HARRISON, R.E., GIESEL, M. and HESSE, C. 2024. No evidence for top-down expertise effects on action perception in sprinters using static images. *Neuropsychologia* [online], 202, article number 108945. Available from: https://doi.org/10.1016/j.neuropsychologia.2024.108945

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2024

Neuropsychologia 202 (2024) 108945

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

# No evidence for top-down expertise effects on action perception in sprinters using static images

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ARTICLE INFO

*Keywords:*
Perceptual resonance
Motor expertise
Athletes
Representational momentum
Sprint

ABSTRACT

Athletes have been found to demonstrate a superior ability to detect subtle variations in dynamic displays (e.g., point-light displays and videos) depicting expert actions compared to non-athletes. The current study aimed to determine whether this advantage also exists when dynamic information is unavailable (i.e., using static images). Using a staircase procedure, two frames from a video depicting an athlete either walking (everyday action) or performing a sprint start (expert action) were presented, and athletes (sprinters) and non-athletes were asked to indicate whether the images were identical or different. We examined whether presenting the images sequentially (temporal task) or simultaneously (spatial task) influenced participants' discrimination performance. We predicted that the sprinters would outperform the non-sprinters in the spatial task as body postures could be compared directly but not in the temporal task due to larger representational momentum effects for athletes. Contrary to our hypotheses, the sprinters and non-sprinters performed similarly in all tasks and conditions. In line with the prediction that representational momentum may impair performance, participants' thresholds were lower for the spatial than the temporal task. However, post-hoc analysis suggested that this effect is likely to be better explained by a task order effect whereby participants who completed the temporal task first exhibited an advantage in the spatial task, while there were no performance differences for participants who completed the opposite task order. In sum, our results provide no evidence for the idea that motor expertise affects action perception (i.e., perceptual resonance) in a simple psychophysical task employing static images.

## 1. Introduction

Subtle changes in posture can have important consequences for the successful execution of sport-related actions. For example, achieving an appropriate angle of lean when driving out of the starting blocks can influence a sprinter's ability to accelerate efficiently and reach their top speed in a sprint race. Perceptual resonance is the idea that observers show a selective sensitivity to actions that are related to and share features with their own actions (Schütz-Bosbach and Prinz, 2007), and would predict that athletes are more perceptually sensitive to subtle features of actions related to their sport than non-athletes. Support for this prediction has been demonstrated in previous research where athletes were better able to notice subtle variations in actions from dynamic displays, such as point-light displays (PLDs; Johansson, 1973; Hohmann et al., 2011; Romeas and Faubert, 2015)[1] and videos (Harrison et al., 2023). However, it is not clear whether this advantage persists when dynamic information is unavailable (e.g., in static photographs).

Static and dynamic stimuli have been used in deception detection tasks with athletes, but there is currently no clear consensus about whether the athlete advantage for these tasks is specific to dynamic stimuli or also persists for static stimuli. For example, Sebanz and Shiffrar (2009) investigated basketball players' and novices' ability to identify deceptive passes from videos, PLDs, and static photographs that showed veridical or fake passes up until the ball left (or did not leave) the depicted player's hands. Sebanz and Shiffrar (2009) found that basketball players outperformed novices when presented with video and PLD stimuli, but not when photographs were used. These findings suggest that athletes may only exhibit superior anticipatory performance on visual tasks where dynamic information is available. Conversely, Güldenpenning et al. (2013) found that beach volleyball athletes could

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[1] Point-light displays are animations in which human movements are represented by moving dots corresponding to the body's major joints. This allows the isolation of kinematic/dynamic information.

https://doi.org/10.1016/j.neuropsychologia.2024.108945
Received 21 September 2023; Received in revised form 7 June 2024; Accepted 27 June 2024

detect deception from static photographs at an earlier phase of a volleyball shot than novices. Taken together, the two studies seem to provide contradicting evidence on whether athletes outperform novices on perceptual tasks using static action photographs. However, the discrepant results may have also been caused by differences in their task designs. In the static image condition of their task, Sebanz and Shiffrar (2009) presented a single photograph for 4 s and asked participants to identify whether the depicted pass was veridical or fake. Participants could infer from the posture of the person in the static image that the depicted person was moving (i.e., implied motion), but there was no repeated presentation of subsequent images of the movement sequence inducing apparent motion in the task. Conversely, Güldenpenning et al. (2013) presented two stimuli in quick succession, which could have given the illusion of movement (i.e., apparent motion). Hence, it is possible that this distinction between implied motion and apparent motion could account for the differences in findings.

A potential reason for assuming that static images depicting human actions may elicit similar effects to dynamic displays is provided by brain imaging studies (Kourtzi and Kanwisher, 2000). Specifically, Kourtzi and Kanwisher (2000) found that static images containing implied motion of athletes performing sport-related actions activated areas MT/MST to a greater extent than images of athletes which did not contain implied motion (similar effects were also found for images of implied motion in animal and nature photographs). This suggests that brain areas involved in perceiving real motion are also involved in perceiving implied motion from static stimuli. Furthermore, static stimuli depicting implied motion also appear to engage predictive mechanisms (e.g., Verfaillie and Daems, 2002). For example, it has been found in priming studies that the perception of static postures from complex, sport-related actions automatically activates mental representations of postures from later in the action (Güldenpenning et al., 2012). Further empirical evidence for the role of predictive mechanisms in motion perception comes from the representational momentum effect, where people tend to perceive moving objects further along their (real or apparent) motion trajectory than they actually are (RM; Freyd, 1983; Freyd and Finke, 1984). In their seminal study, Freyd and Finke (1984) presented participants with three consecutive rectangles at different orientations, giving the impression of rotation around the rectangle's central axis. Participants were then presented with a fourth, probe rectangle that was either: identical in orientation to the third rectangle, oriented slightly further along the apparent rotation trajectory, or oriented slightly backwards along the apparent rotation trajectory. Participants' task was to indicate whether the probe rectangle was the same as the third or different. Freyd and Finke (1984) reported that when the probe rectangle was oriented further along the rotation trajectory, participants were more likely to incorrectly judge the orientation of the probe rectangle to be the same as the third rectangle. This effect was not observed when the probe rectangle was oriented backwards along the rotation trajectory. Thus, the RM effect is a reliable perceptual bias that leads to erroneous responses in same-or-different tasks with stimuli containing real or apparent motion.

