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HOW DO TASK, EXPERIENCE AND TYPE OF STIMULI CONSTRAINT REACTION TIME IN SCHOOL-AGED INDIVIDUALS?

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ABSTRACT

This study show how reaction time varies according to organismic, environmental and task constraints. The reaction time (RT) and movement time (MT) of thirty-six adolescents with different sport experience (football, tennis players and sedentary individuals) were measured. Participants faced with non-sport related auditory and visual stimuli, and with specific tennis and football visual stimuli (FVS). All the participants were asked to respond with the upper and lower limb. Football players showed shorter RT than sedentary individuals responding with their lower limb and shorter MT aimed to the non-dominant side in FVS. Auditory and FVS caused shorter RTs, with no differences between them, particularly for football players. RT is influenced by organismic and task constraints and by the way the individuals face the task and perceive their opportunities of action. These factors should be taken into account to assess perceptive responses, and to design tasks directed to improve sport reaction skills.

Key words: motor control, performance, team sport, measurement

¿CÓMO LA TAREA, LA EXPERIENCIA Y EL TIPO DE ESTÍMULO CONSTRIÑEN EL TIEMPO DE REACCIÓN EN INDIVIDUOS EN EDAD ESCOLAR?

RESUMEN

Este estudio muestra cómo el tiempo de reacción varía en función de los constreñimientos del organismo, el ambiente y la tarea. Se midió el tiempo de reacción (RT) y tiempo de movimiento (MT) de treinta y seis adolescentes con diferente experiencia deportiva (jugadores de fútbol, tenistas y sedentarios). Los participantes se enfrentaron ante estímulos no deportivos auditivos y visuales, y ante estímulos específicos de tenis y fútbol (FVS). Todos los participantes tuvieron que responder tanto con sus miembros superiores como con los miembros inferiores. Los jugadores de fútbol mostraron menores RT que los sedentarios cuando respondieron con sus miembros inferiores y menor MT acentuado en respuestas con el lado no dominante en FVS. Estímulos auditivos y FVS obtuvieron los menores RT, sin diferencias entre ellos, y sobre todo en jugadores de fútbol. RT es influido por los constreñimientos del organismo y la tarea y por la forma en que cada individuo se enfrenta a la tarea y percibe sus oportunidades de acción. Estos factores deben tenerse en cuenta para evaluar las respuestas perceptivas y diseñar tareas dirigidas a la mejora de las habilidades deportivas de reacción.

Palabras clave: control motor, rendimiento, deporte de equipo, medida

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INTRODUCTION

Many authors state that successful performance in sport requires not only efficient execution of motor behaviour, but also a high level of perceptual abilities, especially in team sports or in sports with an opponent (Mori, Ohtani & Imanaka, 2002). These athletes must face spatial and temporal constraint situations imposed on the performer by the environment, the opponent and the game regulations (Williams, Davids & Williams, 1999). The characteristics of sports entail the need of a fast and accurate response to the demands of the environment, and consequently, one of the most widely used tools in the study of perceptive response has been reaction response.

Previous studies in which reaction response has been assessed have frequently taken three temporal parameters of the response into consideration: response time (RT), movement time (MT) and the sum of both parameters, reaction response (RR). All these components have been identified as potential variables influencing on sport performance (Williams, Davids &Williams, 1999).

Researches on this issue have analysed how different variables affect RT. For example, some studies have stated that age can be a factor to be taken into consideration, so that RT reaches the lowest values between 15-25 years of age and then starts to decrease (Ashoke, Shikha, & Sudarsan, 2010; Der & Deary, 2006). Regarding gender, literature shows contradictory results, as some studies state that men show better results than women, attributing these differences to neuromuscular and neurophysiologic factors, such as strength or cognitive strategies (Heirami et al., 2012; Der & Deary, 2006). Some authors attribute these differences to the participant's physical condition level and experience in sport situations or in reaction response situations (Davrenche, Audifren & Denjeam, 2006; Yagi et al. 1999), in the same way that lower reaction times can be seen in experts compared with novel athletes (Mann et al., 2007; Wang et al., 2013). On the other hand, differences between men and women decrease when faced with visual stimuli and verbal response (Spierer et al., 2010; Spiteri, Cochrane, & Nimphius, 2013), so consequently the type of stimuli and the characteristics of the response can influence the RT.

