

## Visual Orienting in College Athletes: Explorations of Athlete Type and Gender

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Jeanette Lum, James T. Enns, and Jay Pratt

*Covert orienting was measured in 50 college athletes and 51 nonathletes of both genders. Visual environments of the sports were both static (swimming, track) and dynamic (soccer, volleyball). Participants made speeded responses in a task measuring vigilance, alerting, automatic orienting, voluntary orienting, modulation of automatic orienting, and modulation of inhibition of return. Gender differences were found in the overall response times of nonathletes and in the alerting measures for all participants. However, all participants were similar in their automatic orienting. Sports-specific effects were seen in voluntary orienting and in the modulation of automatic orienting. These gender and sports-related findings are interpreted in light of the experience athletes have in the dynamic control of spatial attention.*

*Key words:* attention, sport, visual environment

**W**hat differentiates an athlete from a nonathlete, or an athlete in one sport versus another? This study focuses on visual attention, the system that selects the region of the visual field given priority in processing. This selection is critical to athletic performance, because an athlete can process only a limited amount of the information in the visual field at any given moment. Simply put, directing attention to locations relevant to the task at hand, while ignoring locations that provide little information, can have a large impact on athletic performance. Failing to attend to useful information, or attending to irrelevant information, can result in a breakaway, a turnover, a missed block, or a false start. Thus, athletes may not only be bigger, faster, or more determined than nonathletes, they must be especially good at controlling the mechanisms of visual-spatial orienting.

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The importance of visual attention to sports has not gone unnoticed by researchers. However, they have typically used narrow methodologies on a restricted range of athletes. The present study was conducted to explore in some detail a wider range of performance relevant to visual-spatial orienting. Among the unique features of the present study:

1. Two kinds of athletes were tested in addition to nonathlete controls: athletes who perform in relatively dynamic versus static visual environments. This distinction is sometimes referred to as “open skill” and “closed skill” (Farrell, 1975; Nougier, Rossi, Alain, & Taddei, 1996), but it is difficult to define exclusively. It is more reasonable to select sports that fall at either end of the continuum of visually static and dynamic environments. Two of the sports examined here (volleyball, soccer) clearly have more dynamic visual environments than the other two sports (swimming, track).
2. Male and female participants were tested in all skill groups to understand some of the gender differences seen in tasks requiring speeded responses.
3. A wide range of well known and extensively researched measures of visual attention was tested,



including measures of vigilance over time, momentary alertness, automatic orienting, voluntary orienting, and the modulation of automatic orienting.

We will first provide a brief overview of the relevant research in visual attention. This will be followed by a review of studies that have examined visual attention in athletes versus nonathletes and between the genders. Finally, we will give an overview of the specific attentional measures used in the present study, along with associated hypotheses.

### *Covert Visual Orienting*

Reports of the ability to move visual attention in space, independently of eye and head movements, have been made for over 100 years. However, it was only late in the most recently past century that a reliable behavioral test was made available (Posner, 1980). In a typical version of what has now become known as the "covert orienting paradigm," participants are shown a display consisting of two or more horizontally aligned boxes and are required to maintain fixation at the center of the array. During each trial, one of the peripheral boxes undergoes a brief flash, which is quickly followed by the appearance of a target object in one of the three boxes. Importantly, the target is equally likely to occur at any of the locations, and participants are aware that the flash gives no indication about the target location. Nonetheless, reaction times (RTs) to detect the target are shorter at the location of the recently flashed box, suggesting that participants are already attending to it when the target appears. The flash is, thus, said to draw attention *automatically* to that location.

Research has revealed a particular time course for automatic orienting. When the stimulus onset asynchrony (SOA) between the flash and the target is less than 300 ms, RTs are faster to targets at flashed than other locations. However, at SOAs of around 300 ms this response benefit typically disappears, and by SOAs of 400–2,000 ms the effect is reversed (i.e., RTs are now longer for targets at flashed locations). This reversal has been termed *inhibition of return* or IOR (Posner & Cohen, 1984) to reflect the idea that attention is inhibited in returning to previously attended locations. Specifically, it is thought that flashes initially capture attention, but, as time passes without a target, attention is reoriented to the point of gaze. It should be noted that the precise nature of the IOR effect is a topic of considerable debate, with several plausible neural origins being advanced (e.g., Posner & Cohen, 1984; Maylor & Hockey, 1985; Pratt, Spalek, & Bradshaw, 1999; Tassinari & Berlucchi, 1993; Taylor & Klein, 1998). For the purposes of this paper, it is sufficient that IOR has an automatic influence on visual orienting.

*Voluntary orienting* occurs when symbolic cues are presented at fixation, and participants are asked to shift attention deliberately to a peripheral location. This is typically done by presenting an arrow or a digit at the fixation box, indicating which location should be attended. To encourage a shift in attention to this cue, the target is given a higher chance of appearing at the cued location than any of the other locations, and participants are informed of the exact probabilities.

There are two major differences between automatic and voluntary cueing effects. First, while automatic benefits may occur immediately after the onset of the cue, voluntary benefits may take as long as 300 ms or more to appear (e.g., Shepard & Muller, 1989). Presumably, this is because an automatic shift of attention operates like a reflex, while a voluntary shift is under conscious, cognitive control. Second, symbolic cues do not give rise to the inhibition of return effect (Posner & Cohen, 1984). Rather, voluntary effects typically last .5 s or more and then slowly dissipate until RTs do not differ between cued and uncued locations.