Motor expertise research has shown that athletes tend to exhibit larger RM effects than novices (Gorman et al., 2011; Jin et al., 2017; Nakamoto et al., 2015). For example, Nakamoto et al. (2015) presented baseball players and novices with apparent motion of a "target" along a 400 cm-long track of 200 light-emitting diodes (LEDs) that either travelled the entire length of the track (non-occlusion condition) or suddenly disappeared halfway down the track (occlusion condition). In each trial, participants were asked to indicate with a button press when they expected the target to reach the end of the track (timing control task), and then verbally indicate the location at which they perceived the target to have vanished (RM task). Nakamoto et al. (2015) reported that the baseball players perceived the target as disappearing further along the trackway than did the novices (i.e., a larger RM effect in baseball players than novices). However, the baseball players were more accurate at the timing control task than the novices. Importantly, this negative correlation between RM magnitude and performance in the timing control task was observed in both baseball players and novices, suggesting that the RM may help to control response timing. RM may circumvent neural processing delays and facilitate response timing when interacting with moving objects, such as a ball in sports settings. RM is, therefore, an adaptive phenomenon – despite manifesting as an error when experimentally testing the accuracy of perception. This means that accuracy scores may capture superior performance in tasks where RM effects are unlikely to be observed, but not necessarily in tasks where RM effects would be expected.

The aim of the current study was to investigate whether athletes would outperform novices on a basic perceptual task involving static images of expert and everyday actions. The study addresses the lack of consensus on whether the athlete advantage persists when dynamic information is unavailable (c.f., Güldenpenning et al., 2013; Sebanz and Shiffrar, 2009). Previous work within our lab suggested that track sprinters were more accurate than non-sprinters on a same-or-different task in which participants were presented with pairs of consecutive videos depicting either an expert (sprint start) or everyday (walking) action. The task aimed to assess participants' ability to notice subtle kinematic differences between similar movement executions. We used expert and everyday actions to investigate whether any expert advantage was specific to actions within the domain of expertise (i.e., specific advantage hypothesis; Quarona et al., 2020) or whether it transferred to other familiar actions (i.e., general advantage hypothesis; Quarona et al., 2020). The current study was designed to be a comparable experiment with static images. We filmed high-frame rate videos of an athlete performing a sprint start and walking and extracted the frames from these videos to use in an adaptive staircase procedure. In every trial, participants were presented with two frames from the same video and were asked to determine whether they were identical or different. Thresholds were obtained for each participant and action using a one-up/three-down adaptive staircase procedure (see methods for more detail). We employed two presentation conditions: one in which the images were presented sequentially (temporal task), and another in which the images were presented simultaneously (spatial task). The temporal task maintained the consecutive presentation of stimuli used in our previous study with videos (Harrison et al., 2023). We predicted that this task may elicit RM effects due to the implied motion in the standard frame and the need to compare one depicted posture to another posture that would no longer be visible. The depicted posture in the first image may be misremembered as further along the athlete's implied motion trajectory (due to RM), thus the perceived differences between the two images may be smaller than the veridical differences between them. If the temporal task elicits RM effects, then this should result in impaired performance (i.e., higher thresholds in the temporal task than in the spatial task). Further, this impairment (due to RM) should be more pronounced in sprinters than in non-sprinters (Gorman et al., 2011; Jin et al., 2017; Nakamoto et al., 2015). The spatial task was designed to allow participants to directly compare the postures between the two images, removing any potential RM effects and allowing us to directly address the question of whether sprinters are better at noticing subtle differences between similar postures from expert and everyday actions. Accordingly, we predicted that the sprinters would exhibit lower thresholds than the non-sprinters in the spatial task if the athlete advantage observed with dynamic stimuli transferred to static stimuli. In line with the results from our previous work with video stimuli (Harrison et al., 2023), we predicted that if an athlete advantage existed, the sprinters should outperform the non-sprinters for both the sprint and walk stimuli (i.e., general advantage hypothesis; Quarona et al., 2020). We did not predict a domain-specific expert advantage (i.e., that sprinters would outperform non-sprinters only in the sprint condition).

## 2. Methods

### 2.1. Participants

Two groups of volunteers were recruited to complete the experiment: an expert group and a non-expert group. The expert group consisted of 21 track sprinters who regularly trained for athletics and practised sprint starts (10 female, 11 male). One male sprinter was excluded during data analysis (see Data Processing and Analysis section for detailed information). This left a total of 20 participants (10 female, 10 male) in the expert group. The mean age of the expert group was 23.9 years (*SD* = 4.4 years, range = 18–32 years). Participants in the expert group had been involved in athletics for an average of 11.6 years (*SD* = 5.6 years, range = 1–22 years) and trained for an average of 11.5 h (*SD* = 2.6 h, range = 5–17 h) per week at the time of participation.

The non-expert group consisted of 22 people (12 female, 10 male) who did not participate in athletics. Two participants (one male, one female) were excluded from analysis (see Data Processing and Analysis section for detailed information), leaving a total of 20 participants (11 female, 9 male) in the non-expert group. The mean age of this group was 22 years (*SD* = 4.8 years, range = 18–32 years).

The sample size of 20 sprinters is comparable to other similar studies in the field: 24 experts in Calvo-Merino et al. (2010); 16 experts in Güldenpenning et al. (2013); 18 experts in Hohmann et al. (2011); 9 experts in Nakamoto et al. (2015); 12 experts in Experiment 1, 14 in Experiment 2 in Sebanz and Shiffrar (2009); 11 experts in Weast et al. (2011); 12 per group in Gorman et al. (2011); 15 per group in Klein-Soetebier et al. (2011).

McKay and colleagues' (2021) classification framework was used to characterise participants' level of fitness and performance. The framework comprises six tiers: Tier 0 (Sedentary); Tier 1 (Recreationally Active); Tier 2 (Trained/Developmental); Tier 3 (Highly Trained/National Level); Tier 4 (Elite/International) and Tier 5 (World Class). Tier 0 characterises individuals who do not reach the World Health Organisation's (WHO) physical activity standards (>150 min of moderate activity or >75 min of vigorous activity per week). Tier 1 describes individuals who meet the WHO physical activity standards but do not have a specific commitment to or focus on competition within a particular sport. Tier 2 characterises individuals who participate in sport-specific training and intend to compete in local-level competitions. Athletes did not need to achieve a certain level of performance to be classified into Tier 2. Athletes were, however, required to achieve performance standards to be classified into Tiers 3, 4 and 5. The performance standards used in the current study were adapted from McKay et al. (2021) and calculated from 2022 World Athletics statistics. There were three or four performance indicators associated with each tier, and athletes were put into a certain category if their best performance from the last two years was faster than the mean + the SD of the indicators in each category (see Table A in Supplementary Materials). The expert group comprised six Tier 2 (Trained/Developmental) sprinters, 10 Tier 3 (Highly Trained/National Level) sprinters and four Tier 4 (Elite/International Level) sprinters. The non-expert group comprised three Tier 0 (Sedentary) participants and 17 Tier 1 (Recreationally Active) participants.

