Original Article

# The effect of self-awareness on the ability to recognize personal motion

TAMARA L. BORIES[1] ✉, RANDAL HYLLEGARD[1], PRATISTHA MAHARJAN[2], JASMINE A. BROWN[1]

[1]*Department of Kinesiology, Western Illinois University, Macomb, United States of America*
[2]*Central Park Physical Medicine and Rehabilitation, New York, United States of America*

## ABSTRACT

The purpose of this study was to examine the abilities of athletes with specific gait training (i.e., runners) discriminating personal gait from point-light videos were compared to athletes for whom gait is not a trained aspect of the sport (i.e., swimmers), and that of a control. It was hypothesized that runners would discriminate their gait among different individuals with greater accuracy than the other two groups and that runners would also devote more attention to the lower extremities for recognition indications. Results showed that runners group recognized themselves more often than the other two groups ($p$ = .048, $\eta^2$ = 0.18), and that runners allotted more visual attention to the lower extremities ($p < .05$, $\eta_p^2$ = 0.16) when viewing the point-light videos than the other groups. The findings were consistent with other investigations with point-light video representations of movement and suggest that experience and training lead to movement self-awareness that is both recognizable and accessible by a performer.

**Keywords:** Areas of interest; Human gait; Monitoring of performance; Movement perception; Point-light videos.

**Cite this article as:**
Bories, T.L., Hyllegard, R., Maharjan, P., & Brown, J.A. (2021). The effect of self-awareness on the ability to recognize personal motion. *Journal of Human Sport and Exercise*, *in press*. doi:https://doi.org/10.14198/jhse.2022.174.15

✉ **Corresponding author.** *Department of Kinesiology, Western Illinois University, Macomb, IL 61455-1390, United States of America.*
E-mail: TL-Bories@wiu.edu
Submitted for publication December 01, 2020
Accepted for publication February 09, 2021
Published *in press* March 09, 2021
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

**doi:10.14198/jhse.2022.174.15**

## INTRODUCTION

Virtually all sports have specific motor skills that are highly trained in advanced performers, such as baseball pitching or tennis groundstrokes, and skilled athletes invest a considerable amount of time and effort practicing and performing those specific skills (Helsen, Starkes, & Hodges, 1998; Nugent, Comyns & Warrington, 2017). For track-and-field runners, gait motions are a key skill that effects performance and running gait is trained extensively by competitive runners (Young & Salmela, 2010). Because gait motions are so central to effective running, self-awareness theory (Duval & Lalwani, 1999; Duval & Wicklund, 1972; Silvia & Duval, 2001) would predict that experienced runners develop strong mental representations of those motions due to the extensive practice and training they experience. In the present study, the principle of self-awareness was used to investigate how well individuals can discriminate personal gait movements from point-light representations depending on the influence of specialized gait training.

Point-light videos have been used extensively in investigations of motion perception and recognition of personal movements. The main advantage of point-light video is that all recognizable characteristics such as hair, facial features, clothing and so on are masked and leave only points of reflected light to represent the body performing motions. In a comprehensive review article, Blake and Schiffrar (2007) reported that biological motion perception from point-light video is robust and begins to develop in infants as young as 4 to 8 months old and extends well into old age (Norman et al, 2004).

The majority of early studies using point-light videos centred on gait recognition (Johansson 1973; Kozlowski & Cutting, 1977). Since then, studies with point-light videos have investigated a wide range of activities such as playing certain sports (Loula, Prasad, Harber, & Shiffrar, 2005), dancing (Brownlow, Dixon, Egbert, & Radcliffe,1997), lifting objects (Bingham, 1993), the movements of different kinds of animals (Mather & West, 1993), expressing emotions (Clark, Bradshaw, Field, Hampson, & Rose, 2005), and expressing emotions through dance (Ditrich, Troscianko, Lea & Morgan, 1996), to mention a few. A variety of investigative methods have been employed in point-light investigations including filming live participants, creating computer-generated models, using different masking methods, and a host of other approaches depending on the technology available at the time and the goals of the study (e.g., Ahlstrom, Blake, & Ahlstrom1997; Bertenthal & Pinto, 1994; Ikeda & Watanabe, 2009; Johannson, 1973).

Notwithstanding the particular methodology, studies have consistently reported that individuals can recognize motion of different types at rates greaten than chance. For example, in a meta-analysis of 21 point-light gender-identification studies, Pollick, Kay, Heim and Stringer (2005) found recognition accuracies ranging from 66% to 71%, depending on the type of model shown to study participants. Other investigations have found that some motion cues are more relevant to observers than other cues when making discriminations. For example, Mather, Radford & West (1992) found the wrist and ankle cues are crucial when discriminating walking direction in plain videos, while elbow, knees, shoulders and hips motions provide important cues point-light images are embedded within other extraneous images (Pinto & Schiffrar, 2009). Likewise, Takahashi et al. (2011) found that motion cues originating from the upper regions of body were more important than the lower regions when discriminating between the traditional Japanese Hakobi gait motion patterns and normal gait patterns.

