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The Size and Shape of the Attentional "Spotlight" Varies With Differences in Sports Expertise

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Focused attention enhances processing of some aspects of the world at the expense of unattended items. Although focused attention has been studied for decades, few studies have measured individual and group differences in how people distribute attention. In three studies, we explored differences in the breadth and distribution of attention as a function of athletic expertise. Study 1 found 25% greater attention breadth in expert athletes than in novices. Study 2 found that the distribution of focused attention for experts varied as a function of the type of athletic expertise: Experts in sports that demand greater horizontal distribution of attention (e.g., soccer) showed greater horizontal breadth of attention than did those whose sports demand more vertical attention (e.g., volleyball), and vice versa. Study 3 used a slightly modified design to replicate the results of Studies 1 and 2. Overall, the findings reveal a systematic association between the measured "shape" of focused attention in a laboratory task and expertise in a real-world skill.

Keywords: visuospatial attention, focus of attention, zoom lens

The shape, capacity, and spatial distribution of focused attention (i.e., how focused attention is applied to a subset of the visual world) have been topics of investigation for decades (e.g., Cowan, Fristoe, Elliott, Brunner, & Saults, 2006; Galera, von Grünau, & Panagopoulos, 2005; Gold et al., 2006; Wiley & Jarosz, 2012). Prominent metaphors liken the focus of attention to a spotlight (Posner, 1980), a zoom lens that trades breadth for precision (Eriksen & St. James, 1986), or a gradient (LaBerge & Brown, 1989). Each metaphor acknowledges the flexibility of focused attention: Its shape and breadth are influenced by task requirements and display elements (Duncan, 1984; Galera et al., 2005; Lavie, 1995; Rees, Frith, & Lavie, 1997), as well as by the observer's emotional state (e.g., Fredrickson, 2001; Gasper & Clore, 2002).

Individuals vary in their ability to distribute visual attention spatially (e.g., Ahmed & de Fockert, 2012), to divide attention (e.g., Colflesh & Conway, 2007), and to shift the focus of attention (e.g., Heitz & Engle, 2007; for a review see Cave & Bichot, 1999). People also vary in their ability to apply attention selectively (e.g., Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003) and to apply executive control to attentive processing (Conway, Cowan, & Bunting, 2001). The flexibility of attention across tasks (Cowan, 2005), coupled with evidence for individual differences in these basic processes, raises the intriguing possibility of systematic individual differences in the way people distribute focused attention across the visual field. Few studies have explored individual differences in the shape of the "attentional spotlight" (e.g., Ahmed & de Fockert, 2012; Cave, 2013; Pype, Lin, Murray, & Boynton, 2010), and none have explored how that shape varies with domain-specific expertise.

Such individual differences could have practical significance. For example, people with greater attention breadth in the horizontal direction might have an advantage when driving relative to those with greater attention breadth in the vertical direction. Conversely, those with greater vertical breadth of attention might excel in tasks that demand more vertical attention, such as painting a façade or constructing a building. To the extent that the shape and breadth of attention is malleable, it might change with experience as well.

We examined differences in the scope and distribution of attention by comparing expert athletes to novice athletes. Visual attention is essential in sport performance, especially in fast-paced team sports (Abernethy, 1990; Memmert, Simons, & Grimme, 2009; Williams, Davids, & Williams, 1999), and expert athletes show better attention performance than novices in a variety of attention tasks (e.g., Castiello & Umiltà, 1992; Nougier, Ripoll, & Stein, 1989; Pesce Anzeneder & Bösel, 1998; for reviews see Mann, Williams, Ward, & Janelle, 2007; Voss, Kramer, Prakash, Roberts, & Basak, 2010). For example, they can adjust the scope of their attentional spotlight more effectively to focus on multiple locations (e.g., Nougier, Azemar, Stein, & Ripoll, 1992), shift it between objects more efficiently, and maintain attention longer than novices (e.g., Pesce Anzeneder & Bösel, 1998; Turatto, Benso, & Umiltà, 1999).

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Although many studies have documented expertise effects, none has systematically measured expertise differences in the maximum breadth and spatial distribution of focused attention. A soccer player in possession of the ball must simultaneously track both the ball and the defender in order to successfully counter the defense, and the ability to spread attention more broadly would be advantageous. Given the demands of sports, if attention varies across individuals, we should expect greater attention breadth for expert athletes than for novice athletes. Note, though, that such an association would not permit a causal conclusion: Individual differences could lead to athletic success, they could result from athletic training, or a third factor could contribute both to greater breadth and to athletic expertise.

Study 1 explored such expertise differences by requiring participants to focus attention simultaneously on two spatially separated stimuli and make judgments about both (Hüttermann, Memmert, Simons, & Bock, 2013). Participants maintained fixation on the midpoint between the targets, a strategy that maximizes attention breadth compared with a strategy of fixating one target and processing the other peripherally (Hüttermann et al., 2013). By systemically varying the stimulus positions and the distance between targets, we characterized the maximum extent of the attentional spotlight along several spatial dimensions and compared that "shape" for experts and novices.

Although some attention demands are common across sports, sports also differ in the demands they place on attention (Nideffer & Sagal, 2001). The attentional demands of sport vary in their need for focus (e.g., narrow vs. broad: the number of stimuli athletes have to attend to at any given moment) and whether they require internal or external focus (focusing inward on feelings and thoughts or outward on events; Burton & Raedeke, 2008). Sports also vary in the primary spatial dimension that requires attention: Some sports require greater horizontal breadth of attention (e.g., team handball, soccer) and others require greater vertical breadth of attention (e.g., volleyball, basketball; Allard, Graham, & Paarsalu, 1980; Allard & Starkes, 1980).

Studies 2 and 3 examine differences in attention performance as a function of the type of sport the athlete plays. If the shape of attention varies as a function of the demands of the expertise domain, then athletes who specialize in different sports should show a corresponding difference in the spatial distribution of attention, even in our nonsport attention task. Consequently, those who play horizontal sports should show a relative advantage for horizontal attention, and those who play vertical sports should show a relative advantage for vertical attention.

Study 1

Efficient performance in most team sports demands simultaneous attention to multiple, spatially separated objects. Consequently, we might expect team-sport experts to show greater attention breadth than novices, even on a task that is unrelated to their domain of expertise.

Method

Participants. Twenty-two subjects (13 female) aged 22 to 36 years (M_{age} = 26.77, SD = 4.22 years) participated in Study 1. Data from two additional subjects were excluded because they did not consistently achieve 75% accuracy on all meridians (see below). Following Ericsson (1996), subjects with more than 10 years of intensive training in a team sport were categorized as experts (n = 12, 7 female, M_{age} = 27.92, SD = 5.12 years, $M_{team\ sports\ experience}$ = 16.00, SD = 2.66 years), and the remaining subjects were classified as novices (n = 10, 6 female, M_{age} = 25.40, SD = 2.37 years, $M_{team\ sports\ experience}$ = 3.10, SD = 3.76 years). Primary team sports included basketball (n = 1), handball (n = 4), hockey (n = 2), soccer (n = 9), and volleyball (n = 3); three novices participated in no team sports at the time of the experiment. All subjects reported normal, uncorrected vision and had not participated in any sensorimotor research within the preceding 6 months.