The studies that have compared RT when faced with stimuli with different physical characteristics (e.g. auditory or visual) have shown certain controversy. As while some studies state that the best RT values are obtained with auditory stimuli (Ashoke, Shikha, & Sudarsan, 2010; Pain & Hibbs, 2007), others obtained lower values when faced with visual stimuli (Tejero, Soto-Rey, & Rojo-González 2011; Spierer et al., 2010; Yagi et al. 1999).

The differences found in the literature, depending on the sport experience, the characteristics of the stimuli and the task are probably a consequence of the way in which each individual faces the reaction time conditions, perceiving and responding according to the opportunities for action – affordances – provided by the environment characteristics (Gibson, 1986). The environmental affordances can lead to different responses depending on the subject's characteristics and on the task, in an inseparable perception-action process. In this way different stimuli may offer similar responses, and same characteristic stimuli may offer different responses. Due to all this, the responses will be influenced by the specific constraints of the individual, the environment and the task (Davids, Button & Bennett, 2008).

Researches on RT in sport, nevertheless, have frequently used decontextualized types of stimuli not related with sport practice. Furthermore, they mainly evaluated responses carried out by the upper extremity in fine motor control movement tasks –such as pressing a button with a finger– which does not imply great muscle groups. These situations are quite distant from sport practice, being less numerous the studies that analyse the response with the lower limbs (Spiteri, Cochrane & Nimphius, 2013). Currently, the development of new technologies allows the implementation of new devices for the measurement of RT, allowing an approach to a more real context. The use of stimuli and responses related to the specific sport, would provide trainers with indexes on cognitive or athletic abilities of their athletes which can help them to focus their training (Spiteri, Cochrane & Nimphius, 2013).

The aim of the present study is to analyse to what extent the reaction response is conditioned by the specificity of the stimuli situations, the experience of the participant and by the type of response to be issued. In order to do so, reaction response shall be compared in different tasks (upper and lower limbs) when faced with auditory and non-sport related visual stimuli (AS and NVS) and with specific visual stimuli in two sports such as football and tennis (FVS and TVS respectively). These situations will be measured in young players in the aforementioned sports and age-matched people with no sport experience (sedentary individuals).

In this way, the objective is to examine if the difference in the reaction response in the presence of different stimuli conditions (auditory, non-sport related visual stimuli and specific sport visual stimuli) are influenced by the experience of the participant (sedentary individuals or sport players) and by the type of response (response with lower or upper limbs).

METHOD

Participants

Thirty-six adolescents (M_{age} = 16.28 ± 1.02 years) with different sport experience (M = 8.25 ± 2.92 years) took part in the study. Twenty-four of them practiced sport activities (12 football, 12 tennis) with frequency of of at least three sessions per week for at least three years prior to the study. Twelve adolescents with no sport experience (except the PE classes at school) took part in the study, out of which two did not complete it.

Participants did not show visual problems nor did they have any type of injury in their upper or lower limbs. Written informed consent form was completed by the legal guardian of each participant prior to testing. The experimental procedures used in this study were in accordance with the Declaration of Helsinki and were approved by the ethics standards of the committee on Human Experimentation of the hosted institution.

Instruments

Data of the parameters of the reaction response were gathered using an automated system designed for this purpose. To measure upper limb response (Figure 1a), participants were placed in front of a table with a height of 0.76 m, on which they placed the palms of their hands on two contact sensors (0.20 x 0.15 m each one, and separated from each other by a 0.02 m distance). After the stimuli was shown they had to hit one of two sensors which were adjoining and lateral to the first ones, the centres of which were placed at 0.16 m to the left and to the right of the previous sensors (0.24 x 0.14 m).

To measure lower limb response (Figure 1b), the participants were placed standing on two contact sensors (0.42 x 0.20 m). Two targets, consisting in two more contact sensors (0.20 x 0.20 m), were placed on both sides, the centres of which were located 0.2 m to the right and left and at 0.32 m forward regarding the first two sensors. After the stimuli appeared, the participant had to step on one of the sensors in the lesser time possible. The images were shown via an EB-S02 projector (Seiko Epson Co. Tokio, Japan). In both situations, the participant was placed at a distance of 3 m from the screen (0.63 x 1.12 m size).

