How to Serve Faster in Tennis: The Influence of an Altered Focus of Attention and Augmented Feedback on Service Speed in Elite Players

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Abstract

Keller, M, Kuhn, YA, Lüthy, F, and Taube, W. How to serve faster in tennis: the influence of an altered focus of attention and augmented feedback on service speed in elite players. *J Strength Cond Res* 35(4): 1119–1126, 2021—Different approaches, such as providing augmented feedback (AF) or adopting an external focus of attention (EF), have been shown to directly enhance performance in recreational athletes. Furthermore, research has shown that combining AF with EF (AF + EF) results in superior performance compared to AF and EF alone. Here, we tested the influence of AF, EF, AF + EF, and an internal focus of attention (IF) on service speed in elite tennis players. High-level national tennis players (19.2 ± 3.7 years) were asked to serve flat serves to a target zone with maximum speed. With respect to service speed, a significant main effect of condition was found ($p \leq 0.001$). Post hoc comparisons revealed faster serves for AF compared to control serves without instruction/feedback ($p < 0.01$) and compared to EF ($p < 0.05$), whereas no significant difference was found between EF and IF ($p = 0.81$). The fastest service speeds were found in the AF condition, whereas the combination of AF + EF did not further promote performance. The number of serves landed in the target zone did not differ between conditions ($p = 0.17$). Thus, no speed-accuracy trade-off was found, indicating that enhanced service speeds did not result in less serves landed in the target zone. Augmented feedback seems most beneficial to instantly enhance tennis serve performance. In contrast to previous studies with recreational sportsmen, EF did not differ from IF, providing further evidence that expertise level and task-relevant instructions mediate the influence of attentional focus on motor performance.

Key Words tennis serve, elite athletes, serve speed, motor performance

Introduction

The tennis serve has evolved into a powerful tool to achieve direct points or to take instant initiative within a rally. It is therefore well established that a good first and second serve is advantageous for being successful in tennis (11,21). However, despite the importance of the tennis serve, training exposures are usually limited due to the associated risk of injury to the elbow (2). Thus, as only a limited number of serves can be executed within a single training session, the quality of the training process (i.e., the technical performance of each serve) has to be improved to optimize training outcomes.

Numerous factors are known to influence motor performance in the short term and long term. For example, the use of augmented feedback (AF)–referring to feedback that is given from an external source and added to the task-intrinsic feedback that originates from a person's sensory system–was demonstrated to be beneficial for motor performance and motor learning (18). Several studies provided evidence for a direct effect of AF on performance by comparing trials with AF to trials without AF. A directly enhanced performance in the presence of AF was (inter alia) reported for jumping movements (12,13,31), pedaling effectiveness during cycling (23), and strength tasks (3,8). Besides these direct (within-session) effects, several studies reported a performance-enhancing effect of AF for long-term interventions with several training sessions (12,22,38). In these studies, all subjects performed an identical training regimen but received different amounts of AF about their achieved performance. In contrast to learning studies with simple tasks such as lever pulling (27), there is now increasing evidence that higher frequencies of AF are more beneficial for adaptations in complex motor tasks. With respect to tennis,

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Moran et al. (22) demonstrated the need and benefit of AF on service speed in tennis. The authors showed that even elite players were not able to judge whether a maximally performed service was faster/slower than the previous one. Therefore, it was hypothesized that providing AF about the achieved performance (i.e., service speed) during training should help to foster training gains. Indeed, enhanced training outcomes were observed in the group that received AF about the service speed compared to a group that trained the same number of serves but without obtaining AF. Most importantly, the enhanced training gains with AF were still evident in a delayed retention test. The exact mechanism(s) underlying the performance-enhancing effect of AF are still unclear and might differ from task to task. It was suggested that one benefit of AF is additional information that potentially guides the subject toward a more optimal movement strategy (27). Other authors discussed the possibility of an increased motivation in the presence of AF (12,22), which enhances the training intensity. Most likely, both mechanisms contribute to improved motor performance outcomes with AF but their relative influence may strongly depend on the task.