While the majority of point-light investigations have involved participants viewing videos and responding to questions, few investigations have examined eye movement patterns and areas of interest (AOI) when viewing such videos. One exception was the study conducted by Bardi, Di Giorgio, Lunghi, Troje and Simion (2015) who investigated eye movement activity in infants and adults on perceptions of walking direction. The main goal of the study was to determine if infants can automatically shift visual attention on the basis of walking direction cues displayed in different orientations from a point-light display. With respect to the AOI measures, three areas were measured: the centre of the screen where the point-light walker appeared, and two areas to the right and left of the centre where other stimuli used in the study might appear. The finding suggested that biological motion is a strong attractor for visual attention both during development during infancy and in adulthood.

The present study entailed two aspects of point-light motion perception. The first was to examine whether experience plays a role in the accuracy of self-identification discrimination when viewing point-light representations of gait motions. The second was to examine if experience influences visual scanning patterns when viewing the same videos through the use of AOI measurements. It was hypothesized that participants with more experience with gait training (i.e., runners) would more accurately discriminate personal gait motions than those without such training (i.e., swimmers or controls). It was also hypothesized that there would be an interaction between the regions of visual interest by the groups and that runners would allot more visual attention to the lower extremities AOI than the other two groups.

## METHOD

### *Study design and Setting*

An independent groups design was used and involved three groups (runners, swimmers, and controls), along with two AOI visual attention regions (upper body region and lower body region), and two dependent variables: discrimination accuracy of personal gait and visual attention when viewing the point-light videos of walking. The study took pace in two settings: a general-purpose biomechanics lab where participants were videotaped while walking on a motorized treadmill and where the subsequent videos were digitized and transformed into point-light videos. The other setting was a lab containing eye movement tracking equipment where participants viewed the videos for the purpose of determining discrimination accuracy and visual attention patterns.

### *Participants*

A total of 34 participants (12 collegiate track-and-field team runners, 12 collegiate swim team members, and 10 collegiate controls) completed all phases of the study. All individuals in the running and swimming groups had a minimum of 10 years of experience in their respective sports and were members of a university team for at least one year at the time of the study. Control group participants reported having no experience participating with organized track-and-field running or swimming teams prior to the study. In addition, five other individuals (three females and two males) served as foil point-light walkers shown during the gait discrimination trials. Foil participants were selected because their gait movements were largely generic for their respective gender and had no obvious mannerisms that might attract the attention of the participants. The Institutional Review Board at Western Illinois University granted approval for the study because the procedures presented a low level of risk for harm to the participants or the foils.

### *Gait videos*

Participants and foils were video recorded from the anterior view while walking on a motorized treadmill (Confidence Power Plus Treadmill, Golf Outlets of America, Inc.). That treadmill model was used because the hand-support bar, with the control panel, could be lowered to floor-level and was out of view of the video camera. The video camera was positioned 425 centimetres from the treadmill and at a height of 110-centimeters above the floor. The rear of the treadmill was raised approximately 4 centimetres so the treadmill deck was level with the floor. Treadmill speeds were set to match the average of three timed walking trials across a 12.19-meter (40 feet) distance. Participants were instructed to walk at a pace consistent with their typical walking speed with resulting measured speeds ranging from 1.65 to 2.15 m/s.

Reflective makers were placed on 15 sites including the middle of the forehead, the top of the sternum, just above the navel, the right and left acromioclavicular joints (shoulders), lateral radial heads (elbows), radial styloid processes (wrists), anterior superior iliac spines (hips), centre of each patella (knees), and between the second and third metatarsal bones of both feet.

Following a familiarization period walking on the treadmill, participants were video-recorded for 10-seconds using a JVS digital video camera (60 Hz). During the recordings, the room lights were turned off and the reflective markers on the participants were illuminated by the video camera spotlight. The subsequent videos were transformed into standardized size point-light videos using the Peak Motus (v. 8.0) digitizing system (Contemplas, Kempten, Germany).

***Procedures***

The point-light videos were used in two types of trials: paired-walkers and single-walker. The paired-walkers videos were used for the gait discrimination trials. For those trials, participants viewed seven videos showing two, side-by-side, point-light walkers. The particular participant appeared in three of the videos and was paired with a different foil walker in each video. Only combinations of paired foil walkers appeared in the other four trials. The duration of the paired-walker trials was 10-seconds, with a 30-second transition between trials.

