
GENDER INFLUENCE ON RESPONSE TIME TO SENSORY STIMULI

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ABSTRACT

Spieler, DK, Petersen, RA, Duffy, K, Corcoran, BM, and Rawls-Martin, T. Gender influence on response time to sensory stimuli. *J Strength Cond Res* 24(4): 957–963, 2010—The purpose of this investigation was to examine the effect of auditory stimuli (AS) and visual stimuli (VS) on response time, speed, and distance in male and female college athletes. Thirty-five healthy National Collegiate Athletic Association Division I men's soccer and women's lacrosse athletes (mean age 20.7 ± 2.3 years) participated in the study. This experiment was conducted in a laboratory environment, using a Cybex "Reactor" a 14-sensor force plate device used to detect response times, speed, and distance. Subjects stood on the "start" sensor and were instructed at the prompt (auditory: a prerecorded "go" command, visual: an illuminated circle on a television monitor) to run through the "end" sensor without braking. Three trials of each condition were performed by each subject. Movement time, speed, and distance were recorded for each trial. General linear model repeated measure analyses and post hoc 1-way analysis of variance were conducted on all dependent variables ($p \leq 0.05$). Movement time was significantly faster in men compared with women under AS ($p = 0.008$) and VS ($p < 0.05$) conditions. A trend toward a faster transit time was noted in men in the AS condition ($p = 0.072$), but transit time was faster in men in the VS condition ($p < 0.001$). Transit speed (distance covered) was faster in men in response to AS ($p < 0.05$) and VS ($p < 0.001$). Male athletes respond faster as compared with female athletes, and cover greater distance when presented with VSs as compared to ASs. Data suggest that performance in male athletes related to response times, speed, and distance may be enhanced with the use of visual cueing or VSs.

KEY WORDS motor behavior, agility, quickness, reaction

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INTRODUCTION

Response time can be defined as elapsed time between the presentation of a sensory stimulus and subsequent behavioral response. Response times can be significant when interpreting human performance, specifically in athletes participating in activities that require quick reactions and rapid movement. Response to sensory stimuli has been examined in various populations (6,8,17,24,27), and results demonstrate different response times based on factors including neural processing time (3,17,23), fitness or skill (10), age (17,27–30), and gender (2,16,17,19,20,27).

Gender differences in response to stimuli are suggested to be a function of the type of stimuli presented (4,9,21). Specific reaction time tasks that employ a semantic, verbal stimulus or auditory stimulus (AS, e.g., numbers, letters, or spoken words) are more favorable to women, whereas responses to stimuli of a spatial or visual nature (e.g., a flashing light on a screen) exhibit a male advantage (17). Men's superiority in visual and spatial abilities is sometimes attributed to differences in cognitive strategies (7,12,13,26); however, others believe the response differences are associated more with innate processing of verbal and spatial tasks (4,9,14,21,31).

Bauer et al. examined this male-related phenomenon in athletes (6). He looked at the correlation of performance related variables (upper and lower extremity reaction times, strength, and endurance) to sensory stimuli in the form of auditory and visual cues. The purpose was to compare reaction time, stability performance capacity, and upper and lower body strength in elite race car drivers compared with age-matched controls. Reaction times of the drivers were significantly faster than the controls under both auditory and visual conditions (6). Bauer et al (6) and others have demonstrated that reaction time and other response times are important variables that may influence performance. However, until this time, these investigations have been carried out with male subjects only.

In addition, previous literature demonstrates response times as a function of fine motor control or coordination (e.g., movement with a stylus, small instrument, or finger) with the use of a touch pad or a touch screen to record response (2,8,17,18,22). Consequently, these studies may not

be appropriately applied to athletes, who typically perform complex movements involving large muscle groups. To our knowledge, Baur et al.'s (6) is the only study to explore the response times of large muscle groups in response to sensory stimuli.

