International Journal of Sports Science 2016, 6(5): 180-186
DOI: 10.5923/j.sports.20160605.03

The Influence of Imposed Optic Flow on Basketball Shooting Performance and Postural Sway

Joseph D. Kennedy, William P. Berg*

Department of Kinesiology and Health, Miami University, Oxford, Ohio, USA

Abstract The purpose of this experiment was to determine the influence of imposed optic flow on basketball shooting performance and postural sway. Thirty-four participants each performed 96 basketball shots, half in the presence of imposed optic flow, and half in a static visual environment. Imposed optic flow was generated using a moving background behind the basket that translated horizontally as participants shot. Participants stood on a force plate while shooting to allow for the measurement of postural sway via recording center of pressure (CoP) position and computing the range in the anterior-posterior (AP) and medial-lateral (ML) axes. Imposed optic flow caused a reduction in basketball shooting percentage from 56.7 to 52.1 (p = .006) (-8.22%). Imposed optic flow caused a reduction in shooting score from 3.15 to 3.05 (p = .007) (-3.17%). Imposed optic flow had no effect on CoP position range in either the anterior-posterior (p = .990) or medial-lateral (p = .678) axes. Imposed optic flow negatively impacted shooting performance, but for reasons other than by causing postural instability. The possible effect of imposed optic flow on aiming, visual attention and gaze are discussed.

Keywords Basketball Shooting, Free Throw, Imposed Optic Flow, Postural Sway, Distraction

1. Introduction

At basketball games, fans often attempt to distract the opposing team's free throw shooters in hopes of having a detrimental effect on performance. Efforts to distract free throw shooters fall into two categories, auditory and visual. Auditory distractions consist of fans making as much noise as possible by screaming or using other noisemakers in hopes of drawing a shooter's attention away from the free throw task. Visual distractions usually attempt to introduce an attention-capturing visual stimulus, thereby decreasing the attention a player devotes to free throw shooting. For example, fans sitting behind the basket commonly wave their arms or towels, and sometimes display signs containing words, drawings or photos.

Few studies have evaluated the effect of fan behavior on performance in actual sport settings, and most have lacked control over fan behavior. [1-3] Epting, Riggs, Knowles and Hanky, [4] however, controlled auditory crowd behaviors (cheers, jeers and silence) experienced by athletes engaged in a basketball free throw, baseball pitch, and golf approach shot. Cheers and jeers negatively affected performance of the baseball and golf tasks, but not the basketball free throw. Researchers speculated that the latter result was due to the free throw shooters being too highly skilled and the free throw task too simple. Free throw statistics are consistent with Epting et al's. findings, [4] revealing little to no audience effect on free throw shooting performance in men's North American professional and NCAA Division I collegiate basketball. Analyses by Team Ranking.com [5] of Division I men's collegiate free throw percentages revealed that teams shot 68.7% at home and 68.8% away in 2013-2014, and 70.2% at home and 69.5% away in 2014-2015. Men's professional basketball (NBA) teams shot 75% at home and 74.9% away in 2013-2014, and 76% at home and 75.3% away in 2014-2015. These data suggest that the efforts to distract free throw shooters by home team fans are apparently ineffective, at least for highly skilled men's basketball players.

Although there is anecdotal evidence that visual distraction of free throw shooters may be possible, [6] the apparent futility of efforts to distract free throw shooters may lay in the nature of the distractions used. [7] Engber [7] suggested that typical efforts to distract free throw shooters, such as visual motion created by fans sitting behind the basket, are too random to capture a shooter's attention. Engber [7] hypothesized that a background field of uniform motion, which could be generated by fans moving the same direction in unison, might prove distracting to shooters. Engber [7] posited two mechanisms by which a background field of uniform motion might impair free throw shooting performance.

One way in which uniform background motion might impair free throw performance is by disrupting the aiming process. This idea is based in part on the work of Whitney,

* Corresponding author:
bergwp@miamioh.edu (William P. Berg)
Published online at http://journal.sapub.org/sports

Westwood and Goodale, [8] who studied the influence of background motion on near-aiming movements to a stationary target. Participants reached towards a briefly presented target on a computer screen in the presence of background motion. The background motion caused hand trajectory to be biased and accuracy in the near-aiming task to decrease. Engber [7] hypothesized that something similar might occur in far-aiming tasks such as free throw shooting.

