Perceiving Dance
Schematic Expectations Guide Experts' Scanning of a Contemporary Dance Film

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Abstract

Eye fixations and saccades (eye movements) of expert and novice dance observers were compared to determine the effect of acquired expectations on observations of human movement, body morphology, and dance configurations. As hypothesized, measured fixation times of dance experts were significantly shorter than those of novices. In a second viewing of the same sequences, novices recorded significantly shorter fixations than those recorded during viewing session 1. Saccades recorded from experts were significantly faster than those of novices. Although both experts and novices fixated background regions, most likely making use of extra-foveal or peripheral vision to anticipate movement and configurations, novices fixated background regions significantly more than experts in viewing session 1. Their enhanced speed of visual processing suggests that dance experts are adept at anticipating movement and rapidly processing material, probably aided by acquired schemata or expectations in long-term memory and recognition of body and movement configurations.

Several neuroimaging studies have illuminated effects of specialist expertise on networks of neural activation while observing dance.[1,2] A tantalizing question that remains unanswered concerns the form of the underlying knowledge that mediates visual perception of dance by expert and novice observers. The present study tests the hypothesis that dance generates expectations based on implicit knowledge about common features of a particular genre or style, as well as knowledge of the constraints and characteristics of human anatomy and biological motion. In this study eye movements of expert and novice dance observers are analyzed for evidence of experts' implicit knowledge and expectations regarding contemporary dance.

While reading, looking at a scene, or searching for an object we continually make eye movements, called "saccades." Between saccades the eyes remain relatively still, with fixations of about 200-300 milliseconds. Saccades are rapid, with velocities as high as 500° per second. During saccades, sensitivity to visual input is reduced. This is called "saccadic suppression," wherein vision is blurred and little information is taken in. While reading, a typical saccade is 2°, taking around 30 ms, whereas a 5° saccade, more typical of scene perception, takes around 40-50 ms.[3,4] One reason that saccades are made frequently is because of acuity limitations.[4] The visual field can be divided into three regions that vary in acuity: foveal (central 2° of vision; good acuity), parafoveal (extends out to 5° on either side of fixation; poor acuity), and peripheral (region beyond the fovea; very poor acuity). We move our eyes to fixate on that part of the stimuli we want to see clearly or focus attention on. Characteristics of stimuli in the parafovea and periphery determine whether or not a saccade needs to be made to identify it; moving stimuli frequently drive saccades and fixations. Beyond this perceptual level, knowledge from long-term memory—"expectations"—also influence saccades and fixations.

In another of the temporal arts, music, implicit knowledge about common features of the genre generates expectations. Variations in how these expectations are met or violated are important in determining emotional and aesthetic response to

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music.[5-9] Differentiation between two kinds of expectations, "schematic" and "veridical," solves a paradox of musical expectation,[10] and we extend these ideas to dance. Schematic refers to information acquired from experience and stored in long-term memory. The term veridical means true, or coinciding with reality. A familiar piece of music contains no surprises. If the violation of expectations is aesthetically or emotionally important, then a piece should become less aesthetically or emotionally interesting with each listen. This is not the case. Schematic expectations are automatic, culturally generic, and develop from assimilation of abstracted regularities of the music of a genre over years of experience. Veridical expectations refer to the actual next event in a familiar piece, even though the event may be schematically unexpected. Because schematic expectations are acquired from hearing many individual pieces, the two kinds of expectancies will often converge, but at times diverge, creating a continuing sense of violation in familiar pieces of music. There is a tension between what one expects and what one hears, and this tension contributes to emotional response to music.[8]

Along similar lines, Hagendoorn[11] theorized an interplay of expectancies concerning human biological motion and particular choreographic styles or works elicited by movement trajectories as dancers watch dance. The empirical challenge is to develop a behavioral method whereby expectations for dance can be elicited and quantified. Patterns of eye fixations and saccades appear to differentiate novices and experts in cognitively demanding domains, such as reading and chess, and dynamic environments, such as driving, aviation, and sport. Thus, some of the forms of knowledge that distinguish novice and more expert observers of dance may begin to be inferred from differential patterns of fixation and saccades while watching dance.