Gender differences in response times to sensory stimuli exist. Because time variables are often associated with athletic performance, an examination of these variables in response to sensory stimuli as a function of gender in athletes is warranted. Accordingly, the intent of this study was to examine collegiate athlete's gender differences as defined by movement time, reaction time, speed, and distance in response to sensory stimuli.

METHODS

Experimental Approach to the Problem

A between- and within-subject repeated measures analysis was used to test the experimental hypothesis. Thirty-five college athletes (15 male soccer players and 20 female lacrosse players) were familiarized with all experimental tests before mean response times, speed, and distance were determined. The study was designed such that subjects were recruited from collegiate sports that require short intermittent bursts of speed and quick reaction times. For this reason, we thought it prudent to measure these variables in the laboratory before conducting any similar tests on the field. All subjects were in their off-season when this study was conducted. The experiment was performed on a Cybex Reactor (Cybex International, Inc., Medway, MA), a 14-sensor electrical force plate designed to detect movement time, reaction time, speed, and distance. We used the Cybex Reactor as the implement to detect changes in response to auditory stimulus (AS) and visual stimulus (VS). The study consisted of 6 experimental trials (3 AS and 3 VS conditions) from which data were recorded and analyzed. All subjects performed under both conditions and were randomly assigned to each condition to avoid an order effect bias. The purpose of this study was to observe and analyze how gender differences might influence movement time, reaction time, speed, and distance in response to AS and VS. We hypothesized that the VS would result in quicker movement time, reaction time, increased speed, and a greater distance covered in men as compared

with women. This is congruent with other studies that have examined similar hypotheses (7,12,13,26). The dependent variables in this study were chosen for 2 reasons: First, they are measures often associated with athletic performance and second they can be accurately recorded with the 14-sensor Cybex Reactor system used in this investigation.

Subjects

Thirty-five subjects with a mean age of 20.7 ± 2.3 years were recruited on a volunteer basis from NCAA Division I athletic teams at Long Island University. Subject characteristics are reported in Table 1. Subjects consisted of 15 male soccer and 20 female lacrosse players. Subject pools were chosen based on the nature of each sport, requiring short, intermittent bursts of speed and quick reaction. Subjects were not in-season at the time of testing. To ensure subjects met entry criteria, an intake form was provided before testing to screen for personal or family history related to cardiac, pulmonary, or neurological conditions that might preclude them from participating in the study. As deemed by a preparticipation physical examination, all subjects had normal or corrected-to-normal vision. Subjects were informed of the experimental risks, and they signed an informed consent document before the investigation. This study was approved by the Long Island University Institutional Review Board for use with human subjects.

Procedures

Before testing, subjects were familiarized with the Human Performance Laboratory and the Cybex Reactor that would be used for data collection. Subjects were instructed, in accordance with established guidelines (1), to refrain from maximal exercise for 24 hours and consumption of caffeine and heavy meals 2–3 hours before testing (1). For both AS and VS protocols, subjects were instructed to stand approximately 24 in. from a television screen powered by an adjacent desktop computer (Dell Dimension XPS H233, Round Rock, TX) and interfaced with a Cybex Reactor (Cybex International, Inc.). Cybex Reactor is a 14-sensor force plate that detects movement through a series of circular platforms (sensors) (Figure 1). The entire sensor field ($2.74 \text{ m} \times 3.59 \text{ m}$) uses a force transducer to detect when force is applied to the platform. Proprietary software using the force transducer allowed for movement to be monitored and recorded using protocols for reaction time and movement responses. Investigators were provided with a televised view of the sensor pads in a mirror image to their arrangement on the floor, so they were aware of the subject's position at all times (Figure 2). An

TABLE 1. Subject characteristics.

| | Men ($n = 15$) | Women ($n = 20$) | All ($n = 35$) |
|-------------|------------------|--------------------|------------------|
| Age | 21.9 ± 2.7 | 19.8 ± 1.6 | 20.7 ± 2.3 |
| Weight (kg) | 76.7 ± 12.6 | 63.5 ± 8.5 | 69.2 ± 12.2 |
| Height (m) | 1.78 ± 0.79 | 1.66 ± 0.88 | 1.70 ± 0.09 |
| BMI | 24.3 ± 3.3 | 23.0 ± 2.7 | 23.6 ± 2.9 |

All results are reported in means \pm SD. BMI = body mass index.