All participants reported that they had normal or corrected-to-normal vision and were naïve to the purpose of the experiment. All participants provided written informed consent before the start of the experiment and the study was approved by the School of Psychology Ethics Committee at the University of Aberdeen (PEC/5061/2022/9). Participants were reimbursed with course credit or £10.

### 2.2. Apparatus and Stimuli

The experiment was run using a HP Probook Intel® Core i7 laptop and programmed in MATLAB (Version 2018, Mathworks, Natick, MA, USA) using the Psychtoolbox (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997) and Palamedes Toolbox (Prins and Kingdom, 2018) extensions. Stimuli were presented on a 28-inch Iiyama G-master monitor (61 cm × 35 cm, resolution: 2560 × 1440 pixel) with the refresh rate set to 60 Hz. Participants sat at a table in a darkened room at a viewing distance of 68 cm from the monitor. A height-adjustable chin rest was used to maintain a constant viewing distance throughout the experiment. A standard keyboard and mouse were placed on the table in front of the participants. Glow-in-the-dark tape was placed on the keys of interest ("s", "d" and the spacebar) to highlight the locations of the relevant keys to participants.

The stimuli consisted of frames from two high frame rate (500 frames-per-second) video clips showing a male athlete performing a sprint start (expert action) or walking (everyday/control action). These videos were part of the stimulus set used in Harrison et al. (2023). The videos were filmed using a Sony RX100 VII Cyber-shot digital camera set up on a tripod on an indoor athletics track, approximately 4 m away from where the athlete was running. The viewing direction was perpendicular to the athlete's movement direction and the athlete covered approximately 8 m in each video.

Individual frames were extracted from the videos. The height and width of the images were cropped to 133 × 466 pixels to reduce the amount of redundant space in the images (mostly the wall and track), and for each video frame the pixel greyscale mean was set to 0.5 and the pixel greyscale SD was set to 0.18. The images were presented on the monitor against a grey background, placed 30 pixels above or below a central fixation cross.

Three images each from the sprint and walk condition were selected as "standard" frames (see Fig. 1). In both the sprint and walk conditions, one standard frame was taken from early in the sequence and showed the athlete leading with the knee in their first step off the start line. Another standard frame was taken from the middle of the sequence and showed the athlete in full flight (i.e., the full length of their stride), and the third standard frame was taken towards the end of the video and showed the athlete's knees crossing. In any staircase, one of these images would be shown in every trial with a comparison frame that changed in line with participants' responses and the rules of the staircase.

### 2.3. Procedure

Before the beginning of the experiment, participants were given verbal instructions about the task and were asked demographic questions about their age, sex, and sport participation. The experiment involved a same-or-different task where two images appeared on the screen above and below a central fixation cross. The images were presented above and below the fixation cross to minimise potential apparent motion effects that could be caused by presenting the images side-by-side. One image was always the "standard frame" (see Apparatus and Stimuli), and the other image was another frame from later in the video (i.e., further along the athlete's movement trajectory) that acted as a "comparison frame". In each trial, participants were asked to indicate whether the images were identical (by pressing the "s" key) or slightly different (by pressing the "d" key). The experiment employed a one-up/three-down adaptive staircase procedure as implemented in the Palamedes Toolbox (Kingdom and Prins, 2010) to determine the comparison frame shown in each trial and compute each participant's threshold (i.e., the approximate frame at which participants could reliably detect differences between the standard frame and the comparison frame). The standard frame was always displayed in the same position (i.e., either above the fixation cross or below the fixation cross), and the comparison frame was displayed in the opposite position (i.e., below or above the fixation cross). The position of the standard frame was counterbalanced across participants in each group (male sprinters, female sprinters, male non-athletes, female non-athletes), with the standard frame being shown above the fixation cross for half the participants, and below the fixation cross for the other half of

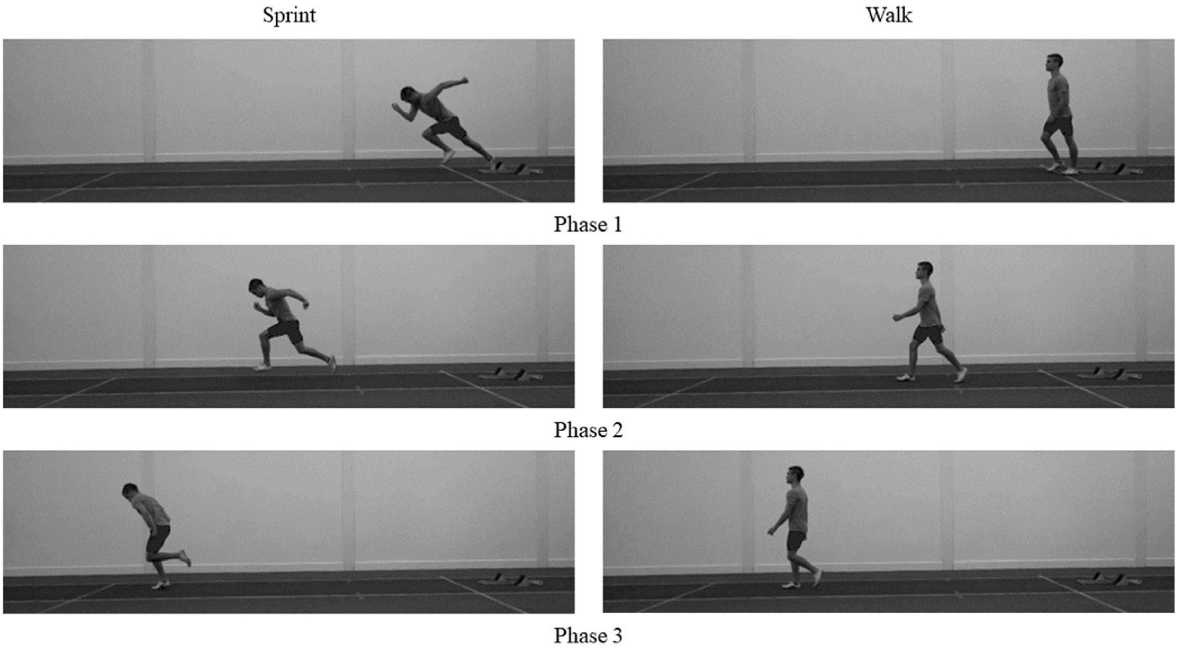

**Fig. 1.** Standard frames.
*Note.* The three standard frames used for each action. One standard frame was selected from the beginning, middle and end of each action. Participants completed one staircase for each standard. Every trial showed the standard frame for that particular staircase in conjunction with a comparison frame.

participants. This was implemented to avoid potential effects of the position of the standard frame on performance. Participants were not informed that one frame would remain the same throughout each staircase or the position of this frame.