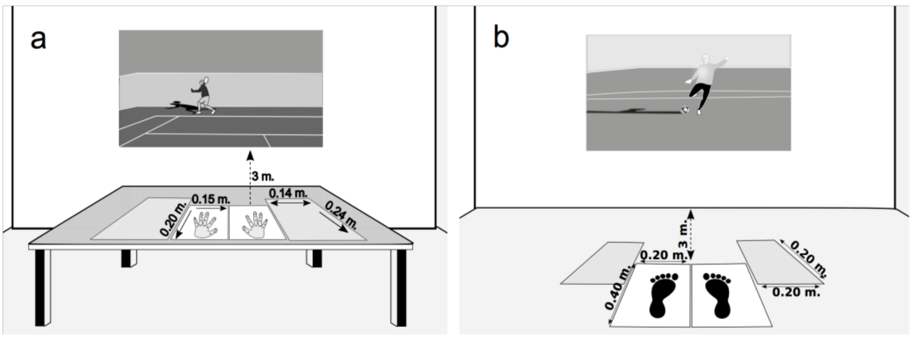

FIGURE 1: Experimental set up in which a) demonstrate measuring upper limb response and b) demonstrating Measuring lower limb response.

Data acquisition was carried out LabVIEW 2011 (National Instruments Co. Austin, Tx, USA) on a personal computer connected to the sensors at 1000HZ sampling frequency. RT was measured from the moment the stimuli appeared until the body segment that carried out the response separated from the contact sensor. MT was measured from the moment the movement was initiated until the sensor to the right or to the left was hit by the participant. The sum of both parameters gave the RR.

Procedure

Participants carried out a test to asses their RT when faced with four stimuli conditions, two of which were stimuli non related to sports: auditory stimuli (AS) and visual stimuli (NVS); and the other two were specific sport stimuli recorded on video which corresponded to the gesture of hitting a ball in tennis (TVS) and of kicking a ball in football (FVS). The participants were asked to respond with the upper limbs or with the lower limbs in different series of trials.

In the AS situation the stimulus was a brief sound (90 dB). The NVS situation, a yellow dot (10 cm in diameter) on a black background appeared either to the right or to the left of the participants. In both situations, the stimuli was shown after a visual 3 second countdown and a random fore-period of between 0.5 and 1.5 seconds.

To acquire FVS and TVS tapes, two professional football players and two professional tennis players, were filmed. In the FVS situation, penalty kicks to the left and to the right of the goalkeeper were filmed from the goalkeeper’s perspective. In the TVS situation, parallel and cross tennis shots from the baseline were filmed from the perspective of a tennis player who has come up to the net to volley.

Each measuring session consisted in five series of trials. One first series of 10 warm-up trials combined different stimuli situations. After the warm-up, the participants performed 18 trials for each situation NVS, FVS and TVS (half of the trials aimed at the non-dominant side). In the AS situation 9 trials were carried out only on the dominant side. All the participants performed two measuring sessions, one for the upper limb and one for the lower limb, completing 146 trials (2 x 73 trials) including warm-ups.

The order of the stimuli situations (AS, NVS, FVS, TVS) and the type of response (upper limb and lower limb) were counterbalanced. The video sequences were randomly selected for the player that appeared in the images, and for the direction of the response (dominant and non-dominant side).

Participants were instructed to place themselves in the same initial position and to respond fast and accurate on the area designated for the response.

Statistical analysis

Statistical treatment of the data was carried out using a statistical software package SPSS v.20 (IBM Co. Armonk, NY, USA). To avoid outlier effects, every value that differ by twice the standard deviation or more from the mean on each participant's series, were excluded. The trials in which the response was erroneous and those series in which the participants made more than 15% of errors were also excluded.

The normality of the variables was evaluated using the Kolmogorov_Smirnov test with Lilliefors correction. To observe the effects of the variables analysed, a two-way mixed ANOVA was conducted with experience (sedentary individuals vs. tennis players vs. football players) as a between-groups factor and two within-participants factors: stimulus (AS vs. NVS vs. FVS vs. TVS) and response (upper limb vs. lower limb). Post hoc analyses with the Cheffé procedure were conducted to assess significant differences. Statistical significance was set at $p < .05$.