### *Attention, Athletics, and Gender*

The literature on covert orienting in various athlete groups points to four general findings. First, effects of voluntary covert orienting are usually smaller in magnitude for highly skilled athletes than for less skilled athletes or nonathlete participants (Anzeneder & Boesel, 1998; Castiello & Umiltà, 1992; Enns & Richards, 1997; Nougier, Azemar, & Stein, 1992; Nougier, Ripoll, & Stein, 1989; Nougier et al., 1996; Nougier, Stein, & Azemar, 1990). This has been given a variety of interpretations, including that athletes are able to distribute their attention more effectively over multiple locations (Nougier et al., 1992; Nougier et al., 1989), better able to switch attention rapidly among locations (Castiello & Umiltà, 1992), and adopt different strategies from nonathletes, such as withholding an early commitment to the cued location (Enns & Richards, 1997).

A second trend is that voluntary orienting effects vary systematically with the kind and amount of training provided by a sports environment. In particular, athletes who have had more training show smaller attentional effects than those who are younger or have had less training (Enns & Richards, 1997; Nougier et al., 1992; Nougier et al., 1990), and athletes in more visually dynamic sports (e.g., water polo, fencing) have more flexible attentional control than those in less dynamic sports (e.g., swimming; Nougier et al., 1996). This points to the importance of experience and training in understanding attentional abilities.

Third, in addition to spatial orienting effects, there are temporal orienting effects that distinguish athletes and nonathletes (Anzeneder & Boesel, 1998; Enns & Richards, 1997). In both of these studies, athletes were



better able to maintain alertness in response to the cue than nonathletes.

Fourth, there is some indication that the modulation of automatic orienting to sudden flashes is different for athletes than nonathletes. For instance, in one study of nonpredictive flashes, young high-skilled hockey players showed greater sensitivity to the cues than low-skilled players (Enns & Richards, 1997). In another study, the predictiveness of sudden onset cues was varied systematically (Nougier et al., 1996). Elite water polo players and fencers were better able to use this knowledge to attenuate the orienting effect than swimmers and nonathletes. However, there have been no studies in which automatic and voluntary orienting mechanisms have been measured separately as well as in combination, so that the relations between these modes of orienting can be examined. Doing so allows one to ask whether more effective control over voluntary orienting in some athletes also permits them to modulate automatic orienting effects more effectively. Having this ability would certainly help in not being fooled by the head fake of an opponent or by salient movement in the visual field of players, officials, and fans not immediately relevant to the task at hand.

Gender differences in visual attention have also not been explored systematically in the sports literature. Yet, the dramatic increase over the past several decades in participation, skill level, and public interest in athletics by women and girls suggests this should be undertaken. For the present study, we reviewed gender differences in attention without regard to athletics and then speculated about what they might predict for possible gender differences in athletes who spend much more time engaged in specific visual orienting tasks than the rest of the population. This review pointed to three generalities. First, studies of vigilance (sustained attention over time) have consistently failed to find reliable effects favoring one gender over the other (Ballard, 1996; Davies & Parasurman, 1982). Yet, when vigilance tasks feature *perceptual or cognitive judgments in domains where gender differences favoring men are reliable*, such as fine spatial judgments and arithmetic calculations (Kimura, 1999), then these tasks also yield better performances by men (Dittmar, Warm, Dember, & Ricks, 1993; Lysaght, Warm, Dember, & Loeb, 1984). Finally, studies of speeded responses generally indicate faster responses in men (Ballard, 1996; Seidel & Joschko, 1991), although we are unaware of any theoretical reasons for such differences.

### Scope of the Present Study

The present study extended the methodology of Enns and Richards (1997), focusing more closely on the relations between longer term vigilance, momentary alertness, and visual orienting in athletes. In all, six different mea-

asures of attention were tested, and four different sports were represented, separated into those with relatively static (swimming, track) versus dynamic (soccer, volleyball) visual environments. Previous reports have examined swimmers (Nougier et al., 1996) and volleyball players (Anzeneder & Boesel, 1998; Castiello & Umilta, 1992) but not in the same study. Although this design generated a large number of data relations, there are important predictions of primary interest for each measure. Each measure and its most important hypotheses was as follows:

1. *Vigilance* was assessed by the change in average RTs over trial block in the testing session. By virtue of their training and selection, athletes were expected to sustain high levels of performance throughout the testing session. Gender differences were not predicted based on the existing literature.
2. *Alerting* was measured by the change in RT over SOA within trials in which no cue preceded the target. Because Enns and Richards (1997) had found sports skill differences in this measure, we were interested in comparing both different athletes on this measure as well as examining any gender differences.
3. *Automatic orienting* was measured by RTs on trials in which the target was preceded by a nonpredictive brief flash at a peripheral location. Because of its theoretical status as basic visual reflex, this ability was not predicted to vary with either athletic skill or gender.
4. *Voluntary orienting* was measured by RTs on trials in which the target was preceded by a predictive arrow at the fixated location. Most previous reports indicated that this measure was reduced in magnitude with athletic skill, presumably because athletes were able to allocate their attention to multiple locations more rapidly or efficiently. The present study was the first to examine this ability in the context of nonpredictive flashes, which had to be ignored, and so we predicted that in this case high-skilled athletes might actually show a stronger tendency to attend to the predicted location.
5. *Voluntary modulation of automatic facilitation* was measured by RTs on trials in which both flash and arrow cues were presented. Only the two shortest SOAs were used in this measure, because automatic facilitation was restricted to this time range. Note that in this situation, the flash and the arrow could either indicate the same location for attention (consistent) or each could indicate a separate location (conflict).
6. *Voluntary modulation of inhibition of return* was also measured by RTs on trials in which both flash and arrow cues were presented. Here, the three longest SOAs were used, because inhibition of return was restricted to this time range. Again, the flash and arrow could either indicate a single location



or separate locations for attention. Athletes, especially those who participate in dynamic visual environments, were expected to have better modulation of this automatic effect.

