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Striking a balance: Exploring attention, attack accuracy and speed in fencing performance

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Abstract

In fencing, it remains unclear whether practice enhances visual-spatial attention allocation. We explored whether this ability is improved in fencers and if it is related to attack speed and accuracy. Twelve novices (<1 year of experience) and 12 trained epee fencers (18 ± 10 years of experience) visited the laboratory twice (familiarization and testing session). They performed a covert orienting of visuo-spatial attention test (COVAT) on a computer and an epee test, involving 30 trials of 3 shuttles followed by fast attack phases where the fencers quickly hit a target (randomly proposed out of 8). We measured COVAT reaction time, number of successful target hits, and execution time to hit in the fencing test. We found shorter COVAT reaction time for trained fencers (332 ± 24 ms) versus novices (367 ± 32 ms; $p < 0.001$). The number of hits was greater for trained fencers (22 ± 3) versus novices (16 ± 3 ; $p < 0.001$). ANCOVA showed a difference in execution time at the test (823 ± 73 ms vs. 913 ± 141 ms, $p = 0.035$). A relationship was found between hits and execution time and between execution time and COVAT reaction time for the trained group ($r = 0.62$, $p = 0.03$ and $r = 0.70$, $p = 0.01$, respectively) but not in the novice group ($r = 0.11$, $p = 0.72$ and $r = 0.45$, $p = 0.14$, respectively). Mediation analysis showed that the relationship between execution time and number of hits (ADE: $p = 0.008$) was not mediated by COVAT reaction time (ACME: $p = 0.17$). These results evidence the importance of visual-spatial attention allocation in fencing and evidence differences between novices and trained fencers with important implications for talent development in the early career stage.

KEYWORDS

combat sport, COVAT test, covert-orienting attention ability, epee, escrime

Highlights

- This is the first study investigating visual-spatial attention allocation ability by comparing computer and fencing-specific tests in trained versus novice epee fencers.
- Speed and accuracy at the fencing test and reaction time at the computer test were greater for trained epee fencers compared to novices.

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- Only trained epee fencers showed a trade-off between accuracy and speed of execution at the fencing test.
- This relationship was not mediated by covert-orienting attention ability despite a correlation between speed of execution and reaction time at the computer test.
- These results underline the importance of attention allocation and technical abilities, which could improve independently with practice and play a role in epee fencing performance.

1 | INTRODUCTION

In fencing and other combat sports, cognitive skills such as attention, anticipation, visual discrimination, and decision-making are essential to perform well and win the game (Mann et al., 2007; Russo & Ottoboni, 2019). This is because athletes are constantly interacting with their opponents, quickly adapting their responses to new situations that are generated from such interactions (Voss et al., 2010). Thus, the ability to extract information (or perceptual cues) and execute an appropriate response with the necessary precision is crucial (Russo & Ottoboni, 2019; Voss et al., 2010). To understand the impact of such abilities on performance, previous studies have mainly focused on paradigms such as choice reaction time and response reaction time to discriminate elite from non-elite fencers or for talent identification (e.g., Borysiuk & Cynarski, 2010; Gutierrez-Davila et al., 2013). Cognitive skills related to the visual strategy and attention have received less attention in fencing, although they are crucial, given the distance that separates opponents before an attack is greater than in other combat sports (e.g., Turner et al., 2017).

Previous studies in a laboratory (Hagemann et al., 2010) or during a simulated fencing competition (Bagot et al., 2023) have shown that expert fencers use specific visual strategies to extract perceptual cues. In particular, two visual search strategies have been identified, called “gaze anchor” and “visual pivot” (for a review, see Vater et al., 2020). Both visual strategies are based on the so-called covert-orienting attention ability, that is, the ability to allocate visuospatial attention to different locations without eye movements (i.e., within the visual field, Nougier et al., 1992). In this case, in order to extract perceptual cues and thus acquire information, the gaze should be fixed and attention should be distributed to different peripheral cues (Ripoll et al., 1995). This ability might be particularly relevant in epee (Bagot et al., 2023), where information should be retrieved from multiple body locations because the whole body serves as a target, as opposed to foil or saber where the target is limited to specific areas. At present, it is not clear if covert-orienting attention ability is related to performance level.