A second way in which uniform background motion might worsen free throw performance; by acting as imposed optic flow and, in turn, generating postural instability; is the focus on this study. Optic flow is the continuous change that occurs in the optic array (i.e., pattern light makes when it strikes the retina) due to movement of the eye or objects in the environment. [9] Local flow occurs when only a portion of the optic array changes, [10, 11] and it specifies object motion for an observer. Global flow occurs when the entire optic array changes, and because it is created by movement of the eyes through the environment, [12] it specifies self-motion for an observer. Humans are so sensitive to optic flow that they can be tricked into perceiving motion by artificially generating optic flow and presenting it to an individual. This stimulation is referred to as imposed optic flow. [13]

When people are exposed to imposed global optic flow, they can incorrectly perceive self-motion, often referred to as vection. This misperception occurs because global optic flow nearly always occurs naturally only when an individual is moving through the environment. The misperception of self-motion resulting from imposed global optic flow can affect postural stability, as revealed by Lee and Lishman's moving room study. [14] Participants in the moving room experiment exhibited increased postural sway due to imposed global optic flow created by movement of the walls and ceiling of the small room in which they stood. As the walls and ceiling moved, the optic array was changed in a way that is equivalent to changes produced when humans move or sway. [15] Whether global optic flow is created by self-motion or is artificially imposed on a static individual, the visual perception of self-motion remains unchanged. Therefore, misperception of self-motion by the moving room study participants elicited involuntary compensatory responses intended to restore balance, but which in fact disturbed postural stability. Toddlers were impacted by imposed global optic flow enough to fall, whereas adults merely increased sway. [14]

If imposed global optic flow can trigger the perception of self-motion and consequent postural instability, might global optic flow imposed on a free throw shooter during a shot impair performance by generating postural instability? Perhaps postural sway occurring during the basketball shot would render the initial motor plan for the shot unsuitable because of changes to the shooter's initial position. The visuomotor system may not be able to update the motor plan successfully in time because of the brief duration of the shooting action.

Stone, Dolgov, DaSilva and McBeath examined the impact of background motion on free throw performance by projecting moving dot and line patterns on a basket backboard. [16] The background motion had no effect on free throw performance, which the authors attributed to the likelihood that the perception-action system responsible for aiming is able to resist distractions in static tasks and/or can correct itself prior to the release of the shot. [16] Stone et al. did not evaluate or speculate about the effect of background motion on postural stability. [16] It would seem unlikely, however, that imposed optic flow projected on the backboard only would fill enough of a free throw shooter's visual field to constitute global optic flow and specify self-motion.

The current study empirically tested the ability of an imposed optic flow field that was much larger than that used by Stone et al. [16] to distract basketball shooters. It must be noted that an analogous distraction method has been attempted by fans (e.g., at Duke University). Fans behind the basket move their raised arms in unison from left to right, or vice versa, precisely as the free throw shot is taken. The effect of this or comparable efforts is unknown. Therefore, the purpose of this experiment was to determine the effect of imposed optic flow on basketball shooting performance and postural sway.

The experiment utilized a within-subjects design whereby participants shot basketballs under two conditions: a static environment and one including imposed lamellar (horizontal/side-to-side) optic flow. We wish to make it explicit from the outset that because of the need to precisely control imposed optic flow and measure postural sway, we needed to conduct our experiment in a laboratory setting using a basketball shot that differed from a regulation free throw.

We hypothesized that imposed optic flow would impair basketball shooting performance by causing postural sway during the shot. Specifically, we posited that imposed lamellar optic flow would cause postural sway along the medial-lateral (ML) axis, but not the anterior-posterior (AP) axis. If imposed optic flow generated postural sway but did not affect shooting performance, it would suggest that the visuomotor system can update during this far-aiming task to compensate for changes in a shooter's position. If imposed global optic flow failed to generate postural sway, but did impair shooting performance, it would suggest that imposed optic flow influences basketball shooting performance via mechanisms unrelated to postural instability.

2. Materials and Methods

2.1. Participants

The study included 34 participants (males = 18; females = 16) who ranged in age from 18-29 years (*M*=22.06; *SD*=2.29). Inclusion in the study required that participants had at least two years' experience playing high school basketball (*M*=3.35; *SD* =.81). Seven participants also currently or previously played collegiate basketball. Most participants were right handed (R = 31; L = 3) and the mean participant height and weight were 178.07 cm (*SD*= 10.09*)* and 78.05 kg (*SD* = 12.98), respectively. The research was approved by our institutional review board, and all participants provided informed consent.

