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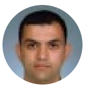

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COINCIDENCE-ANTICIPATION TIMING REQUIREMENTS ARE DIFFERENT IN RACKET SPORTS[1, 2]

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Summary.—The aim of this study was to compare the coincidence-anticipation timing accuracy of athletes of different racket sports with various stimulus velocity requirements. Ninety players (15 girls, 15 boys for each sport) from tennis (*M* age = 12.4 yr., *SD* = 1.4), badminton (*M* age = 12.5 yr., *SD* = 1.4), and table tennis (*M* age = 12.4 yr., *SD* = 1.2) participated in this study. Three different stimulus velocities, low, moderate, and high, were used to simulate the velocity requirements of these racket sports. Tennis players had higher accuracy when they performed under the low stimulus velocity compared to badminton and table tennis players. Badminton players performed better under the moderate speed comparing to tennis and table tennis players. Table tennis players had better performance than tennis and badminton players under the high stimulus velocity. Therefore, visual and motor systems of players from different racket sports may adapt to a stimulus velocity in coincidence-anticipation timing, which is specific to each type of racket sports.

to some extent all sports require high perceptual abilities to perform motor skills proficiently (Mori, Ohtani, & Imanaka, 2002). Accurate coincidence-anticipation timing plays a major role in most of the sports that require catching or hitting a ball. Coincidence-anticipation timing is mainly defined as the ability to predict when an object/image would arrive at a designated target point in time and space (Williams, Davids, & Williams, 2000). Coincidence-anticipation timing is generally used to test hand-eye coordination and its anticipation on visual accuracy. In racket sports, for instance, it is very essential to track the ball movement (visual accuracy is needed), to anticipate the arrival of the ball, and finally to hit the ball toward the opponent's court. Especially in sports requiring precise catching or hitting, this perceptual ability could be speculated as a major factor which may contribute to a successful performance (Magill, 2004; Schmidt & Lee, 2005). Therefore, it is crucial not only to routinely test this mo-

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tor ability but also to monitor possible changes in coincidence-anticipation timing accuracy. Coincidence-anticipation timing has been frequently used to test athletes and select talented individuals (Ripoll & Latiri, 1997). Many studies have shown a better accuracy on the coincidence-anticipation timing obtained from expert athletes when compared to the novices (Tenenbaum, Sar-El, & Bar-Eli, 2000; William & Starkes, 2002; Lyons, Al-Nakeeb, & Nevill, 2008). This superior performance of elite athletes may support the idea to use coincidence-anticipation timing for talent identification.

Previous studies of coincidence-anticipation timing have mainly focused on the differences between skill levels (Tenenbaum, *et al.*, 2000; Rowe & McKenna, 2001; William & Starkes, 2002; Del Villar, Garcia Gonzalez, Iglesias, Perla Moreno, & Cervello, 2007; Lyons, *et al.*, 2008). The results of these studies mainly showed better coincidence-anticipation timing accuracy for expert athletes than the novice ones. Despite the wide research topics in coincidence-anticipation timing, there are only a very few studies that studied the coincidence-anticipation timing among different sports. This can be very helpful to find out whether coincidence-anticipation timing depends on the characteristics of different sports.

Anticipating the direction and the velocity of the approaching object (e.g., a ball) is crucial in sports that require hitting, such as tennis, badminton and table tennis. Athletes of these sports require good anticipation timing ability to perform the necessary footwork, to take the right position, and to get ready for a return shot. The contact position of the ball/shuttlecock with the racket/paddle and the timing of the stroke are two of the factors determining the direction of the ball as it is sent to the opponent's court. A slight change in timing may cause the ball go out of the court or table (Ak & Koçak, 2010). Most of the athletes of tennis, badminton, and table tennis players are capable of receiving a ball, but the difference between elite and non-elite players is the ability to send the ball at desired locations on the opponent's court or table. In order to perform this action, players should be able to contact the ball or shuttlecock at the right time and position. Thus, coincidence-anticipation timing is one of the most important skills requiring improvement by the athletes.