The results in the literature are not always consistent, depending on the combat sport practiced and the experience of the athletes (Chen et al., 2017; Del Percio, 2009). Regarding the first point, these abilities seem to be different in fencers compared to other combat sports: for instance, Di Russo and Spinelli (2010) observed lower switch costs (i.e., the difference in reaction times between GO and NO-GO trials) and higher visual attention in fencers compared to

boxers. These results were confirmed by Bianco et al. (2017) who also found greater attentional resources and greater accuracy in fencers. Regarding the second point, as recently suggested (Witkowski et al., 2021), knowledge acquired by elite athletes is not necessarily applicable to novices, and comparison between novices and trained fencers (i.e., athletes with experience in fencing) is needed. To the best of our knowledge, there is currently a lack of data on covert-orienting attention ability in relation to movement execution speed and accuracy in fencing.

In the present study, we aimed to compare trained epee fencers and novices on (i) a specific epee fencing test to assess the interaction between covert-orienting attention ability, speed of attack execution, and accuracy and (ii) a standard covert-orienting of visuospatial attention test (COVAT; Chen et al., 2017) on a computer to isolate covert-orienting attention ability. We hypothesized a better covert-orienting attention ability in the trained fencers compared to the novices, which would lead to better performance in terms of speed of movement execution and accuracy on the fencing test. We also hypothesized a negative relationship between speed of execution and accuracy for both groups.

2 | METHODS

2.1 | Participants

Twelve novice and 12 epee trained fencers from the Nantes Escrime Club Team volunteered to participate in the present study. The characteristics of the participants are shown in Table 1. Fencers in the novice group were required to have less than 1 year of experience and could be defined as “Tier 1: Recreationally Active level” according to the participant classification framework in sport science proposed by McKay et al. (2021). The trained group was required to have >5 years of experience and regular competition participation and could be defined as Tier 2 (Trained/Developmental level, McKay et al., 2021). The sample size was calculated a priori using the data presented in Chen et al. (2017) on taekwondo athletes versus non-athletes (allocation ratio = 0.92), with α set at 0.05 and β set at 0.2 to show an effect size of approximately 1.4 [Cohen's d (Cohen, 1988)] for differences in covert orienting of visuospatial attention test (COVAT) reaction time (two-tailed independent t -tests). Prior to the first session, participants were fully informed of the testing procedures and the purpose of the study. Exclusion criteria were age over 60 or under 18 years, recent history of injury or surgery to the upper

TABLE 1 Participant's characteristics.

| | Novice group | Trained group | Effect size (g) | p-value |
|----------------------------|--------------|---------------|----------------------------------|-------------------|
| Men/women | 9/3 | 9/3 | | |
| Age (years) | 34 ± 7 | 37 ± 8 | 0.36 (−0.45, 1.17) | 0.37 |
| Height (m) | 1.77 ± 0.08 | 1.74 ± 0.08 | −0.33 (−1.13, 0.48) | 0.41 |
| Body mass (kg) | 73 ± 13 | 74 ± 14 | −0.10 (−0.70, 0.90) | 0.81 |
| P.A. (hours/week) | 6 ± 4 | 4 ± 2 | −0.28 (−0.64, 0.18) ^a | 0.26 ^a |
| Fencing experience (years) | | 18 ± 10 | | |

Note: Data expressed as mean ± SD. Effect sizes (Hedge's *g*) are presented with 95% confidence intervals. P.A. = hours of intentional and deliberate physical activity excluding activities of daily living (e.g., commissions, commuting).

^aBecause Levene's test was significant (violation of equal variance assumption), Mann–Withney test was used and effect size is given using the rank biserial correlation. Because inclusion criteria for the novice group required less than 1 year of fencing experience, comparison was not computed.

or lower limbs, and presence of neuromuscular deficits or diseases affecting coordination or locomotion. Participants in the novice group did not practice other combat or opposition sports. Specifically, they practiced recreational weight training ($n = 4$), running or cycling ($n = 5$), rock climbing ($n = 1$), football ($n = 1$), or no other sport ($n = 1$). An interview was conducted to check for exclusion criteria before obtaining written consent. The study was approved by the University Ethical Committee (CEDIS n°24022023) and met the requirements of the Declaration of Helsinki (2013) for research on human beings (except registration on a publicly available database).

