiment and the importance to adhere to the procedure was stressed several times during the experiment.

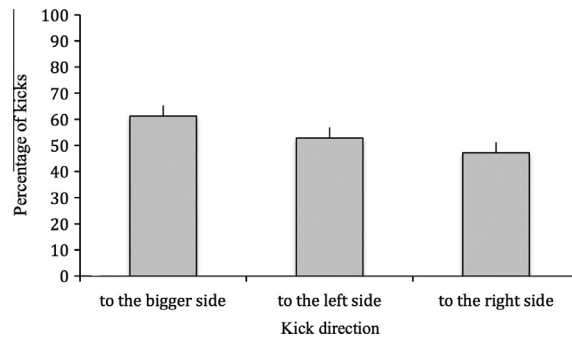
When the penalty taker believed that the goalkeeper was standing in the exact centre of the goal, he/she was asked to kick the ball and to score a goal without the experimenter indicating in any way that goal sides could differ in space (kicking task). Run-ups (not angled in any way) started at the exact position from where participants verbally guided the goalkeeper (i.e., approx. 1 m behind the ball). Before the experiment, goalkeepers were encouraged to try and save the penalty kick, but with some limitations. They were advised that after they had identified their position they should not move before the penalty taker contacted the ball and to not commit to one side too early. Goalkeepers were told to assume an arms-parallel posture throughout the experiment to avoid influences of their posture on perception (van der Kamp & Masters, 2008). The penalty takers were also informed about these instructions for the goalkeeper in order to avoid that they employed a keeper dependent strategy during the run-up (van der Kamp, 2006). This way, we made sure that penalty takers decided for a goal side independent of the goalkeeper's actions rather than waiting for the goalkeeper's to commit to one side and kick the ball to the undefended side.

## 2.4. Analysis

The data of the positioning task is described from the penalty taker's perspective. For both the paper line bisection and the positioning task positive values indicate a bias to the right of the veridical centre, whereas negative values indicate a bias to the left. Distance from the paper line's midpoint was measured in millimetres, whereas distance in the positioning task was measured in centimetres. One-sample *t*-tests were used to compare the mean distance of the midpoint with zero (i.e., the actual midpoint is defined as zero). In addition, separate one-sample *t*-tests were used to test whether more than 50% of the kicks were directed to the side with more space and to either the left or right side of the goal.

## 3. Results

A one-sample *t*-test comparing the mean distance from the midpoint on the paper line bisection task to zero showed a significant bias to the left,  $t(75) = -2.38$ ,  $p < .03$ ,  $d = 0.26$ . The distance to the *left* side was 0.5% of the total length of the line (SD = 1.9%). A similar *t*-test for the goalkeeper positioning task revealed that on average, participants positioned the



**Fig. 1.** Choice for target location as a function of size of the sides to the left/right of the goalkeeper and preferences to kick to the left/right side. Error bars indicate standard errors.

goalkeeper significantly to the *right* of the centre of the goal,  $t(75) = 2.61$ ,  $p < .02$ ,  $d = 0.3$ . On average, the goalkeeper was placed to the right of centre for 0.6% (SD = 2.1%) of the goal line's length (i.e., 4.5 cm). Participants placed the goalkeeper in the true centre of the goal in less than 3% of all trials. No participant placed the goalkeeper in the true centre more than once. In 464 trials (62%), the participants placed the goalkeeper to the right side of the goal's true centre, while in the remaining 280 trials (38%) participants erred by placing the goalkeeper to the left side of the centre. There was no significant correlation between the results of the paper line bisection and the goalkeeper positioning task,  $r(73) = -.038$ ,  $p > .7$ .

For trials in which the goalkeeper was placed to either the left or right side of the goal's centre (unbeknownst to participants), a one-sample  $t$ -test comparing the mean percentage of kicks to the greater side to 50% (i.e., chance level) showed that penalty takers kicked to the side of the goal with more space above chance level,  $t(81) = 4.17$ ,  $p < .001$ ,  $d = 0.48$  (Fig. 1). However, they did not kick to one side of the goal (i.e., left or right) significantly more often,  $t(75) = 0.83$ ,  $p > .4$  (Fig. 1). Furthermore, the effect of the goalkeeper's position on kick direction does occur as often for goalkeepers that were displaced to the left (i.e., 62%) as for goalkeepers that were displaced to the right (i.e., 59%),  $\chi^2(2, N = 744) < 0.1$ ,  $p > .9$ .