2.2. Apparatus

Basketball shooting data was collected in a laboratory in order to utilize a force plate to measure postural sway indirectly via center of pressure (CoP) position range. Regulation basket and court dimensions were modified to conform to room constraints. The basket was 2.59 m high (84% of regulation) and 3.54 m from the foul line (77.5% of regulation), which was located on a 60x90 cm force plate (Model #6090-15, Bertec Instruments, Columbus, Ohio, USA). To adjust for the compact environment, a smaller 381 mm diameter rim (83.3% of regulation) was used to optimize task difficulty, and thus sensitivity. Male participants used a men's regulation size basketball (circumference = 749 mm, 623 g), and female participants used a women's regulation size basketball (circumference = 723 mm, 566 g).

To generate imposed lamellar optic flow, a 4.88 m x 3.05 m panel was hung on rollers directly behind the backboard on a level track that permitted 0.91 m of horizontal movement. The tan panel surface was sponge painted with a brown random pattern to provide visual texture. Because the panel moved behind a frame constructed of the same material, participants never saw the edges of the panel - only its surface. The dimensions of the exposed portion of the panel (i.e., visible to participants) were 3.96 m x 2.84 m. (11.3 sq. m) (see Figure 1), and it filled a portion of shooters' visual field that was 60 degrees across by 45 degrees vertically. The movable panel was also visible to participants through the transparent backboard. Monochrome tan canvas curtains were hung from ceiling to floor on both sides of the room.