Materials and procedure. Participants were tested individually in a laboratory room and sat approximately 1.30 m from a 2.80 m × 2.20 m (94° horizontal × 80° vertical) white projection screen. On each trial, a pair of stimuli appeared, with members of the pair equidistant from and on opposite sides of a central fixation point along one of four meridians (horizontal: 0°/180°, vertical: 90°/270°, diagonal 1: 45°/225°, diagonal 2: 135°/315°). Each pair was equally likely to appear along the horizontal, vertical, or one of the two diagonal meridians, and for analyses, we combined data from the two diagonal meridians. The members of a pair were separated by a visual angle that ranged from 2° to 60° (in 2° increments). The meridian and stimulus separation were fully crossed, with each combination tested twice (30 separations × 3 meridians × 2 repetitions), giving a total of 180 experimental trials, with a 30 s break after every 60 trials. Participants completed an additional 12 practice trials at the start of the experimental condition, followed by the experimental trials in a random order, resulting in a total of 192 trials.

Each stimulus (19 cm × 19 cm or 8.38°) consisted of four elements (9 cm × 9 cm, or 3.97°; with a gap of 1 cm, or 0.44° between the elements), each of which was assigned a shape (circle or triangle) and color (light or dark gray). Each stimulus included 0, 1, 2, 3, or 4 light gray triangles with equal probability (i.e., on 20% of trials). The color and shape of the other items in each stimulus were determined randomly. On each trial, subjects reported the number of light gray triangles in each stimulus, and responses were considered correct only if they reported the number correctly for both stimuli on that trial. Given that the target items within each stimulus were defined by a conjunction of features, identifying the number of light gray triangles in each stimulus required focused attention (Schneider, Dumais, & Shiffrin, 1984; Shiffrin & Schneider, 1977; see Hüttermann et al., 2013, for a complete description of this task).

Before participating in the attentional breadth task, and to assess the visibility at each possible target position, each subject was tested in a control condition. On each trial, a single stimulus, created using the same procedure as in the experimental condition, appeared peripherally while subjects fixated on the middle of the screen. Again, subjects reported the number of light gray triangles in that stimulus. As in the experimental task, there were 30 possible stimulus locations on each of the meridians, with distances from fixation ranging from 1° to 30° from fixation along each meridian. Each stimulus distance from fixation was tested twice on the same side of the meridian. And, for each distance, we randomly chose the side of fixation with the constraint that half of the distances were tested on each side of fixation. Consequently, participants completed the same number of control trials as experimental trials (30 distances × 3 meridians × 2 repetitions).

In both the control and experimental conditions, each trial started with a central fixation cross (1000 ms) and was followed for 200 ms by a precue (a circle 3.52° in diameter) that indicated the location(s) at which each stimulus would appear. After a 200 ms blank screen, the target(s) appeared (for 150 ms in the control trials or 300 ms in the experimental trials). Subjects then verbally reported the number of light gray triangles (0–4) in each target stimulus, and the experimenter recorded their responses (see Figure 1). Subjects fixated on the central fixation cross throughout each trial, and fixation was monitored with a mobile video-based eye tracking system (Mobile Eye®, Applied Science Laboratories, Bedford, MA, sampling rate of 30Hz and resolution of 1°).

Results and Discussion

We excluded data from trials in which the subjects failed to maintain fixation (control condition: 4% for experts, 5% for novices; experimental condition: 3% for experts, 5% for novices). For analysis, we combined data from the two diagonal meridians because we had included both only for counterbalancing purposes and had no reason to expect any difference between them. Given that accuracy data tend not to be normally distributed, particularly with high accuracy levels, data were transformed using the arcsine of the square root before all analyses in the control condition (cf. Manikandan, 2010; Osborne, 2010). However, the reported means and standard deviations are based on the untransformed data (see Table 1).

The control condition was designed to verify that stimuli were perceptible at all distances from fixation. Given that we had relatively few trials for each distance on each meridian, we computed the average accuracy across a moving-window of five stimulus distances from fixation, centered on the critical distance. This technique was used to find a cutoff point that then served as the dependent measure in our analyses. For example, to calculate average accuracy at a distance of 7°, we averaged performance for distances of 5, 6, 7, 8, and 9°. All participants achieved greater than 80% accuracy at all distances on all meridians. The averaged accuracy rates along each meridian across subjects are presented in Table 1. Both experts and novices performed accurately, with no significant differences between the groups. A 2 × 3 (expertise [expert, novice] x meridian [horizontal, vertical, diagonal]) ANOVA revealed a nonsignificant effect of expertise, $F(1, 20) = 2.551$, $p = .126$, $\eta_p^2 = .113$, and a significant main effect of meridian, $F(2, 40) = 7.435$, $p = .002$, $\eta_p^2 = .271$. Accuracy was comparable for the vertical ($M = 96.67\%$, $SD = 1.45\%$) and horizontal meridians ($M = 96.44\%$, $SD = 0.93\%$), $t(21) = 0.993$, $p = .332$, $d_z = 0.21$, and slightly worse for the diagonal meridians ($M = 95.08\%$, $SD = 1.58\%$), (horizontal vs. diagonal: $t(21) = 3.070$, $p = .006$, $d_z = 0.66$; vertical vs. diagonal: $t(21) = 3.570$, $p = .002$, $d_z = 0.76$; Bonferroni corrected post hoc comparisons had an adjusted alpha of 0.017). The interaction between expertise and meridian also was nonsignificant, $F(2, 40) = 0.139$, $p = .871$, $\eta_p^2 = .007$. Because both groups performed well in the control condition, any differences between groups in the experimental trials presumably reflect differences in the ability to focus attention on multiple objects rather than differences in visual acuity for peripheral objects. This finding is consistent with evidence that expert athletes generally do not differ from novices in basic visual perception tasks (Blundell, 1985; Hughes, Blundell, & Walters, 1993; Memmert et al., 2009; West & Bressan, 1996), but do differ in attention-demanding tasks with multiple objects (for reviews see Mann et al., 2007; Voss et al., 2010).

For each meridian in the experimental trials we defined "attention breadth" as the largest stimulus separation at which each subject reliably identified the number of light gray triangles in both stimuli on at least 75% of the trials (cf. Clay et al., 2009). Given that we had few trials for each combination of separation and meridian, we calculated this 75% criterion using a moving-window of five separations between stimuli like that used to analyze the control condition (e.g., to calculate average accuracy at a separation of 6°, we averaged performance for separations of 2, 4, 6, 8, and 10°). From these moving-window averages, we determined the largest distance on each meridian at which performance surpassed 75% accuracy for that separation and all smaller separations. As noted earlier, two subjects did not reliably perform better than 75% as the separation decreased, and their data were excluded from analyses. We compared the separations corresponding to that 75% accuracy threshold in a 2 × 3 (expertise [expert, novice] x meridian [horizontal, vertical, diagonal]) ANOVA with a Greenhouse-Geisser correction for sphericity.

