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ORIGINAL ARTICLE

Comparison of reaction time between beginners and experienced fencers during quasi-realistic fencing situations

MARKO MILIC[1], ALEKSANDAR NEDELJKOVIC[1], IVAN CUK[2], MILOS MUDRIC[1], & AMADOR GARCÍA-RAMOS[3,4]

[1]*Faculty of Sport and Physical Education, University of Belgrade, Belgrade, Serbia;* [2]*Faculty of Physical Culture and Sports Management, Singidunum University, Belgrade, Serbia;* [3]*Faculty of Sport Sciences, Department of Physical Education and Sport, University of Granada, Granada, Spain &* [4]*Faculty of Education, Department of Sports Sciences and Physical Conditioning, Universidad Católica de la Santísima Concepción, Concepción, Chile*

Abstract
This study aimed (I) to investigate the impact of the number of stimulus-responses alternatives on reaction time (RT) under quasi-realistic fencing situations, and (II) to elucidate whether the regression slope based on the RT and the number of stimulus-responses alternatives could distinguish between beginners and experienced fencers. Ten beginners (7 men) and 10 experienced (6 men) fencers participated in the study. A video-based method was used to present four typical fencing movement techniques (i.e. "stimulus") after which the participants had to perform an offensive (high or low attack) or defensive (high or low defence) action (i.e. "response"). The simple-RT (specific stimulus known in advance), 2Choice-RT (only defensive or offensive stimuli), and 4Choice-RT (all possible stimuli) were evaluated. The increase in the number of stimulus-responses alternatives was associated with higher RT (4Choice-RT > 2Choice-RT > Simple-RT; $p < 0.05$). Beginners always presented higher RT compared to fencers (range: 25.5–34.8%; $p < 0.05$) and also showed a steeper slope of the relationship between RT and the number of stimulus-responses alternatives (range: 35.2–55.2%; $p < 0.05$). These results suggest that the capability to quickly respond to specific fencing stimuli increases with training experience, being the differences accentuated with increasing number of stimulus-responses alternatives.

Keywords: *Fencing, quickness, perception-action coupling, simple reaction time, choice reaction time*

Highlights

- Reaction time increased with the number of stimulus-responses alternatives (4Choice-RT > 2Choice-RT > Simple-RT).
- Beginners reported a higher reaction time compared to experienced fencers regardless of the number of stimulus-responses alternatives.
- The differences in reaction time between beginners and experienced fencers were accentuated with increasing number of stimulus-responses alternatives.

Introduction

The ability of an athlete to quickly identify and respond to different stimuli can be a key factor for successful performance, particularly in combat sport such as fencing (Borysiuk, 2008), kendo (Yotani et al., 2013), karate (Mori, Ohtani, & Imanaka, 2002), and taekwondo (Sadowski, Gierczuk, Miller, & Cieśliński, 2012). The stimulus-response relationship is commonly assessed as the amount of time necessary to process the stimulus information and select an adequate response (Schmidt & Lee, 2005). This temporal aspect of the stimulus-response relationship is commonly named reaction time (RT). Different authors have considered RT as a variable with evident logical validity for the estimation of the capacity to quickly respond to a stimulus (Englert & Bertrams, 2014; Gutierrez-Davila, Rojas, Antonio, & Navarro, 2013; Kokubu, Ando, Kida, & Oda, 2006; Mori et al., 2002; Mroczek, Kawczynski, & Chmura, 2011; Mroczek, Kawczynski, Superlak, & Chmura, 2013;

Correspondence: Amador García-Ramos, Faculty of Education, Department of Sports Sciences and Physical Conditioning, Universidad Católica de la Santísima Concepción, Catholic University of the Most Holy Concepción, Concepción, Chile. Email: amagr@ugr.es

Ripoll, Kerlirzin, Stein, & Reine, 1995). The Simple-RT (stimuli and adequate response are known in advance) and choice-RT (stimulus and adequate response are unknown) have been used in the scientific literature (Schmidt & Lee, 2005). The main difference between them is the presence (Choice-RT) or lack (Simple-RT) of the stimulus identification and response selection stage (Schmidt & Lee, 2005). Of note, the Choice-RT is higher than the Simple-RT due to the presence of the response selection stage, which is known to increase with the number of stimulus-responses alternatives (Schmidt & Lee, 2005).

It is known that combat sports are open motor skills (RT-based motor skills) in which athletes must rely on sudden external stimuli since they cannot predetermine opponent next action (Wang, 2009). For example, the defensive action of fencers depends on how quickly and accurately they can respond to a variety of the opponent's possible attacks (Wang, 2016). The greater the variety of motor skills a fencer can perform for attacking, the more challenging it is for the opponent to execute an effective defence. The existence of multiple stimulus-responses alternatives makes combat sports more cognitively demanding and, therefore, the ability to quickly respond to a stimulus during these sports should be preferably assessed by the Choice-RT. However, most of the literature that have assessed Simple and Choice-RT in open motor skills have used non-specific stimuli, which can explain the lack of differences in RT between beginners and expert athletes (Balkó, Borysiuk, & Šimonek, 2016). Therefore, more studies should be conducted with combat athletes (e.g. fencers) to gain knowledge of the RT behaviour under realistic sport situations (i.e. using specific stimuli and responses).