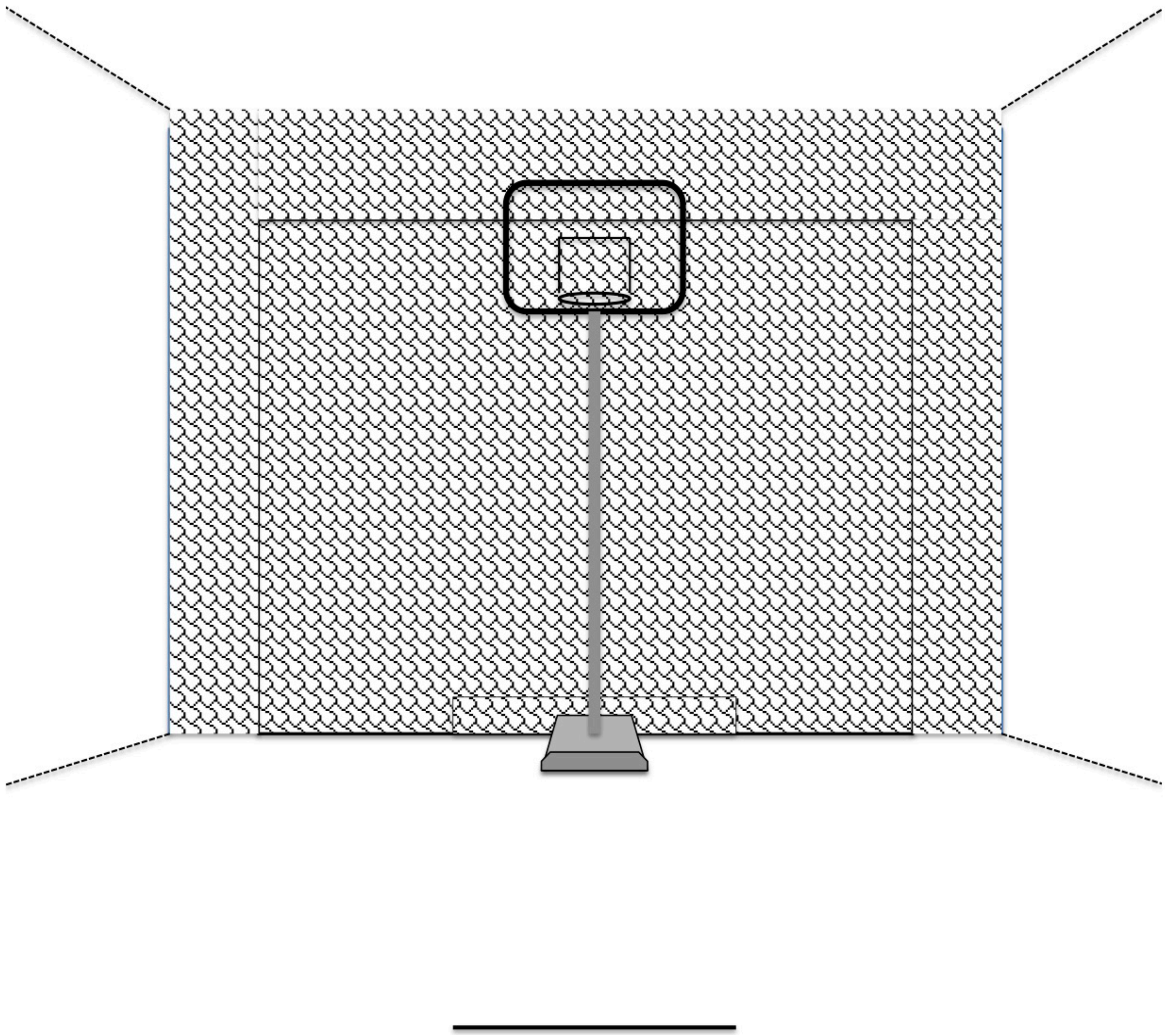

Figure 1. Experiment Apparatus

2.3. Procedures

Participants visited the laboratory on one occasion and shot basketballs under both the static environment and imposed optic flow. Participants began each trial with their back toward the basket, and then were instructed to "turn around and get into position". Participants stood at the foul line with both feet entirely on the force plate. Once participants assumed their shooting stance, a research assistant delivered the basketball to the participant and then exited the participants' field of view. After indicating that he or she was ready, the participant was allowed to "start their routine and shoot". Participants were asked to use the same pre-shot routine throughout data collection. Following a shot, participants returned to the starting position (back toward the basket) while a research assistant retrieved the basketball. Participants were given 10 s to shoot after receipt of the ball, and approximately 20 s between shots.

Participants were asked to shoot as they normally would, trying and make each shot, and keeping their feet in contact with the floor (i.e. no jumping). Participants were given 20 practice trials in the static environment to allow for a warm up and to gain familiarity with the task. The practice trials also permitted researchers to determine the participant's pre-shot routine, which subsequently facilitated consistent initiation of force recording and imposed optic flow. Force recording began when the participant ended their pre-shot routine but before he or she began the initial upward motion of the shot. Force recording ended when the ball first made contact with the net, rim or backboard.

Imposed optic flow was generated by a research assistant who observed the participant (but could not be seen by the participant) and physically moved the background panel, which glided smoothly and silently on a hidden track, during the shot. The research assistant's familiarity with the participant's pre-shot routine enabled her to time the optic flow to begin just prior to the initial upward motion of the shot (precisely mimicking how this potential distraction has been applied by spectators in actual games). Imposed optic flow velocities of approximately 23 cm/s (slow) and approximately 46 cm/s (fast) were included to prevent participant habituation to the imposed optic flow (i.e., reduction in between trial postural and shooting responses). The slow velocity was achieved by moving the panel .91 m over 4 s, and the fast velocity was achieved by moving the panel .91 m over 2 s. Following a shot and once the participant was facing away from the basket, the research assistant moved the panel back to its starting position.

Data collection for the actual trials occurred in four sets of 24, for a total of 96 trials. Participants were given a 3-min rest between each set of 24 trials. One-half of trials (48) were performed under the static environment condition. Imposed optic flow occurred on the other half of trials (48) and consisted of four variations (12 trials each) of flow direction and speed: left/fast, right/fast, left/slow, right/slow. All variations of imposed optic flow were pooled together for the analysis. The static environment and imposed optic flow trials were randomly ordered across the 96 trials, and the optic flow variations were randomly ordered across the imposed optic flow trials.

2.4. Dependent Variables

The dependent variables in this experiment were shooting percentage (shots made / number attempted) and shooting score. The shooting score was calculated using a scale by Hardy and Parfitt. [17]

5 points = ball goes in, touching only the net
4 points = ball goes in, with the rim being the point of initial contact
3 points = ball goes in, with the backboard being the point of initial contact
2 points = ball does not go in, with the rim being the point of initial contact
1 points = ball does not go in, with the backboard being the point of initial contact
0 points = ball does not go in, and makes no contact with the rim or backboard