Eye movements provide detailed, quantitative information about moment-to-moment visual attention. Although rapid covert shifts of attention do not necessarily involve eye movements,[12-14] the pattern of eye fixations and the trajectory of eye movements are informative (though not unique) behavioral indicators of aspects of visual selective attention. Fixation time measures the processing time given to overtly attended regions. Longer times are often associated with more interesting, puzzling, or difficult material,[4,15] and are likely to be influenced by observer expertise. For example, novice pilots dwell nearly twice as long as experts on the information-rich attitude directional indicator, requiring more time to extract less obvious information,[16] and novice car drivers record longer head-down dwells than experts.[17] Effects of expertise have also been observed in saccades and scanpaths: short latencies for an initial saccade distinguish good from poor cricket batting,[18] and expert radiologists prioritize their attention, scanning areas where tumors are most likely to occur, while the novice scans a radiograph evenly.[19]

The cognitive processes inferred from these patterns of eye movements in experts relative to novices include encoding configurations rather than individual elements, and guidance from extra-foveal processing. Movement in the periphery will prompt saccades.[20] Like expert pilots and athletes, it is likely that dance experts have access to knowledge in long-term memory of dance schemata and expectancies that guide visual perception and interpretation. In a study comparing expert and novice dance teachers, Petrakis found no significant differences in fixation durations, but some differences in search patterns.[21] For example, novice dance teachers concentrated on the lower body, while expert teachers attended to the upper body. The present study extends the earlier work of Petrakis by recruiting participant groups that are qualitatively different from each other with respect to their experience and expertise with contemporary dance; that is, people with little or no experience observing contemporary dance and people with extensive experience observing and performing dance.

Investigations of memory for dance movement suggest that those with experience performing and observing dance have better recall than novices of movement that is choreographed or structured.[22-24] Differences between expert and novice dancers have also been demonstrated with respect to body image, cognitive imagery, and spatial ability.[25] Most recently, neuroimaging studies have shed light on effects of specialist dance expertise on action observation and motor simulation.[2,26] For adults, it is also likely that there are schematic expectancies pertaining to biological motion, anatomically possible human movement, and the dynamics of motion, including gravity and other forces.[27-29]

For individuals with experience performing and observing contemporary dance, it is anticipated that perception is rapid, with the encoding of configurations and phrases more than discrete units. Knowledge in long-term memory acquired from experience with the art form guides this perceptual organization. Accordingly, it is hypothesized that expert observers fixate for shorter times and have faster saccades than novice observers.

The aim of this study was to investigate the effect of expertise (novice versus expert) and viewing session (first or second) on overt visual attention while watching a filmed performance of contemporary dance. The dependent measures were fixation time and average and peak saccadic velocity. Regions of fixation were recorded. Based on eye movement correlates of expertise, it was hypothesized that: 1. fixation times recorded by expert observers are shorter than those of novice observers; 2. average saccadic velocity recorded by experts is greater than that of novices; and 3. peak saccadic velocity recorded by experts is greater than that of novices. If observers develop veridical expectations for a particular dance piece, then responses will differ across viewing sessions and, more specifically, response patterns from novice observers will move toward those of expert observers during a second viewing session.

Methods and Materials

Participants

The sample consisted of eight female participants (mean age = 28.63 years, SD = 6.12), four with extensive dance training (M = 19.5 years, SD = 3.87) and dance performance experience (M = 13.5 years, SD = 5.20), and four with no dance training. In addition, eye movements were recorded from the choreographer of the work in question (see below) as a manipulation check, as she would be highly familiar with the work and have detailed veridical expectations for the piece. However, because of the choreographer's extreme familiarity with and knowledge of the work, her eye movement data were treated separately and not included in the expert sample. Regions of fixation recorded by the choreographer will be reported as descriptive data for comparison purposes only.