Figure 1. An athlete responding to a sensory stimulus (monitor pictured in the background), running toward the end sensor (pictured in the foreground).

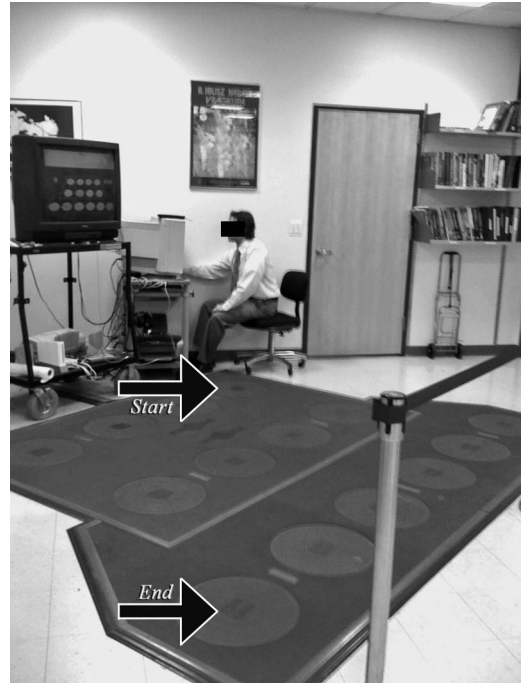


Figure 2. Cybex Reactor (14-sensor force plate) measuring 2.74 m × 3.59 m. The start sensor and end sensor are labeled to demonstrate the distance each athlete was required to run.

acclimation protocol was included before acquisition of data to ensure that subjects fully understood the procedures. After subjects performed 3 trials each of the AS and VS protocols and stated they were comfortable with the instructions, data collection began.

Visual and Auditory Stimulus Protocol

To begin both the AS and VS protocols, subjects were instructed to face the monitor and stand with their right foot on the “start” sensor plate located in the top row, top right corner (Figure 2, top black arrow). During the AS, the television monitor was turned off. When subjects applied force (weight) to the “start” sensor, an audible “beep” was heard, indicating that the sensor plate detected pressure. After a short pause, the auditory command “GO” was heard through the computer speaker system. At the sound of the command, subjects were instructed to run as fast as possible toward and across the sensor located in the bottom left corner (“end” sensor) of the force plate (Figure 2, bottom black arrow).

For the VS protocol, the television monitor was turned on, and the speaker system was turned off to avoid the “GO” command from being heard. Subjects viewed a mirror image of the sensors on the television screen. When the subject applied force (weight) to the “start” sensor, it was illuminated on the screen indicating that a pressure change was detected;

however, no audible “beep” was heard. After a short pause, a second sensor (end) became illuminated on the television monitor. This was the visual cue to which subjects were instructed to run as fast as possible toward and through the sensor without braking. After the completion of an AS or VS protocol, subjects recovered for 2 minutes before the next stimuli was presented.

Each participant performed 3 identical trials in each of the AS and VS protocols. AS and VS protocols were randomly assigned with the flip of a coin. During AS and VS conditions, prerecorded crowd noise was played through a stereo system (Techniques SA-GX130) with strategically placed speakers in each corner of the room to ensure equal amplification of sound from each direction and to make certain that both conditions were performed under distracting stimuli, similar to what is heard during practice and game situations.

Measurements Defined

Mean values of the 3 trials were used for analysis. Measured variables: move time, transit time, transit speed, acceleration time, and reaction time are explained below.

Move time = Sum of reaction time, acceleration time, and transit time, measured in seconds.