Even though tennis, badminton, and table tennis are somewhat similar sports, there are major distinctions among them, such as swing patterns used by athletes, the size of the playing area, and the ball or shuttlecock speed. Few studies focused on the required motor abilities in these sports (Ripoll & Latiri, 1997; Benguigui & Ripoll, 1998; Williams, Katene, Fleming, & Bennett, 2002). Ak and Koçak (2010), recently compared coincidence-anticipation timing abilities between tennis and table tennis players and found better coincidence-anticipation timing accuracy for tennis players than those obtained from table tennis players. The aforementioned study used only one constant speed (2 m/sec.) to test coincidence-anticipation timing. However, considering the size of the playing area and the speed of the ball in the two sports, testing coincidence-anticipation timing at a constant speed may not represent the actual performance of the table tennis and tennis players. Understanding the fundamental perceptual abilities (e.g., coincidence-anticipation timing) in different sports could be beneficial for trainers to select or to direct individuals according to their perceptual abilities. Moreover, this could also be helpful when applying specific test protocols for each sport type that monitor the improvement of the athletes. For instance, the distance between two baselines in tennis is approximately 25 m. The average speed of the tennis ball during an adult game is approximately 100 km/hr. (27 m/sec.) and much slower in younger players (Ferrauti & Bastiaens, 2007; Iino & Kojima, 2009). Considering the distance between players and the speed of the ball, players have less than one second to prepare for the return shot after the opponent hits the ball. As another example, the distance between two baselines in badminton is approximately 13 m. The average speed of the shuttlecock in badminton was measured as approximately 125 km/hr. (35 m/sec.; Tsai, Huang, & Jih, 1997; Chen, Pan, & Chen, 2009). In this case, badminton players have nearly 0.5 sec. to prepare for the return shot after the opponent hits the shuttlecock. Based on these differences, compared with the tennis, badminton players should have different coincidence-anticipation timing abilities. That is, tennis players have more time than badminton players to anticipate the location of arrival ball. Therefore, it can be assumed that badminton players should have better coincidence-anticipation timing accuracy when the time for anticipation is limited or when the task requires faster response.

Compared with tennis and badminton, the distance between players in table tennis is approximately 3 m (playing area). The speed of the ball in table tennis is around 36 km/hr. (10 m/sec.; Durey & Seydel, 1994). In table tennis, therefore, players have less than 0.5 sec. to prepare for a return shot after the opponent hits the ball. When one compares the three racket sports, table tennis players can be expected to have the fastest responses. Considering the differences in the distance between players and the speed of the ball, coincidence-anticipation timing should be measured with the different stimulus velocities (low, moderate, and high). Therefore, the focus of this study was to test coincidence-anticipation timing with three different speed requirements in tennis, badminton, and table tennis. To date, significant advances have been made in understanding of coincidence anticipation with respect to practice effects, gender, and expert-novice difference. However, there are only a very few studies that were aimed to point out the differences or similarities of coincidence-anticipation timings among different sport types. As the time to anticipate the location of arrival ball or shuttlecock is different for tennis, badminton, and table tennis players, it was hypothesized that coincidence-anticipation timing acuity of players would be different in these sports with the change of different stimulus velocities.

METHOD

Participants

The total of 90 players (15 girls, 15 boys for each sport) from tennis, badminton, and table tennis participated to this study. As there are some factors that could affect coincidence-anticipation timing accuracy (e.g., developmental effect (Bard, Fleury, Gagnon, Michaud, Teasdale, & Proteau, 1995) and expert-novice differences (Benguigui & Ripoll, 1998), deliberate sampling strategy was used. Coincidence-anticipation timing improves continuously with age, thus, minimum age of the participants was set at 10 years. In order to limit the effect of expertise, the participants with a minimum of three years of sport experience in their sports were recruited. To ensure homogeneity, all participants' weekly practice time was set as three days per week and the group had equal representation by boys and girls. Participants in each racket sport were in a pre-competition regional camp for the category of under age 15 years. The mean age and playing experience of 30 tennis players were 12.4 yr. ($SD = 1.4$) and 3.65 yr. ($SD = 0.46$), respectively. The mean age and playing experience of 30 badminton players were 12.5 yr. ($SD = 1.4$) and 3.5 yr. ($SD = 0.5$), respectively. Finally, the mean age and playing experience of 30 table tennis players were 12.4 yr. ($SD = 1.16$) and 3.5 yr. ($SD = 0.49$), respectively. The exact nature of the experiment aim was explained to each participant prior to the data collection.