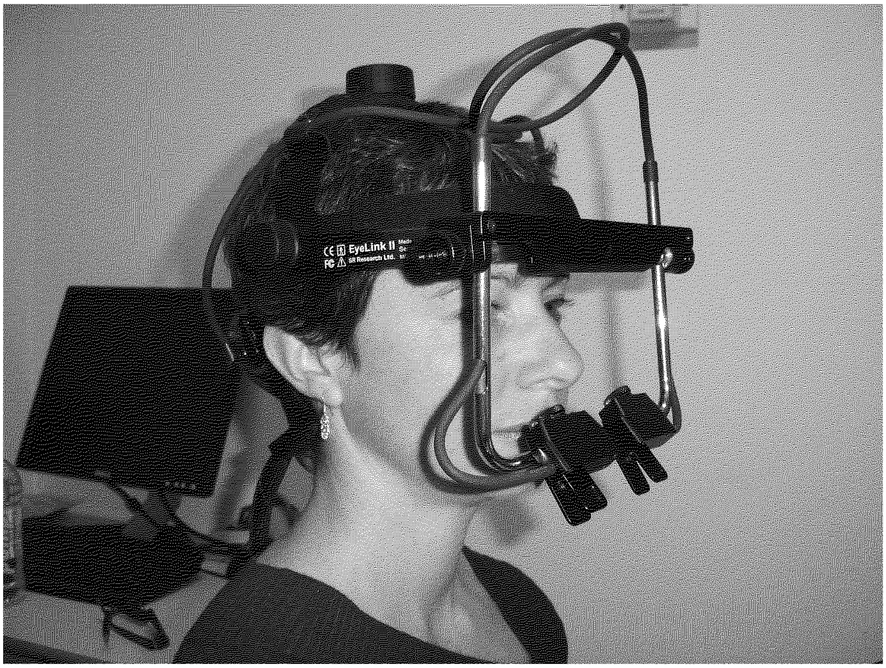

Figure 1 The EyeLink II head-mounted binocular eye tracking device consists of two miniature cameras for eye tracking and a third camera for head tracking.

Stimuli

The stimulus material was a five-minute contemporary dance film of a light-hearted duet between two male dancers that was filmed from a single camera angle to control viewpoint. The choreographer used partitions on either side of the frame to provide depth and varied entry and exit points. To constrain the amount of data to be analyzed and to ensure comparable cell sizes for analysis, a 17 s section midway through the film (235-252 s) was selected for detailed analysis. The section was chosen as it involved the dancers working both together and apart. This ensured that the dancers were co-located in some frames and moving in different regions of the screen in other frames, thus offering different possible viewing strategies to observers (i.e., opportunities to observe one dancer or the other, or to use peripheral vision to observe both when the two dancers were not co-located).

Equipment

The film was presented to participants on a desktop PC with external speakers. An EyeLink II pupil-based video monitoring system (SR Research, Osgoode, Ontario, Canada) was used with a sampling rate of 500 Hz, equivalent to a temporal resolution of 3 ms. EyeLink II is a state-of-the-art head-mounted binocular eye-tracking device, with dual image processing consisting of three miniature cameras mounted on a headband (Fig. 1). Two eye cameras allow binocular eye tracking. The third camera tracks the head, enabling accurate tracking of the participant's point of gaze without the need for a bite bar and associated immobilization. Software generates fixation reports, including current, next and previous fixations, fixation count, and current, next and previous saccadic amplitude, angle, average velocity, direction, start, end, peak velocity, saccade count, and saccade duration. Viewing in the present experiment was binocular, but as is the convention data recorded from the right eye were used in analyses. For description of current eye-tracking methods and protocols see Duchowski.[30]

In a second phase of data processing, custom-written software was used to relate eye fixations to the region of the frame that was fixated. Sixteen regions of interest were specified manually, namely the background and each dancer's head, neck, torso, left and right shoulder, left and right arm, left and right hand, left and right hip, left and right leg, left and right foot.

Procedure

Written consent was obtained from each participant in accordance with the approval received from the University of Western Sydney Human Research Ethics Committee (HREC05/026). Participants were tested individually and were given a brief introduction to the dance film, including its title. They were asked to watch the dance film in the way that they would normally watch a performance. Participants watched the film twice. Between viewings and as a filler task, participants completed a background questionnaire and provided a written description of their reactions to the film. The experiment lasted 40 minutes.