Experience and specific practice may be helpful to increase the speed of internal processing and consequently to reduce RT in presence of few stimulus-responses alternatives (Borysiuk & Waskiewicz, 2008). It is well known that experienced and skilful athletes have shorter RT compared to beginners (Schmidt & Lee, 2005), mostly due to experts' superior perceptual-cognitive skills (i.e. ability to pick-up early or advance cues emanating from the postural orientation of opponents and the capacity to recognise task-specific patterns when compared with their less-expert counterparts) (Roca & Williams, 2016). Such capability enables experienced athletes to immediate progress to the response-initiation stage of the information processing (Martniuk, 1976). This has been recognised as an exception of the Hick's law due to the high familiarisation of the subjects with a particular stimulus (Mowbray & Rhoades, 1959; Seibel, 1963).

It is plausible that the regression slope between RT and the number of stimulus-responses alternatives could provide valuable information to discriminate between experienced and non-experienced athletes. A steeper slope would be an indicator of lower performance since athletes would need more time to react when the number of stimulus-responses alternatives is increased. The slope would represent the "speed" of decision-making during the response-selection stage (Schmidt & Lee, 2005). Contradictory findings exist regarding the sensibility of RT (both the Simple-RT and Choice-RT) to differentiate between athletes of different level of expertise (Moscatelli et al., 2016; Mouelhi Guizani et al., 2006; Mudric, Cuk, Nedeljkovic, Jovanovic, & Jaric, 2015; Williams & Walmsley, 2000). The possible cause of these discrepancies could be related to the use of "ecological" vs. "non-ecological" settings (Farrow & Abernethy, 2003). Measuring RT in settings that resemble sport-specific situations increases the representativeness of the test and provides more meaningful information regarding the athlete's ability to respond to specific stimuli (Mori et al., 2002; Peiyong & Inomata, 2012). In line with this, Travassos et al. (2013) showed that expertise effects in RT were accentuated when participants were required to perform sport actions. A solution could be to evaluate RT with video-based methods that are able to provide sport-specific stimuli and responses in quasi-realistic situations (Mudric et al., 2015). In this regard, it would be important to determine whether the slope based on the RT and number of stimulus-responses alternatives can distinguish between athletes with different level of expertise when sport-specific stimuli and responses are used.

Therefore, the aims of this study were (I) to investigate the impact of the number of stimulus-responses alternatives on RT under quasi-realistic fencing situations, and (II) to elucidate whether the slope based on the RT and the number of stimulus-responses alternatives is able to distinguish between beginners and experienced fencers. We hypothesised that (I) the number of stimulus-responses alternatives would be associated with an increase in RT both for beginners and experienced fencers, and (II) the increase in the number of stimulus-responses alternatives would be associated with a steeper increase in RT in beginners compared to experienced fencers. These hypotheses are justified by the findings of Mudric et al. (2015) who revealed shorter RT for experienced karate kumite competitors compared to beginners when specific stimuli and responses were provided, while the differences in RT were increased together with the number of stimulus-responses alternatives.

Methods

Participants

Twenty participants, 10 physical education students (i.e. beginners) (7 men and 3 women; age: 22.5 [1.4] years) and 10 fencers with more than 10 years of experience from the Serbian National Team (6 men and 4 women; age: 21.4 [2.9] years), participated in this study. The physical activity of the beginners was based on their ongoing academic curriculum, which included six to eight physical activity classes per week of low and high intensity. Although none of the beginners was an active fencer, adequate familiarisation was conducted. Familiarisation consisted of four fencing classes (two sessions per week) in which participants practised basic fencing techniques, such as the fencing footwork, the attack techniques (trusts and lounges) and the defence techniques (such as "quarte" and "octave" parries). Each class lasted 90 minutes, and during the last class they were introduced to the testing protocol.

Only one participant per group was left handed and accordingly they preferred the left guard position, while all remaining participants were right handed and preferred the right guard position. All participants had normal or corrected-to-normal acuity and colour vision and none of them reported any difficulty regarding the use of video-based stimuli (see further text for details). The study was approved by the Institutional Review Board. In accordance with the Declaration of Helsinki, the written informed consent was provided and signed by all participants prior to the study.

Experimental procedure

Reaction time (RT) was recorded in quasi-realistic fencing situations using a video-based method, which was described in detail elsewhere (Mudric et al., 2015). The experimental procedure was conducted in two steps. In the first step, we simultaneously recorded the video of four typical fencing movement techniques (i.e. the "stimulus") and the corresponding kinematic data that enabled the determination of the onset of the stimulus initiation. In the second step, we recorded corresponding offensive and defensive responses performed by the participant, triggered by the recorded video of the stimulus, which finally provided the main set of kinematic data used to determine the onset of the response. The time interval between the onset of the stimulus and the adequate response represented the RT.