Dependent variables also included indirect measures of postural sway. AP and ML CoP position range was recorded by the Bertec force plate (interfaced with Vicon Nexus software v1.8.5) sampling at 1000 Hz for approximately two seconds. CoP position range was calculated by subtracting the minimum CoP position from the maximum CoP position for both AP and ML axes for each trial. The period during which sway was recorded was sufficiently long to detect sway if it was present. Postural responses to induced optic flow occur at latencies well less than 1 sec. [18, 19]

2.5. Experimental Design and Statistical Analysis

This experiment utilized a within-subjects design whereby each participant was exposed to all levels of the independent variable of visual condition, that is, the static environment and one including imposed optic flow. Paired samples t-tests were used to analyze the mean values of the dependent variables under the two conditions. An alpha level of .05 was used for the statistical tests. However, a Bonferroni correction was utilized to control for the family-wise error rate across the paired samples t-tests. Thus, the effective alpha level was .008.

3. Results

The results of the experiment are shown in Table 1. The paired samples t-test between the mean shooting percentages under the static environment and imposed optic flow conditions was significant, $t(33) = 2.935$, $p = .006$. Imposed optic flow caused a reduction in basketball shooting percentage from 56.7 to 52.1 (-8.22%). The paired samples t-test between the mean shooting score under the static environment and imposed optic flow conditions was also significant, $t(33) = 2.889$, $p = .007$. Imposed optic flow caused a reduction in shooting score from 3.15 to 3.05

(-3.17%). In summary, imposed optic flow had a negative effect on basketball shooting performance.

Table 1. Mean (SD) basketball shooting performance and CoP range in two visual conditions

Dependent Measures	Visual Conditions		$t(33)$
	Static Visual Environment	Imposed Optic Flow	
Shooting Percentage (0-100)	56.73 (13.45)	52.14 (13.88)	2.953 (p = .006)*
Shooting Score (0-5)	3.15 (.42)	3.05 (.47)	2.889 (p = .007)*
Medial-lateral CoP Range (mm)	110.47 (47.6)	109.86 (47.34)	0.419 (p= .678)
Anterior-posterior CoP Range (mm)	132.63 (36.39)	132.64 (36.54)	-.013 (p= .999)

* Significant at the effective alpha of .008.

The paired samples t-test between the mean AP CoP range under the static environment (132.63 mm) and imposed optic flow (132.64 mm) conditions was not significant $t(33)$ = -0.013, p = .990. The paired samples t-test between the mean ML CoP range under the static environment (110.47 mm) and imposed optic flow (109.86 mm) conditions was also not significant $t(33)$ = 0.419, p = .678. In summary, imposed optic flow had no effect on postural sway during basketball shooting.

4. Discussion

The purpose of this experiment was to test the effect of imposed lamellar optic flow on basketball shooting performance and postural sway. We hypothesized that imposed optic flow would impair basketball shooting performance as well as generate postural sway. The first hypothesis was confirmed; imposed optic flow impaired shooting performance. The second hypothesis was not confirmed; imposed optic flow had no effect on postural sway. Therefore, imposed optic flow negatively impacted shooting performance for reasons other than by causing postural instability. How might have imposed optic flow impaired shooting performance?

4.1. Shooting Performance

One possibility is that imposed optic flow affected aiming behavior, which in turn impaired shooting performance. Whitney et al. found that in a near-aiming task to a briefly presented target on a computer monitor, hand trajectory could be biased and accuracy degraded by the presence of background motion. [8] As target presentation time increased, however, accuracy was no longer affected although initial hand trajectory remained biased, meaning that corrective action was being taken during the reach. Although basketball shooting is a far-aiming task, it is possible that imposed optic flow altered participants' initial shot trajectory, just as it had in Whitney et al's. study, [8] but that bias correction did not occur in our shooters. If initial shot trajectory bias correction did not occur, it may be because the bias was not perceived, perhaps because of the disadvantageous spatial proximity of the hand and the target (basket). However, even if initial shot trajectory bias was perceived, the brief duration of the shooting action would likely leave little time for feedback-based correction.