#### 4. Discussion

The current study compared performance on a line bisection task that requires participants to explicitly identify the centre of the goal with performance on a kicking task that also involves the judgment of the goal's centre, but implicitly, without the participants explicitly using this information. Specifically, participants first verbally guided the goalkeeper to the centre of the goal (positioning task) and then carried out a penalty kick subsequently (kicking task). The results show that the participants typically failed to deliberately place the goalkeeper in the exact centre of the goal. Unbeknownst to the participants, this split the soccer goal into two uneven halves, creating more space on one goal side. Although penalty takers believed the goalkeeper to be standing in the exact centre of the goal, they more often kicked to the side with greater space. Put differently, even if penalty takers would deliberately attend to the goalkeeper's position – and there is no reason to think they would because they were merely asked to score against a goalkeeper they had just positioned in the middle of the goal and it was in no way indicated that one side could be bigger than the other – they would have explicitly perceived him to stand in the exact middle. Importantly, the prevalence of kicks to the side with greater space occurred regardless of the direction of the goalkeepers' displacements (to the left or right). This indicates that asymmetries in spatial perception are more prevalent when judgments are based on explicit attention than when they are based on implicit attention.

When deliberately trying to place the goalkeeper in the centre of the goal, participants erred to the right side of the veridical centre. On average the goalkeeper was positioned 4.5 cm too far to the right. This indicates that the explicitly perceived centre of the goal line systematically differs from the veridical centre of the goal. Previous studies have reported similar misbisections to the right for lines in far space (e.g., Nicholls et al., 2010). However, typically lines in near space are bisected too far to the left side (for an overview see Jewell & McCourt, 2000), suggesting that the distance to the line mediates the direction of the error (e.g., Longo & Lourenco, 2006). The current study corroborates this suggestion. While participants positioned the goalkeeper to the right of the centre of the goal, they systematically erred to the left side of the veridical centre on the paper line bisection task. In addition, the errors on the paper line bisection and goalkeeper positioning tasks were not significantly correlated, which is in line with earlier, statistically unsubstantiated observations for line bisections in near and far space (Gamberini, Seraglia, & Prifits, 2008; Longo & Lourenco, 2006; McCourt & Garlinghouse, 2000).

Previc (1990, see also, 1998) posited an influential model on the perception of space based on physiological, anatomical and neuropsychological data. Roughly, Previc (1990) distinguished a peripersonal or near space, which is biased to the lower visual field and underlies action (in particular object manipulation), and an extra-personal or far space, which is biased towards the upper visual field and serves object perception. He proposed that different brain systems mediate these functions. Previc's model can accommodate that line bisection errors are not identical in near and far space, or indeed do not relate to each other, as observed in the current study. However, this and other models do not readily – as far as we

can understand – explain the reversal in the direction of line bisection errors as a function of space (see also [McCourt & Garlinghouse, 2000](#)). Hence, it is an important task for future research to also incorporate the *nature* of the distance-specific asymmetries in spatial perception, as they are observed in line bisection studies, in an encompassing framework.

Taken together, we show that performance on the current version of the line bisection task (i.e., verbally directing the goalkeeper to the centre of the goal) points to an attentional asymmetry for explicit bisection judgments. This confirms the occurrence of systematic misbisections when *deliberately* trying to identify the midpoint of a line or space in a task design representative for daily activities. Significantly, however, the current study is the first to show that the asymmetrical errors do not directly translate into implicit judgments (i.e., deciding where to kick) that similarly involve information about the goalkeeper's position relative to the midpoint of the goal line. That is, regardless of the direction of the goalkeeper's misplacement relative to the goal centre, participants were inclined to kick the ball to the side of the goalkeeper with more space more often, even though they explicitly perceived the goalkeeper to be standing in the exact middle (while in fact this was only the case in roughly 3% of the trials). This replicates the typical findings in the off-centre paradigm ([Masters et al., 2007](#); [Weigelt & Memmert, 2012](#); [Weigelt et al., 2012](#)), yet, in a more representative task design on the field with an acting goalkeeper that attempts to save the ball, instead of stationary pictures on a screen in the lab. More importantly, however, the off-centre effect shows that the explicitness of attention for the midpoint of a line affects the accuracy of spatial perception and subsequent decision-making. This is reminiscent of a larger body of research suggesting that implicit or unconscious perception or decision-making can be enhanced relative to more explicit or conscious perception or decisions (e.g., [Mattler & Palmer, 2012](#)).