The single-walker videos were used for the AOI trials. For those trials, participants had their eye movements tracked and recorded while they viewed a sequence seven videos. The particular participant appeared in two of the videos and different foil walkers appeared in the other five videos. The duration of the single-walker trials was also 10-seconds, but with a 10-second transition interval between each video.

The completed point-light videos were displayed on a Dell 23-inch flat panel monitor for both the single and paired-walkers trails. Participants were seated approximately 50-centimeters from the monitor with the centreline of the body lined-up with the centre of the monitor in the horizontal direction. During both the single and paired-walker trials, the point-light walker images were approximately 23-centimeters tall, and 9-centimeters wide, as seen on the monitor. For the paired-walker trials, the two point-light walkers were separated horizontally by a 20-centimeter space, when measured from the sternum-to-sternum reflective markers.

For the single-walker trials, a Gazepoint camera (Gazepoint GP3 Eye Tracker System. Gazepoint. Vancouver, British Columbia V6K0E9, Canada) was positioned approximately 48-centimeters from the participants and at an approximately 60-degree upward angle, with respect to the participant's eyes. The specific angle depended slightly on the height of the participant when seated in a lab chair. The eye movement tracking accuracy was assessed by running the Gazepoint calibration routine that displays a series of targets on the monitor that a participant tracks with eye movements. If the calibration indicated inaccurate eye tracking, the camera or participant were repositioned, and the calibration routine was repeated until accurate tracking was achieved. In most cases, then calibration routine indicated accurate eye tracking during the initial testing.

Just prior to start of both the single-walker and paired-walker trials, several familiarization point-light walking videos were shown so the participants knew how and where the video images appeared on the monitor. Participants were instructed to inspect the videos only using eye movements and to keep head movements to a minimum. A circular target appeared at the centre the monitor just before to each trail so that participants were looking at the same location on the monitor immediately prior to the appearance of each of the point-light videos.

### *Gait discrimination trials*

The purpose of these trials was to assess discrimination ability between self and foil walkers from the paired point-light videos. During the trials, participants were instructed to inspect each pair of point-light walkers with the goal of determining if they were included in each pair. During the 30-second interval between videos, the participants verbally indicated if they believed they appeared in the trial, and if the answer was yes, they indicated if they were the left or right-side walker.

### *Areas of interest trials*

The goal of these trials was to assess visual attention to determine the extent to which different regions of the body attracted the attention of the participants. The participants viewed seven single-walker videos and were instructed to assess if each video showed themselves, or another person. The subsequent recordings of the eye movement activity of the participant's was analysed based on two AOI regions: the upper body (including the head, shoulders, sternum, elbows, wrists, navel and hips reflective markers), and the lower body (including the knees and feet markers). The Gazepoint system reported total fixation viewing times, in milliseconds and as a percentage of total viewing time, for each individual viewing trial.

### *Statistical analysis*

Mean and standard error of the mean values were calculated for each dependent variable. A one-way analysis of variance (ANOVA) was conducted on the gait discrimination scores and based on the hypothesis that runners would have greater self-awareness of gait motions, a complex comparison was planned, in the event that the ANOVA was significant, between the runner's discrimination scores and the combined discrimination scores for the swimmers and the control. For the AOI scores, a 2 (AOI) x 3 (group) ANOVA was conducted. Follow-up 2 x 2 ANOVAs were planned if a significant interaction was found in the initial ANOVA. Eta-square effect size was found for the gait discrimination scores, and partial eta-square effect size for the AOI by group scores Effect size criteria were 0.01 (small), 0.09 (medium) and 0.25 (large) for both effect size measures. Levene's test for equal variance and skew statistics were used to examine parametric assumptions about the nature of the data for both the gait discrimination and the AOI data. An alpha level of $\alpha = .05$ was used for all ANOVAs, planned comparisons, and equal variance tests, while a Bonferroni adjusted alpha was used for the follow-up two-way ANOVAs ($\alpha = .02$)

## RESULTS

### *Gait discrimination*

Gait discrimination scores from the paired-walker trials were recorded as the percent correct discriminations (mean and standard error of the mean values were rounded to nearest whole number). There were two possible correct discriminations (the word self, in these discrimination definitions, refers to a given participant viewing the videos): 1. When self was shown in the given video and the position of self was also correctly indicated (the right side or the left side walker), and 2. when self was not shown and correctly indicated as such. There were three possible incorrect discriminations: 1. When self was shown in a given video, and indicated, but the right side-left side indication was incorrect, 2. when self was shown, but indicated as not being shown, and 3. when two foils were shown, but one of the two foils was indicated as being self.