Apparatus

A Bassin anticipation timer device (Lafayette Instrument Co., Model 50575) was used to measure coincidence-anticipation timing accuracy of the players. This device is widely used in the measurement of coincidence anticipation (Magill, Chamberlin, & Hall, 1991; McNevin, Magill, & Buckers, 1994; Williams, *et al.*, 2002; Coker, 2005). In the review by Sanders (2011), it is documented that 29 studies used this device from 1980 to 2011. Moreover, Abernethy and Wood (2001) examined the effect of various training programs on sport-specific motor performance and found the Bassin anticipation timer to be a valid assessment for comparing anticipation timing and sport performance for both males and females. The reliability of the Bassin runways was tested by Nettleton and Smith (1980) and found reliable at various stimulus velocities.

The Bassin anticipation timer has three sections of runway (2.24 m) with the system's LED lights (49 lamps). The first lamp was a yellow warning-light and the remaining 48 were red movement-simulating lights. The runway was connected to a controller that caused the lights to turn on and off sequentially down the length of the runway. A button is used to respond anticipating the arrival of the light at the target lamp. The sequentially lighted LED lamps illuminate in a linear pattern and are designed to give the appearance of a moving stimulus coming toward the participants. The stimulus "velocity" is determined by how rapidly the lights were turned on and off. The runway sections were mounted on two tripods and the lights were 1 m from the floor. The players were seated 2 m away from the center of the device directly in front of and facing to the target light (the last light in the runway). Warning light times about the impending trials were set as random on the device, between 0.5 and 3 sec. (Lyons, *et al.*, 2008).

Procedure

In line with the previous studies (Durey & Seydel, 1994; Chen, *et al.*, 2009; Iino & Kojima, 2009), athletes of different sports typically have different amounts of time to prepare for the return shot after the opponent hits the ball or shuttlecock in tennis, badminton, and table tennis. This prediction is based on the speed of the ball and the playing area (see introduction for details). Normally, stimulus velocities in Bassin anticipation timer device should have been set as 2, 4, and 6 m/sec. for these three sports, respectively.[3] The pilot test with the 6 m/sec. were too quick and responses were unreliable in the age group selected (10–15 years of age) (Iida, Miyazaki, & Uchida, 2010) for the present study. Therefore, the stimulus velocity requirements were adjusted as 1 m/sec., 3 m/sec., and 5 m/sec. (low, moderate, and high) for the three sport groups. Coincidence-anticipation timing was measured with these three different speeds among all players. Considering the length of the Bassin anticipation timer runway and stimulus velocities, participants had 2.2 sec., 0.7 sec., and 0.44 sec. duration between the first red light illuminating and the end light for the low, moderate, and high stimulus velocities, respectively. Half of the players (15 players) in each sport type was tested in the order 1, 3, and 5 m/sec. stimulus velocities and the other half was tested in the opposite order so as to prevent an effect of task difficulty.

Following five practice trials, each participant performed 30 trials at each stimulus velocity. To avoid fatigue a rest period of 3 min. was given between the blocks of three different stimulus velocities (Millslagle, 2004). The measurement was performed in a dark room with a single participant. Players were asked to anticipate the light reaching the target and

[3]Note that the speed of the ball and shuttlecock stated in the introduction belong to experienced adult players.

press a button with the thumb of the preferred hand to coincide with the arrival of the light at the target. For each trial, scores were recorded in milliseconds. Participants neither received any kind of feedback after each trial or block of trials nor were they informed about the stimulus velocities. Each participant was provided standardized instructions regarding the general nature of the experiment.

Analysis

The results were expressed as the mean and standard deviations. The dependent variables were (1) absolute error (AE), the average absolute deviation of a set of scores from a target value (i.e. a measure of overall error) and (2) variable error (VE), the standard deviation of a set of scores about the subject's own average score (i.e., a measure of consistency; Schmidt & Lee, 2005). To test whether different stimulus velocities in coincidence-anticipation timing differ among three racket sports, mixed design ANOVAs with racket sports (tennis, badminton, and table tennis) as the between-subjects variable and stimulus velocities (low, moderate, and high) the within-subjects variable were conducted separately for absolute error and variable error. Pairwise comparisons were adjusted by Bonferroni corrections. JMP software was used for all statistical calculations. Statistical significance was set as $p < .05$.