In this regard, the off-centre effect can be analysed by using the framework of [Dehaene, Changeux, Naccache, Sackur, and Sergent \(2006\)](#). These authors distinguish two different kinds of unconscious processing. On the one hand, decision making can be affected unconsciously by stimulus information that is strong enough to gain access to consciousness, but goes unnoticed because attention is directed elsewhere. This is called preconscious processing. On the other hand, stimulus information can be too weak to be perceived consciously, but still be sufficiently strong to influence decision-making unconsciously – provided that it is attended to implicitly ([Naccache, Blandin, & Dehaene, 2002](#)). This is called subliminal processing. Arguably, it is subliminal processing that triggers the off-centre effect; the magnitude of goalkeeper displacement is too small to be noticed. The stimulus information specifying that the goalkeeper stands marginally off-centre is too weak and below subjective threshold. Nevertheless, this implies that participants must have attended to the goalkeeper's positioning implicitly; otherwise it could not have systematically influenced the decisions to kick to the side with greater space.

In the goalkeeper positioning task, the task instructions enforced that participants deliberately searched for the goal centre. This deliberate search might have blocked or overridden any influences of subliminal processing, the subliminally detected information simply being too weak to compete with the explicitly gained information.<sup>3</sup> In the kicking task, however, there is reduced or no explicit attention for the goalkeeper's position relative to the goal centre, and hence, the weak, but more-fine grained, subliminally detected stimulus information becomes more influential. This results in the participants aiming for the side of the goal with greater space in about 60% of the trials, irrespective of whether the goalkeeper stood closer to the right or left of the veridical centre. The off-centre effect thus appears relatively immune to the systematic errors in spatial perception that occur when participants deliberately judge the centre of the goal. This shows that subliminally processed information regarding the goalkeeper's position is largely spared from the attentional *asymmetries* that characterize the equivalent explicit judgments: otherwise only goalkeepers standing to the left of the veridical centre (i.e., clearly away from the explicitly perceived centre) should have led to an off-centre effect, while displacements of the goalkeeper to the right of veridical centre (i.e., in the direction of the explicitly perceived centre) would not have affected kicking direction. The present findings therefore indicate that the observed asymmetries in line bisection judgments are based on explicit attention.

We have framed the current findings in terms of the distinction between explicit and implicit attention, but alternative interpretations cannot be ruled out completely. For example, the goalkeeper positioning and kicking tasks differ on other aspects than explicitness of attention. [Hughes et al. \(2004, 2008\)](#) related the occurrence of misbisection to the existence of two functionally and neuro-anatomically dissociated systems of stimulus information processing for perception and action (see two-visual systems model by [Milner & Goodale, 1995, 2008](#)), with attentional asymmetries occurring only for the perception system. At first sight, the current goalkeeper positioning task would rely much stronger on the perception system than the kicking task, which would be dependent on the action system. However, recent evidence indicates that far aiming tasks, such as throwing or kicking objects to targets at a distance, require important contributions of the perception system as well. Aiming towards a target is systematically biased by optical illusions (e.g., [Shim et al., 2014](#); [van der Kamp & Masters, 2008](#); [van der Kamp, van Doorn, & Masters, 2009](#)). This bias suggests that in far aiming contextual or allocentric stimulus information is used, which is uniquely processed by the perception system (e.g., [Milner & Goodale, 2008](#)). Hence, the distinction between the current positioning and kicking tasks in terms of perception and action systems might be less straightforward as it appears on first sight. That is, it is not unlikely that the off-centre effect would also have emerged if we had asked the participants to only verbally indicate to which side they kick (see [Masters et al., 2007](#), Exp. 1 & 2). In addition, the perceptual error observed in the present positioning task was similar to the error observed by [Nicholls et al. \(2010\)](#) in their kicking task. Of course, this does not rule out that misbisection stronger relates to the perception than

<sup>3</sup> In subliminal priming studies there is typically only a subliminal prime without any other competing (conscious) stimuli that can influence decision-making. This is regardless of the way the primes are presented (e.g., masking, or making use of attentional blink).

the action system, not in the least, because the action system typically functions implicitly. However, we think that further scrutinizing the hypothesis that subliminal processing, as conceptualized in the model of Dehaene et al. (2006), is immune to spatial asymmetries may be more fruitful.

In sum, although the current study is only a first step, the findings of the present study suggest that asymmetries in spatial perception, as reported for line bisection tasks, but also in more typical everyday activities, such as aiming in ball sports, particularly occur when people engage in explicit judgments of the relevant environmental property. By contrast, equivalent judgments that are made implicitly are largely spared from these spatial biases.

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