Participants completed two versions of the same-or-different task: the “temporal task”, in which the images appeared sequentially (e.g., the standard frame appeared and disappeared above the fixation cross before the comparison frame appeared and disappeared below the fixation cross); and the “spatial task”, in which the images appeared simultaneously (e.g., the standard frame and comparison frame appeared and disappeared above and below the fixation cross, respectively, at the same time). Participants were assigned to complete either the temporal or spatial task first, which was counterbalanced across participants in each group (half of the participants completed the temporal task first, half completed the spatial task first). For each task, participants completed a practice staircase with images of a female athlete performing a sprint start before they started the main blocks of trials. The stimulus durations were the same in the practice staircase and main experimental staircases, but the images and staircase procedures differed slightly between the practice and main staircases. Participants

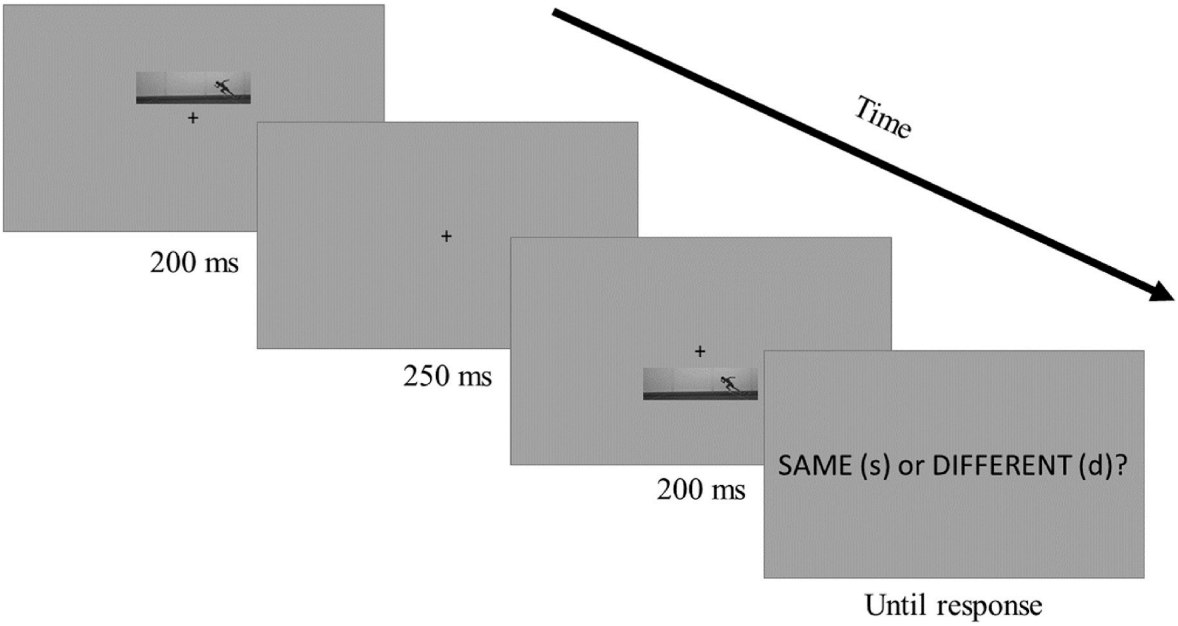

**Fig. 2.** Trial timeline in the temporal task.
*Note.* The standard frame and the comparison frame were presented sequentially for 200 ms each, with an inter-stimulus interval of 250 ms. The standard frame always preceded the comparison frame. A response screen appeared after the comparison frame had been shown and remained on the screen until the participant responded with a key press.

could take breaks between the staircases and the duration of the experiment was approximately 1 h.

### 2.3.1. Temporal task

In each trial of the temporal task, the standard frame and comparison frame were shown sequentially for 200 ms each with an inter-stimulus interval of 250 ms (see Fig. 2). The standard frame always preceded the comparison frame; therefore, half of the participants were presented with an image above the fixation cross then an image below the fixation cross, and vice versa. After the comparison frame had disappeared, participants were presented with a response screen reminding them to press the “s” key if they thought the images were identical, and the “d” key if they thought that the images were different. Participants completed one staircase for each standard frame, resulting in a total of six staircases (three sprint frames, three walk frames). The trials for each staircase were completed together in a block, and the order of the blocks was randomised.

### 2.3.2. Spatial task

In each trial of the spatial task, the standard frame and comparison frame were shown simultaneously for 400 ms (see Fig. 3). After the images had disappeared, participants were presented with a response screen reminding them to press the “s” key if they thought the images were identical, and the “d” key if they thought that the images were different. Participants completed one staircase for each standard frame, resulting in a total of six staircases (three sprint frames, three walk frames). The trials for each staircase were completed together in a block, and the order of the blocks was randomised.

### 2.3.3. Staircase rules

The experiment employed a one-up/three-down adaptive staircase procedure to determine the comparison frame shown in each trial. Each staircase began with a comparison image that was a set number of frames later in the video than the standard (i.e., the standard frame depicted a posture from earlier in the movement trajectory than the comparison frame). Pilot data (N = 2 non-experts) were used to determine appropriate starting distances between the standard frame and the comparison frame for the sprint and walk conditions. The starting distances were 20 frames for the sprint condition and 35 frames for the walk condition. The starting distance needed to be larger for the walk images, presumably because the movement was comparably slower and there was less relative change between each frame in the walk sequence than in the sprint sequence.

At the beginning of each staircase in the main block, the distance between the standard frame and the comparison frame decreased by one frame every time that the participant correctly identified that there was a difference between the two images. In other words, the comparison frame moved backwards towards the standard frame when participants responded correctly. However, after the first reversal point, the distance only decreased by one frame after three consecutive (correct) “different” responses. The distance increased by one frame after one (incorrect) “same” response. The staircase terminated once participants had completed 10 reversals, 10 consecutive trials showing the standard frame as the comparison frame, or 250 trials (the mean number of trials completed in a staircase across participants was 78).

The staircase rules for the practice staircase were slightly different. After the participant had responded with the “s” key for the first time, the distance between the standard frame and the comparison frame decreased by one frame after two consecutive (correct) “different” responses (c.f., three in the main block). The distance increased after one (incorrect) “same” response, just as it did in the main block. The practice staircase terminated after seven reversals or five consecutive trials showing the standard frame as the comparison frame. The stimulus durations were the same in the practice staircases as they were in the main block’s staircases.