RESULTS

Figure 2 shows mean values in RT, MT and RR for each research group and for each stimuli situation. Regarding RT (Figure 2a), differences only appeared in FVS situations between the football players and sedentary individuals, in which football players showed lower RT levels when the response comes from the lower limb ($F(2, 24) = 3.91$, $p < .05$; $\eta^2 = .246$). The main differences between groups appear in MT (Figure 2b), but only when the response was carried out by the lower limb. The tennis players were the participants that obtained the best results, significantly lower than the sedentary individuals in AS ($F(2, 28) = 4.47$, $p < .05$; $\eta^2 = .242$), NVS ($F(2, 31) = 6.20$, $p < .01$; $\eta^2 = 0.286$), TVS ($F(2, 25) = 9.16$, $p < .01$; $\eta^2 = .423$) and in FVS, in which they also show lower values than football players ($F(2, 24) = 5.97$, $p < .01$; $\eta^2 = .332$). Football players only showed MT values lower than sedentary individuals in NVS and TVS. When analysing the response in function of laterality, the differences when compared with the sedentary participants arise when the response is performed by the non-dominant limb (NVS: $F(2, 31) = 5.17$, $p < .05$; $\eta^2 = .250$, FVS: $F(2, 24) = 5.38$, $p < .05$; $\eta^2 = .310$, TVS: $F(2, 25) = 11.50$, $p < .001$; $\eta^2 = .479$).

Regarding RR (Figure 2c), football players showed better results than sedentary individuals when faced with FVS in their response with their upper limb ($F(2, 26) = 4.70$, $p < .05$; $\eta^2 = .265$). When the response was performed with their lower limb, these differences were significant when the non-dominant body segment was used (upper limb: $F(2, 24) = 4.86$, $p < .01$; $\eta^2 = .288$, lower limb: $F(2, 24) = 6.11$, $p < 0.05$; $\eta^2 = .337$).