## Method

### Participants

A total of 50 university varsity athletes (28 women, *M* age = 20 years) and 51 university students who were not varsity athletes (25 women, *M* age = 21 years) were tested. Athletes were recruited from four sports teams (soccer: 6 women, 5 men; volleyball: 8 women, 5 men; swimming: 7 women, 7 men; track: 7 women, 5 men) that compete at a national level and are sponsored by the Athletics Department of the University of British Columbia. Athletes spanned the first 3 years of university eligibility and also the full range of competence among their peers, as judged by their coaches. The mean number of self-reported years of experience in the sport prior to college was soccer: women = 6.3 years, men = 6.4 years; volleyball: women = 7.4 years, men = 6.2 years; swimming: women = 10.9 years, men = 8.8 years; track women = 6.3 years, men = 6.4 years. The athletes each received \$7 for a 1-hr testing session. Nonathletes were recruited from the undergraduate psychology pool at the University of British Columbia. Each undergraduate received extra course credit for participating. All participants reported normal or corrected-to-normal visual acuity. Informed consent was obtained from all participants.

### Stimuli

Visual displays were presented on an Applevision monitor controlled by an Apple Macintosh computer running Vscope software (Enns & Rensink, 1992). Displays consisted of four outlined square boxes (1.2° per side, lines 2 pixel in width, black on a white screen) centered at the corners of an imaginary square either 3.0° (Near) or 7.0° (Far) from the center of the screen. At the onset of a trial, either an arrow occupied the center location (black, 0.06° in length), pointing to one of the four boxes as a predictive orienting cue, or a small square (black, 0.03°), serving as a spatially neutral warning cue that the trial had begun.

The duration of the directional arrow cue or the neutral square warning cue was 150 ms. This cue was followed by a 30-ms flash of one of the four boxes (an additional 2 pixels of black line). After an SOA of 30, 105, 210, 405, or 795 ms, the target was displayed (a black disk, 0.5° diameter) in the center of one of the boxes. The display then remained unchanged until the ob-

server responded. Note that for trials in which no flash cue was presented, the SOAs between the onset of the arrow cue and the target were, therefore, 180, 255, 360, 555, or 945 ms.

### Procedure

Each observer performed a simple response time (RT) task that took about 1 hr to complete. On each trial participants were asked to depress a key with their dominant hand as quickly as possible in response to the onset of the target disk. On the small number of trials in which no target appeared (5%), they were asked to withhold a response.

Observers sat at a table in a small room lit with standard office fluorescent lighting. A chinrest was used to maintain a screen viewing distance of 60 cm and assist in capturing a clear video image of any eye movements. The display consisted of the four outline square boxes centered either 3° or 7° from the center of the screen, where a solid square fixation marker was constantly visible.

At the beginning of the session observers were engaged in a discussion of how it is possible to move attention without making any eye movements. After some practice, observers were instructed not make eye movements during a trial (between the onset of the four boxes and the key press). However, they were also instructed to respond to the arrow cue by moving attention, but not their eyes, to the indicated location as rapidly as possible. They were told to blink only during the 1–2-s interval between making a response and the onset of the next trial. Observers were given 20 practice trials before they began the test.

Observers were told that on most trials they would see two events prior to the target. First, an arrow would appear at the center of the screen, pointing to one of the four boxes with 77% reliability. They were told to move their attention to the indicated box. They were also told that research has shown there is a response time benefit if these instructions are followed. If the display began with a small square instead of an arrow at the center, they were told the target would appear equally often in any one of the boxes.

Observers were also told that the second event in most trials would be a brief flash of one of the boxes. They were also warned that there was a random relation between the flash and target locations, so the flash should not be used to predict target location.

The test session consisted of 1,000 trials: 10 blocks of 100 trials separated by brief rests. Trial order was random for each observer with the following constraints: both a flash cue and a predictive arrow cue occurred on 60% of trials, only flash cues occurred on 16%, only arrow cues on 16%, neither cue on 3%, and no target on 5%.



## Eye Movement Analysis

Relative frequency estimates of the eye movements made by each participant were derived from videotape using a time sampling procedure. Three one minute sessions were sampled in each condition, the first beginning at the 2 m mark in the session, one at the 25 m mark, and one at 45 m. This is a very liberal estimate of the number of eye movements, since it was sometimes difficult to distinguish movements made during a trial from those made in the intertrial interval.

## Results

For each dependent measure, a mixed design analysis of variance (ANOVA) examined the influence of sports skill (nonathletes, static-sport athletes, dynamic-sport athletes) and gender (female, male). Although our primary interest was in response time, as this provided the most direct measure of visual attention, it was important to know whether the groups differed in their control of eye movements and response style, as revealed by response errors. Therefore, we report the eye movement and error measures before turning to the RT data. It should also be noted that the factor of target distance from fixation ( $3^\circ$ ,  $7^\circ$ ) was not significant in any analysis and was, therefore, combined in all results reported here.