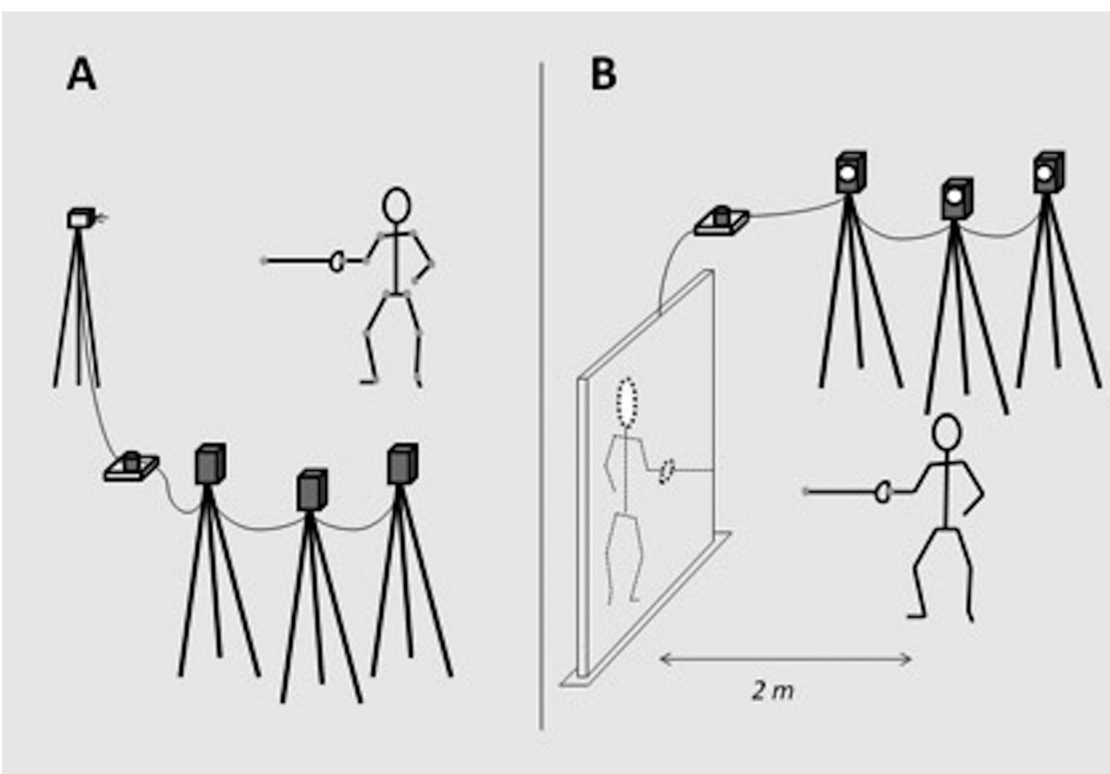

Figure 1. Schematic illustration of (A) the experimental setup used for the initial video recording of the offensive actions, (B) subsequently used as a stimulus shown on the screen for measuring the defensive action responses. The three cameras represent the video system used for recording the reflexive markers (small circles), while the connecting device represents a common trigger.

Recording the four fencing movement techniques of model ("stimulus"). The video recording of stimuli actions was carried out with a high definition video camera (Basler BIP2, Ahrensburg, Germany) with the recording frequency of 60 Hz and initiated by external triggering (see Figure 1(A)). The stimulus actions were performed by an elite fencer who was also a member of the Serbian national fencing team. The video camera was placed in such a position to simulate both the viewing distance and the eye level of a hypothetical opponent in a real combat situation. While providing the stimulus the fencing expert stood in a right on guard position toward the recording camera and performed separately four typical fencing movement techniques. Specifically, "outside arm move" and "half step forward with arm pulled back" were used as a stimulus for offensive response (Figure 2(1,2)). The "lounge in high line" and the "lounge in low line" were selected as the most typical offensive techniques, which were used as a stimulus for defensive response (Figure 2(3,4)). The reason why we decided to choose these techniques is their frequent presence both during individual lessons and fencing competitions. A fifth recording was performed without any offensive action (i.e. "catch trial"). The video recording was synchronised with the 3-dimensional (3D) infrared recording of 13 retro-reflective, spherical markers conducted by three cameras (Qualisys AB, Gothenburg, Sweden). These markers were positioned on the centre of both wrists (centre of carpals, proximal row), elbows (epicondylus radialis), shoulders (tuberculum majus), hips (trochanter major), knees (epicondylus fibularis femoris), ankles (medial malleolus) and one marker situated on the "point" of epee (i.e. the sword). The 3D kinematic movement analysis was subsequently performed to determine stimulus onset of four recorded movement techniques. All five recordings were performed under standardised laboratory conditions and there were no discernible differences in initial postures among them.

Recording of offensive and defensive actions ("responses"). The recording method of offensive and defensive action responses is schematically illustrated in Figure 1(B). Participants were standing in a ready stance 2 m from a large 2 × 3 m screen, where the previously recorded four movement techniques of fencing model were displayed in real dimensions as stimuli (Mudric et al., 2015). Participants held their preferred on-guard position, using their personal weapon and glove. RT was recorded for each testing situation (high attack, low attack, high defence, and low defence) and under three different experimental conditions (Simple-RT, 2Choice-RT,