A second possibility for direct and long-term performance gains is to provide instructions with a specific focus of attention (34). There is evidence from a variety of studies showing that adopting an external focus of attention (EF) results in better motor performance and motor learning than an internal focus of attention (IF) or a control (CON) condition (34). While an EF directs the subject's attention to the effect or the outcome of their movement, an IF directs attention on movements of the body. For example, enhanced jump performance was found with an EF (e.g., "focus to jump as close as possible to a target") compared to an IF (e.g., "focus to extend your legs as rapidly as possible") in a series of studies (13,35,36). The exact underlying mechanism of the focus of attention theory is not fully understood, but evidence suggests that adopting an EF allows for (more) automatic modes of motor control processes, which in turn results in an improved movement efficiency (20,37). This assumption was supported by the finding that with an EF, agonistic or antagonistic muscles show–despite enhanced motor performance–lower muscular activity (31,36), an increased intracortical inhibition in the prime mover (15,16), and an enhanced level of surround inhibition in adjacent muscles (14).

When comparing the immediate performance-enhancing effects of AF and EF, AF outperforms EF in countermovement jumps (13). Furthermore, combining AF with EF (AF + EF) was recently shown to further enhance performance compared to solely receiving AF or adopting an EF (31). The authors, therefore, assumed that the performance-enhancing effects of AF and EF depend on 2 largely independent mechanisms: on the one hand, providing performance-related feedback (AF) seems to enhance intrinsic motivation (30). On the other hand, EF enhances movement efficiency (20).

Most previous studies investigated the immediate performance-enhancing effect while adopting an EF or while receiving AF in recreational athletes or in novices. Thus, it is not known whether similar performance enhancements can also be found in elite athletes who frequently train a specific motor task. The aim of our study was therefore to evaluate the immediate influence of different conditions (CON, IF, EF, AF, and AF + EF) on service speed in tennis. Because a trade-off between ball spin rate and horizontal ball velocity exists (26), athletes in the current study were asked to serve flat serves with maximal speed and minimal ball rotation. Based on the previous studies mentioned above, an immediate performance-enhancing effect was expected for EF, AF, and AF + EF compared to CON. By contrast, it was expected that the CON condition would outperform the IF condition. Because the potential underlying mechanisms for AF and EF seem to differ and the combination of AF + EF likely results in an additive effect, we hypothesized to find the fastest service speeds in the EF + AF condition.

Methods

Experimental Approach to the Problem

To examine the hypotheses of this study, tennis players were asked to serve balls with maximum speed to a target zone. The effect of different conditions on tennis serves was assessed by measuring the service speed and the serve accuracy (percentage of balls landed in the target zone). Thus, the influence of different instructions and AF (independent variables) on service speed and serve accuracy (dependent variables) was assessed. The chosen instructions and AF conditions are known to immediately enhance performance in laboratory settings or in recreational sportsmen, but their effects on performance of elite athletes are not yet investigated. The aim of this study was, therefore, to test whether principles derived from the study of simple tasks or from studies in recreational sportsmen can be transferred to tennis serves in elite athletes. Furthermore, a second aim was the identification of responders and nonresponders per condition. A high response rate would constitute conclusive evidence that this specific condition should be used by elite tennis players for immediate performance gains.

Subjects

Ten national young elite tennis players were recruited for the experiment (mean $\pm$ *SD*: age range: 15–23 years; mean age: 19.2 $\pm$ 2.7 years; body mass: 71.62 $\pm$ 9.26 kg; height: 184 $\pm$ 7 cm; $n = 8$ right-handed subjects; all subjects were male). None of the subjects trained with AF during their regular training. All subjects provided written informed consent to participate in the experiment and were naive to the hypotheses of the experiments. For all subjects younger than 18 years, parental consent was obtained in addition. The experimental procedure was approved by the ethics commission of the Canton of Fribourg and was in line with the latest version of the Declaration of Helsinki.

Procedures

Testing took place in the indoor training center of Swiss Tennis on a hardcourt (Rebound Ace Sports, Victoria, Australia). A 0.8×2 m square was marked in the service box with a wooden board and served as target zone (Figure 1). Right-handed subjects served the ball from the right side of the center mark to the left service box. For left-handed players, the target was placed in the right service box and players served from the left side of the center mark. The size of the target zone was different compared to the one used in the study by Moran et al. (22) (1.5×1.5 m). The reason for the adapted target size was that pilot experiments with a former Davis cup player indicated that it was essential to have a narrow target zone. Due to the narrow target, a potential opponent would be forced to return the serve with the backhand, which is deemed to be a disadvantage.