### Eye Movements

The frequency of eye movements is shown in Table 1. The grand mean of 4.2 movements in a 6-min period

**Table 1.** Means and standard error for number of sampled eye movements and percentage of false alarms

Gender	Nonathletes		Sports skill		Dynamic-sport	
	<i>M</i>	<i>SE</i>	Static-sport athletes <i>M</i>	<i>SE</i>	athletes <i>M</i>	<i>SE</i>
	Eye movements					
Women	6.8	3.7	3.0	1.2	1.5	0.3
Men	3.9	1.3	1.1	0.6	0.8	0.6
Combined	4.9	1.5	1.8	0.6	1.2	0.3
	False alarms					
Women	6.2	1.6	13.7	3.3	18.0	3.6
Men	9.8	1.8	12.2	3.9	11.5	2.6
Combined	7.8	1.2	13.0	2.5	15.3	2.4

Note. *M* = mean; *SE* = standard error.

indicates that observers were following instructions by making very few eye movements. Under everyday conditions, observers make around 2–3 eye movements per second, which projects to 100–200 movements per minute. An ANOVA revealed a marginally significant effect of skill,  $F(2, 80) = 2.81$ ,  $p < .07$ , indicating that both groups of athletes tended to make eye movements less frequently than nonathletes. There were no significant effects involving gender (all  $F$ s  $< 1$ ).

### Errors

False alarms are also shown in Table 1. These are failures to withhold a response on the 5% of trials in which no target was presented. An ANOVA revealed a main effect of sport,  $F(2, 95) = 5.14$ ,  $p < .01$ , indicating that both groups of athletes tended to make more false alarms than nonathletes. There were no significant effects involving gender (all  $F$ s  $< 2$ ).

Misses (failures to respond to the target) were extremely rare, with an overall mean of less than 0.5%. The within-participant factors included flash (valid, none, invalid), arrow (valid, none, invalid), and SOA (30, 105, 210, 405, or 795 ms). The ANOVA revealed main effects of flash,  $F(2, 190) = 2.97$ ,  $p < .05$ , reflecting slightly fewer misses on no flash (0.4%) than on valid flash (0.6%) or invalid flash (0.6%) trials, and flash-target SOA,  $F(4, 380) = 8.67$ ,  $p < .001$ , reflecting the tendency for misses to increase with SOA (0.2% for a 30-ms SOA rising to a high of 1.1% for a 795-ms SOA). Only two other effects were significant, Arrow Validity x Flash Validity,  $F(4, 380) = 3.09$ ,  $p < .02$ ,  $MSE = .045$ , and Flash Validity x SOA,  $F(8, 760) = 5.03$ ,  $p < .001$ ,  $MSE = .100$ . Each of these effects reflected a slight tendency for misses to occur when the target occupied the same location as the flash (valid), especially when an arrow cue was also valid or when the flash-target SOA was long. There were no significant effects involving sport or gender (all  $F$ s  $< 2$ ).

In summary, the eye movement and error data revealed small differences between athletes and nonathletes (athletes made fewer eye movements and more false alarms) but not between static and dynamic-sport athletes or between the genders. This indicates that RT differences between athlete groups or gender were not confounded by these factors.

### Response Time Measures of Attention

In addition to the between-groups factors of sport and gender, the ANOVA for each RT measure included several within-participant factors. These will be indicated at the beginning of the results section for each measure.

*Vigilance.* Mean RT for each block of 100 trials (the within-participant factor) is shown in Figure 1. An

ANOVA indicated significant main effects of sport,  $F(2, 95) = 8.51, p < .001, MSE = 11,344$ , and block,  $F(9, 855) = 7.37, p < .001, MSE = 275$ , and a significant three-way interaction of Sport  $\times$  Gender  $\times$  Block,  $F(18, 855) = 1.65, p < .04, MSE = 275$ . This interaction reflected both the finding that gender differences in mean RT favoring men were only apparent in the nonathlete group,  $F(1, 95) = 3.13, p < .05, MSE = 11,344$ , and that the decrease in RT over blocks was greater for the nonathletes (20-ms average) than for the athletes (11-ms average),  $F(9, 855) = 6.33, p < .001, MSE = 275$ .

**Alerting.** Mean RT for trials in which there was neither an arrow nor a flash is shown in Figure 2. The within-participant factor was SOA. The ANOVA revealed a significant effect of SOA,  $F(4, 380) = 15.12, p < .001, MSE = 1,211$ , and an interaction of SOA  $\times$  Gender,  $F(4, 380) = 2.74, p < .03, MSE = 1,211$ . The difference in SOA effects between the two genders is readily apparent in Figure 2. The RT of all female participants tended to first decrease

and then increase with increasing cue-target SOA, linear trend:  $F(1, 380) = 21.21, p < .001$ ; quadratic trend:  $F(1, 380) = 26.11, p < .001$ . In contrast, the RT of male participants tended only to decrease with cue-target SOA, linear trend:  $F(1, 380) = 25.35, p < .001$ ; quadratic trend:  $F(1, 380) < 1$ . There were no gender differences in overall RT,  $F(1, 95) = 1.07, MSE = 9,616$ , and no interactions involving gender and sport, all  $F$ 's  $< 1$ .

**Automatic Orienting.** The RT differences between invalid and valid flashes (with no accompanying arrow) are shown in Figure 3. The within-participant factor was SOA. The ANOVA revealed a significant main effect of SOA,  $F(4, 380) = 12.26, p < .001, MSE = 1,724$ , indicating the expected effect of a nonpredictive flash on simple RT. Valid flash RT was shortest in the first two cue-target SOAs (mean RT difference = 10 ms,  $p < .01$ ), and invalid flash RT was shortest in the last three cue-target SOAs (mean RT difference = 16 ms,  $p < .01$ ). No interactions involving gender or sport were significant.