2.2 | Experimental procedures

Participants visited the laboratory twice (familiarization and test session), where they performed after a 10-min warm-up, a specific fencing test and a standard COVAT test on a computer (Chen et al., 2017). The fencing test and the COVAT test were separated by 5 min of rest.

2.3 | Fencing test

The specific consisted of included 3 shuttles (forward and backward) over 2 m for men and 1.75 m for women. This adjustment for the women group was deemed necessary based on the height difference and observations made during a pilot study. Shuttles that had to be completed within 9 s (Figure 1A). Participants focused their attention on a fixation cross projected on a board (2 m × 1 m) presenting 8 targets (equipped with impact sensors, Figure 1B). After the 9 s, a red circle was projected on a random target (Figure 1A). The presented target underwent a simple randomization procedure (randomization with replacement), that is, the same target could be presented multiple times. Participants were instructed to attack the target as quickly as possible. Furthermore, to better simulate the possible correction situation during a fencing attack and the cognitive operations performed during the COVAT (see below), a false cue was presented in 10% of the trials: a target was flashed for 300 ms before

the real target was shown. The false target was presented close to the real target (i.e., within 40 cm) to mimic real-fight fast displacements. Pilot testing showed that it was possible to correctly hit these false cue trials. Trials were separated by 9 s of rest. Thus, each trial lasted 18 s. The test consisted of a total of three sets (10 trials per set) of 3 min separated by 1 min of rest, simulating the time requirements of an actual epee fencing bout (Bottoms et al., 2013). Participants used their fencing equipment to complete the specific fencing test. To illuminate a specific target (Figure 1A), the projector (EB-805F, Epson, Nagano, Japan) was connected to Superlab 6 software (Cedrus, San Pedro, California), which randomly selected the targets proposed during the test (see above) and sent parallel signals to a StimTracker (Cedrus) connected to an acquisition system (Powerlab 16/30-ML880/P, ADInstruments, Bella Vista, Australia). Analog signals from the impact sensors (TP70S, Yamaha, Hamamatsu, Japan) were sampled at 2 kHz using the same acquisition system. All signals were then transferred to a computer via the Labchart 8 interface (ADInstruments). The outcomes measured were the number of hits on the targets in the fencing test and the execution time required to hit a target. The latter was calculated as the time difference between the moment the target was highlighted and the moment it was hit. Only the targets were equipped with sensors so that the execution time could not be recorded if participants missed the target.

2.4 | Covert-orienting attention ability test

The COVAT is an adaptation of Posner's cueing paradigm, which uses a central cue (e.g., an arrow) to indicate the location of a target on most trials (Figure 1C). The participant completed the 104 trials presented while seated ~60 cm from the computer screen (black background) with the left and right indices positioned on the "Q" and "M" letters of an AZERTY keyboard, respectively (Figure 1D). Each trial began with a white fixation cross (0.5° × 0.5° visual angle) positioned in the center of screen and the outlines of two boxes (2.0° × 2.0° visual angle) positioned 2.0° to the left or right of the fixation cross. After 2 s, a yellow arrow replaced the fixation cross in