Results

In the analyzed segment, the mean number of fixations recorded by experts was 36.50 (SD = 5.49) and from novices 32.13 (SD = 6.57). Raw data recorded from the right

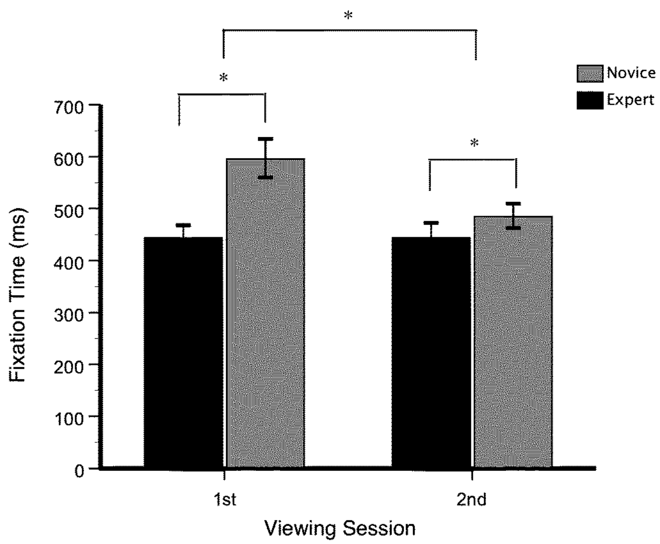

Figure 2 Fixation duration (ms): expertise x viewing session. Fixation times of experts are significantly shorter than those of novices, p < .05, and viewing session and expertise interact, p < .05; there is a greater difference between expert and novice fixation times during the first viewing session than the second.

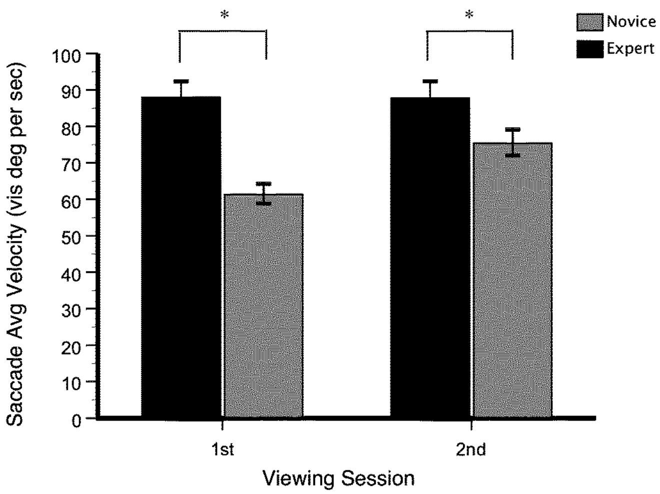

Figure 3 Saccadic average velocity (visual degrees per second): expertise x viewing session. Saccadic average velocity recorded from expert observers is significantly greater than that of novice observers, p < .000.

eye of participants were analyzed in two-way (expertise, viewing) ANOVAs conducted separately for each of the three dependent measures. The first hypothesis, that fixation times recorded by experts are shorter than those of novices, was supported, $F(1,246) = 6.91$, $p < 0.05$, $\eta^2 = 0.03$ (Fig. 2). There was a significant interaction between viewing session and expertise, $F(1,246) = 4.49$, $p < 0.05$, $\eta^2 = 0.02$, with a greater difference between expert and novice fixation times during the first viewing of the film relative to the second viewing (Fig. 2). Supporting the hypothesis that veridical expectancies develop for a particular piece, fixation times were significantly longer in response to the first viewing of the film (M = 521.02 ms, SD = 391.18) than the second viewing (M = 449.89, SD = 325.83), $F(1,246) = 5.04$, $p < 0.05$, $\eta^2 = 0.02$.

On the second viewing the differences between fixation times of novice and expert observers decreased. Significant differences in fixation times were recorded by novices between the first and second viewing, $F(1,123) = 7.98$, $p < 0.05$, with shorter fixation times recorded in the second viewing (M = 458.85 ms, SD = 300.89) than in the first (M = 579.11 ms, SD = 455.00).