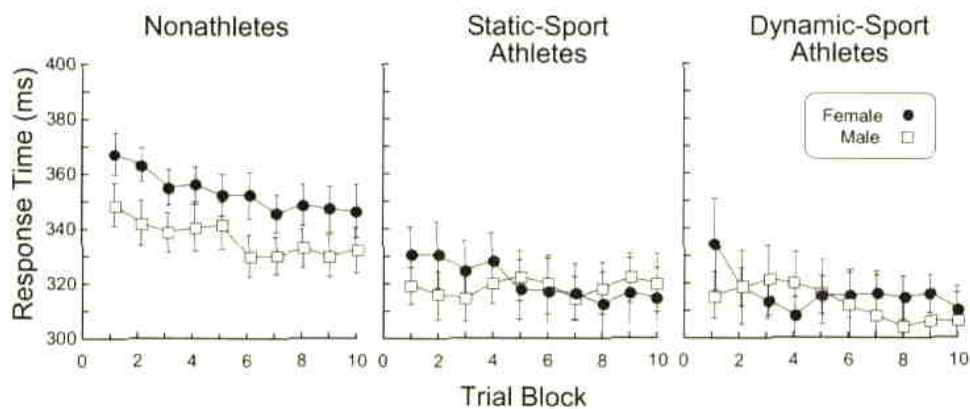


Figure 1. Mean correct RT (with one standard error bars) over all trial types as a function of trial block (100 trials per block).

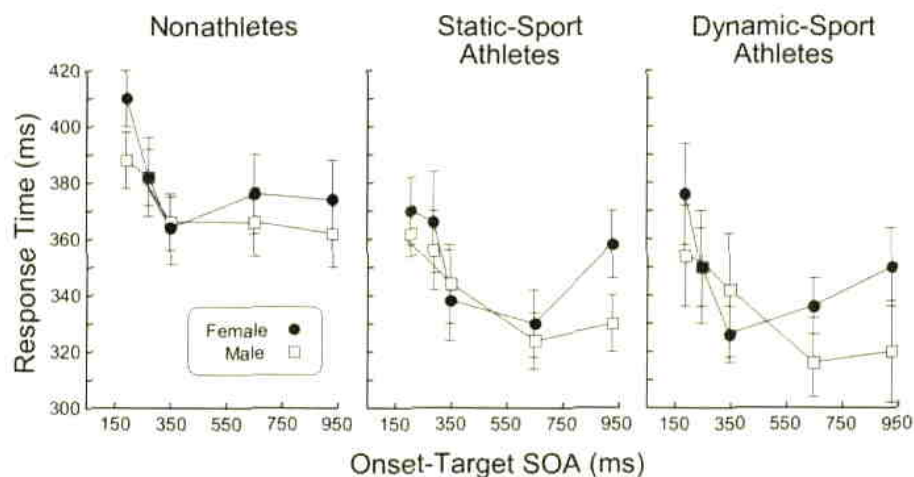


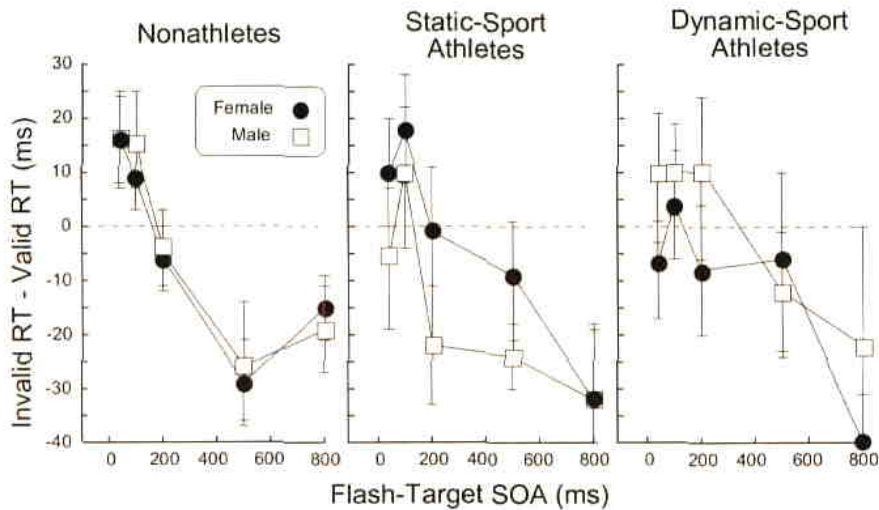
Figure 2. Alerting: the correct mean RT (with one standard error bars) on neutral cue trials. These trials contain no spatial cues, making this a measure of alerting in the absence of spatial orienting.



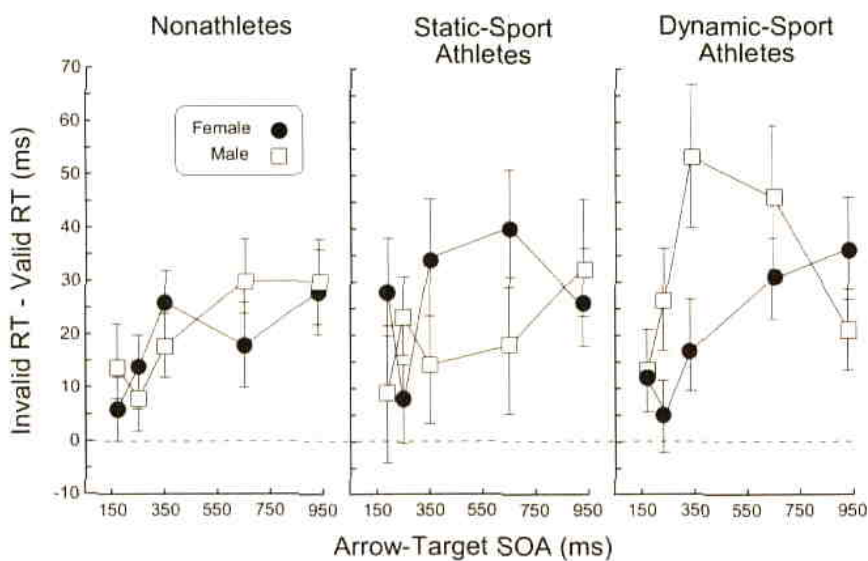
**Voluntary Guidance.** The RT difference between invalid and valid arrows (with no accompanying flash) are shown in Figure 4. The within-participant factor was SOA. The ANOVA revealed that RT differences were significantly greater than zero,  $F(1, 95) = 91.68, p < .001, MSE = 1,152$ , indicating shorter RT on valid than on invalid trials. SOA was also significant,  $F(4, 380) = 5.75, p < .001, MSE = 1,143$ , reflecting a general trend for the RT difference to increase with cue-target SOA, linear trend:  $F(1, 380) = 17.60, p < .001$ ; quadratic trend:  $F(1, 380) = 1.02$ . A significant SOA x Gender x Sport interaction,  $F(8, 380) = 2.61, p < .01, MSE = 1,143$ , indicated that this trend was not the same for all groups. Specifically, the