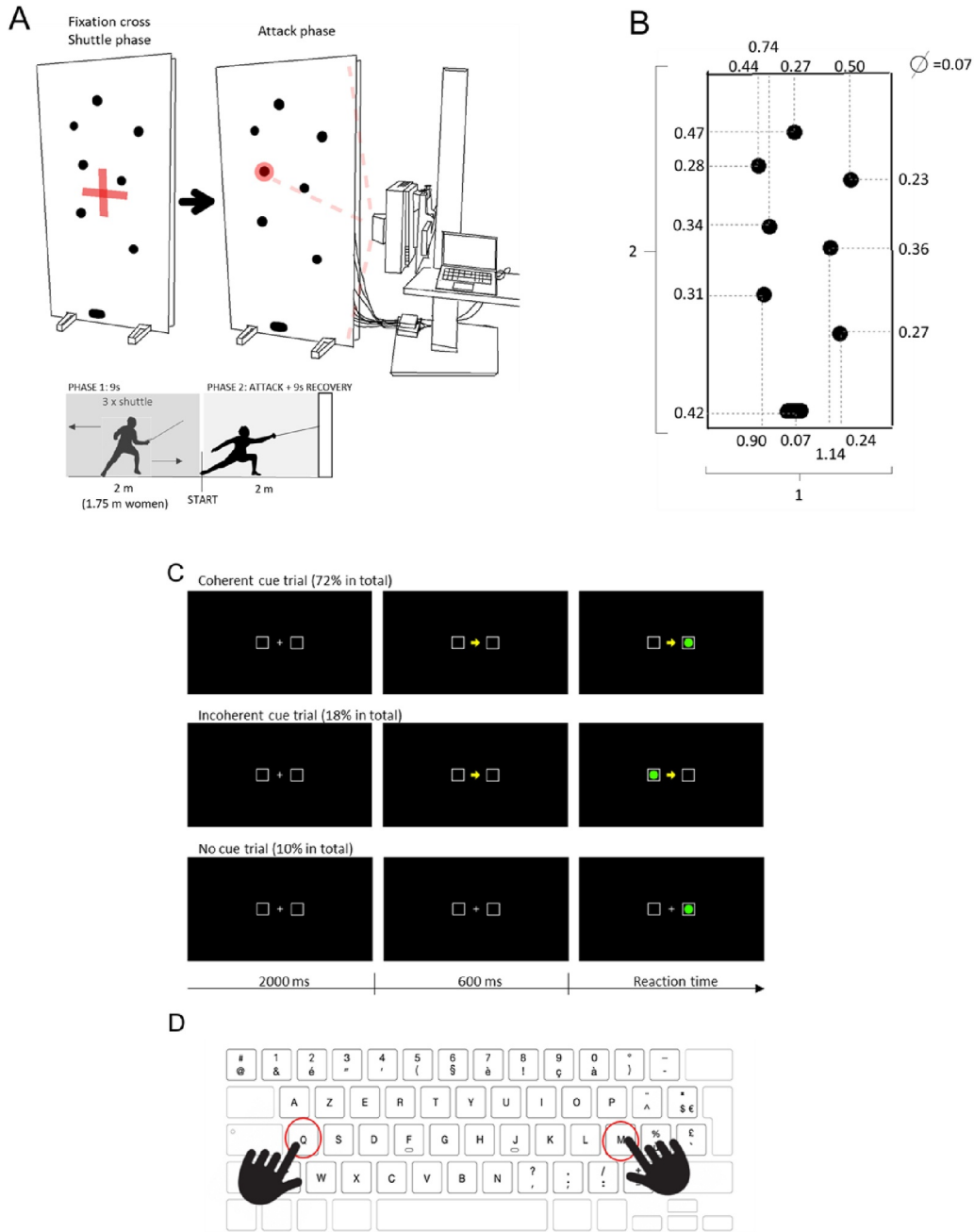


FIGURE 1 Experimental setting for the tests. (A) Presents the two phases of each trial for the fencing test: first, participants needed to maintain the attention on the fixation cross projected in the center of the target board and perform 3 shuttle runs over a given distance (2 m for men, 1.75 m for women) within 9 s. This was followed by an attacking phase to a target equipped with an impact sensor out of 8. The outline of the designed target was projected on the board. (B) Presents the dimension and the position of the targets on the board, and distances are expressed in meters. (C and D) Present the experimental setting for the computer covert orienting of visuospatial attention test. (A) Presents the three possible conditions (coherent cue, incoherent cue, and no cue) for each trial. (B) Presents the layout of the keyboard and the position of the index fingers of individuals.

the center of the screen. After 600 ms, a green circular target stimulus filled one of the two boxes. Participants had to respond as quickly as possible pressing “Q” or “M” if the green target appeared on the left or right side. After a response, the next trial began. The cue could be coherent (arrow pointing to the correct target, 72% of trials) or incoherent (18% of trials). In the remaining 10% of trials, no

cue was presented (the white fixation cross remained on the screen for an additional 600 ms). This paradigm slows response time compared to classical reaction time tests by requiring three cognitive operations: (a) disengagement from the cue, (b) covert attention to both locations, and (c) engagement with the target. We used response time to the green target as a measure of covert-orienting

attention ability and subsequent information processing speed (Chen et al., 2017; Del Percio, 2009). The COVAT test was administered using the SuperLab 6 software interface (Cedrus). The outcome measured was the reaction time on the test.