Results

Absolute Error

The assumptions (normality, homogeneity, and sphericity) were checked for the mix design ANOVA for absolute error. The normality and homogeneity tests were satisfactory. However, the assumption of sphericity was not satisfied (Mauchly's $W_{(2)} = 0.88$, $p < .005$). The Greenhouse-Geisser correction was applied. The mixed design ANOVA (racket sports: between variable and stimulus velocities: within variables) was conducted to test whether coincidence-anticipation timing accuracy was different between three racket sports (tennis, badminton, and table tennis) within three stimulus velocities (low, moderate, and high). The result of this analysis indicated a significant interaction of stimulus velocities and racket sports ($F_{3.58,155.8} = 290$, $p < .001$, $\eta^2 = 0.87$; Fig. 1). *Post hoc* analysis revealed that tennis players had significantly less absolute error than both badminton and table tennis players at the low stimulus velocity (1 m/sec.), respectively. Badminton players, in contrast, showed less absolute errors than both tennis and table tennis players in the moderate stimulus velocity (3 m/sec.), respectively. Finally, table tennis players displayed less absolute errors than both tennis and badminton players in the high stimulus velocity (5 m/sec.), respectively. Considering the within-groups analysis, tennis players displayed superior coincidence-anticipation timing accu-

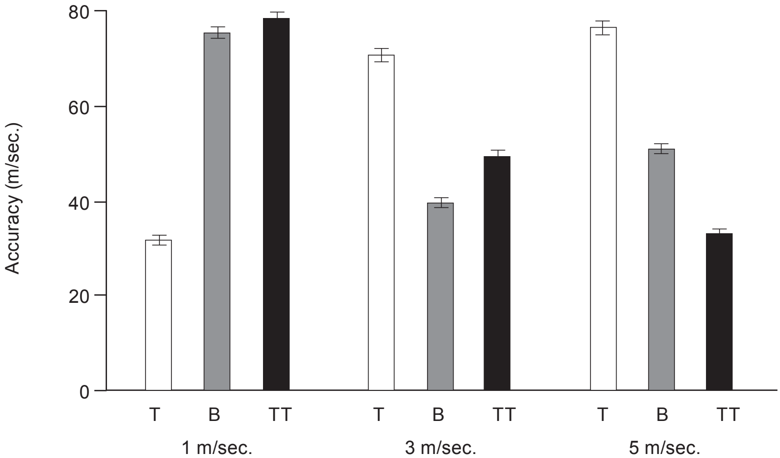

FIG. 1. Coincidence anticipation timing accuracy (absolute error) in three stimulus velocities for tennis, badminton, and table tennis players. T = Tennis (□); B = Badminton (■); TT = Table Tennis(■). Error bars represent standard errors.

racy performance in the low stimulus velocity compared to moderate and high stimulus velocities, badminton players displayed superior coincidence-anticipation timing accuracy performance in the moderate stimulus velocity compared to low and high stimulus velocities, and table tennis players displayed superior coincidence-anticipation timing accuracy performance in the high stimulus velocity compared to low and moderate stimulus velocities (see Table 1).

Variable Error

The assumptions (normality, homogeneity, and sphericity) were checked for the mixed design ANOVA for variable error. Although the normality and homogeneity tests displayed satisfactory results, the assumption of sphericity was not satisfied (Mauchly's $W_{(2)} = 0.97$, $p < .001$). Similar to the analysis for absolute error, a Greenhouse-Geisser correction was used. The mixed design ANOVA (racket sports: between variable and stimulus velocities: within variables) was conducted to test whether coincidence-anticipation timing consistency differed between three racket sports (tennis, badminton, and table tennis) at three stimulus velocities (low, moderate, and high). Similar to absolute error, the result of the analysis for variable error indicated a significant interaction of stimulus velocities and racket sports ($F_{3.4,\ 146.4} = 27.18$, $p < .001$, $\eta^2 = 0.25$; Table 1, Fig. 2).