dynamic-sport male athletes had a larger RT difference at SOAs of 360 and 555 ms combined (mean RT difference = 48 ms) than any of the other groups (range of mean RT differences = 14–36 ms, no significant differences),  $F(1, 95) = 5.71, p < .01$ . No other interactions involving gender or sport were significant.

**Modulation of Automatic Facilitation.** The RT differences shown in Figure 5 gauge the influence of a predictive arrow on the automatic facilitation produced by the two shortest flash-target SOAs. The within-participant factor was arrow validity. The ANOVA indicated that the RT differences were significantly greater than zero,  $F(1, 95) = 58.79, p < .001, MSE = 484$ , indicating that flash



**Figure 3.** Automatic Orienting: The difference in RT for valid and invalid flashes (with one standard error bars), based only on trials on which there were no arrow cues.



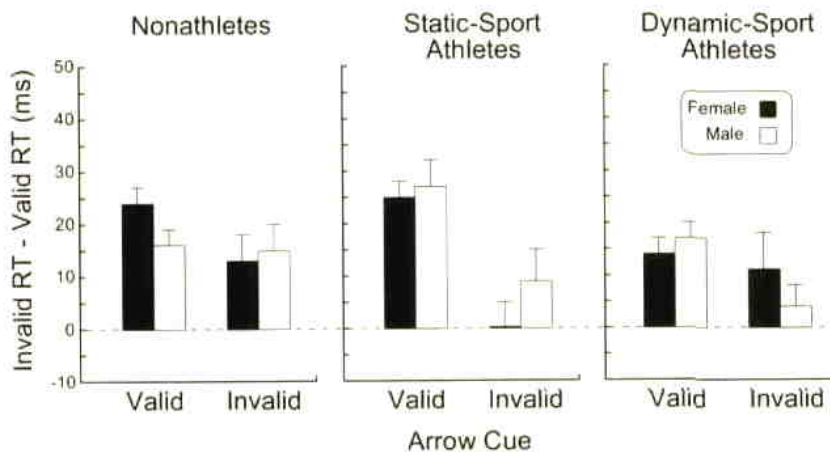
**Figure 4.** Voluntary Orienting: The difference in RT for valid and invalid arrow cues (with one standard error bars), based only on trials on which there were no flashes.

facilitation occurred even in the presence of arrow cues. A main effect of arrow validity,  $F(1, 190) = 18.75, p < .001, MSE = 484$ , indicated that the benefit of the flash was greatest when attention was being voluntarily oriented to the target location (valid arrow) than to a nontarget location (invalid arrow). There was also an interaction of Arrow Validity  $\times$  Sport,  $F(2, 190) = 3.34, p < .04, MSE = 324$ . Simple effects showed that the benefit of a valid arrow was larger for static-sport athletes, 22 ms,  $F(1, 95) = 5.96, p < .02$ , than for either nonathletes, 6 ms,  $F(1, 95) < 1$ , or dynamic-sport athletes, 7 ms,  $F(1, 95) < 1$ . No other differences were significant.

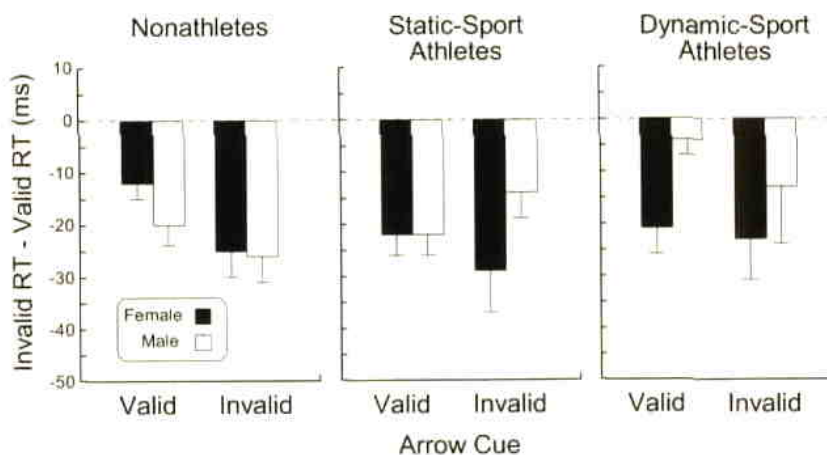
**Modulation of Inhibition of Return.** The RT differences shown in Figure 6 index the influence of arrows on the inhibition of return produced by the three longer flash-target SOAs. The within-participant factor was arrow validity. The ANOVA indicated that the RT differences

were significantly less than zero,  $F(1, 190) = 112.53, p < .001, MSE = 484$ , indicating that RT was slowed by a flash in the target location. A main effect of arrow validity,  $F(1, 190) = 3.04, p < .07, MSE = 355$ , indicated that RT inhibition was smaller when attention had been voluntarily guided to the flash location (valid) than to a nontarget location (invalid). There was also an interaction of Sport  $\times$  Gender,  $F(2, 190) = 3.00, p < .06, MSE = 484$ . Simple effects showed that dynamic-sport male athletes had a smaller inhibition effect (8 ms) than any other group (means ranged from 18 ms to 25 ms),  $F(1, 95) = 5.24, p < .03$ . No other differences were significant.