2.5 | Statistical analysis

Data are presented as mean \pm standard deviation. We evaluated differences between groups in anthropometric data and number of targets hit using independent samples Welch *T*-test. Equality of variance and normality were tested using the Levene's test and the Shapiro-Wilk test, respectively (all $p > 0.05$). As a measure of the effect size, Hedges' *g* was calculated and interpreted as small, moderate, or large effect size for values ≤ 0.2 , ≤ 0.5 , or ≥ 0.8 , respectively. If the Levene's test was significant (violation of the assumption of equal variance), the Mann-Whitney test was used, and the effect size is reported using the rank biserial correlation. This was the case for physical activity only. ANOVA was used to evaluate the effect of the fencing level (novice vs. trained fencers) on cue condition (coherent, incoherent, and no-cue) and target position (left, right). By design, execution time was dependent on the number of hits, that is, execution time could only be measured for one target hit. Therefore, ANCOVA was used to evaluate the difference in execution time between groups with the number of target hits as a covariate. The Q-Q plot of residuals was checked before extracting the results from ANOVA and ANCOVA and η^2_p was calculated for the effect size. η^2_p was interpreted as small, moderate, or large effect size for values ≤ 0.01 , ≤ 0.06 , or ≥ 0.14 , respectively. Tukey's correction to *p*-value was used for post-hoc analysis. We analyzed the association between execution time and the number of targets hit and between execution time and COVAT reaction time using Pearson's correlation coefficient. We compared differences between groups by fitting linear models to the data and performing likelihood ratio tests. Because execution time was associated with both the number of targets hit and COVAT reaction time in the trained group, a causal mediation analysis was conducted to assess whether the relationship between the number of targets hit and execution time on the fencing test was mediated by COVAT reaction time. Statistical analysis was performed in the R environment (R Core Team, 2013) using JASP (v.0.17.2; JASP team, www.jasp-stats.org) and R studio (V2023.06.0 + 421, R Studio team, www.rstudio.com). The code used for analysis is available at https://osf.io/8bnqg/?view_only=438acf07f7b04e1a8671c5b6ce62b810.

3 | RESULTS

The two groups were similar in age, height, body mass, and physical activity (Table 1). The two groups presented the same men/women ratio. The trained fencers who agreed to participate in the study had 18 ± 10 years of experience and performed ~ 3 – 6 competitions per year. None of the trained fencers participated in international competitions.

3.1 | Fencing test

Individual data from the fencing tests with group linear regressions are shown in Figure 2. Violin plots are presented on the margins to visualize the density of data for each parameter. The number of target hits was greater for trained (22 ± 3) versus novice fencers [16 ± 3 ; $p < 0.001$, $g = 2.2$ (1.16; 3.22)]. The execution time was also lower for trained (823 ± 73 ms) versus novice fencers (913 ± 141 ms, $p = 0.035$, and $\eta^2_p = 0.20$). A correlation was found between the number of hits and execution time and between execution time and COVAT reaction time for the trained group ($r = 0.62$, $p = 0.03$ and $r = 0.70$, $p = 0.01$, respectively), but not for the novice group ($r = 0.11$, $p = 0.72$ and $r = 0.45$, $p = 0.14$, respectively). Comparing the regressions, we observed a significant difference in the goodness of fit between groups for the relationship between the number of hits and execution time ($\chi^2 = 6.6$; $p < 0.001$, Figure 2A) and between execution time and COVAT reaction time ($\chi^2 = 12.4$; $p < 0.001$, Figure 2B). Mediation analysis showed a significant direct relationship between execution time and the number of targets hit (ADE: $p = 0.006$) but no significant indirect relationship mediated by COVAT reaction time (ACME: $p = 0.18$).