Averaging across meridians, experts had a greater attention breadth than novices, $F(1, 20) = 27.608$, $p < .001$, $\eta_p^2 = .580$. Averaging across experts and novices, attention breadth differed as a function of the meridian, $F(2, 40) = 14.128$, $p < .001$, $\eta_p^2 = .414$. Attention breadth was greater for the horizontal meridian ($M = 32.55°$, $SD = 8.44°$) than for the diagonal meridian ($M = 27.09°$, $SD = 5.78°$), $t(21) = 5.020$, $p < .001$, $d_z = 1.07$, and the vertical meridian ($M = 25.45°$, $SD = 5.96°$), $t(21) = 3.943$, $p = .001$, $d_z = 0.84$, with no difference between diagonally and vertically oriented stimuli, $t(21) = 1.193$, $p = .246$ $d_z = 0.25$, (again, Bonferroni correction yields alpha of 0.017). This pattern is consistent with the idea that the spotlight of attention is spatially distributed as an ellipse rather than as a circle, with an elongated horizontal axis (Galera et al., 2005; Sanders & Brück, 1991).

The effect of meridian also varied as a function of expertise, as indicated by a significant interaction, $F(2, 40) = 5.259$, $p = .009$, $\eta_p^2 = .208$: Experts performed at 75% accuracy with greater distance between the stimuli than did the novices on both the horizontal, $t(20) = 5.371$, $p < .001$, $d_s = 2.30$, and the diagonal meridians, $t(20) = 4.719$, $p < .001$, $d_s = 2.02$, but the difference for the vertical meridian was not significant, $t(20) = 1.690$, $p = .106$, $d_s = 0.72$ (see Figure 2 & Table 1)[1].

The smaller group difference along the vertical than the horizontal meridian could be related to the fact that most of our experts and novices (15 of 22) played sports in which the horizontal dimension is

[1] For within-subjects comparisons, the effect size we report is Cohen's d_z (Lakens, 2013), calculated as $d_z = \frac{M_{diff}}{\sqrt{\frac{\sum(X_{diff} - M_{diff})^2}{N-1}}}$. Note that Cohen's d_z for within-subjects tests is not directly comparable to Cohen's d_s for between-subjects tests.

For between-subjects comparisons, the effect size we report is Cohen's d_s (Lakens, 2013), calculated as $d_s = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1 - 1)SD_1^2 + (n_2 - 1)SD_2^2}{n_1 + n_2 - 2}}}$.

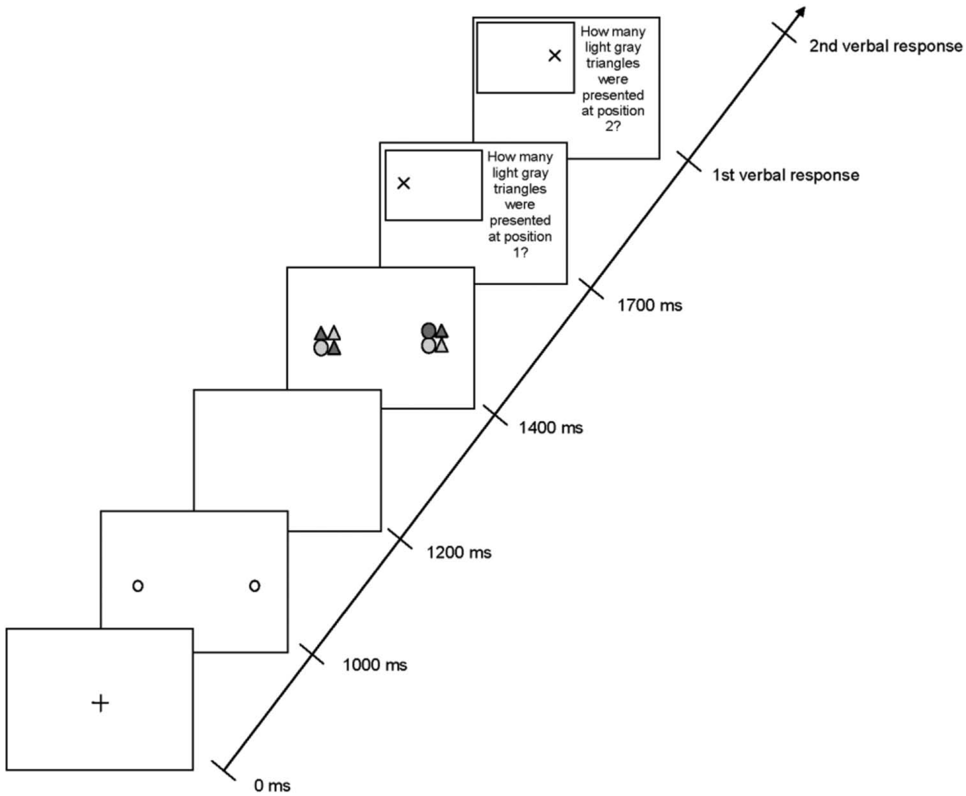

Figure 1. Sequence of events in a trial from the attentional breadth measurement task with the stimuli presented along the horizontal meridian (0°/180°).

more important than the vertical one, and only four of our subjects played sports in which the vertical dimension is more important than the horizontal one. To explore this possibility, we grouped our subjects according to whether their primary sport was more horizontally or vertically oriented. Handball, hockey, and soccer players (M = 34.93°, SD = 7.25°) showed larger attention breadth along the horizontal meridian than did basketball and volleyball players (M = 33.00°, SD = 8.08°). And, basketball and volleyball players showed larger attention breadth along the vertical meridian (M = 31.50°, SD = 5.51°) than did handball, hockey, and soccer players (M = 25.33°, SD = 4.88°). Note, though, that these comparisons are based on only four subjects who played sports with more vertical attention demands. We explored this suggestive trend in Study 2.

Study 2

Study 1 revealed expertise effects in the spatial distribution of attention, particularly for the horizontal meridian. Study 2 was designed to replicate that finding and to explore possible differences in the spatial distribution of attention as a function of the type of sports expertise. Specifically, we predicted that expert

Table 1
For Study 1, Mean Percentage and 95% Confidence Interval of Correct Responses in the Control Condition and Mean Attention Breadth With 75% Accuracy and 95% Confidence Interval in Degrees of Visual Angle, Both as a Function of Meridian and Expertise

	Meridian							
	Horizontal		Vertical		Diagonal		Average - all meridians	
	M	95% CI	M	95% CI	M	95% CI	M	95% CI
Control condition								
Experts	96.25	[95.69, 96.81]	96.39	[95.51, 97.27]	94.72	[93.78, 95.67]	95.79	[95.26, 96.31]
Novices	96.67	[96.05, 97.28]	97.00	[96.04, 97.96]	95.50	[94.46, 96.54]	96.39	[95.81, 96.97]
Average-all groups	96.44	[96.03, 96.85]	96.67	[96.02, 97.31]	95.08	[94.37, 95.78]	96.06	[95.66, 96.46]
Experimental condition								
Experts	38.33	[35.00, 41.67]	27.33	[23.89, 30.77]	30.83	[28.38, 33.29]	32.17	[29.93, 34.41]
Novices	25.60	[21.95, 29.25]	23.20	[19.43, 26.97]	22.60	[19.91, 25.29]	23.80	[21.35, 26.25]
Average - all groups	32.55	[28.80, 36.29]	25.46	[22.81, 28.10]	27.09	[24.53, 29.65]	28.36	[25.88, 30.85]