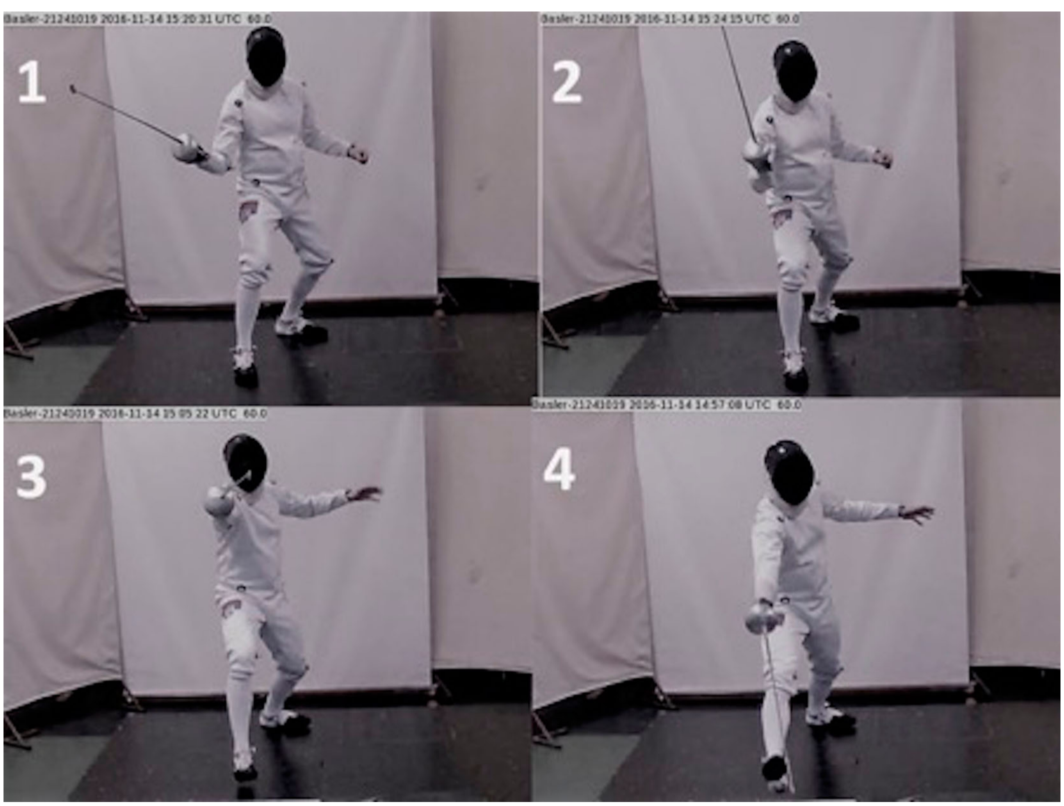

Figure 2. Four fencing movement techniques representing a stimulus for (1) high attack, (2) low attack, (3) high defence, and (4) low defence.

and 4Choice-RT). The movement technique projected as stimulus and the adequate response was known in advance during the Simple-RT condition: (1) High attack: stimulus – "lateral arm move", response – "high line lounge", (2) Low attack: stimulus – "half step forward with arm pulled back", response – "low line lounge", (3) High defence: stimulus – "high line lounge", response – "quarte parry" (i.e. defence of high inside attack), (4) Low defence: stimulus – "low line lounge", response – "octave parry" (i.e. defence of low outside attack). Within the second experimental condition, two out of four possible movement techniques were projected in random sequence and the 2Choice-RT was recorded. Specifically, for defence, the participants were expecting either high line lounge or low line lounge to be projected and, therefore, instructed to react by proper defensive response (i.e. "quarte" parry or "octave" parry, respectively). Also, for attack, the participants were expecting either "lateral arm move" or "half step forward with arm pulled back" to be projected, and, therefore, instructed to react by proper offensive response (i.e. "high line lounge" or "low line lounge", respectively). Within the third experimental condition, four possible movement techniques were projected as stimuli in random sequence and the participants were instructed to react with the proper response to record the 4Choice-RT.

Experimental protocol

A standard warm-up procedure (5 minutes of cycling and 5 minutes of dynamic stretching) was applied prior to the testing protocol. The familiarisation protocol consisted of practical demonstration of four possible stimulus-responses alternatives, followed by three practice trials of each condition. Thereafter, the experimental trials were recorded. Participants performed a total of 36 experimental trials (i.e. 3 trials × 4 responses × 3 conditions). Median value of the three experimental trials was used for further analyses. The sequence of conditions (i.e. Simple-RT, 2Choice-RT, and 4Choice-RT) and of the stimulus within each condition (high attack, low attack, high defence, and low defence) was randomised. In the case of either premature or incorrect responses, the trial was repeated according to the same protocol. The percentage of such trials was 5.83% for beginners and 7.50% for fencers. To prevent participants from anticipating the onset of the stimulus, we randomly varied the foreperiod between 1 and 5 seconds. In addition, 20% of all trials under each condition were catch trials (i.e. no stimulus). A 30 second-rest period was given after each trial. Participants were instructed to take longer rest periods if needed. None of the participants reported physical or mental fatigue through the experiment. All tests were supervised by the same two experienced experimenters under laboratory conditions between 10 am and 2 pm.

Data processing and analysis

The data obtained from the cameras used for the 3D kinematic analysis were sampled at a rate of 200 Hz and low-pass filtered using the recursive Butterworth filter with a cutoff frequency of 10 Hz. A custom-made software (National Instruments LabView 2012, Austin, TX, USA) was used to calculate the movement onset. We presumed that adequate responses might be performed as reactions to a movement of any single body segment of the model. Therefore, the first instant when any of the markers reached 5% of its 3D peak velocity was assumed to be the instant of the stimulus onset. The marker fixed at the knee of front leg was the first to pass this threshold during both lounges (high line and low line), while the marker fixed at the wrist of the armed arm was the first to pass this threshold for "outside arm move" and "half step forward pulled back arm". The same threshold (i.e. 5% of the peak velocity of wrist marker and epee point) was used as the onset of the response. The RT was calculated from the onset of the stimulus to the onset of the response. The slope based on the RT and the number of stimulus-responses alternatives (i.e. Simple-RT, 2Choice-RT, and 4Choice-RT) was calculated with a linear regression.