## 2.4. Data processing and analysis

Data pre-processing was done in MATLAB, data processing and analysis were done in R (R Core Team, 2022) and JASP (JASP Team, 2023). There were 516 staircases before exclusions and two criteria were used to exclude individual staircases. Staircases were excluded from analysis if they consisted of less than 10 reversal points (this applied to nine staircases), or if the standard was reached (i.e., the participants reached a trial where the standard frame and the comparison frame were identical) more than once in a given staircase (this applied to a further 12 staircases in total: for five sprinters and seven non-sprinters). The exclusion criterion related to reaching the standard was necessary because in all trials except where the standard frame and the comparison frame were identical, the distance between the standard and comparison

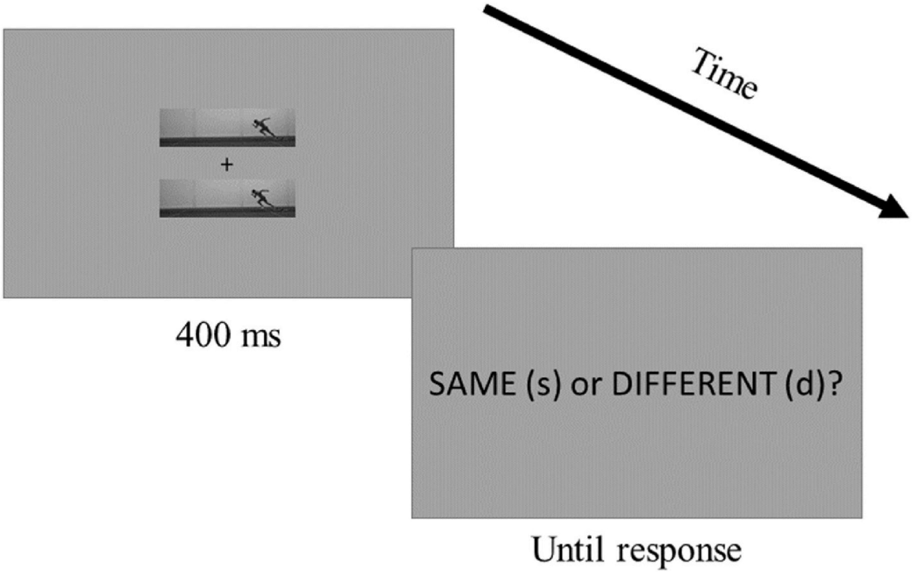

**Fig. 3.** Trial timeline in the spatial task.
*Note.* The standard frame and the comparison frame were presented simultaneously for 400 ms. A response screen appeared after the comparison frame had been shown and remained on the screen until the participant responded with a key press.

frames decreased in the ensuing trial if the participant responded correctly. However, this was not possible when the comparison frame was identical to the standard frame. Thus, if the participant correctly determined that the images were identical, the participant would be presented with the same trial again. Conversely, the distance between the standard frame and the comparison frame would increase in the ensuing trial if the participant incorrectly determined that the images were different. We decided to limit the acceptable number of times that a participant could reach the standard to one per staircase as a result of this caveat. Importantly, a Chi-square test (on the 12 excluded staircases) confirmed that expertise was not associated with reaching the standard, $\chi^2$ (1, 43) $= 0.0601$, $p = .806$, suggesting that the exclusion of these staircases did not mask any expertise effects.

Individual participants were excluded from analysis if three (25 %) or more of their total staircases met our exclusion criteria, or if more than one staircase in any one condition met the exclusion criteria. One male sprinter was excluded from analysis because he reached the standard in four of the 12 staircases and completed two staircases with less than 10 reversal points. Two participants from the non-sprinter group (one male, one female) were excluded from analysis because they completed several staircases that required exclusion due to reaching the standard more than once in a staircase and/or completing a staircase with less than 10 reversal points. The remaining participants had completed at least two staircases with 10 reversal points and without reaching the standard more than once per condition.

Participants' thresholds (i.e., the approximate frame at which participants could reliably discriminate between the standard frame and the comparison frame) were calculated by averaging the frame numbers of the last seven of the 10 reversal points in each staircase. Each threshold frame value was then subtracted from the frame number of the relevant standard to determine the distance in frames between the standard and the threshold frame (just-noticeable frame difference). We then averaged over the just-noticeable frame differences for the three standards in each action and task type. The three standards depicted different body postures and locations, so the mean just-noticeable frame difference is assumed to approximate discrimination performance for the actions as a whole. The participants' mean just-noticeable frame differences were analysed with a 2 (Action: Sprint vs Walk) × 2 (Task Type: Spatial vs Temporal) × 2 (Group: Sprinter vs Non-Sprinter) mixed factorial ANOVA. No part of the study procedures or analyses were pre-registered prior to the research being conducted. The sample size, exclusion criteria and data analysis methods were established prior to data analysis. The data presented here are available from the Open Science Framework (OSF): https://osf.io/5%20x%2047b/?view_only=6819a0408e8e485ba68ff84535d52d06.

## 3. Results

### 3.1. Main analysis

The ANOVA revealed significant main effects of task type: F (1, 38) $= 8.910$, $p = 0.005$, $\eta_p^2 = 0.190$ and action: F (1, 38) $= 237.806$, $p < 0.001$, $\eta_p^2 = 0.862$. The interaction between task type and action was also statistically significant: F (1, 38) $= 7.381$, $p = 0.010$, $\eta_p^2 = 0.163$. As shown in Fig. 4, participants' just-noticeable frame differences were generally smaller in the spatial task (M ± SD = 19.8 ± 12.8 frames from standard) than the temporal task (M ± SD = 22.4 ± 13.3 frames from standard), in line with the idea that the RM may impair performance on the temporal task. Just-noticeable frame differences were also smaller in the sprint condition (M ± SD = 13.7 ± 7.5 frames from standard) than in the walk condition (M ± SD = 28.5 ± 13.3 frames from standard), presumably because the slower speed of movement in the walk condition (see Discussion for more detail). The interaction between task type and action suggests that the advantage for the spatial task was larger in the walk condition (4.3 frames) than the sprint condition (0.8 frames). However, this effect may also be linked to the smaller relative change between frames in the walk condition than the sprint condition. The depicted athlete covered a greater distance between frames in the sprint condition than the walk condition due to the higher speed of the movement. Therefore, the same distance/displacement would unfold over fewer frames in the sprint condition than the walk condition (i.e., there was a smaller rate of change in pixels between successive images in the walk condition than between successive images in the sprint condition). This lower resolution in the sprint condition may mask differences between tasks (i.e., temporal vs. spatial) that are detectable in the (slower) walk condition – potentially providing an explanation for the interaction between task type and action.

