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This is an Accepted Manuscript of an article published by Taylor & Francis in
Journal of Applied Sport Psychology on 11/11/2014, available online:

<http://doi.org/10.1080/10413200.2014.957364>

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3 1 Non-automated pre-performance routine in tennis – An intervention study
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5 2 Abstract
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7 3 The effect of a non-automated pre-performance routine (PPR) on performance in a high-
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9 4 pressure situation was investigated. Twenty-nine tennis players served in a low- and high-
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11 5 pressure condition in a pre- and post-test design. The intervention group learned a non-
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13 6 automated PPR for four weeks. Increases in subjective, but not objective (i.e., cortisol), levels
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15 7 of stress were detected in the high-pressure conditions. The intervention group showed a
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17 8 significant decrease in performance in the high-pressure condition in the pre-test ($p = .005$),
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19 9 but not post-test ($p = .161$). Using a non-automated PPR may benefit athletes who experience
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21 10 a drop in performance in high-pressure situations.
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30 11
31 12 *Keywords:* cortisol, high-pressure, stress, TSST
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15 **Non-automated pre-performance routine in tennis – An intervention study**

16 In tennis, a low error rate on double faults (i.e., two successive serve errors) is crucial
17 especially in critical match situations (Knisel, 2003) where the second serve success rate can
18 be the difference between winning and losing (Djurovic, Lozovina, & Pavicic, 2009). In
19 comparison to the first serve in tennis, after which a player is given an additional chance of
20 serving in case of a fault, the second serve increases pressure because the ball must land in
21 the opponent's service box otherwise the point will be lost immediately (see Knisel, 2003).
22 To effectively perform any tennis (not only a second) serve under pressure in tennis, a free
23 throw in basketball, a penalty kick in soccer, or a 100 m sprint in track and field, many
24 athletes perform a pre-performance routine (PPR). A PPR is defined as a set of cognitive and
25 behavioral elements executed prior to performance execution (see Cotterill, 2010 for a
26 review). Using a PPR prior to the second serve under pressure is appropriate because it is not
27 influenced directly by an opponent and the athlete has time to execute the elements.

28 Theoretically there are two main models that may explain a decrease in performance
29 under pressure: distraction towards irrelevant stimuli (Baumeister & Showers, 1986) and
30 increased self-focus on one's own movement processes (Beilock & Carr, 2001; Masters &
31 Maxwell, 2008). Both processes are still relevant for applied settings, theory-matched
32 interventions, such as non-automated PPR, have recently been developed (Mesagno,
33 Marchant, & Morris, 2008; Mesagno & Mullane-Grant, 2010). Mesagno et al. (2008)
34 explained that a non-automated PPR keeps the focus on executing the routine and helps to
35 maintain optimal attentional focus, which decreases the likelihood of a distraction or a self-
36 focus to occur under the high-pressure situation.

37 To date, only a few studies have investigated the effects of non-automated PPR on
38 performance under pressure. In a single-case design study, three tenpin bowlers improved
39 performance under pressure an average of 29% after a personalized PPR intervention

(Mesagno, et al., 2008). Furthermore, Mesagno and Mullane-Grant (2010) deconstructed the extensive PPR (which included the modification of optimal arousal levels, behavioral steps, appropriate attentional control, and cue words) in a follow-up study with a larger sample of Australian football players to determine which part of the PPR was most beneficial. In the Mesagno and Mullane-Grant study, the performance of each intervention group (i.e., extensive PPR, deep breathing, cue word, or temporal consistency) increased in the high-pressure condition, with the highest increase for the extensive PPR group who used the more complex, rather than singular, PPR. Performance of the control group decreased during the high-pressure situation.