Mean and standard error of the mean (*SE)* percent correct discriminations for the paired-walkers view were: runners $M$ = 84% ± (4%), swimmers $M$ = 71% ± (4%), and control $M$ =68% ± (6%). A one-way ANOVA found a significant difference among the groups, $F(2,31) = 3.35$, $p = .048$, $\eta^2 = 0.18$. The effect size for this analysis was in the medium range indicating that the different groups contributed moderately to the variance for the discrimination means among the groups. The planned complex comparison for the runner's scores compared to the combined swimmer and control group score's was also significant, $t(31) = 2.57$, $p = .02$. While all three groups were able to make correct discrimination at least two-thirds of the time, the runners achieved the greatest level of correct discriminations with a mean of 84%. This finding indicated that the runners were able to discriminate their gait in the point- light videos from the foils at levels greater than the non-gait trained individuals.

***Areas of interest***

The single-walker trials scores used for the analyses were the mean fixation percentages in each of the two AOIs (upper body AOI and lower body AOI) by the three groups. A two-way ANOVA revealed a significant AOI by group interaction, $F(2,62) = 5.80$, $p < .05$, $\eta_p^2 = 0.16$. Follow-up 2 x 2 ANOVAs found significant interactions between the runners and swimmers, $F(1,44) = 9.17$, $p < .05$, $\eta_p^2 = 0.17$, and the runners and the control, $F(1,40) = 6.06$, $p < .05$, $\eta_p^2 = 0.13$, but no interaction between the swimmers and the control, $F(1,40) = .09$, $p = .76$, $\eta_p^2 = 0.002$. Effect size values for the significant ANOVAs were each in the medium range indicating that the interaction between the two AOIs and the three groups contributed moderately to the interaction outcomes.

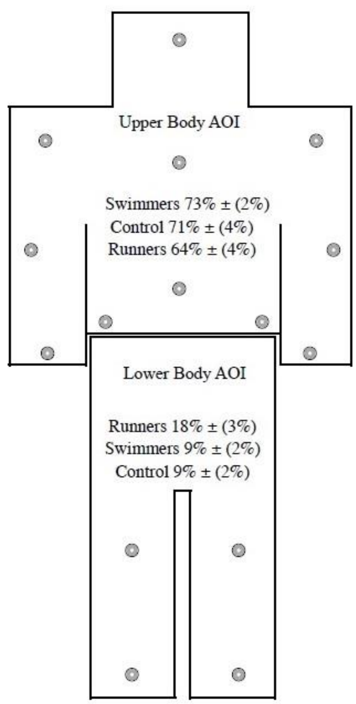


Figure 1. The illustration shows the mean ± (*SE*) area of interest (AOI) viewing time percentages for the three groups. The circles represent the locations of the reflective markers on the body in the point-light videos. A significant AOI by Group interaction was found ($p < .05$, $\eta_p^2 = 0.16$), indicating that the AOI that attracted more visual attention of the participants depended on the group; either the runners, swimmers or control group. The specific interactions were between the runners and swimmers ($p < .05$, $\eta_p^2 = 0.17$), and between the runners and the control group ($p < .05$, $\eta_p^2 = 0.13$). There was no interaction between the swimmers and the control group ($p = .76$, $\eta_p^2 = 0.002$.)

Figure 1 shows the mean fixation percentages (*SE*) of the upper body and lower body AOIs for each of the three groups. The runners allotted about 18% of their visual fixation time to the lower extremities, which was approximately twice as much as the both the swimmers and the control group. Note that the total viewing percentages for each of the three groups respectively do not sum to 100% each. There were two main reasons accounting for the missing times. Only the fixation times for each eye movement were included in the viewing times. The saccadic eye movement durations were not included in the analyses. And second, any fixations outside of the AOI areas were also not included in the viewing times.

## DISCUSSION

The premise for the hypotheses tested in the present investigation stemmed from self-awareness theory (Duval & Wicklund,1972; Silvia & Duval, 2001). The theory suggests that participating in an activity raises self-awareness of performance for the activity. For experienced track-and-field runners, an efficient and effective gait pattern is one crucial element affecting performance. Consequently, many competitive runners invest time and effort into refining and perfecting their gait (along with fitness levels) to help ensure optimal performance (Young & Salmela, 2002; Young & Salmela, 2010). And by extension, dedicated training on specific activities should lead to greater levels of self-awareness for those activities when compared to those without such experience.

Based on self-awareness theory, two hypotheses were proposed for the present study. The first hypothesis predicted that runners would be able to self-recognize gait at levels greater than non-gait trained athletes. While all three groups made largely accurate discriminations between themselves and foil point-light walkers, the runners were approximately 13% to 15% better than the other two groups on this task. The second hypothesis was there would be an interaction between the two AOI regions and the groups and that runners would devote more visual attention to the lower AOI, and less attention to the upper AOI, than the other two groups. This hypothesis was also supported as the runners devoted approximately twice as much time visually examining lower extremities motions than either the swimmers or the control group. Presumably, owing to the self-awareness stemming from gait training, runners have a greater sense of the motions of the legs when walking than individuals without such training and thus directed more visual attention to lower limb motions while viewing the videos. This suggests that this knowledge is both recognizable and accessible by a performer.