A final analysis examined the modulating influence of the arrow cues on the flash effect over all SOAs. This analysis summed the facilitation and inhibition effects in Figures 5 and 6. It revealed a main effect of sport,  $F(2, 95) = 2.96, p < .05, MSE = 719$ , reflecting a



**Figure 5.** Modulation of Automatic Facilitation: The difference in RT for valid and invalid flash cues (with one standard errors bar) in the first two flash-target SOAs (30 and 150 ms), based on trials on which there were also arrow cues.



**Figure 6.** Modulation of Inhibition of Return: The difference in RT for valid and invalid flash cues (with one standard error bars) in the last three flash-target SOAs (210, 405, and 795 ms), based on trials on which there were also arrow cues.



smaller effect for dynamic-sport athletes (27 ms) than for either static-sport athletes (38 ms) or nonathletes (37 ms),  $F(1, 95) = 5.62$ ,  $p < .01$ , who did not differ from one another,  $F < 1$ . A significant Arrow  $\times$  Sport interaction,  $F(2, 95) = 3.97$ ,  $p < .03$ ,  $MSE = 774$ , reflected a larger difference between valid and invalid arrows for static-sport athletes (23 ms) than for the other two groups (-4 ms for nonathletes and 2 ms for dynamic-sport athletes).

## Discussion

The primary contributions of this study were (a) the coordinated examination of sports-related and gender differences in a speeded spatial orienting task, and (b) the measurement of voluntary and automatic aspects of covert orienting within the same study. Participants performed a target detection task in which either no cue, a nonpredictive flash, a predictive arrow, or a combination of these cues were presented at variable times before the target. Because this combination of factors yielded a large amount of data, the discussion will focus on group differences that occurred in the six main measures of this study. It should also be noted that these were college athletes, not international competitors, as in some studies (Nougier et al., 1989; Nougier et al., 1996; Nougier et al., 1990), and so the effects reported probably underestimate the relations that could be observed in more highly skilled athletes.

### Vigilance

The two athlete groups responded generally more rapidly in this task than the nonathlete group. However, all three groups maintained excellent vigilance in this task over trials, as indicated by the decrease in RT over trial blocks for the duration of the testing session. Indeed, the nonathlete group showed the largest improvement in RT over blocks, probably because the athletes were already performing near optimally at the beginning of the testing session. Yet, it is notable that even by the last block of trials, nonathletes were unable to respond as quickly as athletes on the first block. The advantage of athletes in maintaining response readiness in response to cues replicates the earlier findings of Anzeder & Boesel (1998) and Enns and Richard (1997). Moreover, this result points to some long-lasting benefits of sports-specific experience.

By far the most interesting finding for this measure was that the male advantage in RT was seen only in nonathletes. Female athletes were not statistically slower than male athletes to respond to unpredictable target onsets. This strongly suggests that the well known finding of female inferiority in RT (Ballard, 1996; Seidel &

Joschko, 1991) does not generalize to female athletes. Some reason other than a sex-linked one will have to be found to account for gender differences in response speed in the general population.

### Alerting

On trials on which no cue was present, there were no differences in the RT function over SOA that could be attributed to sport. However, there was a gender difference, indicating that men, regardless of athletic experience, remained more alert than women for the target during the SOA period. Thus, in contrast to the gender difference in overall RT, which disappeared with participation in athletics, the gender difference in sustaining short-term alertness for the target was not diminished in the athlete groups. One interpretation is that this measure of alertness reveals general gender differences, because the task of remaining alert for a spatially uncertain target demands the same spatial skills shown to favor men generally (Ditmar et al., 1993). In any case, future research on gender differences deserves to focus on this interesting contrast between simple RT, which does not reveal general gender differences, and the maintenance of short-term alertness, which does.

### Automatic Orienting

As predicted, all groups were similar on this measure: nonpredictive flashes produced early facilitation followed by later inhibition in the same locations. Thus, whatever distinguishes athletes from nonathletes, or dynamic from static-sport athletes, it is not the mechanisms governing automatic covert orienting on their own. It is worth noting that the pattern of early facilitation and late inhibition is the typical pattern of results found with sudden onset cues (Posner & Cohen, 1984), unlike the largely inhibitory findings at all SOAs reported by Enns and Richards (1997).

### Voluntary Orienting

All groups used the arrows to orient attention voluntarily, and this effect was strongest at mid-range SOAs (360 ms and 555 ms). The one group difference that emerged was for male dynamic-sport athletes, who had a larger arrow cue effect at these SOAs than any other group. This indicates that dynamic-sport male athletes were better at voluntarily orienting attention to locations where useful information (i.e., the target) was most likely to occur. The finding that this group was also best able to modulate the inhibition of return effect confirms that the modulation of automatic orienting is related to the same mechanisms used to accomplish voluntary orienting (Nougier et al., 1996). It is, therefore, also impor-



tant that these participants were athletes in sports in which these skills received the most advanced training.