As hypothesized, saccadic average velocity (visual degree per second) recorded by expert observers (M = 88.06, SD = 53.64) was greater than that of novice observers (M = 68.55,

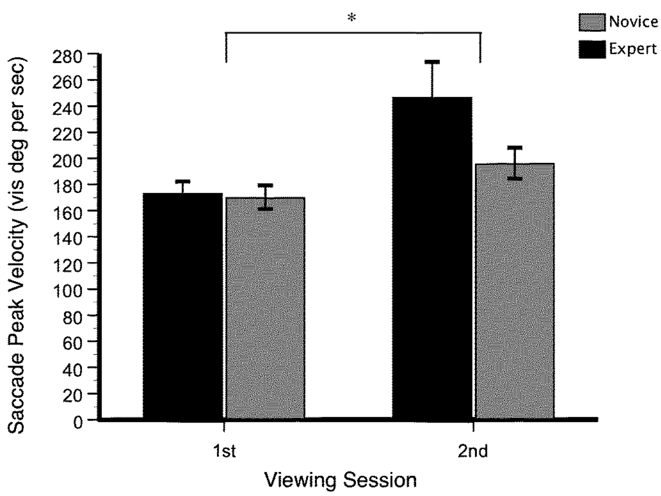

Figure 4 Saccadic peak velocity (visual degrees per second): expertise x viewing session. Peak velocity of saccades increased in novice and expert observers in the second viewing session, with the greatest increase recorded in the expert group, p = .004.

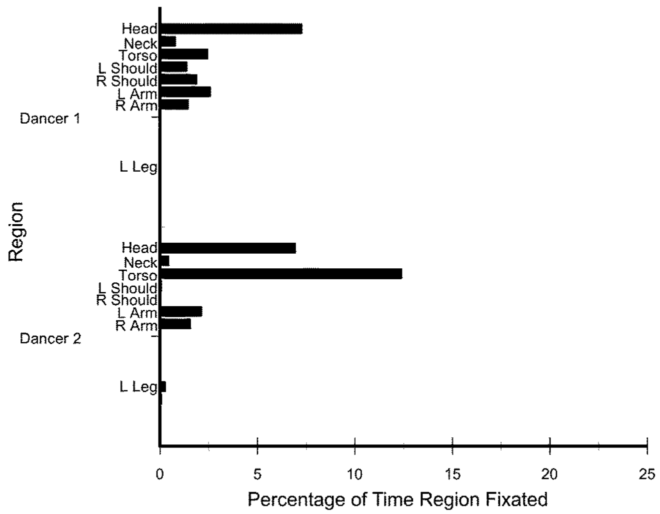

Figure 5 Mean percentage of time that each region (excluding background) is fixated by expert observers (N = 4; total segment = 17 s) during viewing session 1.

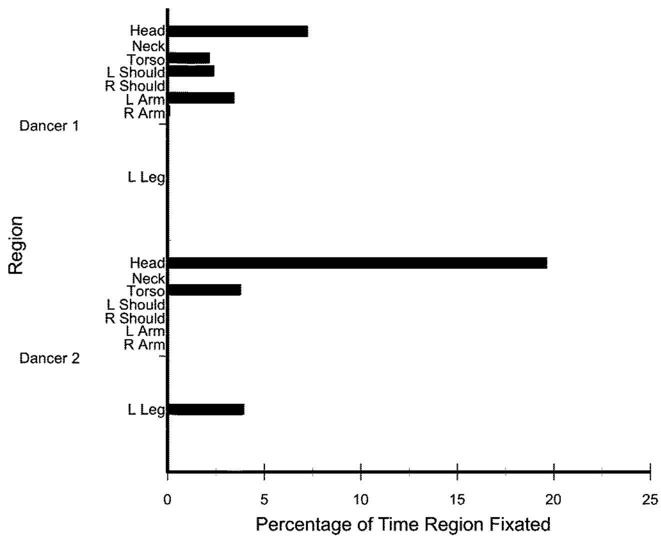

Figure 6 Mean percentage of time that each region (excluding background) is fixated by the choreographer—a highly expert observer (N = 1; total segment = 17 s) during viewing Session 1.