Another way in which imposed optic flow may have affected free throw performance is by interrupting the visual attention or gaze of the participants. Vickers' quiet eye studies demonstrated the importance of gaze behavior in free throw shooting. [20, 21] The quiet eye is the final gaze fixation on the target prior to movement in far-aiming tasks. [20, 21] Vickers [20] demonstrated that expert free throw shooters had fewer fixations on the target, but had longer fixations and quicker offset of the quiet eye than non-expert counterparts. Vickers and Williams, Singer and Frehlich suggested that the explanation for the quiet eye effect lies in the information it provides for motor programming. [20, 21] According to Vickers, [23] a free throw is performed under open-loop control. So, the critical period for gathering and processing information relevant to the task is directly before the action begins. [22] When the quiet eye is disrupted, information processing and motor programming may be degraded, resulting in diminished performance. [22, 23] In the current study, imposed optic flow commenced just prior to participants' shooting motion, likely coinciding with quiet eye processes. Perhaps imposed optic flow caused gaze to shift, fixation duration to change, or gaze offset to be mistimed, thereby degrading the motor plan for the shot. [20-23]

4.2. Postural Stability

The experiment found that imposed optic flow had no effect on postural sway during basketball shooting. It is possible that the moving background panel, which consisted of 11.3 square meters of visible surface area and occupied a portion of a participant's visual field that was 60 degrees across and 45 degrees vertically, was still not large enough to trigger perceived self-motion and subsequent instability. In other words, the moving background may not have filled enough of a participant's visual field to constitute global flow. Moreover, the static surfaces in the environment that remained visible to participants (i.e., wall curtains, floor, ceiling, basket) naturally continued to provide veridical visual information about postural stability. It is possible that if the visual angles subtended by the moving background panel had been much larger, the imposed optic flow may have generated postural sway.

Wang, McBeath and Sugar used a large moving background (projection on a wall) (25 m x 5.2 m) to examine how imposed optic flow affected navigational behavior of fielders when intercepting a fly ball. [24] Results indicated that background motion systematically altered the running paths of fielders. In short, the moving background caused fielders to misperceive the position of the ball, although they ultimately arrived at successful interception locations. Wang et al. [24] contrasted their finding of a significant effect of background motion on dynamic running with that of Stone et al., [16] who as already noted, found no effect of background motion on free throw performance. Wang et al. explained the apparent incongruence by referring to the disparate tasks used in the experiments. [24] A free throw shooter is stationary, as is the target (basket), and according to Wang et al., [24] this may foster resistance to the effect of a moving background. In contrast, active-interceptive situations like tracking a fly ball apparently require information from the background to calibrate the position of the ball. [24]

It is possible, however, that the salient difference between the Wang et al. [24] and Stone et al. [16] experiments was not the tasks employed, but rather the sizes of the imposed optic flow fields. Recall that Stone et al. [16] projected moving patterns on the basket backboard only, which consists of less than 2 square meters of surface area. The backboard occupies a very small portion of a free throw shooter's visual field, especially in contrast to the very large imposed optic flow field presented to fielders by Wang et al. [24] Large imposed optic flow fields should be more expproprioceptively influential than small ones.

The contradictory findings of Stone at al's. [16] and our experiment on basketball shooting may, likewise, be attributed to the disparate sizes of the imposed optic flow fields. That is, our experiment found a detrimental effect of imposed optic flow on shooting performance while Stone et al's. [16] did not, likely because the size of the imposed optic flow field used in the current study was much larger than the one used by Stone et al. [16] If we could have employed an imposed optic flow field as large as Wang et al's., [24] it is possible that the negative effect on shooting performance we observed would have been amplified, and that postural sway may have been induced. It is worth noting that the current study generated imposed optic flow by moving an actual physical surface rather than projecting moving images onto a stationary surface as Stone et al., [16] and Wang et al.[24] did. With projected imposed optic flow, it is unclear if the static nature of the projection surface is perhaps partially perceived by an observer.

5. Conclusions

A limitation of the current study was its use of a basketball shooting task that differed from a regulation basketball free throw. While the shooting accuracy required was proportional to an actual basketball free throw, nonetheless, caution must be exercised when considering the generalizability of the results to real world settings. Although we can conclude that imposed optic flow impaired shooting in our experiment, we cannot say that imposed optic flow generated by fans sitting behind the basket has the ability to hinder free throw shooting in real world settings. Future research should endeavor to determine the mechanisms by which imposed optic flow impairs basketball shooting performance by testing the effect of imposed optic flow on aiming kinematics and gaze behavior. Moreover, immersive virtual reality could also be helpful in studying the influence of imposed optic flow on basketball shooting performance and postural sway.

ACKNOWLEDGMENTS

We would like to thank Kathleen Mellano, Jamie Carder, Elizabeth Lieblein, Morgan Eckenrod, Trey Saari and Katie Corrigan for their contributions to this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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