It is well-known that dedicated athletes invest a considerable amount of time and effort into developing the specific skills needed to perform at a high level of competition. A variety of studies have reported that movement-based experiences play an important role in forming self-perceptions of motion (Jacobs & Shiffrar, 2005; Knoblich & Flach, 2001; Knoblich & Prinz, 2001; Prinz, 1997; Shiffrar & Freyd, 1990; Viviani & Stucchi, 1992). Track-and-field runners spend a considerable amount of time gait training, so their running style is as efficient and effective as possible. Young and Salmela (2010) reported that by the time runners reached 7-years into their running careers, national-level runners had accumulated approximately 10,000 minutes of technique training, while provincial level runners reached about 5,000 minutes, and club level runners about 4,000 minutes. While the runners in this study were endurance athletes, and most of the runners in the present study were either sprinters or middle-distance specialists, the finding from the study give a general sense of the amount of time competitive running athletes invent into gait training.

In a similar study, Nugent, Comyns, and Warrington, (2017) reported that competitive swimmers participating in the Long-Term Development Model for training (LTDM) typically completed from about 5 to about 25 hours of training per week involving anywhere from 3 to 14 or more sessions per week, and the accumulated training distances range from about 5,000 meters of swimming up to about 70,000 meters. The differences in training schedules were mainly due to the age of the swimmers with the youngest groups between 9 and 12 years old and oldest groups being 16 years or older. So, while both experienced runners and swimmers train extensively, the specific motions trained are very different because of two sports are fundamentally different. Presumably, those differences contributed to the effects observed in the present study.

The findings for gait discrimination from point-light videos largely were consistent with other investigations on this topic with the percent correct discriminations ranging from 68% for the control group, to 71% for the swimmers and 84% for the runners, respectively. Kozlowski and Cutting (1977) found that observers were able to identify the gender of a point-light model at rates greater than chance with females identified correctly 67% of the time and males 72% of the time. Similarly, Loula, Prasad, Harber, and Shiffrar (2005) reported discrimination accuracies well above random chance when determining if a point-light display was showing the participant, a friend or a stranger. Although in the same study, they found that discrimination accuracies were actually better for activities where individuals motions differ such as when dancing, than for more uniform motions such as walking and running. Cutting and Kozlowski (1977) also found that individuals were able to identify friends when viewing point-light video at rates greater than chance.

In the present study, participants from all three groups directed the majority of their attention to upper body AOIs. This was consistent with Saunders, Williamson, and Troje (2010), who reported that upper body clues originating from the pelvic region and the shoulders were most relevant when examining point-light walking videos. But the key difference, which was consistent with the main premise of the study and self-awareness theory, was that the runners directed comparatively more attention to lower body motions than the other two groups.

While the present study took a psychological approach based in self-awareness theory, the findings also aligned with motor control research investigating the unique characteristics of individual motor patterns (Horst, Mildner & Schollhorn, 2017; Pataky, Mu, Bosch, Rosenbaum, & Goulermas, 2012; Slowinski et al., 2016). For example, Hug et al. (2019) reported that individuals involved in gait and cycling tasks produced unique muscle activation profiles EMG recordings that could be used to identify specific individuals at rates of up to 99%, depending on the number of muscles used to make identifications. When recording EMGs from eight muscle groups, accurate identifications exceeded 99%, and while recording from just two muscle groups, accurate identifications were at least 80%. The unique muscle activation patterns when walking may be one factor that allowed individuals to distinguish personal gait patterns along with other visible attributes such as relative body proportions and motions as represented in the point-light videos.

The finding that experienced performers direct visual attention differently than novices is not new. Many studies in a wide range of fields have reported similar findings including aircraft pilots (Papin, Naureils, & Santucci, 1980), baseball players (Bahill & LaRitz, 1984; Hunfalvay, Roberts, Ryan, Murray, Tabana, & Martin, 2017; Kato & Fukuda, 2002; Muraskin, et al., 2016; Shank & Haywood, 1987) soccer players (Savelsbergh, Van der Kamp, Williams & Ward, 2005), and while driving automobiles (Seya, Nakayasu, & Patterson, 2008), among many others. For example, in a study of video game players, Khromov, Korotin, Lange, Stepanov, Burnacev, and Somov (2018) recorded visual gaze heatmaps in four groups of players with different levels of experience. The gaze patterns for the most experience group were more homogeneous than the patterns from the other groups with the least experience. The interpretation of the finding was that highly skilled players were more familiar with the game and were aware of areas that contained more cues relevant to the current situation. Similarly, in a study of batsmen in the sport cricket, Mann, Spratford, and Abernathy (2013) found that experienced batsmen used different saccadic eye movement patterns than lower level players when visually tracking a cricket pitch. The implication was that due to experience, higher level players were more able to direct visual attention to the predicted location of the ball during the flight of the pitch than lower level players. In the present study, the runners directed more visual attention to the lower limbs than the other two groups suggesting that their gait training informed the visual gaze patterns used to help identify themselves in the point-light videos.