Statistical analyses

A two-way mixed ANOVA with group as between- (beginners and fencers) and condition as within-participants factor (Simple-RT, 2Choice-RT, and 4Choice-RT) was applied on RT values separately for each response (high attack, low attack, high defence, and low defence). In case of significant main effects without interactions, one-way repeated measure ANOVAs with Bonferroni post hoc corrections were applied to compare the RT between different conditions, whereas independent samples T-tests were applied to compare the RT between groups. The magnitude and the Z-transformed Pearson's correlation coefficients of the regression slopes based on the RT and the number of stimulus-responses alternatives were compared between beginners and experienced fencers through T-test for independent samples. Pearson's correlation coefficients from the individual linear regressions were Z-transformed to provide normally distributed data. Eta squared (η^2) was calculated for all ANOVAs where the values of the effect sizes 0.01, 0.06 and above 0.14 were considered small, medium, and large, respectively (Cohen, 1988). The level of statistical significance was set to $p < 0.05$. All statistical tests were performed using SPSS 20 (IBM, Armonk, NY) and Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA).

Results

The main effect of group always reached statistical significance (high attack: $F_{(1,19)} = 26.5$, $\eta^2 = 0.33$, $p < 0.01$; low attack: $F_{(1,19)} = 28.7$, $\eta^2 = 0.40$, $p < 0.01$; high defence: $F_{(1,19)} = 20.0$, $\eta^2 = 0.28$, $p < 0.01$; low defence: $F_{(1,19)} = 52.8$, $\eta^2 = 0.34$, $p < 0.01$). Similarly, the experimental condition was always significant (high attack: $F_{(2,18)} = 17.2$, $\eta^2 = 0.22$, $p < 0.01$; low attack: $F_{(2,18)} = 29.2$, $\eta^2 = 0.36$, $p < 0.01$; high defence: $F_{(2,18)} = 15.8$, $\eta^2 = 0.20$, $p < 0.01$; low defence: $F_{(2,18)} = 13.1$, $\eta^2 = 0.13$, $p < 0.01$). However, the interaction group x condition never reached statistical significance ($F_{(2,18)}$ range = 0.4–2.1, $\eta^2 \leq 0.02$, p range = 0.16–0.71). Pairwise comparisons are depicted in Figure 3.

The coefficient of determination (r^2) of the relationship between the number of stimulus-reaction alternatives and RT ranged from 0.738 to 0.956 and no significant differences in the strength of the slopes were observed between beginners and experienced fencers (p range = 0.345–0.674). However, beginners showed a steeper slope of the relationship between the number of stimulus-

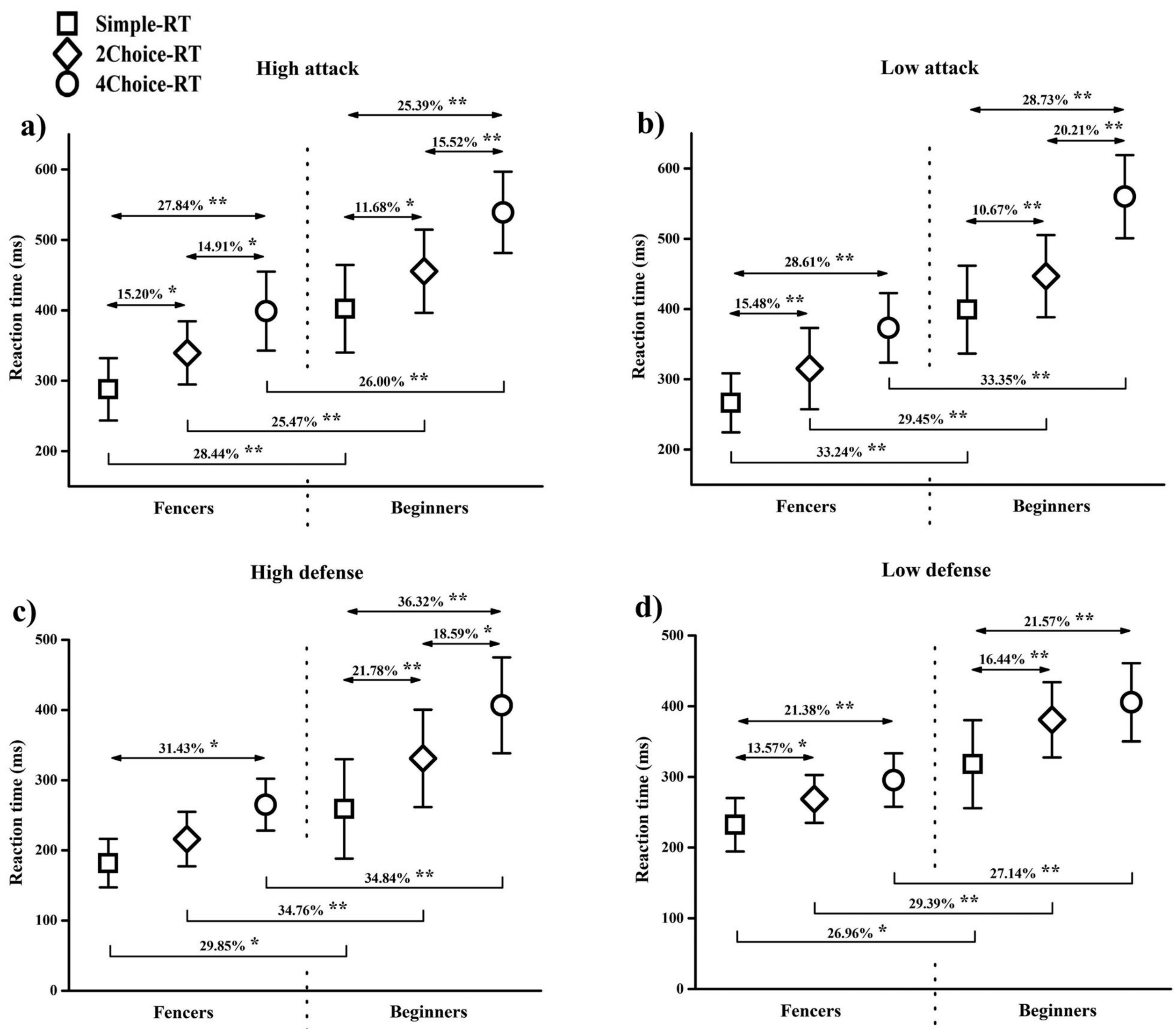

Figure 3. Comparison of reaction time values between different groups (beginners and fencers) and experimental conditions (Simple-RT, 2Choice-RT and 4Choice-RT). Data presented as means and standard deviations. *, $p < 0.05$; **, $p < 0.01$.