Post hoc analysis for variable error revealed a similar trend to the results reported for the absolute error. Namely, tennis players had significantly less variable errors than both badminton and table tennis players at

TABLE 1

Absolute and Variables Errors by Group and Stimulus Velocity, With *Post Hoc* Comparisons by Group and Stimulus Velocity

Group	Velocity, m/sec.	Absolute Error, msec.		*Post hoc* velocity comparisons	Variable Error, msec.		*Post hoc* Velocity Comparisons
		M	*SD*		*M*	*SD*	
Tennis	1	31.4	10.4	1 < 3†, 5†	3.14	1.1	1 < 3†, 5†
	3	70.4	15.8		5.12	1.7	
	5	76.2	18.8		5.40	2.1	
Badminton	1	75.2	12.6	3 < 1†, 5†	7.50	1.6	3 < 1†, 5*
	3	39.3	10.8		3.96	1.8	
	5	50.8	12.5		4.50	1.9	
Table tennis	1	78.3	15.8	5 < 1†, 3†	7.80	1.8	5 < 1†, 3†
	3	49.3	11.7		4.20	1.7	
	5	33.0	9.8		3.60	1.2	
Post hoc group comparisons		Low: T < B†, TT† Moderate:B < T†, TT† High: TT < T†, B†			Low: T < B†, TT† Moderate: B < T† High: TT < T†, B†		

Note.—T = Tennis, B = Badminton, TT = Table tennis. *$p < .01$. †$p < .001$.

the low stimulus velocity (1 m/sec.), respectively. Badminton players had lower variable error than tennis players, but no difference was found with table tennis players at the moderate stimulus velocity (3 m/sec.), respectively. Finally, table tennis players displayed less variable errors than both

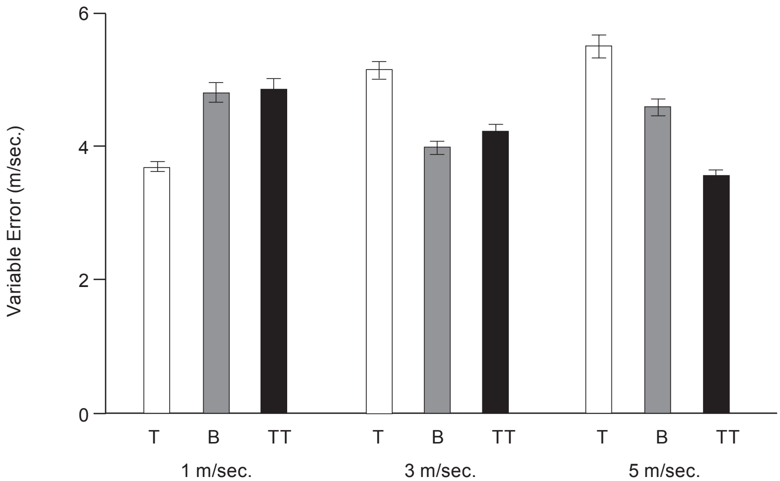

Fig. 2. Coincidence anticipation timing variable error in three stimulus velocities for tennis, badminton, and table tennis players. (T = Tennis, B = Badminton, TT = Table Tennis). Error bars represent standard errors.

tennis and badminton players at the high stimulus velocity (5 m/sec.), respectively. Considering the within-groups analysis, tennis players displayed superior coincidence-anticipation timing consistency performance in the low stimulus velocity compared to moderate and high stimulus velocities; badminton players displayed superior coincidence-anticipation timing consistency performance at the moderate stimulus velocity compared to low and high stimulus velocities, and table tennis players displayed superior coincidence-anticipation timing consistency performance in the high stimulus velocity compared to low and moderate stimulus velocities.

Discussion

One of the important processes in the performance of open skills is to anticipate or to predict the arrival of a moving object (Rothstein & Wughalter, 1987), which in turn, contributes to success in many sports (Molstad, Kluka, Love, Baylor, Convington, & Cook, 1994). This case is particularly important in externally paced sports containing uncertainty like racket sports (Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996). However, considering the distance between players and the speed of the ball or shuttlecock, each racket sport may require different coincidence-anticipation timing and players need to be more precise in this perceptual ability. Therefore, the focus of this study was to test coincidence-anticipation timing accuracy and consistency at three different stimulus velocities (low, moderate, and high) in tennis, badminton, and table tennis players.