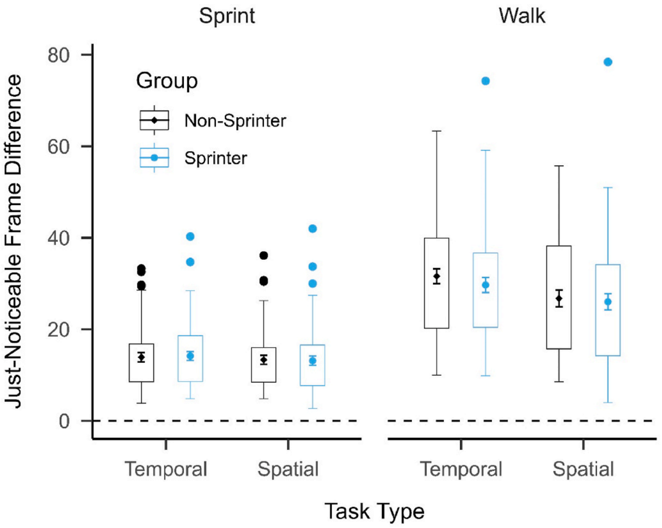

**Fig. 4.** Mean and distributions of the just-noticeable frame differences as a function of motor expertise, task type and action (N = 40).

*Note.* The mean ± 1 standard error of the mean (between participants) is superimposed on a boxplot for each task type, group, and action. The bottom of each box in the boxplot represents the 25th percentile for that group, whereas the top of each box represents the 75th percentile for that group. The lower whiskers represent Q1 – 1.5*IQR, whereas the higher whiskers represent Q3 + 1.5*IQR. The horizontal dashed line represents the standard (i.e., 0 frames above the standard). Participants' just-noticeable frame differences were smaller (i.e., closer to the standard) in the spatial task than the temporal task, and in the sprint condition compared to the walk condition. Sprinters and non-sprinters performed similarly in all conditions.

Contrary to our hypotheses, we observed no statistically significant interaction effects between group and any other factor (all $p > 0.460$), and no significant main effect of group ($p = 0.802$), suggesting that there was no difference in performance between sprinters and non-sprinters.

### 3.2. Exploratory analysis

The main effect of task type in the main analysis suggested that participants performed better in the spatial task than the temporal task, regardless of motor expertise. However, Fig. 5 illustrates that the advantage for the spatial task was not consistently shown by all participants. Therefore, we investigated whether other aspects of the experimental design may be associated with enhanced performance in the spatial task. We specifically examined whether the order in which participants completed the temporal and spatial tasks was associated with differences in the just-noticeable frame differences.

A 2 (Action: Sprint vs Walk) × 2 (Task Type: Spatial vs Temporal) × 2 (First Task: Temporal vs Spatial) mixed factorial ANOVA applied to the just-noticeable frame differences revealed the same significant main effects of task type: F (1, 38) $= 17.159$, $p < 0.001$, $\eta_p^2 = 0.311$; action: F (1, 38) $= 237.493$, $p < 0.001$, $\eta_p^2 = 0.862$; and task type × action interaction: F (1, 38) $= 9.380$, $p = 0.004$, $\eta_p^2 = 0.198$ as observed in the previous analysis. However, the ANOVA also uncovered significant

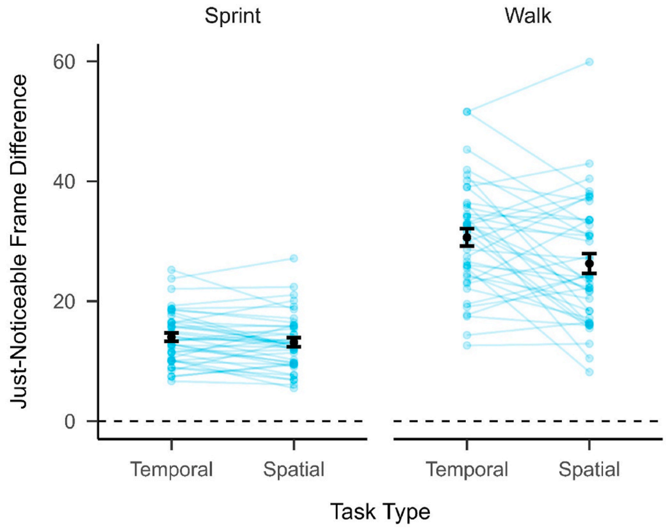

**Fig. 5.** Participants' just-noticeable frame differences as a function of task type and action (N = 40).
*Note*. The mean ± 1 standard error of the mean (between participants) is superimposed on individual data points (blue) representing each participant's mean just-noticeable frame difference. Data points from the same participant are joined by blue lines. The slopes of the blue lines indicate that the advantage for the spatial task was not exhibited by all participants.

interactions between task type and first task: F (1, 38) = 35.394, $p < 0.001$, $\eta_p^2 = 0.482$; and between task type, action and first task: F (1, 38) = 10.997, $p = 0.002$, $\eta_p^2 = 0.224$. Participants who completed the temporal task first showed a significant advantage on the spatial task (M ± SD = 17 ± 8.2 frames from standard), compared to the temporal task (M ± SD = 23.3 ± 10.8 frames from standard): $t$ (19) = 7.442, $p < 0.001$, $d = 1.62$. Conversely, participants who completed the spatial task first exhibited no significant difference in performance between the spatial task (M ± SD = 22.5 ± 11.7 frames from standard) and the temporal task (M ± SD = 21.3 ± 11.3 frames from standard): $t$ (19) = −1.2591, $p = 0.223$, $d = 0.28$. Fig. 6 shows that this pattern is observed in the sprint and walk conditions, but it is exaggerated in the walk condition. This is presumably due to the increased sensitivity of the task resulting from the smaller relative change between frames (i.e., slower speed of movement, as discussed above) and is reflected in the significant three-way interaction between task type, action and first block.

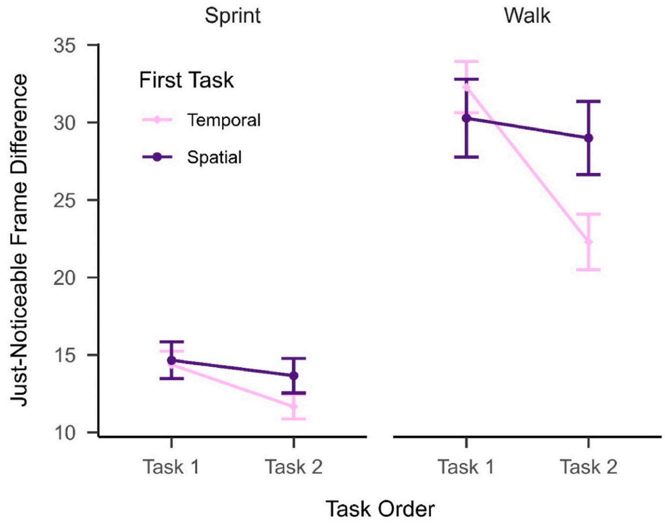

**Fig. 6.** Just-noticeable frame differences as a function of task type and task order (N = 40).
*Note.* The mean ± 1 standard error of the mean (between participants) for the task participants completed first (Task 1) and second (Task 2). Participants who completed the temporal task first (pink) showed a significant improvement in their second task (spatial task). Participants who completed the spatial task first (purple) exhibited no significant difference in performance between the two tasks. The effect is more pronounced in the walk condition (right) than the sprint condition (left).