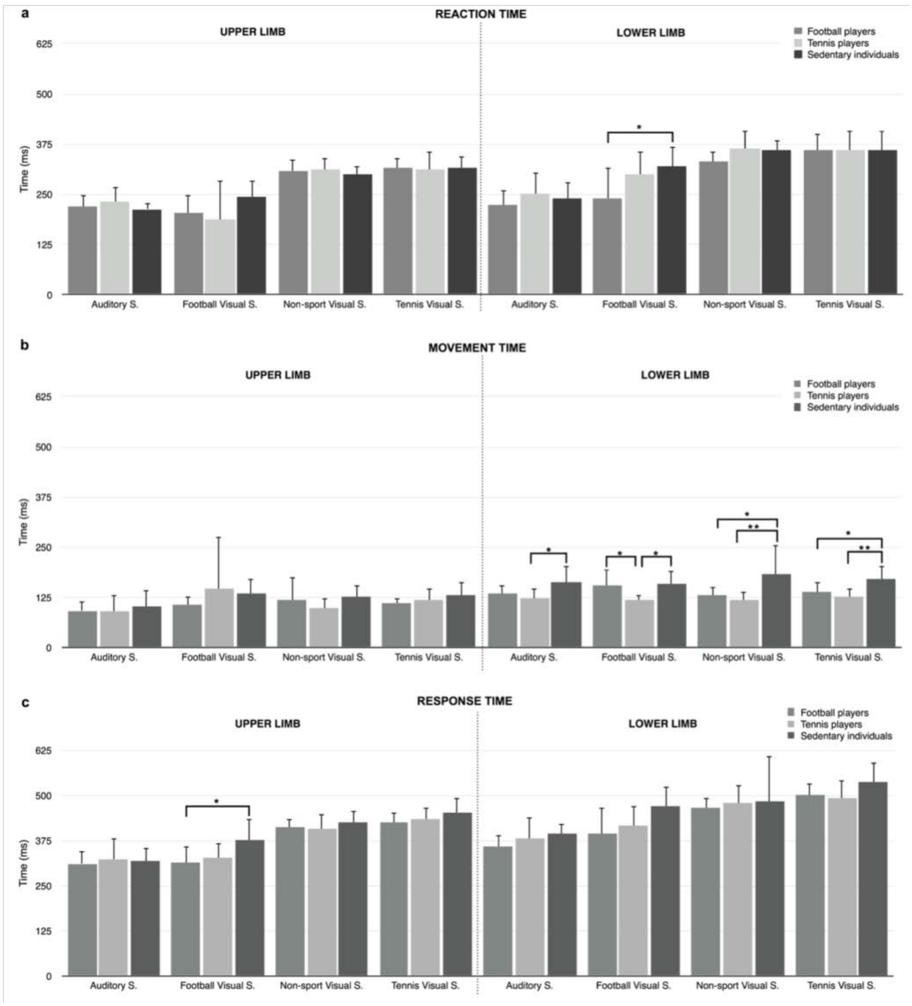

FIGURE 2: Mean values and standard deviation of reaction time (a), movement time (b) and reaction response (c) in the experimental situations specific to the body segment used to perform the response (upper limb at the left and lower limb at the right). S. = stimuli. * p < .05, ** p < .01.

Table 1 shows values obtained by each group in RR in each experimental situation and differentiated by the body segment that performed the response. To facilitate data comprehension Table 2 has been added, showing RT, MT and RR differences, and the relations between different stimuli situations for the entire sample are arranged differentiating between experimental groups and body segment used.

Both for the upper limb and for the lower limb, the best RR values were those obtained in the AS followed by FVS situations. The situations in which the highest times were obtained were in NVS and TVS situations (TVS showing the slowest times in the lower limb response). Analysing these relations by groups, we can highlight that both tennis players and football players showed no differences in AS and FVS situations.

TABLE 1
Mean reaction response values and standard deviations showed by each group in the experimental situations, with the body segment used to perform the response (upper limb and lower limb). Values expressed in milliseconds.

Group	Response	AS	NVS	FVS	TVS
Football players	Upper	311.43 ± 31.60 NT	412.29 ± 22.63	314.16 ± 43.88 NT	427.71 ± 23.65
	Lower	358.19 ± 32.78 NT	466.90 ± 24.66 T	395.65 ± 69.12 NT	503.31 ± 29.80
Tennis players	Upper	321.61 ± 60.62 NT	408.71 ± 39.81	326.25 ± 40.14 NT	432.45 ± 31.17
	Lower	380.36 ± 56.63 NT	481.26 ± 48.11	418.48 ± 53.30 NT	493.02 ± 48.74
Sedentary individuals	Upper	316.44 ± 37.42 NFT	425.54 ± 31.54 T	376.61 ± 55.80 NT	452.47 ± 40.39
	Lower	395.10 ± 27.93 NFT	484.28 ± 124.78	470.50 ± 53.45 NT	539.09 ± 51.55
Total	Upper	316.50 ± 44.26 NFT	414.92 ± 31.95 T	337.71 ± 52.51 NT	437.22 ± 33.07
	Lower	375.10 ± 44.10 NFT	477.08 ± 72.67	426.29 ± 64.60 NT	510.77 ± 48.06

AS = auditory stimuli; FVS = football visual stimuli; NVS = non-sport related visual stimuli; TVS = tennis visual stimuli; F = significant differences regarding EVF (p < .05); N = significant differences regarding NVS (p < .05); T = significant differences regarding EVT (p < .05).

RT shows similar results to those shown for RR. Football players showed no differences between AS and FVS, although the other two groups showed differences when faced with these two situations when they responded with their lower limb. NVS and TVS situations showed no differences between them (except for football players with their upper limb and for sedentary participants with their lower limb). Regarding MT, no differences were appreciated between the stimuli situations when the response was performed with the lower limb. In the responses with the upper limb, all groups showed lower MT in AS situations.

TABLE 2
Relations between different stimuli situations as it relates to reaction time (RT), movement time (MT), and reaction response (RR) for all experimental groups, related to body segment used (upper limb and lower limb).