Similar to previous studies (Williams, *et al.*, 2002; Ak & Koçak, 2010), a significant advantage of coincidence-anticipation timing accuracy and consistency was observed under the low stimulus velocity in tennis players when compared to badminton and table tennis players. Considering the velocity of the ball and the distance between players, tennis players should have more experience with and perform better at the lower stimulus velocity; the results supported this statement. Tennis players had lower coincidence-anticipation timing accuracy under the moderate and high stimulus velocities compared to the low stimulus velocity. The average playing experience of tennis players was approximately 3.5 yr., and it is plausible that visual and motor systems of tennis players adapt to lower velocity during this time. Such adaptations may be specific to each sport and also develop in individuals as they gain experience and expertise in the sport.

Badminton players showed better accuracy and consistency on coincidence-anticipation timing under the moderate stimulus velocity compared to tennis and table tennis players. Considering the speed of the shuttlecock (Tsai, *et al.*, 1997; Chen, *et al.*, 2009) and the distance between players, experienced badminton players have nearly 0.5 sec. to prepare for the return shot after the opponent hits the shuttlecock. In this study, badminton players showed superior coincidence-anticipation timing accuracy and consistency performance when the stimulus velocity was 3 m/sec. Time to anticipate the arrival stimulus at the target was almost 0.7 sec. Considering the age of badminton players in this study, this duration is very close to required time to get ready for the return shot in a real badminton game situation. This can explain why badminton players showed superior performance under this speed requirement.

Comparing with tennis and badminton, table tennis should require the fastest responses. This is based on the distance between players and speed of the ball (Durey & Seydel, 1994). Consistent with this idea, the results of coincidence-anticipation timing accuracy and consistency for table tennis players displayed better performance under the high stimulus velocity compared to tennis and badminton players. Although Ak and Koçak (2010) found better coincidence-anticipation timing accuracy in tennis players compared to table tennis players, they had used a single constant stimulus speed. In the current study, tennis and table tennis players displayed superior performance under different stimulus velocity requirements (low stimulus velocity for tennis and high stimulus velocity for table tennis). Some studies reported that both young children and adults display worse performance on coincidence-timing tasks when the stimulus velocity varies from trial to trial during an experimental session (Wrisberg & Mead, 1983; Gagnon, Bard, & Fleury, 1990; Millslagle, 2008). Although stimulus velocities were not varied from trial to trial during each experimental session, significant coincidence-anticipation timing accuracy and consistency differences were observed among groups of three racket sports players in this study. Haywood, Greenwald, and Lewis (1981) suggested that children might assimilate the various velocities to an average velocity that would correspond to the stimulus's velocities on previous trials. If the visual and motor systems of players from these racket sports adapt to different stimulus velocities in coincidence-anticipation timing, it may be difficult to deal with slower or faster velocities.

In conclusion, coincidence-anticipation timing performances of tennis, badminton, and table tennis athletes were found to be different. Since coincidence-anticipation timing has been used as a perceptual and motor test in assessing the improvements of athletes and also for talent identification (Ripoll & Latiri, 1997), it is important to note that trainers and coaches should use sport-specific stimulus velocities when testing coincidence-anticipation timing. Longitudinal studies are needed to explore whether coincidence-anticipation timing performance with different stimulus velocities changes over the course of development in players of these racket sports. More research is certainly needed to investigate whether the similar findings could be observed in sports that require catching (i.e., baseball, American football, basketball, team handball, etc.). Future research could also focus on investigating other sources of information to anticipate the speed of the ball (or shuttlecock) before it is actually struck by the opponent. As these racket sports require different patterns of swing, future studies should also investigate whether swing pattern influences coincidence-anticipation timing. In their practice regime, for instance, if teachers and coaches use a ball-tossing machine, they should implement different types of ball speed for the players. By doing this, players will be able to acquire experience with different ball speeds which can improve coincidence-anticipation timing accuracy.

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