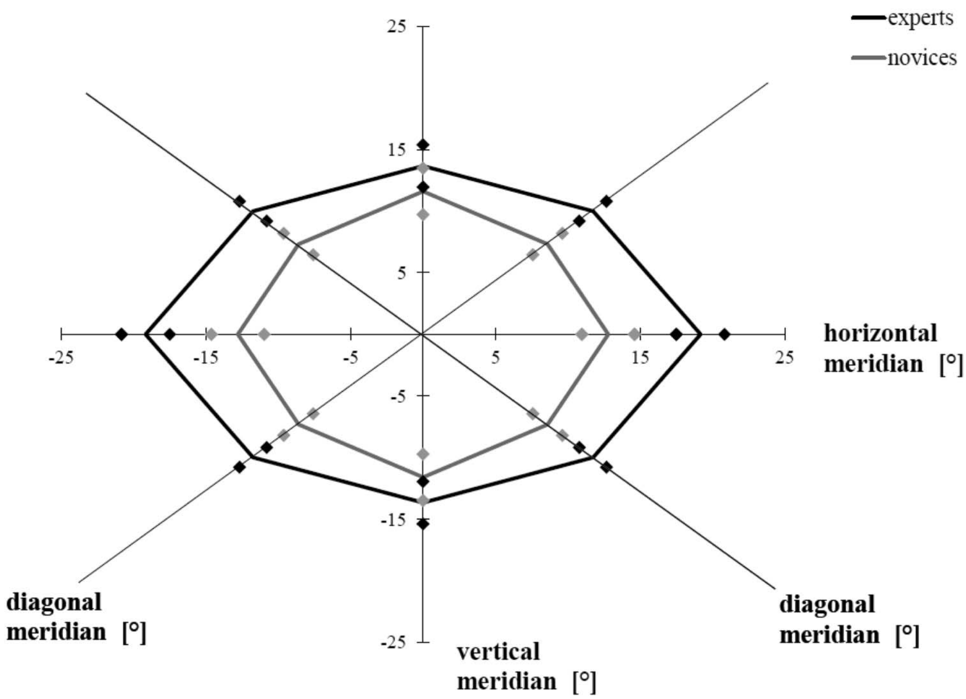

Figure 2. For Study 1, Attention breadth with 75% correct performance as a function of meridian and expertise. Because each stimulus pair was presented symmetrically about the center, the data are also symmetrical. Symbols represent across-subject means, and error bars indicate 95% confidence interval.

athletes from horizontally oriented sports would show greater horizontal attention breadth than those from more vertically oriented sports (and vice versa).

In the exploratory analysis in Study 1, the classification of a sport as horizontal or vertical was based primarily on the size of the playing court. Soccer (105 m × 68 m) and handball (40 m × 20 m) courts are much bigger than basketball (28 m × 15 m) and volleyball (18 m × 9 m) courts. We assumed that larger courts would depend relatively more on horizontal viewing angles. We also subjectively judged the amount of time that the attended objects (balls, players) spend on the ground versus in the air. Study 2a[2] was intended to confirm the reliability of our classifications by asking a group of naive raters to judge whether each sport is horizontal or vertical. Study 2b compared the performance of experts in vertical or horizontal sports on the horizontal and vertical dimensions in our attention task.

Study 2a

Method

Thirty-one subjects (18 female) aged 18 to 37 years (M_{age} = 26.19, *SD* = 5.02 years) completed a survey in which they rated each of a number of sports on the degree to which athletes playing that sport would need to focus on multiple objects in the horizontal or vertical dimension using a −5 (completely horizontal) to + 5 (completely vertical) rating scale. To illustrate how the scale should be used, they were given the example of a façade painter to illustrate the need for vertical attention and a bus driver to illustrate the need for horizontal attention. They were then asked to consider whether participants in each of a number of sports have to focus attention on more horizontally or vertically positioned objects.

Results and Discussion

All of the sports played by the experts in our studies showed a significant difference from the zero point, with soccer ($M = -2.24$, $SD = 1.67$) and handball ($M = -2.04$, $SD = 1.28$) judged to be significantly more horizontal than the scale midpoint (soccer: $t(30) = -7.483$, $p < .001$, $d_z = -1.34$; handball: $t(30) = -8.864$, $p < .001$, $d_z = -1.59$), and basketball ($M = 0.74$, $SD = 1.80$) and volleyball ($M = 1.99$, $SD = 1.51$) significantly more vertical (basketball: $t(30) = 2.275$, $p = .03$, $d_z = 0.41$; volleyball: $t(30) = 7.320$, $p < .001$, $d_z = 1.31$). The pattern of results confirms our classification based on court size. Table 2 includes means and standard deviations for all sports included in the survey. Some sports like darts or golf showed little deviation from the zero point, suggesting that they were neither horizontal nor vertical. Hockey and pole vault showed the greatest deviations from the zero point, meaning that these two sports were rated as activities requiring either a particularly wide-ranging horizontal or vertical focus of attention.

[2] Study 2a was conducted after Study 2b because we collected these data in response to a reviewer's suggestion.

Table 2
For Study 2a, Mean and 95% Confidence Interval of Vertical/Horizontal Scale Ratings for Different Sports

Sport	M	95% CI	Primary orientation
American football	−1.28	−2.85, −1.63	Horizontal
Badminton	1.52	1,44, 2.55	Vertical
Baseball	1.01	−4,01, −2.77	Vertical
Basketball	0.74	−0.81, 0.63	Vertical
Beach volleyball	1.84	−1.11, 0.44	Vertical
Broad jump	−0.14	−0.83, 0.87	Horizontal
Cricket	−1.98	0.08, 1.40	Horizontal
Dancing	−1.64	−1.73, −0.60	Horizontal
Dart	0.02	0.20, 1.82	Vertical
Golf	−0.09	0.90, 2.14	Horizontal
Gymnastics	0.63	−2.43, −0.77	Vertical
Handball	−2.04	1.27, 2.41	Horizontal
High jump	2.49	−0.25, 0.74	Vertical
Hockey	−3.39	−3.88, −2.61	Horizontal
Ice hockey	−3.25	2.56, 4.04	Horizontal
Pole vault	3.30	−1.80, −0.77	Vertical
Rugby	−1.17	−2.74, −1.22	Horizontal
Skiing	−2.56	1.70, 3.28	Horizontal
Soccer	−2.24	2.18, 3.59	Horizontal
Squash	0.25	−3.14, −1.99	Vertical
Swimming	−0.19	−2.48, −0.80	Horizontal
Table tennis	−1.60	−2.51, −1.57	Horizontal
Tennis	−0.34	−1.27, 1.00	Horizontal
Trampolining	2.88	0.13, 1.13	Vertical
Volleyball	1.99	−1.22, 0.84	Vertical

Study 2b

Method

Fifty-six subjects (23 female) aged 19 to 25 years (M_{age} = 22.05, *SD* = 1.48 years) participated under the same ethical and health constraints as in Study 1. Data from seven additional subjects were excluded because they did not reliably perform better than 75% as the separation decreased. All subjects were competitive athletes who trained at least eight hours per week and competed in organized events ($M_{\text{team sport experience}}$ = 10.82, *SD* = 1.82 years)[3]. Thirty subjects played team sports with primarily horizontal attention demands (handball: $n = 11$, or soccer: $n = 19$) and 26 played sports with more vertical attention demands (basketball: $n = 8$, or volleyball: $n = 18$; see Allard et al., 1980; Allard & Starkes, 1980). Given that performance in the control condition of Study 1 was excellent at all distances for all meridians, we did not repeat the control condition in Study 2. All other aspects of the design were identical to those of Study 1.