Although these studies provide preliminary empirical evidence for the benefit of theory-matched interventions such as non-automated PPR, a few limitations existed: First, no objective, physiological measures of stress were included, which Hale and Whitehouse (1998) indicate can differ from the athletes' subjective perception of physical signs. Second, the short time period in which the PPR was learned was unrealistic, with most athletes not being asked to learn a PPR within a few minutes prior to a competition. Finally, Mesagno and Mullane-Grant (2010) argued that a non-automatic PPR would be beneficial, however, no assessment of automaticity was included. Therefore, this current study aimed to address these gaps by investigating the effects of a non-automated PPR, learned for a longer period of time (i.e., four weeks), on tennis serving performance in a low and high-pressure condition, with a physiological marker of stress (i.e., salivary cortisol). Additionally, we measured the degree of automation of the non-automated PPR using a dual-task condition. We hypothesize that performance will decrease and stress levels will increase (i.e., using both subjective, visual analogue and objective, salivary cortisol, markers of stress [Kirschbaum & Hellhammer, 2000]) in both groups during the pre-test of the high-pressure condition in comparison to the low-pressure condition. Further, we hypothesize that from the low- to the high-pressure

condition in the post-test, stress levels will increase in both groups. Regarding performance in the post-test, we hypothesize from the low- to the high-pressure condition that the intervention group would maintain, or even increase performance due to the learned non-automated PPR and that the control group would decrease performance (similar to Mesagno & Mullane-Grant, 2010 findings).

Method

Participants

Twenty-nine experienced tennis players ($M_{age} = 24 \pm 4.9$ years; 14 females) were involved in the study. Participants practiced an average of 3.75 hr per week ($SD = 2.25$) and played tennis for an average of 16.7 years ($SD = 5.4$), which indicates that participants were competing at a high level.

Materials and Measurements

Subjective and objective measures of stress level. A visual analogue scale (VAS) was used (Hayes & Patterson, 1921). Participants were asked to answer the question “How stressed do you feel right now?” and make a cross on a 100 mm line with two end poles (*not at all stressed* and *very much stressed*).

Cortisol was assessed six times for pre- and post-test (according to Kirschbaum & Hellhammer, 2000) via plastic saliva collection tubes (see Figure 2). Samples were stored at -80°C within the same day. Levels of salivary cortisol were determined by using commercial enzyme-linked immunosorbent assay (ELISA) kits (SLV-2930, DRG Instruments GmbH, Germany).

The baseline (BL) level of cortisol was computed with the mean of the two measurements (i.e., $t-15$, $t-2$) in each low-pressure condition (see Kirschbaum & Hellhammer, 2000). The cortisol response to the anxiety induction was calculated by the average (AVE) cortisol response (i.e., $t+2$, $t+12$, $t+15$, and $t+32$; see Fekedulegn et al., 2007).

Anxiety induction. The anxiety inductions leading to the high-pressure conditions were the 2nd part of Trier Social Stress Test (TSST; Kirschbaum, Prike, & Hellhammer, 1993) for the pre-test, and the number sequencing subtest of the Wechsler-Memory-Scale Revised (WMS-R; Wechsler, 1945) for the post-test. For the 2nd part of the TSST, participants were asked to count backwards from 2013 in steps of 17. If a mistake was made, the experimenter asked participants to start from the beginning. For the WMS-R, participants were asked to repeat a sequence of figures read aloud by the experimenter in the reverse order. Gradually the sequence of figures increased from two to a maximum of seven figures. Only at the end of each sequence the experimenter gave feedback. They were chosen as they offered a standardized way to induce stress, shown to increasing anxiety and cortisol level (Laessle & Hansen-Springer, 2010). Also, we chose to use different anxiety inductions in order to avoid learning and/or habituation effects (Petrowski, Wintermann, & Siepmann, 2012).

Performance measurement. For the pre- and post-test, participants were asked to perform two sets of 35 well-aimed second serves from the deuce-side using their own rackets. The total number of faults was the dependent variable.

Non-automated pre-performance routine. Two applied sport psychologists and one researcher developed the non-automated PPR, which combines several aspects of sport psychological training (Weinberg & Gould, 2007) and was identical for each participant. In detail, first participants were asked to look at the ball in order to reduce the impact of distractions (Moore & Stevenson, 1994), then to breath in and out while adjusting the strings used as a relaxation cue (Foster, Weigand, & Baines, 2006). Next, they were instructed to focus on the service box and the point where the ball will be hit, followed by looking at one's own feet to bounce the ball eight times with the purpose of having to focus their attention on task-relevant cues (Boutcher, 1992). Finally, they were told to mentally verbalize, used as a

word cue (Foster et al., 2006), the area where the ball will be hit. In accordance to the guidelines recommended by Cotterill (2011) and results of interventions in tennis (Masassis & Doganis, 2004), each participant was informed about the functions of the different parts of the routine.