TABLE 2. Gender related response to auditory and visual stimuli.

| | AS | | | VS | | |
|-------------------|----------------------|------------------------|----------|----------------------|------------------------|----------|
| | Men (<i>n</i> = 15) | Women (<i>n</i> = 20) | <i>p</i> | Men (<i>n</i> = 15) | Women (<i>n</i> = 20) | <i>p</i> |
| Move time | 1.19 ± 0.13 s | 1.34 ± 0.17 s | 0.008 | 1.18 ± 0.16 s | 1.30 ± 0.14 s | <0.05 |
| Transit time | 0.56 ± 0.06 s | 0.65 ± 0.06 s | <0.001 | 0.59 ± 0.13 s | 0.65 ± 0.08 s | NS |
| Transit speed | 16.72 ± 3.10 ft/sec | 14.66 ± 1.59 ft/sec | <0.001 | 16.98 ± 1.79 ft/sec | 14.77 ± 1.41 ft/sec | <0.05 |
| Acceleration time | 0.17 ± 0.23 s | 0.21 ± 0.23 s | NS | 0.18 ± 0.23 s | 0.24 ± 0.25 s | NS |
| Reaction time | 0.1782 ± 0.189 s | 0.1317 ± 0.192 s | <0.05 | 0.31 ± 0.14 s | 0.04 ± 0.29 s | NS |

*VS = visual stimulus; AS = auditory stimulus.

Gender differences in response to AS and VS in regard to all measured variables. All results are reported as means ± *SD*.

Transit time = Point from the departure of the start platform to the point of initial impact on the end sensor, measured in seconds.

Transit speed = Total distance covered calculated from the time it takes to move 3.3 m from the start sensor to the end sensor, measured as a function of time (ft·s⁻¹).

Acceleration time = Time between the first detected movement off of the start sensor and the point departure time from the start sensor, measured in seconds.

Reaction time = Time between the presentation of auditory and/or visual cue and the first detected movement off of the start sensor, measured in seconds.

Statistical Analyses

All data were processed using a statistical analysis software package (SPSS v. 16.0, SPSS Inc., Chicago, IL). Values are expressed as means ± *SD* (Table 2).

A 2 × 2 (Gender vs. Stimulus) General Linear Model was used to understand the impact of gender and stimuli on the following dependent variables: Move time, transit time, transit speed, acceleration time, and reaction time. Variables in which a gender influence was evident were further analyzed for significance with a post hoc 1-way analysis of variance. Statistical significance was set at an alpha level of $p \leq 0.05$.

RESULTS

Subject characteristics are presented in Table 1.

Move Time

Men demonstrated a reduction in move time as compared with women in the AS condition (1.19 ± 0.13 vs. 1.34 ± 0.17 seconds, $p = 0.008$) and in the VS condition (1.18 ± 0.16 vs. 1.30 ± 0.14 seconds, $p < 0.05$) (Figure 3A). The range of data for move time across all subjects for the AS condition was 0.972–0.1773 seconds. In response to the VS condition, the range was 0.940–1.643 seconds.

Transit Time

Men demonstrated a significantly decreased transit time in the VS condition (0.56 ± 0.06 vs. 0.65 ± 0.06 seconds,

$p < 0.001$) (Figure 3B). Men also demonstrated a trend toward a decreased transit time in response to the AS condition (0.59 ± 0.13 vs. 0.65 ± 0.08 seconds, $p = 0.072$) as compared with women. In response to the AS condition, the range for transit time across all subjects was 0.425–0.950 seconds, and the VS condition produced a range of data from 0.451 to 0.740 seconds.