3.2 | Covert-orienting attention ability test

The number of errors committed in the COVAT test was considered negligible. Two participants in the trained group committed errors (wrong answer, 1 error, and 2 errors, respectively), while 6 participants in the novice group committed errors (1 error: $n = 3$; 2 errors: $n = 2$, and 4 errors: $n = 1$). We observed significant main effects of cue ($F = 17.1$, $p < 0.001$, and $\eta^2_p = 0.205$) and group ($F = 34.1$, $p < 0.001$, and $\eta^2_p = 0.21$). No main effect was found for the target position ($F = 0.09$, $p = 0.77$, and $\eta^2_p < 0.01$). Regarding the type of cue, we did not observe a difference between coherent and incoherent cues ($p = 0.47$) but we did observe significant differences between no-cue and cue (both coherent and incoherent, all $p < 0.001$), indicating longer reaction time when no cue appeared (Figure 3A). No significant group \times cue interaction was found ($F = 0.60$, $p = 0.55$, and $\eta^2_p < 0.01$). Therefore, to compare the results for the COVAT test and the fencing test, the reaction time for each participant consisted of the overall mean reaction time measured in the test, independent of the cue condition. We found a shorter COVAT reaction time for trained (332 ± 24 ms) versus novice fencers (367 ± 32 ms, $p = 0.006$; Figure 3B).

4 | DISCUSSION

In the present work, we analyzed the differences between novice and trained epee fencers in terms of performance on a standardized test of accuracy and speed and on the COVAT test, which measures the covert-orienting attention ability. As expected, we observed better performance in both speed and accuracy on the fencing test for

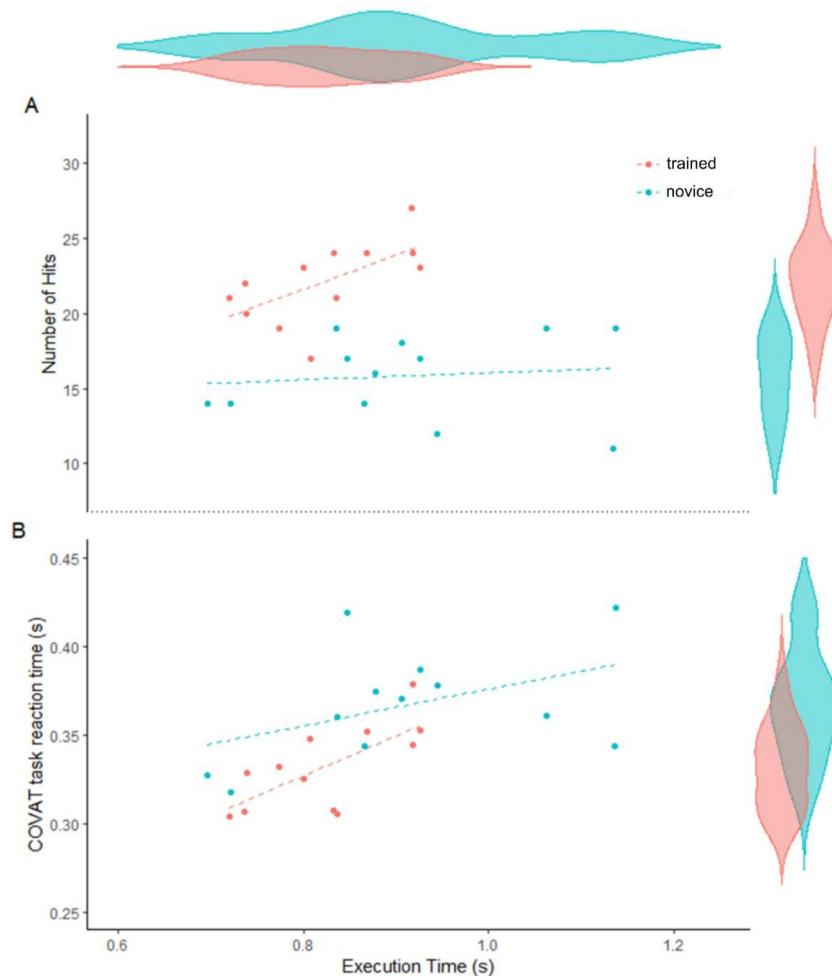


FIGURE 2 Individual data for participants of the novice and trained fencers' groups. Dashed lines represent the linear regressions for the two groups. Violin plots showing the density distribution of the data for each group are presented on the margins of the panels. (A) Relationship between the number of targets hit and the execution time necessary to hit the target at the specific fencing test. (B) Relationship between the execution time at the covert orienting of visuospatial attention test task and the execution time necessary to hit the target at the specific fencing test.

trained epee fencers. We also observed better reaction time for the trained epee fencers on the COVAT test compared to the novices. Contrary to what hypothesized, only trained epee fencers showed a trade-off between accuracy and speed of execution on the fencing test. This relationship was not mediated by covert-orienting attention ability despite a correlation between execution speed and reaction time on the COVAT test.