The present findings may speak to the effects of knowledge of performance feedback often provided by teachers and coaches during practice. Previous research has shown that knowledge of performance feedback effectively increases practice performance and performance following practice when compared to other forms of feedback (Sharma, Chevidikunnan, Khan, & Gaowgzeh, 2016; Wallace & Hagler, 1979; Zubiaur, Ona & Delgado, 1999). When describing the kinematic features of movements to learners, increasing levels of self-awareness of the activity may be one consequence of that form of extrinsic feedback.

The findings in the present study are limited by at least three issues. The first limitation was that participants viewed walking gait and not running gait point-light videos. The main reason walking gait was examined rather than running gait was to protect the safety of the participants. It was necessary to lower the hand support bar on the treadmill for videotaping purposes. Also, the running deck of the treadmill was relatively small and not as stiff as the decks found on most larger treadmills. In addition, the video recordings were made in a dark room with only the video camera spotlight on, and which was aimed directly at the participants. Because of this, many participants found walking on the treadmill somewhat visually disorientating. There was a concern that if a participant were asked to run, there was a chance of falling and possibly injury. A second limitation, related to the first, was that all of the participants in all three groups were experienced walkers, as are virtually all adults, and the ability to discriminate one's gait from others, without the benefit of gait training, has been reported in a number of other investigations. Presumably, if the participants did view running point-light videos, the findings may have been stronger. Additionally, if comparisons were made between swimmers, runners and a control on swimming motions, even greater discrimination capabilities would have been seen because highly trained swimming motions are far less common than walking motions in most people. And third, all AOI trials began with the participants visually fixated a target on the monitor screen that corresponded approximately to the area between the navel and sternum reflective markers in the point-light videos. Therefore, all visual scanning patterns produced by the participants started from that area of the body. If the initial fixation target was located at some other area of the screen, the visual scanning patterns may have been different than those found with the present study.

Future research will examine more specialized types of highly trained motions such as baseball or softball pitching, soccer kicking, or tennis serving on self-awareness and the ability to discriminate personal motion style when viewing point-light representations of movement. Examining ability to discriminate personal motion and the types of eye scanning patterns in athletes of differing experience and skill competence may better indicate self-awareness.

## AUTHOR CONTRIBUTIONS

Tamara Bories and Randal Hyllegard: Planned and conducted the study, conducted the data analysis, and prepared the manuscript. Pratistha Maharjan: Assisted with conducting the study and helped perform the recognition trials used to measure eye movement behaviour of the participants when viewing the point-light videos. Jasmine Brown: Assisted with conducting the study, recruited participants, and helped perform the digitizing of the video recordings to produce the point-light videos.

## SUPPORTING AGENCIES

The project was supported by a grant from the Research Council at Western Illinois University for the purchase of the Gazepoint eye tracking equipment.

## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

## ACKNOWLEDGMENTS

We would also like to thank the numerous students that participated in, or worked with us, on this and other related projects.

## REFERENCES

Ahlstrom, V., Blake, R., & Ahlstrom U. (1997). Perception of biological motion. Perception, 26, 1539-1548. https://doi.org/10.1068/p261539

Bahill A. T., & LaRitz T. (1984). Why can't batters keep their eyes on the ball? American Scientist. 72, 249-253.

Bardi L., Di Giorgio, E., Lunghi, M., Troje, N. F., & Simion, F. (2015). Walking direction triggers visuo-spatial orientation in 6-month-old infants and adults: An eye tracking study. Cognition, 141, 112-120. https://doi.org/10.1016/j.cognition.2015.04.014

Bertenthal, B. L. & Pinto, J. (1994). Global processing of biological motions. Psychological Science, 5, 221-225. https://doi.org/10.1111/j.1467-9280.1994.tb00504.x

Blake, J. E., & Shiffrar, M. (2007). Perception of human motion. Annual Review of Psychology, 58, 47-73. https://doi.org/10.1146/annurev.psych.57.102904.190152

Brownlow, S., Dixon, A. R. Egbert, C. A., & Radcliffe, R. D. (1997). Perception of movement and dancer characteristics from point-light displays of dance. The Psychological Record, 47, 411-421. https://doi.org/10.1007/BF03395235

Clark, T. J., Bradshaw, M .F., Field, D. T., Hampson, S. E., & Rose, D. (2005). Perception of emotion from body movement in point-light displays of interpersonal dialogue. Perception, 34, 1171-11180. https://doi.org/10.1068/p5203