Transit Speed

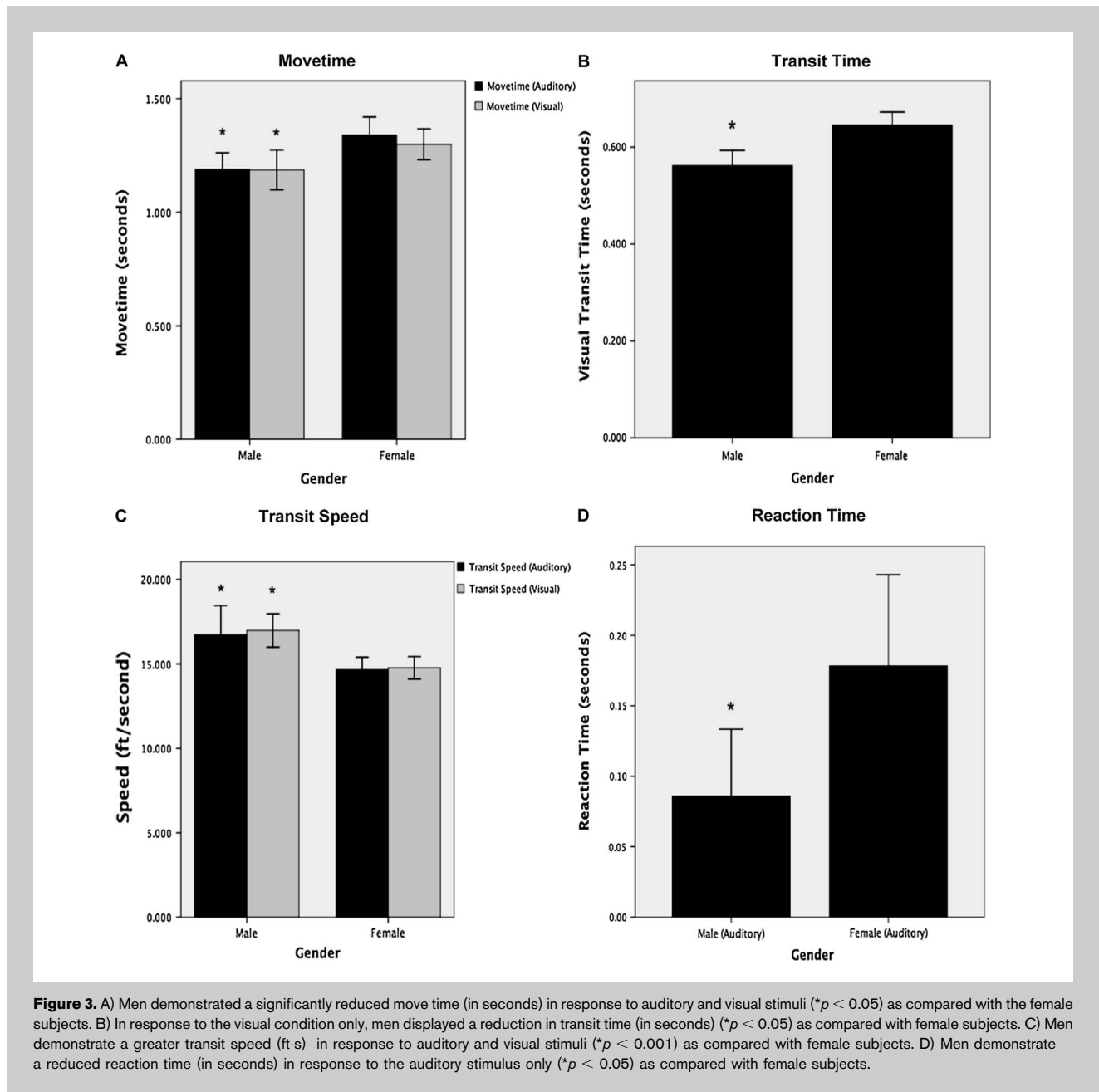
Men exhibited increased transit speed (distance covered as a function of time) as compared with women in response to the AS condition (16.72 ± 3.10 vs. 14.66 ± 1.59 ft·s⁻¹, $p < 0.05$) and the VS condition (16.98 ± 1.79 vs. 14.77 ± 1.41 ft·s⁻¹, $p < 0.05$) (Figure 3C). Regardless of the sensory stimuli presented, mean transit speed did not change significantly within gender. Males demonstrated an increase in transit speed between the AS and VS conditions (15.01–18.44 ft·s⁻¹), but the change was not significant. Transit speed in the female group remained consistent regardless of the stimuli presented. The range of data across all subjects for transit speed was 9.95–22.2 and 12.7–20.9 ft·s⁻¹ for the AS and VS conditions, respectively.