Results and Discussion

As in Study 1, averaging across both types of expertise, performance varied as a function of meridian, $F(2, 108) = 20.910$, $p < .001$, $\eta_p^2 = .279$ (see Table 3). Participants showed greater attention breadth (i.e., a larger attention window, see Figure 3) along the horizontal meridian ($M = 38.93°$, $SD = 4.62°$) than the vertical meridian ($M = 34.25°$, $SD = 4.83°$), $t(55) = 5.850$, $p < .001$, $d_z = 0.78$, and the diagonal meridian ($M = 36.21°$, $SD = 4.22°$), $t(55) = 3.998$, $p < .001$, $d_z = 0.53$, with performance differing between the diagonal and vertical meridians as well, $t(55) = 2.689$, $p = .009$, $d_z = 0.36$. This pattern again confirms the ellipsoidal distribution of spatial attention (cf. Galera et al., 2005). The two types of athletes did not differ in overall performance when averaging across all meridians, $F(1, 54) = 0.002$, $p = .962$, $\eta_p^2 < .001$. Overall, participants in Study 2 outperformed those in Study 1, perhaps because Study 2 included only experts, many of whom played in more competitive leagues than the experts in Study 1. The interaction between expertise and meridian also was statistically significant, $F(2, 108) = 7.752$, $p = .001$, $\eta_p^2 = .126$ (see Figure 3).

Our core hypothesis, based on the exploratory analysis in Study 1, was that the horizontal/vertical orientation of a sport would be associated with better performance along that meridian. The results of a follow-up 2 (horizontal/vertical) × 2 (expertise) ANOVA revealed a nonsignificant overall main effect of expertise, $F(1, 54) = 0.236$, $p = .629$, $\eta_p^2 = .004$, and a significant main effect of meridian, $F(1, 54) = 38.363$, $p < .001$, $\eta_p^2 = .415$. As predicted, we observed a significant meridian x expertise interaction, $F(1, 54) = 13.300$, $p = .001$, $\eta_p^2 = .198$. Experts with primarily horizontal attention demands in their sport had a maximum attentional focus of about 40° along the horizontal meridian and about 33° along the vertical meridian. In contrast, experts with primarily vertical attention demands in their sport showed a maximum attentional focus of about 38° along the horizontal meridian and about 36° along the vertical meridian (see Table 3).

Study 3

Study 1 revealed differences in the breadth of attention for experts and novices, and Study 2 showed that the maximum distribution of attention along the horizontal and vertical meridians depends on the athlete's specific sport (i.e., whether it called for primarily vertical or horizontal visual attention). However, the control group in Study 1 had some sports experience, so they were not truly novices. Study 3 was designed to replicate the expert/novice difference from Study 1 using a control group consisting of sports novices while also attempting to replicate the horizontal/vertical sport difference found in Study 2. Finally, we reduced the number of distinct locations tested in our attention measure in order to increase the number of trials with each distance. That permitted an analysis that did not require us to average across a moving-window of distances.

Method

Thirty-seven subjects (19 female) aged 20 to 31 years (M_{age} = 26.16, *SD* = 3.35 years) participated under the same ethical and health constraints as in Study 1 and 2. Data from three additional subjects were excluded because they did not reliably perform better than 75% as the separation decreased. Overall, 25 subjects were competitive athletes who trained at least 10 hours per week and competed in organized events ($M_{\text{team sport experience}}$ = 14.32, *SD* = 3.53 years). Thirteen subjects ($M_{\text{team sport experience}}$ = 14.69, *SD* = 4.19 years) played team sports with primarily horizontal

[3] Not all of the experts had played sports for more than 10 years, but they participated in sports intensively over that period. Consequently, these experts likely had as much or more practice as those in Study 1.

Table 3
For Study 2b, Mean Attention Breadth With 75% Accuracy and 95% Confidence Interval in Degrees of Visual Angle as a Function of Meridian and Expertise

	Meridian							
	Horizontal		Vertical		Diagonal		Average - all meridians	
	M	95% CI	M	95% CI	M	95% CI	M	95% CI
Experts — horizontal sports	39.93	[38.27, 41.59]	32.80	[31.12, 34.49]	36.60	[35.05, 38.15]	36.44	[35.24, 37.65]
Experts — vertical sports	37.77	[35.99, 39.55]	35.92	[34.11, 37.73]	35.77	[34.10, 37.44]	36.49	[35.19, 37.78]
Average - all groups	38.93	[37.69, 40.17]	34.25	[32.96, 35.54]	36.21	[35.08, 37.35]	36.46	[35.59, 37.34]

attention demands (handball: $n = 4$, or soccer: $n = 9$), 12 subjects ($M_{\text{team sport experience}} = 13.92$, $SD = 2.78$ years) played sports with more vertical attention demands (basketball: $n = 2$, or volleyball $n = 10$), and 12 were nonathletes without any formal team-sport experience.

The design of Study 3 was identical to those of Study 1 and 2 except that there were only 10 possible stimulus locations on each of the meridians, with distances ranging from 3° to 30° (in 3° increments). The meridian and stimulus separation were again fully crossed, but with each combination tested six times (10 separations × 3 meridians × 6 repetitions) rather than twice.

Results and Discussion

As in Studies 1 and 2, attention breadth was defined as the largest stimulus separation at which each subject reliably identified the number of light gray triangles in both stimuli on at least 75% of the trials. Unlike Studies 1 and 2, we analyzed performance at each separation independent of other separations (without using the moving-window approach).

Averaging across all three groups (novices, horizontal experts, and vertical experts), performance varied as a function of meridian, $F(2, 68) = 37.214$, $p < .001$, $\eta_p^2 = .523$ (see Table 4). Participants showed a larger attention window along the horizontal ($M = 40.22°$, $SD = 6.91°$) than the vertical meridian ($M = 30.00°$, $SD = 9.49°$), $t(36) = 6.791$, $p < .001$, $d_z = 1.12$, and the diagonal meridian ($M = 33.73°$, $SD = 9.20°$), $t(36) = 6.693$, $p < .001$, $d_z = 1.10$, with performance differing between the diagonal and vertical meridians as well, $t(36) = 2.557$, $p = .015$, $d_z = 0.42$, (Bonferroni corrected post hoc comparisons had an adjusted alpha of 0.017).