## 4. Discussion

The aim of this study was to determine whether the athlete advantage for perceiving subtle variations in sport-related actions depicted in dynamic displays (Hohmann et al., 2011; Romeas and Faubert, 2015) persists when dynamic information is unavailable (i.e., for static images). Sprinters and non-sprinters completed a same-or-different task with pairs of static images depicting an athlete either performing a sprint start (expert action) or walking (everyday action). An adaptive staircase procedure was used to determine participants' thresholds. Participants completed two different versions of a same-or-different task: one in which the images appeared sequentially (temporal task); and another in which they were presented simultaneously (spatial task). We predicted that representational momentum (RM) may impair performances in the temporal task (i.e., leading to larger just-noticeable frame differences), and that this impairment may be stronger for the sprinters than the non-sprinters (Gorman et al., 2011; Jin et al., 2017; Nakamoto et al., 2015). Conversely, we predicted that the sprinters would exhibit smaller just-noticeable frame differences than the non-sprinters in the spatial task if the athlete advantage observed with dynamic stimuli transferred to static stimuli. The sprint and walk conditions were implemented to test the generality of a potential athlete advantage (similar to Harrison et al., 2023). Contrary to our hypotheses, sprinters and non-sprinters performed similarly across all tasks and conditions. Just-noticeable frame differences were generally smaller in the sprint condition than the walk condition, which is most likely due to the higher movement speed causing larger relative change between frames in the sprint condition compared to the walk condition. Just-noticeable frame differences were also generally smaller in the spatial task than the temporal task, in line with the prediction that RM effects may impair performance on the temporal task. However, our exploratory post-hoc analysis suggested that this effect is potentially better explained by a task order effect whereby participants who completed the temporal task first showed an advantage for the spatial task compared to the temporal task, whereas participants who completed the spatial task first performed similarly in both tasks.

Studies using deception detection tasks to examine whether the athlete advantage for perceiving expert actions persists for static stimuli have yielded contradictory results (c.f., Güldenpenning et al., 2013; Sebanz and Shiffrar, 2009). Whereas Sebanz and Shiffrar (2009) concluded that the athlete advantage could only be observed when dynamic information was available, Güldenpenning et al. (2013) maintained that athletes also exhibited superior performance in perceptual tasks employing static stimuli. A previous study from our lab demonstrated that sprinters were better able to notice subtle differences between videos depicting similar executions of an expert action (sprint start) and an everyday action (walking; Harrison et al., 2023). The task and static stimuli in the current experiment were designed to closely mirror this previous experiment and facilitate a comparison of participants' performance for static and dynamic stimuli. Our results showed that the sprinters' performance on the tasks was similar to that of the non-sprinters', as there were no significant effects on the just-noticeable frame differences involving the factor expertise. It is possible that this null effect could be caused by a lack of statistical power due to the sample size, but this seems unlikely given that we previously found a reliable, statistically significant effect in a study employing a similar design with an identical sample size (Harrison et al., 2023). Statistical power is often a limitation in expertise research due to the difficulty of recruiting large samples of highly skilled individuals, but the current sample size is comparable to other similar studies in the field (e.g., Güldenpenning et al., 2013; Hohmann et al., 2011; Nakamoto et al., 2015; Sebanz and Shiffrar, 2009). Our data corroborate the results reported by Sebanz and Shiffrar (2009) and align with the idea that the athlete advantage may be specific to instances where dynamic information is available.

An important methodological distinction can be made between the studies conducted by Sebanz and Shiffrar (2009) and Güldenpenning et al. (2013). Sebanz and Shiffrar's (2009) static image condition contained only implied motion (i.e., the inference that the depicted person was moving when the photograph was taken), whereas Güldenpenning et al.'s (2013) study likely contained apparent motion (i.e., quick presentation of static images which give the illusion of movement) in addition to implied motion. Expertise studies which only contain implied motion tend not to observe expertise effects (e.g., Gorman et al., 2011; Klein-Soetebier et al., 2011; Sebanz and Shiffrar, 2009). For example, Klein-Soetebier et al. (2011) presented participants with single static images of basketball and soccer players engaging in different actions with either their feet or their hands. These images were irrelevant to the participants' primary task, which was to indicate the colour of the frame in which the image was presented with either their hand or foot (depending on the colour of the frame). Klein-Soetebier et al. (2011) reported faster response times and fewer errors when the effector used to execute the action depicted in the image matched the effector needed to correctly respond to the coloured frame (i.e., effector-specific priming effects). However, the results indicated that the expertise of the participants did not affect their performance on the task. The findings from the current study align with those of Klein-Soetebier et al. (2011) and others which used stimuli containing only implied motion. The stimuli in the current study were presented above and below a fixation cross to minimise potential apparent motion effects that could be caused by presenting the images side-by-side or centrally in quick succession (i.e., the tasks should only contain implied motion). Even if a degree of apparent motion remained in the temporal task due to the sequential presentation of images, this should enhance the RM effects and thus the predicted differences between athletes and non-athletes. The lack of observed expertise effects aligns with the idea that real or apparent motion is necessary to distinguish between the perceptual performance of athletes and non-athletes (Güldenpenning et al., 2012, 2013; Nakamoto et al., 2015; Romeas and Faubert, 2015; Sebanz and Shiffrar, 2009).

Although there was no evidence of any performance differences between the sprinters and non-sprinters, the analyses revealed that just-noticeable frame differences were generally smaller in the sprint condition than the walk condition. This effect was likely a result of the larger relative change between individual frames in the sprint condition than the walk condition. The depicted athlete's velocity was much higher when he was sprinting, compared to when he was walking. Therefore, the athlete covered a larger distance between each frame of the sprint video than the walk video, and the differences between individual frames were larger. Thus, the walk condition appeared to be more fine-grained and hence better suited to unveil potential performance differences than the sprint condition – simply because the relative change between frames was smaller. The relative change between frames in the sprint condition may have been too large to detect group differences but this limitation did not apply to the walk condition. We predicted that athletes would outperform non-athletes in both the sprint *and* walk conditions (in line with Harrison et al., 2023), yet there were no group differences in either condition. It is unlikely that the difference in the rate of change per frame between the sprint and walk stimuli masked performance differences between the sprinters and non-sprinters, but it may underlie the observed interaction between action and task type (see Results for a more detailed discussion).