Group	Response	RT	MT	RR
Football players	Upper	AS, FVS < NVS, TVS	AS < TVS	AS, FVS < NVS, TVS
	Lower	AS, FVS < NVS < TVS	AS, FVS, NVS, TVS	AS, FVS < NVS < TVS
Tennis players	Upper	AS, FVS < NVS, TVS	AS < FVS & NVS < TVS	AS, FVS < NVS, TVS
	Lower	AE < FVS < NVS, TVS	AS, FVS, NVS, TVS	AS, FVS < NVS, TVS
Sedentary individuals	Upper	AS, FVS < NVS < TVS	AS < FVS, NVS, TVS	AS < FVS < NVS < TVS
	Lower	AS < FVS < NVS, TVS	AS, FVS, NVS, TVS	AS < FVS < NVS, TVS
Total	Upper	AS, FVS < NVS, TVS	AS < FVS, NVS, TVS	AS < FVS < NVS < TVS
	Lower	AS < FVS < NVS, TVS	AS, FVS, NVS, TVS	AS < FVS < NVS, TVS

Less-than and greater-than signs mean the direction of the significant differences (p < .05) between experimental situations. Comma symbol means no differences.

AS = auditory stimuli; NVS = non-sport related visual stimuli; FVS = football visual stimuli; TVS = tennis visual stimuli.

DISCUSSION

In the present study, we analysed to what extent reaction response was conditioned by the individual's experience (sedentary and sport trained individuals), the specificity of the stimuli situations (auditory, visual or sport-related visual stimuli), and the type of response issued (execution with the upper limbs or with the lower limbs). For this, several young sportspeople who practiced tennis and football and sedentary adolescents were measured under different conditions.

Regarding the individual's experience, the data showed that the results obtained in the RT and the RR were better for the sportspeople when compared with the sedentary individuals. These differences were only significant in the FVS, in which the football players obtained better RT, when the response was performed with the lower limb. These results agree with those by Heraimi et al. (2012), who compared RT using a Lafayette test between elite athletes and novel athletes, showing that the expert athletes obtained better reaction times than the novel athletes. Similar conclusions were obtained by Wang et al. (2013) analysing tennis players and sedentary individuals, although they state that the differences occurred when the stimuli were presented after short fore-periods, when uncertainty was higher and they had a shorter preparation time. Mann et al (2007) confirm these data in a meta-analysis and they suggested that expert sportspeople could respond approximately a 35% faster than sedentary people.

Ashoke, Shikha & Sudarsan (2010) observed that adolescents between the ages of 15-18, as is the case of the sample in this study, showed their best results in RT compared with people in previous or later stages in their growth, which could minimize the differences found. On the other hand, the differences found in MT in situations in which the response was performed with the lower limb, could favour the football and tennis players when compared with the sedentary individuals, and it can be understood as an index that they show a superior physical condition. In this sense, Wang et al. (2013) compared reaction time depending on the aerobic fitness between sedentary individuals, tennis players and swimmers, finding that tennis players showed lower RT values than sedentary individuals and no differences were found when compared with the swimmers. In this study, they suggested that these differences are due to sport practice and aerobic training, which improve the cerebral functions implied in reaction ability (Wang et al. 2013). In the same line was the study by Davrenche, Audifren & Denjeam (2006), who linked these differences to the higher muscular demands in the lower limb responses. Spiteri, Cochrane & Nimphius (2013) suggested that a deficit in the MT in sportspeople would be a consequence of a lack of strength and power in the lower body and it would be an index to the necessity for a specific work on these qualities.

In our study, the lowest values of MT in the sportspeople can be seen in the responses with the non-dominant lower limb, which could be due to a higher coordination capacity of the sportspeople as a consequence of training and sport experience. The responses required lateral movements similar to those performed in the sport actions of the disciplines practiced by the individuals with which they would be more familiarized. Mori, Ohtani, & Imanaka (2002) observed that the differences between expert and novel sportspeople were maximized in the non-dominant body segments, although these authors only measured the responses provided by the upper limbs. These differences encountered should be taken into account for future research in which dominant and non-dominant body segments should assessed.