Service speed was measured using The Stalker Pro II speed gun, and AF about service speed was given with The Stalker LED Speed Sign (Stalker, Richardson, TX). To minimize measurement errors, the speed gun was placed 5 m behind the baseline and aligned with the direction of the serve. The most precise measurements can be obtained with balls moving directly toward the speed gun because the speed gun works on the Doppler principle. Due to the narrow size of the target zone, the error due to angular deviation was estimated to be smaller than 0.25% of the achieved service speed.

Measurement Procedure. After a standardized warm-up procedure, subjects got accustomed to the experimental setup by trying to serve 30 balls in the target zone. During these trials, verbal feedback about the accuracy (ball in/out the target zone) was given to the subjects. Thereafter, subjects were measured in 5 different conditions (AF, CON, IF, EF, and AF + EF). In each of these 5 conditions, subjects were asked to serve balls with maximum speed to the target zone. A specific instruction (see *Instructions* below) was given in each condition about how to perform the serve. Only serves that landed in the target zone ("in-shots") were used for the speed analysis and counted to the total of the 20 successful serves. Accuracy was determined as percentage amount of serves that landed in the target zone (see details underneath). All 5 conditions were recorded twice and thus, 2 sets of 10 "in-shots" were recorded per condition. The order of conditions was randomized for the first 5 sets but each condition was performed once (AF, CON, IF, EF, and AF + EF). In the second series of sets, the same subject-specific order of conditions was used as in the first series of sets. Overall, the subjects had to serve at least 100 serves (5 conditions $\times$ 2 repetitions $\times$ 10 "in-shots"). Subjects were instructed to serve a ball every 30 seconds. A rest of 2 minutes was given between 2 conditions. Data acquisition took between 90 and 120 minutes per player.

Instructions. Condition-specific instructions were given for directing the attention on specific aspects of the movement or the outcome of the movement. When comparing the effectiveness of an EF to an IF condition, "the respective instructions should be as similar as possible in terms of the content of the information they provide and the amount of information the performer is confronted with" (page 92 in 34). To meet the criteria of this recommendation, the first part of the instructions was identical for all conditions. The condition-specific instructions were explained before the start of a series. After 2 serves, the subjects were reminded of the condition-specific instruction. The following instructions were used in the different conditions:

CON: "Serve as fast as possible while landing the serve in the target zone."

IF: "Serve as fast as possible while landing the serve in the target zone by accelerating your arm as fast as possible."

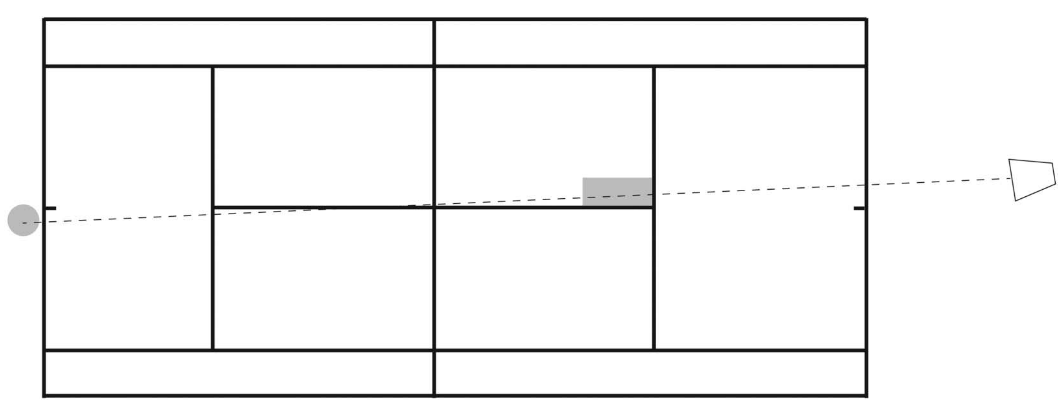

Figure 1. Setup for experiment 1 and experiment 2. In both experiments, subjects served a ball in the target zone (gray rectangle). The speed gun represented on the right side measured the service speed.