Averaging across meridians, the three groups differed in the maximum attention breadth, $F(2, 34) = 5.310$, $p = .01$, $\eta_p^2 = .238$. Attention breadth was comparable for the horizontal experts ($M = 37.54°$, $SD = 4.91°$) and vertical experts ($M = 36.50°$, $SD = 5.98°$), $t(23) = 0.476$, $p = .638$, $d_s = 0.19$, and worse for the

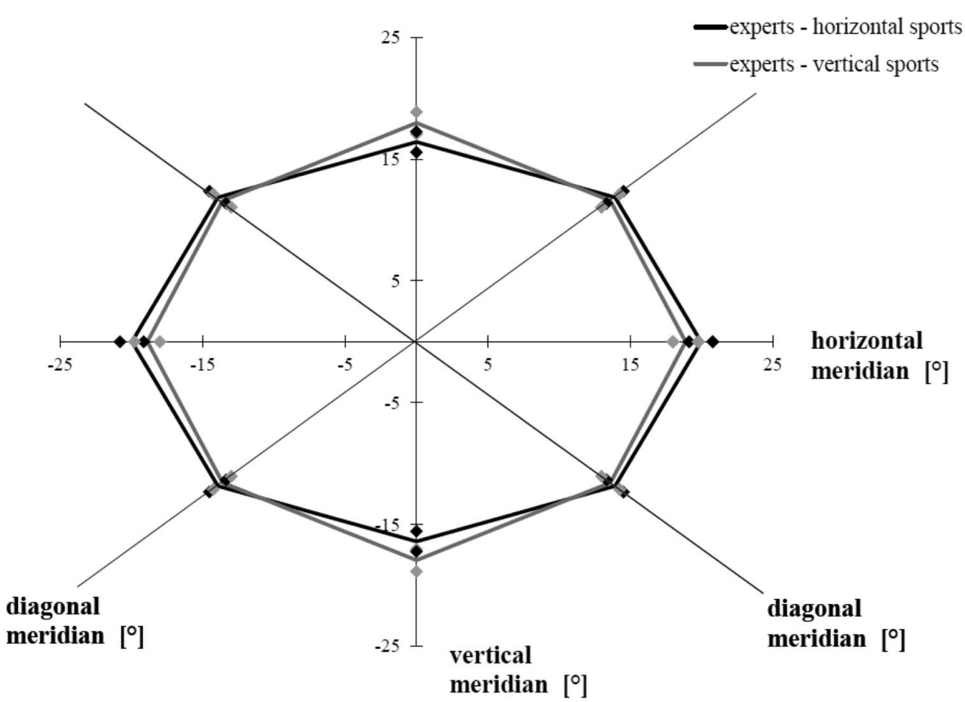

Figure 3. For Study 2b, Attention breadth with 75% correct performance as a function of meridian and type of sport expertise. Because each stimulus pair was presented symmetrically about the center, the data are also symmetrical. Symbols represent across-subjects means, and error bars indicate 95% confidence interval.

Table 4
For Study 3, Mean Attention Breadth With 75% Accuracy and 95% Confidence Interval in Degrees of Visual Angle as a Function of Meridian and Expertise

	Meridian							
	Horizontal		Vertical		Diagonal		Average - all meridians	
	M	95% CI	M	95% CI	M	95% CI	M	95% CI
Experts — horizontal sports	44.31	[40.84, 47.78]	30.00	[25.44, 34.56]	38.31	[33.42, 43.20]	37.54	[33.88, 41.20]
Experts — vertical sports	40.00	[36.39, 43.61]	36.50	[31.75, 41.25]	33.00	[27.91, 38.09]	36.50	[32.69, 40.31]
Novices	36.00	[32.39, 39.61]	23.50	[18.75, 28.25]	29.50	[24.41, 34.59]	29.67	[25.86, 33.48]
Average - all groups	40.22	[37.91, 42.52]	30.00	[26.84, 33.16]	33.73	[30.66, 36.80]	34.65	[32.24, 37.06]

nonathletes (M = 29.67°, SD = 8.26°; horizontal experts vs. nonathletes: $t(23) = 2.924$, $p = .008$, $d_s = 1.17$; vertical experts vs. nonathletes: $t(22) = 2.322$, $p = .030$, $d_s = 0.95$; again, Bonferroni correction yields alpha of 0.017). This pattern replicates the expert/novice difference from Study 1 using a control group with no team-sport expertise.

Replicating the pattern in Study 2, a 2 (horizontal/vertical) × 2 (horizontal experts/vertical experts) ANOVA revealed a nonsignificant main effect of expertise type, $F(1, 23) = 0.303$, $p = .588$, $\eta_p^2 = .013$, a significant main effect of meridian, $F(1, 23) = 27.487$, $p < .001$, $\eta_p^2 = .544$, and a significant meridian x expertise interaction, $F(1, 23) = 10.125$, $p = .004$, $\eta_p^2 = .306$. Experts with primarily horizontal attention demands in their sport showed greater breadth along the horizontal meridian than along the vertical dimensions, $t(12) = 8.949$, $p < .001$, $d_z = 2.48$, whereas those with vertical expertise showed no difference between horizontal and vertical dimensions, $t(11) = 1.134$, $p = .281$, $d_z = 0.33$, Bonferroni corrected post hoc comparisons had an adjusted alpha of 0.025 (see Figure 4).

General Discussion

In three studies, the maximum spatial extent of attention was ellipsoidal, with greater breadth along the horizontal axis than the vertical one (Galera et al., 2005; Sanders & Brück, 1991). Study 1 showed that expert athletes, a group that depends on the ability to focus attention on multiple objects efficiently, had 25% greater maximum attention breadth than did nonexperts. Study 2 confirmed the trend identified in Study 1 that the spatial distribution of attention interacts with the demands of an athlete's primary sport and showed that our classification of sports as horizontal or vertical is reliable. Although athletes for both groups showed an

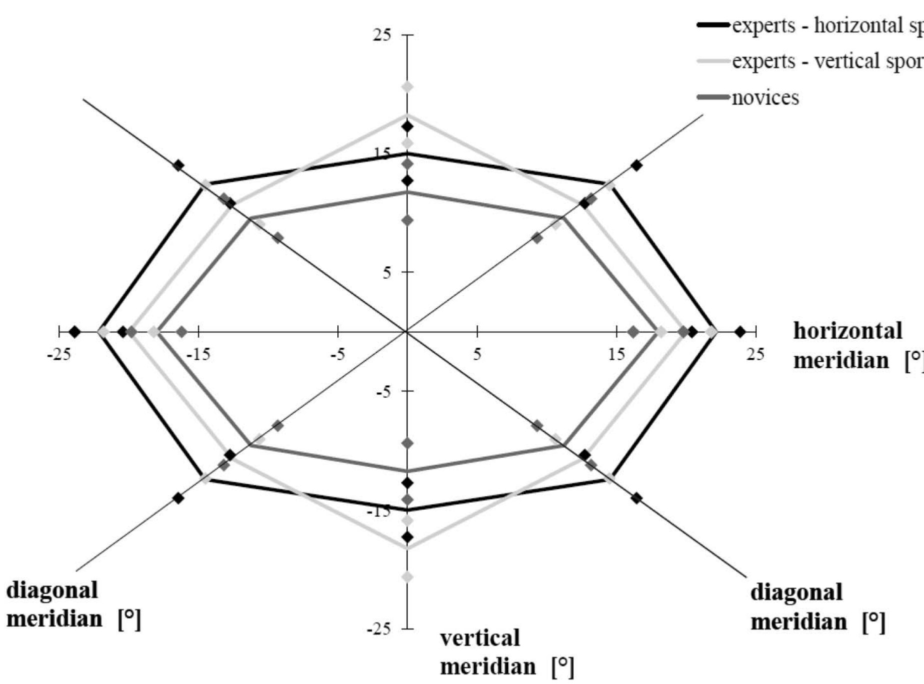

Figure 4. For Study 3, Attention breadth with 75% correct performance as a function of meridian and expertise (experts of "horizontal" and "vertical" sports as well as novices). Because each stimulus pair was presented symmetrically about the center, the data are also symmetrical. Symbols represent across-subjects means, and error bars indicate 95% confidence interval.

advantage for horizontal over vertical stimuli, those who played a sport with more horizontal demands showed an even larger advantage, and those who played a sport with more vertical demands showed a reduced horizontal advantage. Study 3 replicated the expert/novice effect of Study 1 and the horizontal/vertical expertise effect of Study 2.