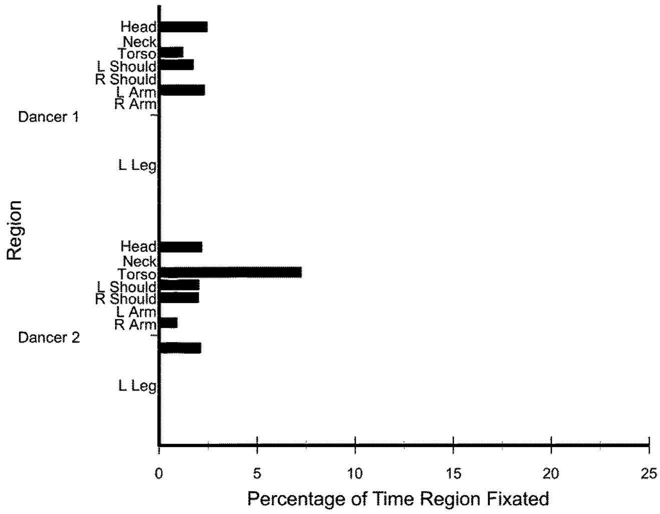

Figure 7 Mean percentage of time that each region (excluding background) is fixated by novice observers (N = 4; total segment = 17 s) during viewing Session 1.

SD = 40.50), $F(1,246) = 22.08$, $p < .000$, $\eta^2 = 0.08$. There was no main effect of viewing session and no interaction between expertise and viewing session (Fig. 3). Analysis of saccadic peak velocity revealed that there was no significant difference between expert and novice groups on initial viewing, but there was an interaction between expertise and viewing session, $F(1,246) = 8.40$, $p = .004$, $\eta^2 = 0.033$ (Fig. 4). Peak velocity of saccades increased for both participant groups in the second viewing session, with a significantly greater increase recorded in the expert group.

One possibility is that experts and novices differ in ways other than their amount of experience with contemporary dance, and this may also affect eye movements. To check for general differences in eye movements and baseline activity between the two groups, fixation count, duration, and saccade amplitude were analyzed from 4 s between the title of the film and the dance starting. These data revealed no significant differences between the expert and novice groups.

A research question concerns differential effects of expertise on dwell time and anticipatory eye movements. Figures 5, 6, and 7 show the mean percentage of dwell time across the 17 s segment devoted to the 15 body regions of each dancer for expert observers, the choreographer (for comparison purposes), and novice observers, respectively. The only significant difference in a comparison of proportions of looking time revealed a difference between the amount of time that the background was fixated by experts compared with novices during Session 1, $z(7) = -.2.89$, $p < ,05$, with novices fixating the background significantly more than experts. All observers, whether expert or novice, fixated the background from 57.87% to 73.25% of the time; the choreographer fixated the background between 42.25% and 57.14% of the time. When the regions of fixation are considered broadly, there is a tendency for novices to fixate the background, while experts spend less time on the background and more time fixating the head and torso regions of the dancers.

The accuracy with which saccades followed the movement was also calculated. The calculation involved comparing the position of a saccade during each movement with the corresponding moving area. The choreographer, obviously a highly experienced observer of this work, was most accurate at following the movement (37.84% in Session 1, 54.84% in Session 2), but experts and novices were also successful, following movement from 29.01% to 36.08% of the time.

Discussion and Conclusions

The assumption investigated here was that watching dance develops schematic expectancies based on knowledge of the art form, dance technique, and choreographic styles, as well as knowledge of human morphology and movement. The activation of schematic expectations was inferred from a comparison of eye movement patterns from expert and novice dance observers as they twice viewed a short dance film. As anticipated, expert dance observers recorded shorter fixation times and faster saccades than novice observers. Novices acquired veridical expectations, with shorter fixation times recorded during the second viewing of the film.