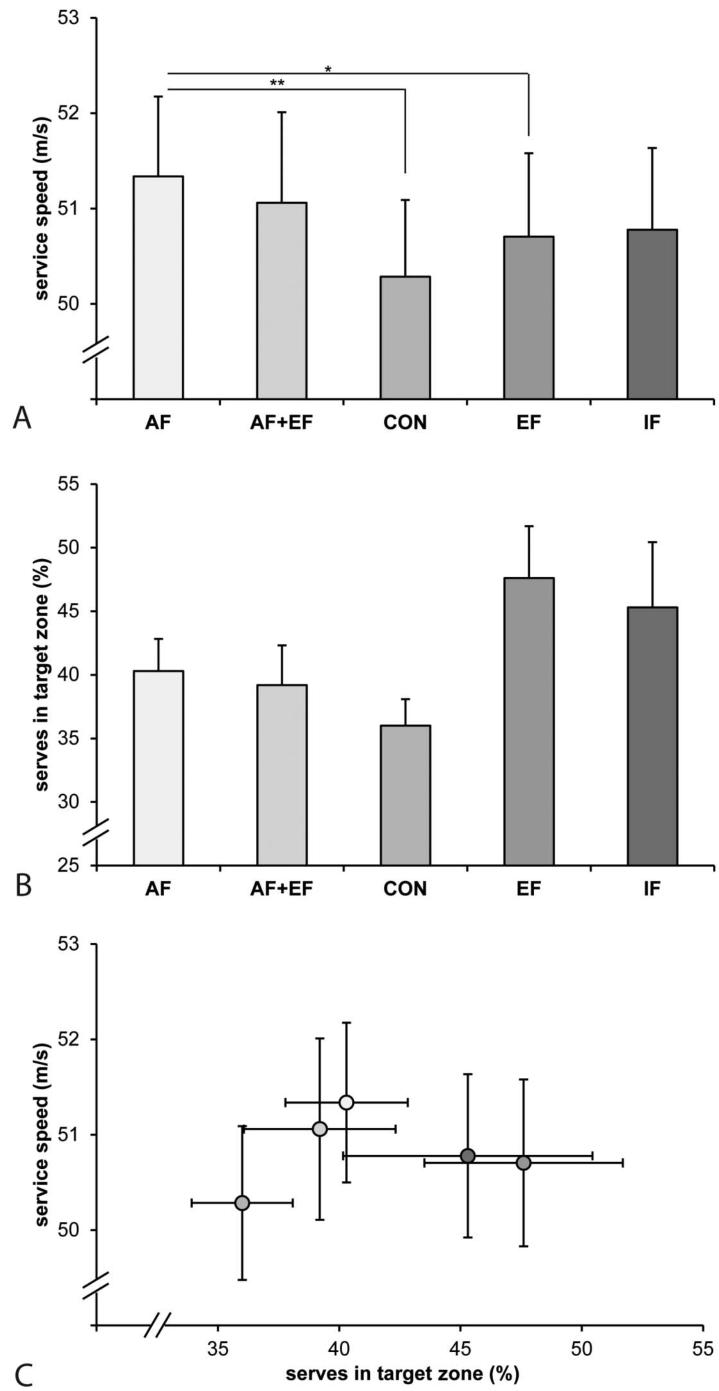

Figure 2. Data from experiment 1 are shown in this figure (please note the adapted scale of the y-axis). A) Shown are the service speeds obtained in experiment 1 under the 5 different experimental conditions. B) Shown are the percentage number of serves that landed in the target zone ("in-shots"). As can be seen in (C), faster serves did not result in a reduced amount of "in-shots." Thus, no speed-accuracy trade-off was found. (*$p < 0.05$; **$p < 0.01$; data are shown as mean ± *SEM*). AF = augmented feedback; AF + EF = augmented feedback with an external focus of attention; CON = control condition; EF = external focus of attention; IF = internal focus of attention.