To the best of our knowledge, this is the first study to compare covert-orienting attention ability across epee fencing expertise groups. Previous literature has mainly used reaction time and choice reaction time paradigms (Borysiuk & Cynarski, 2010; Borysiuk & Waskiewicz, 2008; Gutierrez-Davila et al., 2013; Johne et al., 2013). The most important factor influencing reaction time and choice reaction time performance is attention, which is based on executive functions such as inhibitory control and working memory (Posner & Dehaene, 1994). Studies conducted at rest on a computer showed that elite or trained fencers were generally faster than inexperienced fencers on reaction time and choice reaction time tasks (Borysiuk &

Waskiewicz, 2008; Johne et al., 2013), although some data found no difference between groups (Mouelhi Guizani et al., 2006). When the test was administered in a fencing-specific context where participants were asked to hit a target while performing a *lunge*, no significant difference was found in reaction time, choice reaction time, or execution time between elite and trained fencers (Gutierrez-Davila et al., 2013). However, accuracy (number of targets hit) was greater in the elite group (Gutierrez-Davila et al., 2013). In the present study, the results indicated that trained epee fencers performed better than novices on both the COVAT computer task and the specific fencing task, which aimed to evaluate the combination of covert-orienting attention ability and technical abilities in terms of speed of movement execution and accuracy. Discrepancies between studies might be expected because of different outcomes tested: In reaction time paradigms, participants are asked to focus on a specific, narrow location where information is provided, thus focusing the attention on the center of the visual field (i.e., foveal vision, Stewart et al., 2020). However, in fencing, information cues might originate

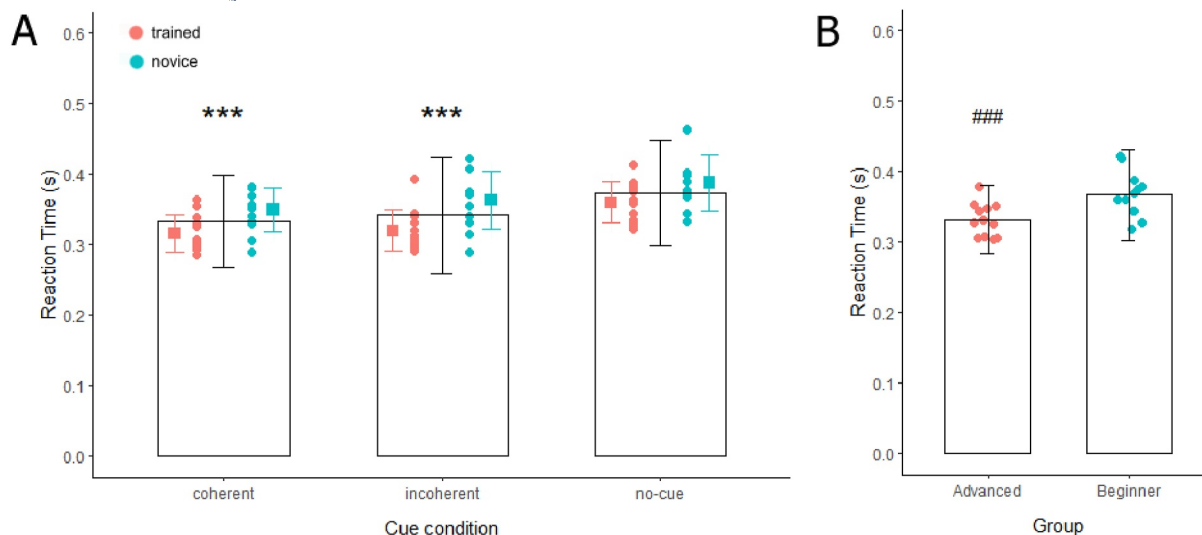


FIGURE 3 Results at the covert orienting of visuospatial attention test for the two groups: trained and novice epee fencers. Data are presented as mean \pm SD and as individual points. (A) Differences across cue conditions, filled squares and bars represent mean \pm SD for each group. *** = significant difference from no-cue for the cue main effect, $p < 0.001$. (B) Group main effect. ### = significant difference between groups, $p < 0.001$.

from various unknown locations within the athlete's visual field (Hagemann et al., 2010; Vater et al., 2020) and it has been suggested that elite athletes rely on peripheral vision to gather information (Bagot et al., 2023; Hagemann et al., 2010). In epee, this might be exacerbated due to the fact that, contrary to foil and saber, the whole body serves as a target.