The brief fixation times characteristic of experts reflect rapid perceptual processing, likely guided by expectancies and schemata in long-term memory. Akin to highly skilled pilots,[16] athletes,[18] and drivers,[17] dance experts are adept at abstracting and extracting key information from complex movement material. Visual and motoric knowledge of dance in general and different choreographic styles in particular—"schematic expectancies"[10]—may enable configural rather than elemental encoding, maximizing short-term memory. Dance experts made faster saccades than novices using visual cues (and possibly sound), building new expectancies that guided systematic and strategic scanning of a performance. With a rapidly moving dancer it will not always be possible for the eyes to make smooth pursuits of the dancer (as in following a target); thus saccades are likely used to catch up with the dancer or target.[4] Interestingly, novices fixated regions more rapidly after just one viewing. A single exposure to a short work appears sufficient to establish perceptual reference points and to begin acquisition of veridical expectancies for a particular work.[10]

The present results demonstrate, for the first time, that expert and novice observers (as well as the choreographer, with a close-to-perfect set of expectations for the work) fixate the background as well as the dancers themselves. This result is comparable to skilled music readers fixating not on the notes but on the blank areas of a musical score,[31] and expert chess players who, relative to intermediate level players, record more fixations on empty squares than on squares with chess pieces on them.[32]

In the case of a dance performance there are at least two reasons for fixating the background. First, with a rapidly moving stimulus such as a dancer, movement attracts the eye to its location.[4] Peripheral vision (i.e., vision outside the foveal area) is particularly sensitive to motion. Thus, with rapid movement it will be beneficial to fixate a distant point and have the moving object in the periphery rather than in the foveal region. At any time it should then be possible for the movement to drive the eye to the location of the movement. Fitzpatrick noted a similar phenomenon in the context of theater performance: something in the periphery prompts saccades.[20] We know too that expert chess players encode chess configurations rather than individual pieces, and that parafoveal or peripheral processing guides their eye movements.[32]

A second and related reason for frequent fixation on the background is that at those times when two dancers occupy different and distant spatial regions fixation on the background and *between* the two dancers will be an effective strategy for detecting movement of either or both dancers in peripheral vision. In this way the use of peripheral vision divides visual attention across two regions. Again, where a particular movement engages visual attention, the eyes can be moved to that region and the region fixated. Fixations tend to be driven by information in parafoveal and peripheral vision (dimensions such as brightness or contours are effective cues in that they use little or no central processing capacity).[4] Knowledge in long-term memory and instructions can also influence viewing patterns.[19,21,24] Although it is often necessary to move the eyes to identify objects, visual attention can be shifted without moving the eyes. However, with complex stimuli, it is more efficient to move the eyes than to move attention.[4]

There are two different decision-making processes involved in computing, *when* and *where* to move the eyes.[4] The present analysis quantifies *where* the eyes are moved. Future research could analyze scanpaths, or the ordinal sequence of eye fixations, and investigate whether novices and experts differ with respect to *when* the eyes move while watching dance. Nearly 20 years ago, Fitzpatrick[20] posed a question in the context of theatrical performance that continues to be relevant today: in what way are different scanpaths associated with different interpretations and different patterns of empathy? The coming of age of methods that measure emotional or empathic responses continuously rather than retrospectively[33] will supplement eye-tracking techniques. Converging operations such as these will shed light on enduring issues concerning audience response commonalities and individual differences.

A hallmark of expertise in other domains is accurate and timely anticipation. All participants in this study predicted some dancer movements, with the choreographer leading the way, followed by expert and novice groups. The dynamics of action anticipation in professional basketball players has recently been investigated.[34] Athletes predicted the success of shots at a basket earlier and more accurately than did individuals with comparable visual experience (coaches, sports journalists) and novices. Athletes and other groups differed in their responses before the ball left the observed player's hands, suggesting that some reading of body kinematics was involved. The investigators concluded that excellence in sport is related to the fine-tuning of specific anticipatory mechanisms.

An important implication of the present results for audience development and education is the way in which expectancies, even in novice observers, develop during one viewing of a work. Repeated exposure to dance is likely to build perceptual fluency. Such fluency becomes associated with a sense of familiarity, and ultimately heightens preference for the movement material.[35-37] Thus, repetition of material within a single work or across a body of dance works by a particular choreographer or ensemble is likely to facilitate recognition and enjoyment.

A significant aspect of these results is the way that moment-to-moment cognitive processes have been captured in response to an ephemeral, dynamic, non-verbal, yet communicative art form. Eye movements provided an indirect measure of rapid cognitive processes without the need for verbalization. Future studies might include strategic manipulation of attentional cues, such as soundscape, lighting, and spatial arrangement of dancers, and scrutinize the interplay of visual, motor, and semantic knowledge.

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