One of the main objectives of this study has been to study if the differences in reaction responses between participants were influenced apart from the experience of the participants, by the characteristics of the response and the stimuli conditions. Previous researches have studied the influence of the type of stimuli in the RT, mainly comparing auditory stimuli against visual stimuli. In this sense, classical studies stated that the auditory reaction time varies from 140 to 160 ms, while the visual reaction time varies from 180 to 200 ms (Welford, 1980). The predominance of auditory neural path postulated by early studies supported that the auditory stimuli need between 8 to 10 ms to reach the brain while the visual stimuli need between 20 and 40 ms (Marshall et al., 1943; Kemp et al., 1973). Nevertheless, these statements have recently been questioned as the auditory neural path has a higher number of synapses than the visual one and furthermore it has more chemical type synapses, which imply a delay in the transmission of the nervous impulse and higher reaction times (Tejero, Soto-Rey & Rojo-González, 2011). Taking into account the global results of this study, the auditory stimuli induce shorter reaction responses than the rest of the visual stimuli. The results agree with those by Ashoke, Shikha, & Sudarsan (2010), who analysed the RT in a sample of 800 individuals from different age groups (5 to 70 years of age) or those by Pain & Hibbs (2007) who analysed young athletes in speed trials. In both studies participants obtained better values in RT in the presence of auditory stimuli when compared to visual stimuli.

Nevertheless, analysing the results by groups, we found these differences varied depending on the experience of the participants. Football players and tennis players showed no differences in RR and RT when the situations with auditory and specific football visual stimuli were compared (except in tennis players in lower limb response, which showed lower RT in AS). The absence of differences between AS and FVS could be due to the fact that perception in certain environmental conditions can cause responses which are as fast in complex situations as those that can be found when confronted with simple stimuli responses. FVS situations would be rich with specific information related to the response with action-relevant properties of the environment, having as a consequence a response with the upper limb as fast as when faced with an auditory stimuli not specifically aimed at a specific response. This effect is attenuated in the responses with the lower limb, possibly because they are not usual responses, except for football players who would be used to this type of responses with the lower limb and in no case show differences between AS and FVS.

Therefore, the results would confirm that both the experience and the type of stimuli determine the time invested to produce a response and reduce the differences found between AS and VS aforementioned. This could be one of the reasons why previous studies have shown controversy between those who state that auditory stimuli would obtain better RT and those who state that the visual stimuli could yield faster RT than auditory stimuli. For example, Yagi et al. (1999), who found lower visual than auditory RT in young university students, stated that these results could be conditioned by the characteristics of the test and by the different intensity of the stimuli. Spierer et al. (2010) also found that football players showed lower reaction times when confronted with a specific visual stimuli related to their sport than when they react to auditory stimuli. This effect aforementioned is not seen in TVS situations nor in the tennis players. Possibly the space and time constraints of the stimuli situation faced, such as the distance and the relative size of the tennis ball could have an influence on the response. Previous studies have shown that the size of complex stimuli affects perception and learning processes (Al-Abood et al. 2002).

The results obtained in this study seem to indicate that the differences in RT between stimuli are influenced by organismic and task constraints (experience and type of response) and by the different ways in which the individuals face the task and perceive their opportunities of action (affordances). Gibson explained this situation through the concept of direct perception (Fajen, Riley, & Turvey, 2009), as the perception that is not mediated by internal representation and can be possible if properties of the environment are specified in patterns of stimulus energy. Pepping & Li (2005) stated that when the connection between the perceptive requisites and those of the task response are more compatible, RT reduces. This means that the perceptive response is not only determined by the perceptive channel through which the stimuli arrives (auditory, visual or tactile) but that there are other factors that can determine the response and they are defined by the constraints that come from the environment, the way of acting and the experience. Therefore, these factors should be taken into account in the evaluation of the perceptive response, as in the choice of the tasks to be performed given to novel players in sport training. The selected tasks must be representative of the desired context and objective (Davids, 2012) and, therefore, the characteristics of the situation and the response must be analysed, as the stimuli are strongly linked to the needs of the response in an inseparable perception-action process. In this way, in a training process of the perceptive response, the chosen stimuli must be specific to the task (e.g., in football training it is advisable to use specific situations of striking the ball instead of unspecific stimuli, such as blowing a whistle, to improve the reaction time of goalkeepers). In the same way, responses must be the specific ones with which one would act in real sport situations (for example, it is more advisable that a goalkeeper's response involves an interception movement with a ball instead of a verbal response). Finally, the organismic constraints (age, experience, physical condition) must be taken into consideration when choosing the most adequate stimulus- in training systems adjusted to the characteristics of the individual and of the environment in order to obtain the best results possible in learning a specific sport task.

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