Cutting, J. E., & Kozlowski, L. (1977). Recognizing friends by their walk: Gait perception without familiarity cues. Bulletin of the Psychonomic Society, 9, 353-356. https://doi.org/10.3758/BF03337021

Ditrich, W. H., Troscianko, T. Lea, S. E., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. Perception, 25(6), 727-738. https://doi.org/10.1068/p250727

Duval, T. S., & Lalwani, N. (1999). Objective self-awareness and causal attributions for self-standard discrepancies: Changing self or changing standards of correctness. Personality and Social Psychology Bulletin, 25, 1220-1229. https://doi.org/10.1177/0146167299258004

Duval, T. S., & Wicklund, R. A. (1972). A theory of objective self-awareness. New York, NY: Academic.

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. Journal of Sport & Exercise Psychology, 20(1),12-34. https://doi.org/10.1123/jsep.20.1.12

Horst, F., Mildner, M., & Schollhorn, W. I. (2017). One-year persistence of individual gait patterns identified in a follow-up study - a call for individualized diagnosis and therapy. Gait Posture, 58, 476-48c. https://doi.org/10.1016/j.gaitpost.2017.09.003

 

Hug, F., Vogel, C., Tucker, K., Dorel, S., Deschamps, T., La Carpentier, E. & Lacoupaille, L. (2019). Individuals have unique muscle activation signatures as revealed during gait and pedaling. Journal of Applied Physiology, 127, 1165-1174. https://doi.org/10.1152/japplphysiol.01101.2018

Hunfalvay, M., Roberts, C. M., Ryan, W., Murray, N., Tabana, J., & Martin, C. (2017). Team sports and the theory of deliberate practice. International Journal of Sport Science, 7(6),215-222.

Ikeda, H., Watanabe, K. (2009) Anger and happiness are linked differently to the explicit detection of biological motion. Perception 38(7), 1002-1011. https://doi.org/10.1068/p6250

Jacobs, A., & Shiffrar, M. (2005). Walking perception by walking observers. Journal of Experimental Psychology: Human Perception and Performance, 31(1), 157-169. https://doi.org/10.1037/0096-1523.31.1.157

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. Perception and Psychophysics, 14(2), 201-211. https://doi.org/10.3758/BF03212378

Kato, T., & Fukuda, T. (2002). Visual search strategies of baseball players: eye movements during the preparatory phase of batting. Perceptual and Motor Skills, 94(2), 380-386. https://doi.org/10.2466/pms.2002.94.2.380

Khromov, N., Korotin, A., Lange, A., Stepanov, A., Burnacev, E., & Somov, A. (2018). Esports athletes and players: A comparative study. Newzoo,5, 1-11.

Knoblich, G., & Flach, R. (2001). Predicting the effects of actions: Interactions of perceptions and action. Psychological Science, 12(6), 467-472. https://doi.org/10.1111/1467-9280.00387

Knoblich, G., & Prinz, W. (2001). Recognition of self-generated actions from kinematic displays of drawings. Journal of Experimental Psychology: Human Perception and Performance, 27(2), 456-465. https://doi.org/10.1037/0096-1523.27.2.456

Kozlowski, L. T., & Cutting, J. E. (1977). Recognizing the sex of a walker from a dynamic point-light display. Perception & Psychophysics, 21(6), 575-580. https://doi.org/10.3758/BF03198740

Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. Journal of Experimental Psychology: Human Perception and Performance, 31(1), 210-220. https://doi.org/10.1037/0096-1523.31.1.210

Mann, D. L., Spratford, W., & Abernethy, B. (2013). The head tracks and gaze predicts: How the world's best batters hit a ball. PLoS ONE, 8(3). https://doi.org/10.1371/journal.pone.0058289

Mather, G., Redford, K. & West, S. (1992). Low level visual processing of biological motion. Proceedings of the Royal Society B: Biological Sciences, 249, 149-155. https://doi.org/10.1098/rspb.1992.0097

Mather, G., & West, S. (1993). Recognition of animal locomotion from dynamic point-light delays. Perception, 22, 759-766. https://doi.org/10.1068/p220759

Muraskin, J., Dodhia, S., Lieberman, G., Garcia, J. O., Verstynen, J. M., Sherwin, J., & Sajda, P. (2016). Brain dynamics of post-task resting state are influenced by expertise: Insight from baseball players. Human Brain Mapping, 37(12),4454-4471. https://doi.org/10.1002/hbm.23321

Norman, J. F., Payto, S. M., Long, J. R., & Hawkes, L. M. (2004). Aging and perception of biological motion. Psychology of Aging, 19, 219-225. https://doi.org/10.1037/0882-7974.19.1.219

Nugent, F. J., Comyns, T. M. & Warrington, G. D. (2017). Quality versus quantity debate in swimming: Perceptions and training practices of expert swimming coaches. Journal of Human Kinetics, 57, 147-158. https://doi.org/10.1515/hukin-2017-0056

Papin, J. P., Naureils, P., & Santucci, G. (1980). Pickup of visual information by the pilot during a ground control approach in a fighter aircraft simulator. Aviation Space and Environmental Medicine. 51(5), 463-469.