The larger field of view of peripheral vision is counterbalanced by lower sensitivity, resolution, higher positional uncertainty, and crowding (i.e., object recognition is compromised by the presence of other objects nearby, Stewart et al., 2020). This makes it difficult to focus attention on peripheral vision, inducing individuals to rather displace foveal vision through saccadic movements in information retrieval processes. It is possible that trained fencers could better focus their attention on peripheral vision, regardless of their individual motor experience or situational probabilities (i.e., expert athletes could better identify which locations are more likely to be a target compared to non-experts, Russo & Ottoboni, 2019). By comparing trained versus novice epee fencers, better accuracy for trained fencers could indicate better movement execution and technical skills, regardless of the paradigm used (Gutierrez-Davila et al., 2013). Additionally, in the present study, shuttle displacements and preparation for the attack phase were added to the protocol to mimic the timing and activity of epee bouts (Bottoms et al., 2013). The execution of the displacements might have been more efficient in trained epee fencers compared to novices. Consequently, a possible lower cognitive cost and distraction could make it easier for trained epee fencers to maintain their focus on the fixation point, and thus on their visual field as a whole, compared to novices. Overall, our results confirm previous findings in other combat sports (Russo & Ottoboni, 2019), evidencing the important role of visual-spatial attention allocation and technical abilities in fencing performance but also showing that improvements in visual-spatial attention allocation with

fencing practice could be extrapolated from the fencing context and might transfer to other tasks (e.g., a computer task in the context of this study).

Interestingly, in the present study, we found a trade-off between accuracy and speed of execution only in the trained epee fencers. The fact that this association was not mediated by the covert-orienting attention ability measured in the COVAT test suggests that technical abilities in wielding the sword and efficiency of displacement execution might play a key role. Indeed, the speed-accuracy trade-off theory postulated in Fitts' law (Fitts, 1992) states that speed is a function of task precision, which depends on task difficulty. It is then possible that the low technical level of novices resulted in missing several targets in order to be as fast as possible, which would explain the large variability in terms of execution time in this group. Indeed, taking into account the number of targets successfully hit during the test, differences between the groups were evident, leading to a greater performance for the trained group.

4.1 | Limitation and future perspectives

The main limitation of the present study was that the results were obtained in small samples and in a standardized environment, and thus they might not be directly transferable to the field (Schabert et al., 1999; Sirotic & Coutts, 2008; Svensson & Drust, 2005). Gutiérrez-Davila et al. (2017) questioned the utility of using reaction time tasks to discrete visual stimuli to predict fencing performance, suggesting that the ability to anticipate the opponent's intentions is more closely related to perceptual and attentional processes. We proposed a fencing test that more closely resembles to the physical and mental demands of a fencing bout, relying on both technical and covert-orienting attention abilities. However, the results could not

apply to a real-fight situation, as procedures adopted in the present work are not accounting for crucial factors in fencing such as the interaction with the opponent (Voss et al., 2010). Furthermore, the present study adopted a between-subject design with groups separated by a considerable experience gap. Future studies could investigate the differences in covert-orienting attention ability and the trade-off between speed and accuracy across a wider range of levels (e.g., including non-athletes and elite fencers), and disciplines (foil and saber). Due to differences in the segment length and muscle mass, sex-related differences in speed of execution could also be of interest. Finally, as competitive fencing has been shown to induce cognitive fatigue (Varesco et al., 2023), it would be of interest to examine the decrease in covert-orienting attention ability, speed of execution, and precision with cognitive-related fatigue.

5 | CONCLUSIONS

Although preliminary, these results seem to confirm previous speculations about the importance of visual-spatial attention allocation in epee fencing performance and suggest a difference between novice and trained fencers in the covert-orienting attention ability, with important implications for coaches. Furthermore, trained fencers showed a trade-off between accuracy and speed of execution. This relationship was not mediated by covert-orienting attention ability, which suggests a possible influence of fencing technical skills that differs between levels.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

All data are available at https://osf.io/8bnqg/?view_only=438acf07f7b04e1a8671c5b6ce62b810.

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