Acceleration Time

Acceleration time was decreased in men as compared with women in response to the AS condition (0.17 ± 0.23 vs. 0.21 ± 0.23 seconds), but did not reach significance ($p = 0.72$). Similarly in response to the VS condition, men were not significantly faster than women (0.18 ± 0.23 vs. 0.24 ± 0.25 seconds, $p = 0.72$). However, men and women demonstrated a faster acceleration time in response to AS (0.38 ± 0.16 seconds) as compared with VS (0.42 ± 0.16 seconds). This finding also did not reach statistical significance. The range of data spanned 0.144–0.810 seconds for the AS condition and 0.115–0.718 seconds for the VS condition.

Reaction Time

No significant differences were noted in response to the VS condition. However, reaction time in response to AS was found to be significantly different between men and women



(0.1782 ± 0.189 vs. 0.1317 ± 0.192 seconds, $p < 0.05$), respectively (Figure 3D). Of note, there were no changes in reaction time within men with either condition, but in the female group, a quicker reaction to the VS condition was demonstrated. The range of values for reaction time across all subjects was 0.100–0.513 and 0.100–0.801 seconds for AS and VS, respectively.

DISCUSSION

The purpose of this study was to determine if a gender influence exists on athletes' response to AS and VS. Our major finding indicates that men, as compared with women, demonstrate

a decreased transit time and an increased transit speed in response to VSs and ASs. Additionally, these data suggest that men are quicker to respond to a VS rather than to an AS. However, acceleration and reaction times did not show significant differences related to gender.

Inherent differences found in the present study are perhaps because of other variables, such as processing time and motor cortex function, as discussed in the literature (3,10,17,23,27–30). In addressing gender-related variances in response times in the literature, a common discussion is centered around the speed at which information is processed. In the Adam et al. study (2), responses of 12 males and

12 females to a choice time reaction test that required a verbal response to a spatial location were examined.

In Adam's work, vocal responses were made into a microphone connected to a voice-operated relay and interfaced with a computer. Subjects were shown "x's" on a monitor, either 2 or 4 "x's" depending on the experiment. The primary "x's" were defined as the display condition, and each "x" was given a position (i.e., 1, 2, 3, or 4). A target "x" was then shown at a particular position associated with the display condition. Subjects were instructed to respond verbally with the correct position of the target "x" (1, 2, 3, or 4). Results demonstrated a near-significant overall reaction time advantage for male participants. Adam attributed this finding largely to inherent gender differences as related to information processing speed.

Based on these findings, males may exhibit more neural activity in situations where they are required to respond to an external stimulus in a controlled environment. This innate difference might have translated to a quicker decision making process in the Adam study. Although our study did not examine the specific brain centers that were activated in males and females in response to AS and VS, previous authors seem to add plausibility to the notion that processing speed is an inherent neurological function that may differ by gender.

In addition to neurophysiological differences, data demonstrate differences in reaction time between men and women may be attributable to type of stimuli presented. Lahtela et al. (17) pointed out that semantic components (e.g., letters and numbers) and verbal stimuli elicit a quicker reaction in women as compared with a VS as in the study by Adam et al. (2). It should be noted, however, that Lahtela's finding was related to a response using fine motor control (e.g., the movement of a finger or thumb). In contrast, the methods of the current study required subjects to activate large muscle groups in response to stimuli rather than the fingers or hands.

Contrary to Lahtela et al. (17), the results of the present study demonstrate that when larger muscle groups are involved, women react quicker to a stimulus that is visual rather than auditory or verbal. This may be because of the experimental protocol used in the present study, which differed greatly from that employed by Lahtela or it may be that a VS induces a quicker processing speed.