As part of our survey about horizontal and vertical sports, subjects in Study 2a rated a range of other sports. Other sports judged to be vertical included pole vault, high jump, trampoline, and badminton. Sports judged to be horizontal included table tennis, rugby, and ice hockey. Future studies could assess whether experts in these sports show a similar pattern to those tested in our studies.

Given that our study compares different groups of experts, we cannot infer a causal link between the spatial distribution of attention and experience playing a particular sport. Expertise can be viewed as an optimal adaptation to task constraints (Ericsson & Kintsch, 1995; Ericsson & Lehmann, 1996), and our subjects showed a spatial distribution of attention that matched the demands of their sport. Experience in a sport might alter the spatial distribution of attention to multiple objects, but these attention differences might have predated sports training, predisposing athletes to eventual expertise in a sport that matched their attention advantage. For example, those athletes with greater attention breadth in the horizontal dimension might be more likely to develop expertise in soccer than in volleyball. Or, a third factor might contribute both to the spatial distribution of attention and the chosen sport. The optimal way to test whether practice with a sport alters the spatial distribution of attention would be to conduct a training study with random assignment of athletes to sports. But, a more practical (although imperfect) approach would be to use a longitudinal design to explore how the spatial distribution of attention changes over time as a function of sports experience.

The experts we tested showed 75% accuracy rates at greater stimulus separations than did novices, a finding we take as evidence that they can spread their attention more broadly. Other explanations are possible, though. Conceivably, experts may be able to shift attention between the two targets more efficiently rather than spreading their attention to both more effectively (Enns & Richards, 1997). The 300 ms display time makes such a rapid shift a possibility, although processing the targets sequentially would require participants to complete a conjunction search at one location and then shift attention to the other target in time to initiate and complete another search. Such attention shifts would have to occur covertly—we monitored eye movements and eliminated any trials in which participants shifted their gaze away from the central fixation point. We find simultaneous processing to be a more plausible account, but future research could directly distinguish these possibilities by requiring sequential processing or limiting processing time even more.

In addition to spreading a single spotlight of attention (Posner & Petersen, 1990) to encompass both targets, participants might also split attention into multiple, spatially discrete spotlights, one for each target (e.g., Müller, Malinowsky, Gruber, & Hillyard, 2003). Our methods cannot distinguish these possibilities, but in either case, our results show that experts are able to spread/split their attention to a greater spatial extent.

Finally, experts might perceive the targets sequentially and then perform the analysis in working memory rather than with the visible displays. If so, then their performance advantage might result from more efficient attention shifts coupled with superior working memory capacity (Bundesen, 1990). Future studies could address this possibility by testing performance while subjects perform a task that interferes selectively with working memory.

One other limitation of our study is that we are mapping horizontal and vertical dimensions on the picture plane to a three-dimensional playing surface. We have assumed that horizontal on the monitor corresponds to the surface of a playing field whereas vertical refers to elevation or height relative to the playing field. The subjects in Experiment 2a agreed with our classification of sports into horizontal and vertical, presumably accepting this mapping. Perhaps our comparison of horizontal and vertical experts would be strengthened by measuring the extent of attention in all three dimensions separately (e.g., by using a virtual reality display), thereby isolating the ability to spread attention across both dimensions of a playing surface and across elevations from the playing surface.

In many respects, sports are an ideal way to examine expertise effects in the distribution of attention—athletes of comparable ability play a diverse range of sports, allowing a comparison of relative equals. Yet, many activities and occupations differ in their attention demands, with some requiring more vertical focus (e.g., painters) and others requiring more horizontal focus (e.g., drivers). Further studies could verify whether long-term differences in attention demands are associated variations in the spatial extent of attention along the horizontal and vertical meridian in other domains. Moreover, short-term training studies could explore whether the maximum breadth of attention is readily malleable. If so, then perhaps training this basic limit of attention might enhance performance in other real-world contexts.

Independent of the origins of such differences, quantifying the ability to devote attention to spatially separate objects could help to identify situations in which the demands on attention exceed our capacities (cf. Maruenda, 2004). For example, a soccer linesman must judge whether a player is offside by comparing the relative position of multiple players when a ball was kicked by yet another player. In some cases, doing so correctly requires them to spread their attention more than 35°, which might explain their frequent errors. Similarly, team sports players cannot see all "open" players on the field (cf. Furley, Memmert, & Heller, 2010) when those players are far enough apart to exceed the maximal breadth of attention. Similar limitations in nonsport domains like driving might be better understood by identifying situations that exceed the maximum attention breadth.

References

Abernethy, B. (1990). Expertise, visual search, and information pick-up in squash. *Perception, 19,* 63–77. doi:10.1068/pp.190063

Ahmed, L., & de Fockert, J. W. (2012). Focusing on attention: The effects of working memory capacity and load on selective attention. *PLoS ONE, 7,* e43101. doi:10.1371/journal.pone.0043101

Allard, F., Graham, S., & Paarsalu, M. E. (1980). Perception in sport: Basketball. *Journal of Sport Psychology, 2,* 14–21.

Allard, F., & Starkes, J. L. (1980). Perception in sport: Volleyball. *Journal of Sport Psychology, 2,* 22–33.

Bleckley, M. K., Durso, F. T., Crutchfield, J. M., Engle, R. W., & Khanna, M. M. (2003). Individual differences in working memory capacity predict visual attention allocation. *Psychonomic Bulletin & Review, 10,* 884–889. doi:10.3758/BF03196548

Blundell, N. L. (1985). The contribution of vision to the learning and performance of sports skills: Pt. 1: The role of selected visual parameters. *The Australian Journal of Science and Medicine in Sport, 17,* 3–11.

Bundesen, C. (1990). A theory of visual attention. *Psychological Review, 97,* 523–547. doi:10.1037/0033-295X.97.4.523

Burton, D., & Raedeke, T. D. (2008). *Sport psychology for coaches*. Champaign, IL: Human Kinetics.