Participants' advantage for the spatial task compared to the temporal task may be explained by a more complex mechanism: RM. In many RM studies, participants are presented with a short video or series of static images depicting real or apparent motion of a person or object. They are then presented with a static, probe stimulus and asked to determine whether the position of the person or object depicted in the probe stimulus matched its last seen position in the first stimulus. Participants are often less accurate at identifying that a probe stimulus from later in the movement trajectory is different from the last shown position, compared to when a probe stimulus is taken from earlier in the movement trajectory (Freyd, 1983; Freyd and Finke, 1984; Gorman et al., 2011; Jin et al., 2017). In the current study, we predicted that this RM effect may interfere with participants' responses in the temporal task because they may extrapolate the position of the athlete depicted in the standard frame further along the movement trajectory. This would cause the last remembered position of the athlete depicted in the standard frame to be closer to the position of the athlete depicted in the comparison frame than the veridical distance between the two frames – leading to larger just-noticeable frame differences. We designed the spatial task to counter this potential effect by facilitating direct comparison of postures between the standard frame and the comparison frame. In line with our predictions, we observed that participants' just-noticeable frame differences were larger in the temporal task than the spatial task. Therefore, this study may provide novel evidence that RM can be observed using static stimuli in a threshold procedure. Gorman et al. (2011) previously investigated RM in athletes and novices using dynamic video stimuli, static images, and static schematic stimuli. All participants exhibited RM effects in the dynamic video condition (i.e., traditional RM paradigm), but not in the static image condition. If RM underlies the spatial task advantage effect, the results from the current study may contradict these findings. However, the RM is usually characterised by a directional disadvantage on a same-or-different task for stimuli presented in chronological order (but not for reverse chronological order; Freyd and Finke, 1984). Since the comparison frames presented in the current experiment always depicted a posture from later in the movement, it was not possible to quantify whether the observed advantage for the spatial task was necessarily a RM effect.

A compelling alternative explanation for the spatial task advantage is the order effect that was uncovered in our exploratory analysis. The advantage for the spatial task compared to the temporal task was not shown by all participants (see Fig. 6). Although most participants (descriptively) performed better on their second task than their first task, only the participants who completed the temporal task first showed a clear advantage on their second task (i.e., the spatial task). It is possible that the structure of the experiment was easier to discern from the temporal task than the spatial task. The standard frame was always presented in the same position in both tasks, but it was presented first in the temporal task. This may have made it easier for participants to notice that the standard frame remained the same image throughout a particular staircase and that it was always presented in the same position. If participants assumed (correctly) that these rules also applied to the spatial task, they could choose to allocate their attention solely to the comparison frame. Since each image was presented for 200 ms in the temporal task and 400 ms in the spatial task, participants could effectively double the stimulus presentation time for the spatial task compared to the temporal task. One would expect to observe consistent differences between the spatial and temporal tasks – regardless of task order – if RM were the underlying mechanism. Therefore, we believe that attentional effects (due to task order) are likely to better explain the advantage for the spatial task than RM.

In summary, we found no evidence to suggest that sprinters were better able to notice subtle differences in postures from static images or exhibited larger RM effects than non-sprinters. This appears to contradict the idea that we generally perceive the actions of others in relation to our own motor capabilities (e.g., Jeannerod, 2003; Prinz, 1997; Wilson and Knoblich, 2005). However, it is possible that expertise effects on perception are limited to real or apparent motion. It is well established that athletes exhibit superior perceptual abilities for expert actions when dynamic information – or real motion – is available (e.g., Harrison et al., 2023; Romeas and Faubert, 2015; Sebanz and Shiffrar, 2009). Expertise studies using single static images which imply motion have tended not to observe an athlete advantage (e.g., Gorman et al., 2011; Klein-Soetebier et al., 2011b; Sebanz and Shiffrar, 2009), whereas those which elicit apparent motion have reported an athlete advantage (Güldenpenning et al., 2012, 2013; Nakamoto et al., 2015). The findings of the current study align with the existing literature and suggest that athletes do not show superior implied motion perception, compared to non-athletes.

## CRediT authorship contribution statement

**Róisín Elaine Harrison:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Martin Giesel:** Conceptualization, Formal analysis, Methodology, Software, Supervision, Writing – review & editing. **Constanze Hesse:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

## Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

## Data availability

The data are available on the Open Science Framework (OSF). A link to the OSF project is included in the manuscript.

## Acknowledgements

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2024.108945.

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# Supplementary Materials

**Table A**

*Performance Standards for Each Tier (seconds).*

| Gender | Event | World Class | Elite | Highly Trained |
|---|---|---|---|---|
| Female | 60m | 7.09 | 7.45 | 8.47 |
| Female | 60mH | 7.89 | 8.40 | 9.36 |
| Female | 100m | 10.80 | 11.47 | 12.82 |
| Female | 100mH | 12.38 | 13.43 | 14.68 |
| Female | 200m | 21.86 | 23.36 | 26.01 |
| Female | 400m | 49.76 | 53.30 | 58.87 |
| Female | 400mH | 51.77 | 58.56 | 62.35 |
| Male | 60m | 6.52 | 6.86 | 7.85 |
| Male | 60mH | 7.45 | 7.95 | 8.78 |
| Male | 100m | 9.92 | 10.43 | 11.84 |
| Male | 110mH | 13.10 | 13.91 | 15.48 |
| Male | 200m | 19.68 | 20.76 | 23.55 |
| Male | 400m | 44.32 | 46.59 | 53.12 |
| Male | 400mH | 47.15 | 50.93 | 55.69 |

*Note*. The performance standards are expressed in seconds and represent the time that athletes needed to have achieved in the last two years to be classified into a certain tier for a certain event. Each performance standard represents the mean + SD of the performance indicators used for each tier. In accordance with McKay et al. (2021), the performance indicators used for the World Class tier were: i) the world record as of 2022; ii) the 2022 world lead; iii) 2% of the world record; iv) 2% of the 2022 world lead. The performance indicators used for the Elite tier were: i) the 300th ranked performance in the world in 2022; ii) 7% of the world record; iii) 7% of the 2022 world lead. The performance indicators used for the Highly Trained tier were: i) the 2022 entry standard for the British Championships (outdoors, where possible); ii) 20% of the world record; iii) 20% of the 2022 world lead.