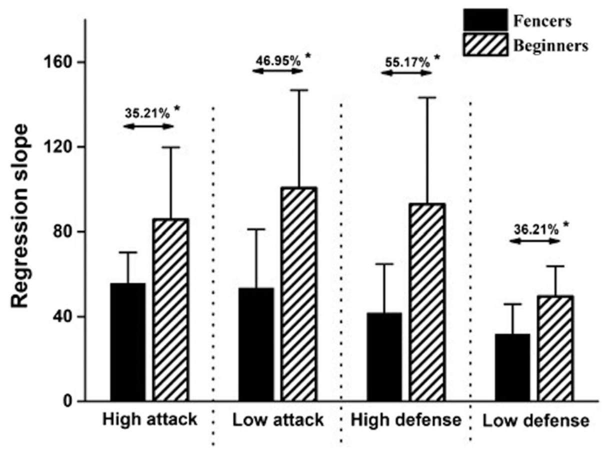

Figure 4. Comparison of the regression slopes based on the number of stimulus-reaction alternatives (Simple-RT, 2Choice-RT, and 4Choice-RT) and corresponding reaction times (RT) between beginners and experienced fencers for the different fencing movement techniques. Data presented as means and standard deviations. *, $p < 0.05$.

responses alternatives and RT compared to Fencers (Figure 4).

Discussion

A validated video-based method was used to investigate the effect of fencing expertise on RT during quasi-realistic fencing situations differing in the number of stimulus-responses alternatives. It was hypothesised that although the increase in the number of stimulus-responses alternatives would be associated with an increase in RT both for beginners and experienced fencers (hypothesis 1), the differences in RT between beginners and experienced fencers would be accentuated with higher number of stimulus-responses alternatives (hypothesis 2). The main findings revealed that (I) the increase in the number of stimulus-responses alternatives was associated with higher RT values in both beginners and experienced fencers (4Choice-RT > 2Choice-RT > Simple-RT), (II) regardless of the type of stimulus and experimental condition, fencers always showed lower RT values compared to beginners, and (III) the between-groups differences in RT were accentuated with increasing number of stimulus-responses alternatives (4Choice-RT > 2Choice-RT > Simple-RT). These results highlight that fencing expertise may contribute to reduce RT when the stimulus and response are known in advance (i.e. Simple-RT), but it may play even a more important role for reducing the duration of the response-selection stage when the number of stimulus-responses alternatives is increased (i.e. 2Choice-RT and 4Choice-RT).

Supporting our first hypothesis, the increase in the number of stimulus-responses alternatives was associated with higher RT values. This result is in line with the seminal works of Hick (1952) and Hyman (1953). Of even more importance could be that experienced fencers showed a lower RT compared to beginners in all situations (see Figure 3). The lower Simple-RT observed in the present study for experienced fencers contradicts previous findings that reported no significant differences between beginners and experienced subjects (Balkó, Borysiuk, Balkó, & Špulák, 2016; Gutierrez-Davila et al., 2013; Mouelhi Guizani et al., 2006; Williams & Walmsley, 2000). This apparent contradiction could be explained because we used more specific stimuli and responses. In line with this, the meta-analysis of Mann, Williams, Ward, and Janelle (2007) showed that the highest differences between experts and beginners in RT were observed for interceptive sports (i.e. sports which require coordination between a participant's body, parts of the body or a held implement) and that experts have the ability to extract perceptual cues more efficiently. In this regard, it is well known that experienced athletes are able to ignore a great portion of signals while focusing on stimuli that are relevant to the effective execution of technical and tactical actions (Borysiuk & Waskiewicz, 2008). For example, a positive relationship between fencing experience and speed of information processing has been previously reported (Borysiuk & Waskiewicz, 2008). On the other hand, the faster decision making during the response-selection stage of processing observed for experienced fencers is consistent with early findings (Mowbray & Rhoades, 1959; Seibel, 1963). These results collectively reinforce the notion that the stimuli and responses used to evaluate RT should be as specific as possible (Pinder, Davids, Renshaw, & Araújo, 2011). Therefore, fencers should be encouraged to use realistic situations through the video-based method proposed in this study or virtual reality for testing and training their ability to quickly respond to specific fencing stimuli.

The regression slopes based on the RT and the number of stimulus-responses alternatives (i.e. Simple-RT, 2Choice-RT, and 4Choice-RT) were calculated to elucidate whether they can distinguish between beginners and experienced fencers. Supporting our second hypothesis, beginners presented a steeper slope compared to experienced fencers during the four actions (see Figure 4). The slope represents the "speed" of decision-making during the response-selection stage (Schmidt & Lee, 2005). Therefore, our results confirm previous findings suggesting that experienced fencers have a quicker decision making than beginners, which could be explained by both specific motor training and competitive experience (Borysiuk & Waskiewicz, 2008). Fencers are continuously under time pressure, which force them to reduce the time for decision-making as well as the time of sensorimotor response in the motor phase. It is also noticeable that offensive actions generally presented a higher regression slope compared to defensive actions. The reason for this result could be the higher motor complexity of offensive actions as well as the lack of a specific stimulus for attack initiation under realistic situations (Czajkowski, 2005). Note that the low defence action is performed only with one segment (weapon arm) and it is obviously less demanding from the coordinative point of view. In addition, during both defensive actions the stimulus is more obvious, which probably increased the speed of decision making (Shiffrar & Freyd, 1990).