Castiello, U., & Umiltà, C. (1992). Splitting focal attention. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 837–848. doi:10.1037/0096-1523.18.3.837

Cave, K. R. (2013). Spatial attention. In D. Reisberg (Ed.), *The Oxford handbook of cognitive psychology* (pp. 117–130). Oxford: Oxford University Press. doi:10.1093/oxfordhb/9780195376746.013.0008

Cave, K. R., & Bichot, N. P. (1999). Viso-spatial attention: Beyond a spotlight model. *Psychonomic Bulletin and Review, 6,* 204–223. doi:10.3758/BF03212327

Clay, O. J., Edwards, J. D., Ross, L. A., Okonkwo, O., Wadley, V. G., Roth, D. L., & Ball, K. K. (2009). Visual function and cognitive speed of processing mediate age-related decline in memory span and fluid intelligence. *Journal of Aging and Health, 21,* 547–566. doi:10.1177/0898264309333326

Colflesh, G. J. H., & Conway, A. R. A. (2007). Individual differences in working memory capacity and divided attention in dichotic listening. *Psychonomic Bulletin & Review, 14,* 699–703. doi:10.3758/BF03196824

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8,* 331–335. doi:10.3758/BF03196169

Cowan, N. (2005). Understanding intelligence: A summary and an adjustable-attention hypothesis. In O. Wilhelm & R. W. Engle (Eds.), *Handbook of understanding and measuring intelligence* (pp. 469–488). London: Sage. doi:10.4135/9781452233529.n25

Cowan, N., Fristoe, N. M., Elliott, E. M., Brunner, R. P., & Saults, J. S. (2006). Scope of attention, control of attention, and intelligence in children and adults. *Memory & Cognition, 34,* 1754–1768. doi:10.3758/BF03195936

Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General, 113,* 501–517. doi:10.1037/0096-3445.113.4.501

Enns, J. T., & Richards, J. R. (1997). Visual attentional orienting in developing hockey players. *Journal of Experimental Child Psychology, 64,* 255–275. doi:10.1006/jecp.1996.2348

Ericsson, K. A. (1996). The acquisition of expert performance: An introduction to some of the issues. In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games* (pp. 1–50). Mahwah, N. J.: Erlbaum.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102,* 211–245. doi:10.1037/0033-295X.102.2.211

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence on maximal adaptations on task constraints. *Annual Review of Psychology, 47,* 273–305. doi:10.1146/annurev.psych.47.1.273

Eriksen, C. W., & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & Psychophysics, 40,* 225–240. doi:10.3758/BF03211502

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden and build theory of positive emotions. *American Psychologist, 56,* 218–226. doi:10.1037/0003-066X.56.3.218

Furley, P., Memmert, D., & Heller, C. (2010). The dark side of visual awareness in sport – inattentional blindness in a real-world basketball task. *Attention, Perception & Psychophysics, 72,* 1327–1337. doi:10.3758/APP.72.5.1327

Galera, C., von Grünau, M., & Panagopoulos, A. (2005). Automatic focusing of attention on object size and shape. *Psicológica, 26,* 147–160.

Gasper, K., & Clore, G. L. (2002). Attending to the big picture: Mood and global versus local processing of visual information. *Psychological Science, 13,* 33–39. doi:10.1111/1467-9280.00406

Gold, J. M., Fuller, R. L., Robinson, B. M., McMahon, R. P., Braun, E. L., & Luck, S. J. (2006). Intact attentional control of working memory encoding in schizophrenia. *Journal of Abnormal Psychology, 115,* 658–673. doi:10.1037/0021-843X.115.4.658

Heitz, R. P., & Engle, R. W. (2007). Focusing the spotlight: Individual differences in visual attention control. *Journal of Experimental Psychology: General, 136,* 217–240. doi:10.1037/0096-3445.136.2.217

Hughes, P. K., Blundell, N. L., & Walters, J. M. (1993). Visual and psychomotor performance of elite, intermediate and novice table tennis competitors, *Clinical and Experimental Optometry, 76,* 51–60. doi:10.1111/j.1444-0938.1993.tb05090.x

Hüttermann, S., Memmert, D., Simons, D. J., & Bock, O. (2013). Fixation strategy influences the ability to focus attention on two spatially separate objects. *PLoS ONE, 8*(6), e65673. doi:10.1371/journal.pone.0065673

LaBerge, D., & Brown, V. (1989). Theory of attentional operations in shape identification. *Psychological Review, 96,* 101–124. doi:10.1037/0033-295X.96.1.101

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for *t*-tests and ANOVAs. *Frontiers in Psychology, 4,* 1–12. doi:10.3389/fpsyg.2013.00863

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 451–468. doi:10.1037/0096-1523.21.3.451

Manikandan, S. (2010). Data transformation. *Journal of Pharmacology & Pharmacotherapeutics, 1,* 126–127. doi:10.4103/0976-500X.72373

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology, 29,* 457–478.

Maruenda, F. B. (2004). Can the human eye detect an offside position during a football match? *British Medical Journal, 329,* 1470–1472. doi:10.1136/bmj.329.7480.1470

Memmert, D., Simons, D. J., & Grimme, T. (2009). The relationship between visual attention and expertise in sports. *Psychology of Sport & Exercise, 10,* 146–151. doi:10.1016/j.psychsport.2008.06.002

Müller, M. M., Malinowsky, P., Gruber, T., & Hillyard, S. A. (2003). Sustained division of the attentional spotlight. *Nature, 424,* 309–312. doi:10.1038/nature01812

Nideffer, R. M., & Sagal, M. S. (2001). Concentration and attention control training. In J. M. Williams (Ed.), *Applied sport psychology: Personal growth to peak performance* (4th ed.) (pp. 312–332). Mountain View, CA: Mayfield Publishing Company.

Nougier, V., Azemar, G., Stein, J. F., & Ripoll, H. (1992). Covert orienting to central visual cues and sport practice relations in the development of visual attention. *Journal of Experimental Child Psychology, 54,* 315–333. doi:10.1016/0022-0965(92)90023-Y

Nougier, V., Ripoll, H., & Stein, J. F. (1989). Orienting of attention in highly skilled athletes. *International Journal of Sport Psychology, 20,* 205–223.

Osborne, J. W. (2010). Improving your data transformations: Applying Box-Cox transformations as a best practice. *Practical Assessment, Research, and Evaluation, 15,* 1–9.

Pesce Anzeneder, C., & Bösel, R. (1998). Modulation of the spatial extent of the attentional focus in high-level volleyball players. *The European Journal of Cognitive Psychology, 10,* 247–267. doi:10.1080/713752275

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3–25. doi:10.1080/00335558008248231

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42. doi:10.1146/annurev.ne.13.030190.000325

Pype, A. D., Lin, J. Y., Murray, S. O., & Boynton, G. M. (2010). Individual differences in the shape of visual attention during object tracking. *Journal of Vision, 10,* 315. doi:10.1167/10.7.315

Rees, G., Frith, C., & Lavie, N. (1997). Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science, 278,* 1616–1619. doi:10.1126/science.278.5343.1616

Sanders, A. F., & Brück, R. (1991). The effect of presentation time on the size of the visual lobe. *Bulletin of the Psychonomic Society, 29,* 206–208. doi:10.3758/BF03335236

Schneider, W., Dumais, S. T., & Shiffrin, R. M. (1984). Automatic and control processing and attention. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of attention* (pp. 1–27). Orlando, FL: Academic Press.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127–190. doi:10.1037/0033-295X.84.2.127

Turatto, M., Benso, F., & Umiltà, C. (1999). Focusing of attention in professional women skiers. *International Journal of Sport Psychology, 30,* 339–349.

Voss, M., Kramer, A. F., Prakash, R. S., Roberts, B., & Basak, C. (2010). Are expert athletes "expert" in the cognitive laboratory? A meta-analytic review of basic attention and perception in sport expertise. *Applied Cognitive Psychology, 24,* 812–826. doi:10.1002/acp.1588

West, K. L., & Bressan, E. S. (1996). The effects of a general versus specific visual skills training program on accuracy in judging length-of-ball in cricket. *International Journal of Sports Vision, 3,* 41–45.

Wiley, J., & Jarosz, A. F. (2012). Working memory capacity, attentional focus, and problem solving. *Psychological Science, 21,* 258–262.

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sport*. London: E. & F. N. Spon.

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