Gender differences seen in the present study may also be influenced by the amount of muscle fiber needed to create movement. Larger muscles possess larger motor units capable of generating increased force and velocity. Thus, an increased activation from larger motor units may contribute to quicker response of men to VS. Although this was not the focus of the current investigation, further research in this area might be very valuable to coaches engaging or motivating their players using specific stimuli. Overall, our data demonstrate that men spend significantly less time between 2 points and possess more speed than women when presented with a VS.

Findings from the majority of studies on athletic and nonathletic populations on the issue of response time and

specifically response time to alternative stimuli have focused on fine motor movement (e.g., pressing keys with fingers [24]). These studies, identifying response differences between genders, are not applicable to the responses commonly required in athletic situations. Unlike previous work, the current study is more applicable to sport because it examines an athlete's ability to process information and then perform gross motor movement using the legs and arms to run from 1 point to another.

To our knowledge, the present investigation is the first to examine gross motor movement differences in male and female athletes in response to AS and VS. These differences may become significant on the field when one is required to react quickly, change direction, or defend against an opponent. Yet, further research is needed to determine if these differences are inherent or if they are attributable to the situation in which the stimuli is presented. Additionally, team-training methods may contribute to the current findings. There is increasing interest in visual training for athletes (15). An awareness or "court sense" that allows athletes to see and integrate large volumes of information, and react while on the playing field, may help them gain an edge on a competitor. Hascelik et al. (10) examined 20 subjects' response to AS and VS before and after 8 weeks of weight training. Although Hascelik's methods did not incorporate large muscle contraction, results showed that auditory and visual reaction times were shortened after the training period.

This training-induced improvement may be related to specific changes in brain function as described by Arito and Oguri (5). In Artio's study, subjects were required to press a button after being presented with a VS. Results show that trained individuals possess a shorter delay interval, which allowed them to move quicker when the stimulus was presented. However, the current findings are most likely not related to training because the study participants were not in season at the time of the study.

In this study, we focused on movement times and speed in response to AS and VS in male and female athletes. We were limited in some ways because the protocol was conducted in a controlled laboratory environment. A more optimal situation would be to conduct a similar protocol on the field. This limitation is being addressed by investigating movement times and gender differences in response to AS and VS on the field. In addition, this study examined athletes from 2 similar sports: lacrosse and soccer. At the time of the study, we were limited to conducting the study on the men's soccer team and not women's soccer because of scheduling conflicts and the university does not sponsor a men's lacrosse team.

In conclusion, the main finding of this study is that gender differences do exist in response to AS and VS. Our findings indicate that men are quicker to respond to a VS than women. Findings of gender-related differences in movement and reaction times to AS and VS may be attributable to several factors. However, an understanding of how male and female athletes react to particular stimuli may warrant

changes in various coaching strategies to provide a competitive edge.

PRACTICAL APPLICATIONS

The data support that men react quicker to a VS rather than to an AS as compared with women. In addition, the findings of the present study demonstrate that women are quicker to react to a VS as well. These differences may suggest the need for alternative gender-specific training and coaching strategies to optimally prepare an athlete. Improving very basic visual search strategies and their relation to visual attention represent key factors in enhancing underlying perceptual skill. Studies have indicated that more experienced athletes are more efficient in searching the field and reacting (11,32).

Pesce et al. (25) reported that expert soccer players are better able to rapidly shift attention and scan the field to pick up relevant information. Gender differences in this regard may lead to various training and coaching strategies to optimally prepare athletes for quick decision making and movement on the field.

Thus, for the coach and the athlete, an understanding about the type of stimulus that best suits the player's gender is an appropriate aspect in the development of quick reactions and movements necessary to achieve success on the field. An identification of gender-specific responses to and AS may VS influence training techniques. This suggests that coaching can be tailored specifically to men and women because it relates to the presentation of an external stimulus that may manifest a quicker reaction and thus may improve sports performance.

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