Table 1. The post hoc comparisons for the different conditions.*†

	AF	AF + EF	CON	EF	IF
AF	x				
AF + EF	$p = 0.72$, $g = 0.09$ 0.28 (−0.54 to 1.10)	x			
CON	$p < 0.01$ $g = 0.37$ 1.05 (0.25 to 1.85)	$p = 0.14$ $g = 0.25$ 0.78 (−0.21 to 1.76)	x		
EF	$p \leq 0.05$ $g = 0.21$ 0.63 (−0.02 to 1.29)	$p = 0.31$ $g = 0.11$ 0.35 (−0.23 to 0.94)	$p = 0.21$ $g = 0.14$ −0.42 (−1.03 to 0.18)	x	
IF	$p = 0.34$ $g = 0.19$ 0.60 (−0.51 to 1.63)	$p = 0.76$ $g = 0.09$ 0.28 (−0.84 to 1.41)	$p = 0.30$ $g = 0.17$ −0.49 (−1.34 to 0.35)	$p = 0.81$ $g = 0.02$ −0.73 (−1.15 to 1.01)	x

*AF = augmented feedback; AF + EF = augmented feedback with an external focus of attention; CON = control condition; EF = external focus of attention; IF = internal focus of attention.

†The *p*-value indicates the level of significance and the *g*-value shows the effect size (Hedges' *g*). In addition, 95% confidence intervals are shown for all post hoc comparisons.

EF: "Serve as fast as possible while landing the serve in the target zone by accelerating your racket as fast as possible."

AF: "Serve as fast as possible while landing the serve in the target zone and try to maximize the speed shown on the screen."

AF + EF: "Serve as fast as possible while landing the serve in the target zone by accelerating your racket as fast as possible and by trying to maximize the speed shown on the screen."

Visual feedback about the service speed was only provided in the AF and AF + EF conditions. However, in all conditions, verbal feedback about the accuracy of a serve (ball served in/out the target zone) was given directly after the serve.

Data Analysis. All sessions were recorded with video cameras that allowed offline analysis of the data. One camera filmed the target zone, whereas the second camera filmed the display of the speed gun. As a wooden board was used to mark the target zone, "in-shots" and "out-shots" could be discriminated in 2 different ways. First, the video allowed visual inspection whether a ball was in/out the target zone. Second, the sound of the touchdown allowed a clear differentiation between balls that landed on the hardcourt (out) or the wooden target (in). Twenty "in-shots" were recorded per condition and subject. Based on these 20 serves, the mean of the service speed was calculated for each subject and condition. Furthermore, the accuracy of the serves was analyzed by counting the number of serves needed for the 20 "in-shots" per condition and subsequently dividing the 20 "in-shots" by the total number of serves. This analysis was mainly performed to test for a potential speed-accuracy trade-off.

Statistical Analyses

The dependent variables in this study were the service speed and the accuracy of the serves (number of serves that landed in the target zone). Data were checked for normality using the Shapiro-Wilk test. The influence of the different conditions on service speed and number of serves in the target zone was tested using repeated-measures analyses of variance (ANOVAs) with the factor "condition" (AF vs. EF. vs. AF + EF vs. IF vs. CON). The assumption of sphericity was tested using the Mauchly's sphericity test. Effect sizes are reported as partial eta square (η_p^2) values, where 0.02 is a "weak" effect, 0.13 a "moderate," and 0.26 a "large" effect. To test whether faster service speeds resulted in more errors ("out-shots"), a correlation analysis was performed using a Pearson's correlation analysis. In case of significant *F*-values, post hoc Student's *t*-tests with Bonferroni-Holm correction and 95% confidence intervals were assessed to look for differences between factor levels (note: the *p*-value of the *t*-tests was corrected and not the level of significance). Hedges' *g* was calculated to assess the effect sizes for the post hoc *t*-tests, with values >0.2 indicating a small, >0.5 a medium, and >0.8 a large effect. The alpha level was set to $p \leq 0.05$. All statistical analyses were conducted using the software SPSS (Version 23.0; IBM Corp., Armonk, NY). Data are presented as group mean values ± *SD*, if not indicated otherwise. To test for individual responses and to distinguish responders from nonresponders, the percentage of athletes improving performance compared to CON was assessed for every condition.

Results

All data were normally distributed and did not violate the assumption of sphericity.