Pataky, T. C., Mu, T., Bosch, K., Rosenbaum, D., & Goulermas, J. Y. (2012). Gait recognition: highly unique dynamic plantar pressure patters among 104 individuals. Journal of the Royal Society Interface, 9, 790-800. https://doi.org/10.1098/rsif.2011.0430

Pinto, J., & Shiffrar, M. (2009). The visual perception of human and animal motion in point-light displays. Social Neuroscience, 4(4), 332-346. https://doi.org/10.1080/17470910902826820
Pollick, F. E., Kay, J. W., Heim, K., & Stringer, R. (2005). Gender recognition from point-light walkers. Journal of Experimental Psychology : Human Perception and Performance, 31(6), 1247-1265. https://doi.org/10.1037/0096-1523.31.6.1247
Prinz, W. (1997). Perceptions and action planning. European Journal of Cognitive Psychology, 9(2), 129-154. https://doi.org/10.1080/713752551
Saunders, D. R., Williamson, D. K., & Troje, N. F. (2010). Gaze patterns during perception of direction and gender from biological motion. Journal of Vision,10(11). https://doi.org/10.1167/10.11.9
Savelsbergh, G., Van der Kamp, J., Williams, A., & Ward, P. (2005). Anticipation and visual search behavior in expert soccer goalkeepers. Ergonomics, 48, 1686-1697. https://doi.org/10.1080/00140130500101346
Seya, Y., Nakayasu, H., & Patterson, P. (2008). Visual search of trained and untrained drivers in a driving simulator. Japanese Psychological Research, 50(4), 242-252. https://doi.org/10.1111/j.1468-5884.2008.00380.x
Shank, M. D., & Haywood, K. M. (1987). Eye movements when viewing a baseball pitch. Perceptual and Motor Skills, 64, 1191-1197. https://doi.org/10.2466/pms.1987.64.3c.1191
Sharma, D. A., Chevidikunnan, M. F., Khan, F. R., & Gaowgzeh, R. A. (2016). Effectiveness of knowledge of result and knowledge of performance in the learning of a skilled motor activity by healthy young adults. Journal of Physical Therapy Science, 28(5), 1482-1486. https://doi.org/10.1589/jpts.28.1482
Shiffrar, M., & Freyd, J. J. (1990). Apparent motion of the human body. Psychological Science, 1(4), 257-264. https://doi.org/10.1111/j.1467-9280.1990.tb00210.x
Silvia, P. J., & Duval, T. S. (2001). Objective self-awareness theory: Recent progress and enduring problems. Personality and Social Psychology Review, 5, 230-241. https://doi.org/10.1207/S15327957PSPR0503_4
Slowinski, T., Zhai, C., Alderisio, F., Salesse, R., Gueugnon, M., Marin, L., Bardy, B. G. di Bernardo, M.& Tsaneva-Atansova, K. (2016). Dynamic similarity promotes interpersonal coordination in joint action. Journal of the Royal Society Interface, 13, 20151093. https://doi.org/10.1098/rsif.2015.1093
Takahashi, K., Fukuda, H., Ikeda, H., Doi, H., Watanabe, K., Ueda, K., & Shinohara, K. (2011). Roles of the upper and lower bodies in direction discrimination of point-light walkers. Journal of Vision, 11(14), 1-13. https://doi.org/10.1167/11.14.8
Viviani, P., & Stucchi, N. (1992). Biological movements look uniform: Evidence of motor-perceptual interactions. Journal of Experimental Psychology: Human Perception and Performance, 18(3), 603-623. https://doi.org/10.1037/0096-1523.18.3.603
Wallace, S. A. & Hagler, R. W. (1997). Knowledge of performance and the learning of a closed motor skill. Research Quarterly for Exercise and Sport, 50, 265-271. https://doi.org/10.1080/10671315.1979.10615609
Young, B. W., & Salmela, J. H. (2010). Examination of practice activities related to the acquisition of elite performance in Canadian middle-distance running. International Journal of Sport Psychology, 41, 73-90.
Zubiaur, G. M., Ona, A. & Delgado, S. J. (1999). Learning volleyball serves: A preliminary study of the effects of knowledge of performance and of results. Perceptual and Motor Skills. 89, 223-232. https://doi.org/10.2466/pms.1999.89.1.223