The question then arises why women in dynamic sports did not show the same large magnitude of voluntary orienting. A possible explanation is that, despite the gains in training and sports participation made in recent decades, the gender gap in sports training specific to the control of spatial attention still favors men. However, the size of this gap must be placed in perspective. One relevant comparison is the difference in voluntary orienting between athletes from visually static sports (which presumably do not place as high a premium on voluntary allocation of spatial attention) versus dynamic sports. The gender difference in this study for dynamic-sport athletes was no greater than between dynamic and static-sport male athletes.

It should also be noted that the voluntary cueing effects of athletes and nonathletes were quite similar and sometime even larger for athletes in this study (dynamic-sport men). This finding contradicts the previous work regarding *smaller* voluntary orienting effects in athletes (e.g., Enns & Richards, 1997; Nougier et al., 1992; Nougier et al., 1989). One reason this study may have elicited these larger effects is because it was the first in which voluntary and automatic cueing effects were systematically combined over a large range of SOAs. This dynamic cue testing environment meant there was probably more incentive (and reward) for using voluntary orienting in this study than in previous studies in which only informational cues have been tested.

One incentive concerned the highly influential, albeit noninformative, flash cues. Without attending to the arrow cue locations, these cues had a powerful automatic influence on where attention was located (see Figure 3). The arrows could, thus, be used to modulate these automatic effects, at least in participants who were skilled in dealing with such combined cues (see male athletes' dynamic in Figure 6). Another incentive came from the intermixed trials on which there were no flash cues at all. Here, use of the arrow provided a strong head start on processing (see Figure 4). Finally, the combined cue trials showed that the two cues could even have synergistic effects that were beneficial for some athletes (see static-sport athletes in Figure 5). It is notable that these incentives were not all present in the earlier studies (Enns & Richards, 1997; Nougier et al., 1992; Nougier et al., 1989), which used fewer cue-target locations, only one type of cue at a time, and a more limited range of SOAs.

#### *Modulation of Automatic Facilitation*

This study was the first to examine spatial orienting in athletes and nonathletes using trials in which both flash and arrow cues were displayed. Examining the effects of such dual cues is especially pertinent, because

success in sports is likely to depend on the coordinated use of automatic and voluntary orienting of attention. Indeed, it may be the case that certain types of sports provide the proper training environment for improved top-down control over automatic attentional processes.

At the shorter SOAs, the combination of arrow and flash cues provides information about possible voluntary intervention on automatic orienting toward the location of the flash. Indeed, all participant groups showed a larger flash facilitation effect when it was accompanied by an arrow cue, meaning that both voluntary and automatic attention were oriented to the same location. However, this effect was also largest among static-sport athletes, who were able to suppress the flash almost completely when it occurred in a location other than the one indicated by the arrow cue. This rather unusual finding may be an effect that is acquired when performing sports in relatively more static environments. Under these circumstances, it is probably adaptive to filter out *all* potential sources of information that are not task relevant. In particular, both swimmers and track athletes face situations in which they must focus attention for a specific stimulus (e.g., the starter signal) to the exclusion of all other stimuli in all other locations (e.g., movements from opponents, officials or spectators). Thus, with considerable practice, it may be possible to voluntarily override automatic orienting to cues such as abrupt movements or onsets of lights.

#### *Modulation of Inhibition of Return*

Examining the combination of arrow and flash cues at the longer SOAs provides information about possible top-down intervention of the inhibition of return effect produced by the flash. Indeed, the arrow cues appeared to be used by all participants in that they showed a smaller IOR effect when the arrow cue indicated the same target location as the flash. In other words, all groups were able to override IOR through voluntary orienting to some extent. However, men in sports with dynamic environments were also better than all others in being able to suppress the IOR effect in the presence of an arrow cue. This group showed the least IOR, as well as the smallest combined automatic effects in the presence of an intention to orient to a specific location. This ability to modulate visual reflexes is especially useful in visually dynamic sports, where important information is likely to occur at a given location regardless of what other stimuli have occurred at that location. The difference between male and female athletes in this measure may also be due to a remaining gender gap in sports training specific to the control of spatial attention.

The evidence from both short and long SOAs is that the voluntary component of attentional orienting can have considerable impact on the automatic component.



In fact, the effect of the arrow cues was generally greater than the effects of the flash cues in the present study. This is opposite to the findings of Nougier et al. (1996), who used flashes in conditions of varying predictive validity to deliver probabilistic information about the upcoming target. However, that method may have been biased toward the automatic component for two reasons. First, the flash cue had to be presented before the associated meaning could be interpreted, depending on the probability condition (e.g., a 25% valid flash meant the target was likely in the opposite location). Including the information to be used voluntarily in the flash itself may have provided an advantage to the automatic component. Second, in that study a response was required to both cues and targets, and it may be that programming and executing this response may have impaired any subsequent voluntary movement of attention.

### Future Directions

This study demonstrated that it is possible to record behavioral correlates of athletic skill in a laboratory covert orienting task lasting only about 1 hr. It also demonstrated important differences between the genders and between different sports environments in such a task. Two of the most promising directions for further research are: (a) The gender difference in basic response time, which was thought to be pervasive, does not hold for college athletes generally. Yet, a gender difference in maintaining short term alertness does apply to college athletes. What lies behind each of these differences, and how malleable are they to improvement through training? (b) The modulation of such automatic effects as orienting to an abrupt flash and the inhibition of return are clearly more important to skill in some sports than in others. Is the superiority in reflex modulation shown by male athletes in dynamic sports acquired through training and coaching, or do coaches select athletes based on their superior abilities? Only a developmental study will help to shed light on this question.

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## Authors' Notes

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