Service Speed

Repeated-measures ANOVA revealed a significant main effect of "condition" (Figure 2A; $F_{4,36} = 5.54$, $\eta_p^2 = 0.38$; $p \leq 0.001$), indicating that the service speed was differently affected by the 5 conditions (AF: 51.31 ± 2.65 m·s^{-1}; AF + EF: 51.06 ± 3.01 m·s^{-1}; CON: 50.28 ± 2.55 m·s^{-1}; EF: 50.71 ± 2.76 m·s^{-1}; and IF: 50.78 ± 2.71 m·s^{-1}). The effect size indicates that the different conditions had a large effect on service speed. Pairwise post hoc comparisons revealed that AF differed statistically significant from CON ($p < 0.01$) and when an EF was adopted ($p \leq 0.05$). After post hoc comparisons, the other conditions did not show statistically significant differences (Table 1). The individual response analysis showed the highest response rate in the AF condition (100%), indicating that all players improved their performance in the presence of AF compared to CON. When comparing the other conditions (IF, EF, and AF + EF) to CON, the subjects could be categorized into responders (AF + EF: 70%; EF: 70%; and IF: 80%) and nonresponders (AF + EF: 30%; EF: 30%; and IF: 20%), indicating less consistent responses.

Serves in the Target Zone

There was no main effect of condition when analyzing the percentage amount of "in-shots" (Figure 2B; "condition" effect: $F_{4,36} = 1.19$, $\eta_p^2 = 0.16$; $p = 0.17$). The effect size indicates a moderate effect of the different conditions on percentage amounts of "in-shots" (AF: $40.30 \pm 7.97\%$; AF + EF: $39.20 \pm 9.89\%$; CON: $36.00 \pm 6.58\%$; EF: $47.60 \pm 12.93\%$; IF: $45.30 \pm 16.24\%$). When testing for individual responses, no clear differences between conditions was found (response rate compared to the CON condition: AF: 70%; AF + EF: 80%; EF: 70%; and IF: 60%). When testing for a potential speed-accuracy trade-off, the correlation analysis showed no statistically significant correlation between service speed and percentage amount of serves in the target zone (Figure 2C; $r = 0.005$; $p = 0.97$), indicating that accuracy was not negatively affected by faster serves.

Discussion

In this study, the influence of different conditions on service speed and accuracy in elite tennis players was investigated. Statistically significant differences between conditions were found with a large effect size. Post hoc comparisons showed that the use of AF results in statistically significant differences compared to CON and EF. Despite faster serves with AF, the number of serves that landed in the target zone was not reduced and no accuracy-speed trade-off was found. In contrast to our hypothesis, the adoption of an EF did not result in faster serves compared to an IF or the CON condition. Similarly, combining AF + EF did not further enhance service speed.

Research on attentional foci has consistently demonstrated that adopting an EF outperforms an IF or a control condition (34). In contrast to these previous studies, adopting an EF did not enhance tennis serve performance compared to an IF or a CON condition in elite tennis players. Our findings are in line with recent studies showing that an IF can result in similar (7,19) or even better (6,10,17) results than an EF. In this respect, Schücker et al. (28) demonstrated that one specific IF can impair movement economy, whereas another specific IF is not detrimental to performance. Thus, it seems reasonable to dispute the well-accepted assumption that an IF invariably results in poorer motor performance (5,9,24).

One possible explanation for the absence of differences between an EF and IF in some studies could be that (inter alia) the expertise level mediates the influence of different foci of attention. For example, Winkelman et al. (32) found EF-mediated performance gains (faster sprint times) in subjects with moderate experience at sprinting but not in highly experienced sprinters. Similar observations were made when attentional focus effects were analyzed in elite acrobats. The author of this study (Gabriele Wulf) concluded "that there may be a limit to the performance-enhancing effects of external focus instructions for top-level performers" (p. 319 in 33). Because all our subjects played on an international level, the high level of expertise might partly explain why performance did not differ between the EF and the IF conditions.