The descriptive values of RT also suggest that more complex fencing techniques produce longer RT. Knowing that the lunge (i.e. high attack action) is probably the most demanding action from a coordinative point of view, it is not surprising that this technique provided the longest RT. Previous studies have already pointed out that more complex motor tasks tend to increase programming time and, consequently, the RT (Borysiuk, 2008). The experienced fencers assessed in the present study showed significant differences in RT between the three experimental conditions (Simple-RT, 2Choice-RT, and 4Choice-RT) during the high attack response. This result further supports the link between task complexity and RT. Also, the shortest RT was observed for both groups during the less demanding technique (i.e. high defence action). These results can be neurologically explained since complex motor tasks require more time to be initiated as the stored programme need to be retrieved from memory and directed to the appropriate motor neurons and muscles (Henry & Rogers, 1960).

One of the strengths of the present study is that RT was evaluated in quasi-realistic fencing situations (Farrow & Abernethy, 2003). Virtual reality technology has been previously used to assess RT under quasi-realistic situations, but this technology is expensive and difficult to use (Vignais, Kulpa, Brault, Presse, & Bideau, 2015; Witte, Emmermacher, Bandow, & Masik, 2012). To solve this problem, a cost-effective and easy-to-use video-based method was developed by Mudric et al. (2015) and validated for the assessment of RT in specific karate situations. Specifically, Mudric et al. (2015) showed not only a high reliability of RT measurements for several specific responses evaluated under different conditions, but also that the RT could discriminate the number of stimulus-responses alternatives (higher RT for Choice-RT compared to Simple-RT) and between beginners and elite karate competitors (higher RT for beginners). The results of the present study are consistent with the results reported by Mudric et al. (2015). Therefore, the simple video-based method used in the present study also seems to be a feasible option to evaluate RT in specific fencing situations.

Few potential limitations from this study need to be recognised and taken into consideration when developing future studies of this type. More than two levels of expertise in a specific sport skill or different athlete populations need to be explored to further investigate RT in sport-specific environments. Moreover, it would be needed to explore whether the slope based on the RT and the number of stimulus-responses alternatives also follows a linear regression when more than 4 stimulus-responses alternatives (e.g. 8Choice-RT) are presented. Future studies should also consider to upgrade this technology, by adding tactile stimulus or non-allocentric viewpoints, possibly by using 3D virtual reality technology. However, such methodology requires a rather complex and, to this day, expensive technology.

Conclusions

Reaction time increased with the number of stimulus-responses alternatives (4Choice-RT > 2Choice-RT > Simple-RT). Beginners always reported higher RT compared to experienced fencers. The regression slopes based on the RT and the number of stimulus-responses alternatives were also higher for beginners suggesting that experienced fencers have a faster decision-making during the response-selection stage. Therefore, these results suggest that the capability to quickly respond to specific fencing stimuli increases with training experience, being the differences between beginners and experienced fencers accentuated with increasing number of stimulus-responses alternatives.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Balkó, Š, Borysiuk, Z., Balkó, I., & Špulák, D. (2016). The influence of different performance level of fencers on muscular coordination and reaction time during the fencing lunge. *Archives of Budo*, *12*, 49–59.

Balkó, Š, Borysiuk, Z., & Šimonek, J. (2016). The influence of different performance level of fencers on simple and choice reaction time. *Brazilian Journal of Kinanthropometry and Human Performance*, *18*(4), 391–400. doi:10.5007/1980-0037.2016v18n4p391

Borysiuk, Z. (2008). The significance of sensorimotor response components and EMG signals depending on stimuli type in fencing. *Acta Universitatis Palackianae Olomucensis*, *38*(1), 43–51.

Borysiuk, Z., & Waskiewicz, Z. (2008). Information processes, stimulation and perceptual training in fencing. *Journal of Human Kinetics*, *19*(1), 63–82. doi:10.2478/v10078-008-0005-y

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, MI: Lawrence Erlbaum Associates.

Czajkowski, Z. (2005). *Understanding fencing: The unity and practice*. Staten Island, NY: SKA Swordplay Books.

Englert, C., & Bertrams, A. (2014). The effect of ego depletion on sprint start reaction time. *Journal of Sport & Exercise Psychology*, *36*(5), 506–515. doi:10.1123/jsep.2014-0029

Farrow, D., & Abernethy, B. (2003). Do expertise and the degree of perception – action coupling affect natural anticipatory performance? *Perception*, *32*(9), 1127–1139. doi:10.1068/p3323

Gutierrez-Davila, M., Rojas, F. J., Antonio, R., & Navarro, E. (2013). Effect of uncertainty on the reaction response in fencing. *Research Quarterly for Exercise and Sport*, *84*(1), 16–23. doi:10.1080/02701367.2013.762286

Henry, F. M., & Rogers, D. E. (1960). Increased response latency for complicated movements and a "memory drum" Theory of neuromotor reaction. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *31*(3), 448–458. doi:10.1080/10671188.1960.10762052

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology*, *4*(1), 11–26. doi:10.1080/17470215208416600

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, *45*(3), 188–196. doi:10.1037/h0056940

Kokubu, M., Ando, S., Kida, N., & Oda, S. (2006). Interference effects between saccadic and key-press reaction times of volleyball players and nonathletes. *Perceptual and Motor Skills*, *103*(3), 709–716. doi:10.2466/pms.103.3.709-716

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *29*(4), 457–478. doi:10.1123/jsep.29.4.457

Martniuk, R. G. (1976). *Information processing in motor skills*. Holt: Rinehart and Winston.