A second possible explanation for the nonsignificant difference between the IF and the EF condition might be that, although our instructions clearly differentiated between an IF and an EF, both instructions nevertheless provided task-relevant information. By contrast, the large percentage differences between the IF and EF conditions of some previous studies might partly be explained by the misleading instruction for the IF condition. For example, previous studies asked subjects to "focus on the finger" (internal focus) or "focus on the rungs" (external focus) while trying to maximize jump height (35,36). While focusing on the aim (rung) is a motivating and task-relevant instruction, focusing on a finger during jumping is obviously a task-irrelevant instruction. Similarly, other studies used very different instructions that clearly referred to different aspects of the motor task (e.g., during standing long jumps: EF: "when you jump, focus on jumping as close to the cone as possible"; IF: "when you jump, focus on extending your knees as rapidly as possible" in 25). The instructions in this study, however, contained task-relevant information for the IF condition ("accelerate your arm") as well as the EF condition ("accelerate your racket"). At the same time, the instructions for IF and EF differed in only one word to avoid confounds with other variables and did, therefore, respect the recommendations given by Wulf (34) for a scientifically sound experimental design in the field of attentional focus research. In many previous studies, the focus-specific instructions concentrated on different aspects of the movement (4,25,35,36) and were therefore not in line with these recommendations.

In the acute setting, the elite tennis players looking to make incremental improvements in serve speed seem to benefit from AF when compared to CON. The immediately enhanced performance with AF that is well known from other motor tasks (3,8,12,13) can therefore be transferred to tennis serves in elite players. The reason for this immediate performance gain can most likely be explained by an increased motivation (12,22,30,31). In this context, it was recently demonstrated that AF is superior to EF (12,31) and it was speculated that AF (motivation) and EF (movement efficiency) depend on different mechanisms (31). In line with this, we also found, in this study, significantly faster service speeds in the AF compared to the EF and CON conditions. A more detailed analysis of individual responses showed that all tested players served faster with AF but not at the expense of serve accuracy (see trade-off analysis). Thus, the provision of AF seems a promising tool to increase service performance in elite tennis players. This is reinforced by the observation of Moran, Murphy, and Marshall (22), who have shown that the application of AF in elite tennis players does also promote service speed in the long run.

In contrast to our hypothesis, AF did not differ statistically significant from IF. As discussed above, there is increasing evidence showing that the expertise level seems to influence the effects of different attentional foci on performance, which might also explain the nonsignificant differences between these 2 conditions. Based on the behavioral measurements in this study, no conclusive explanation for the nonsignificant difference between conditions can be given.

The notion that an EF did not result in significantly enhanced performance might also explain why the AF + EF condition did not–compared to previous research on jump performance in recreational sportsmen (31)–result in faster serves than AF alone. However, the complexity of the movement might also influence which condition (AF + EF or AF) is more successful to enhance performance. One can speculate that demanding motor tasks such as tennis serves require attentional resources that prevent or interfere with the parallel processing of too much other information such as instructions about the focus of attention and–at the same time –the request to increase the speed shown on the display.

As a limitation, conclusions drawn in this study are based on a rather small sample size. However, recruiting a large sample of elite athletes is difficult and therefore we decided to recruit only the top player(s) of each age group. Besides the above-mentioned explanations for the absence of differences between selected conditions, one can consider that verbal feedback about accuracy was built into every condition. Thus, while only 2 conditions received AF about service speed, feedback about accuracy was provided in every condition. Another important aspect is the study design. In this study with 5 conditions, the post hoc t-tests were corrected for multiple comparisons ($n = 10$). On the one hand, Bonferroni corrections reduce the risk of a type I error but, on the other hand, at the expense of a type II error (1,29). Thus, the multiple comparisons might also (partly) explain the nonsignificant differences between EF, IF, and CON. In fact, noncorrected comparisons showed significantly faster serves for EF compared to CON ($p = 0.03$), but also a strong trend for faster serves when comparing IF with CON ($p = 0.06$). No difference between EF and IF ($p = 0.81$) was found in the uncorrected t-tests. Thus, independent of the post hoc correction, an EF did not further promote serve speed than an IF.

Practical Applications

This study offers several practical applications for serve training in elite tennis players. For example, it seems reasonable to dispute the well-accepted assumption that an IF invariably results in poorer motor performance, whereas an EF invariably enhances performance. However, elite tennis players looking to make incremental improvements in serve speed may benefit from AF, with no additional enhancement coming from an EF in the same context. A second important conclusion can be drawn from the individual response analysis showing a 100% response rate for the AF condition, whereas the other conditions showed lower response rates (70–80%). The consistently enhanced performance with AF may indicate that providing feedback about the service speed is a worthwhile addition to the daily training of elite tennis players. To conclude, the provision of objectively measured performance-related feedback is recommended for elite tennis players.

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