Mori, S., Ohtani, Y., & Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science*, *21*(2), 213–230. doi:10.1016/S0167-9457(02)00103-3

Moscatelli, F., Messina, G., Valenzano, A., Monda, V., Viggiano, A., Messina, A., … Cibelli, G. (2016). Functional assessment of corticospinal system excitability in karate athletes. *PloS One*, *11*(5), e0155998. doi:10.1371/journal.pone.0155998

Mouelhi Guizani, S., Bouzaouach, I., Tenenbaum, G., Ben Kheder, A., Feki, Y., & & Bouaziz, M. (2006). Simple and choice reaction times under varying levels of physical load in high skilled fencers. *The Journal of Sports Medicine and Physical Fitness*, *46*(2), 344–351.

Mowbray, G. H., & Rhoades, M. V. (1959). On the reduction of choice reaction times with practice. *Quarterly Journal of Experimental Psychology*, *11*(1), 16–23. doi:10.1080/17470215908416282

Mroczek, D., Kawczynski, A., & Chmura, J. (2011). Changes of reaction time and blood lactate concentration of elite volleyball players during a game. *Journal of Human Kinetics*, *28*, 73–78. doi:10.2478/v10078-011-0024-y

Mroczek, D., Kawczynski, A., Superlak, E., & Chmura, J. (2013). Psychomotor performance of elite volleyball players during a game. *Perceptual and Motor Skills*, *117*(3), 801–810. doi:10.2466/25.29.PMS.117x26z6

Mudric, M., Cuk, I., Nedeljkovic, A., Jovanovic, S., & Jaric, S. (2015). Evaluation of video-based method for the measurement of reaction time in specific sport situation. *International Journal of Performance Analysis in Sport*, *15*(3), 1077–1089. doi:10.1080/24748668.2015.11868852

Peiyong, Z., & Inomata, K. (2012). Cognitive strategies for goalkeeper responding to soccer penalty kick. *Perceptual and Motor Skills*, *115*(3), 969–983. doi:10.2466/30.22.23.PMS.115.6.969-983

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology*, *33*(1), 146–155. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21451175

Ripoll, H., Kerlirzin, Y., Stein, J. F., & Reine, B. (1995). Analysis of information processing, decision making, and visual strategies in complex problem solving sport situations. *Human Movement Science*, *14*(3), 325–349. doi:10.1016/0167-9457(95)00019-O

Roca, A., & Williams, A. M. (2016). Expertise and the interaction between different perceptual-cognitive skills: Implications for testing and training. *Frontiers in Psychology*, *7*, 792. doi:10.3389/fpsyg.2016.00792

Sadowski, J., Gierczuk, D., Miller, J., & Cieśliński, I. (2012). Success factors in elite WTF taekwondo competitors. *Archives of Budo*, *8*(3), 141–146. doi:10.12659/AOB.883279

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis* (4th ed.). Champaign, IL: Human Kinetics.

Seibel, R. (1963). Discrimination reaction time for a 1,023-alternative task. *Journal of Experimental Psychology*, *66*(3), 215–226. doi:10.1037/h0048914

Shiffrar, M., & Freyd, J. J. (1990). Apparent motion of the human body. *Psychological Science*, *1*(4), 257–264. doi:10.1111/j.1467-9280.1990.tb00210.x

Travassos, B., Araújo, D., Davids, K., O'Hara, K., Leitão, J., & Cortinhas, A. (2013). Expertise effects on decision-making in sport are constrained by requisite response behaviours – a meta-analysis. *Psychology of Sport and Exercise*, *14*(2), 211–219. doi:10.1016/j.psychsport.2012.11.002

Vignais, N., Kulpa, R., Brault, S., Presse, D., & Bideau, B. (2015). Which technology to investigate visual perception in sport: Video vs. virtual reality. *Human Movement Science*, *39*, 12–26. doi:10.1016/j.humov.2014.10.006

Wang, J. (2009). Reaction-time training for elite athletes: A winning formula for champions. *International Journal of Coaching Science*, *3*(2), 67–78. doi:10.1152/physrev.1990.70.2.567

Wang, J. (2016). Key principles of open motor-skill training for peak performance. *Journal of Physical Education, Recreation & Dance*, *87*(8), 8–15. https://doi.org/10.1080/07303084.2016.1216341

Williams, L. R., & Walmsley, A. (2000). Response timing and muscular coordination in fencing: A comparison of elite and novice fencers. *Journal of Science and Medicine in Sport*, *3*(4), 460–475.

Witte, K., Emmermacher, P., Bandow, N., & Masik, S. (2012). Usage of virtual reality technology to study reactions in karate-kumite. *International Journal of Sports Science and Engineering*, *6*(1), 17–24.

Yotani, K., Tamaki, H., Kirimoto, H., Yuki, A., Kitada, K., Maesaka, S., & Ogita, F. (2013). Response time and muscle activation patterns of the upper limbs during different strikes in kendo. *Archives of Budo*, *9*(2), 101–106. doi:10.12659/AOB.883904