In order to measure the degree of automation of the non-automated PPR, the time needed to perform five serves under a dual-task condition was compared to the time needed to perform the same amount of serves under normal conditions (according to Beilock & Carr, 2001).

Procedure

The experiment was conducted between 9 a.m. and 7 p.m. and lasted 1 hr for each pre- and post-test. Prior to the experiment, participants were instructed to awake at least 3 hr before the experiment in order to avoid the cortisol awakening response (CAR; Pruessner et al., 1997) and not to eat anything, drink anything but water, or brush their teeth 1 hr before testing started. Prior to data collection, athletes or their parents (i.e., in case they were minors) signed an informed consent form, following appropriate ethics requirements.

The pre- and post-test had the same structure (see Figure 1). Participants were welcomed and the task was explained. After signing the informed consent, participants performed a maximum of 10 practice serves, followed by the 35 second serves (i.e., low-pressure condition). Next, the anxiety induction was performed, lasting four minutes (see Kirschbaum, Pirke, & Hellhammer, 1993), which was followed by another 35 second serves (i.e., high-pressure condition).

The intervention group, which included 15 randomly assigned participants, had four weeks of intervention training (see Figure 1). Each player was trained individually for 30 min per week with a sport psychologist (according to Foster et al., 2006). Additionally, they were instructed to practice the routine by themselves around 70 times per week and they were also

given a diary, in which they were asked to document the amount of times they have practiced and processes, information, and/or problems they encountered with the routine.

During the final intervention session, participants also performed five serves under normal conditions, and another five serves under dual-task conditions to assess automaticity of the movement. The sport psychologist timed the length of the serves under normal and dual-task conditions, both performed with the trained routine, with a stopwatch manually. The routine started when the participant first looked at the ball when, for example taking it out of his/her pocket, and ended when the ball touched the racket on each serve.

During the post-test participants of the intervention group were asked to use their learned routine. Adherence to the learned routine was checked by the experimenter writing down whether the behavioral elements were performed on each attempt (e.g., looking at ball, adjusting strings, bouncing ball, looking at service box). In case the routine was not performed correctly, the serve had to be retaken. The control group was asked to do their best (considering they received no training).

Results

For all dependent measures (i.e., VAS, cortisol, performance), separate 2 (testing time: pre- vs. post-test) x 2 (condition: low- vs. high-pressure) repeated measures Analysis of Variance (ANOVA) with group as a between subject factor were conducted. Bonferroni post-hoc analysis test was used to identify any main effects. Significant interactions were further analyzed using *t* tests, using Bonferroni correction depending on the number of tests. Initially, level of significance was set at $p < .05$ for all analyses.

Stress levels

For the subjective stress, a significant main effect for condition, $F(1, 28) = 36.557$, $p < .001$, $\eta^2 = .566$, was detected (see Table 1). Post-hoc showed significant higher stress levels (i.e., VAS) in the high-pressure (mean difference: -23.834 , $p < .001$, $d = 5.89$) in comparison

to the low-pressure condition. Also, a significant interaction effect for condition and testing time, $F(1,28) = 15.535, p < .001, \eta^2 = .357$, was found. A paired t test showed significantly higher changes in the overall sample in VAS for the pre-test, $t(28) = 3.435, p = .002, d = 0.66$, in comparison to the post-test. No interaction effects were detected, indicating no difference in self-reported stress between groups in reaction to the stress induction.

For the objective stress, no significant interaction effects or main effect of salivary cortisol were detected for testing-time ($p = .134$) or condition ($p = .861$).

Routine automation

Participants practiced the routine by themselves 233 times on average ($SD = 132$) during the intervention phase. Participants needed significantly longer ($M = 0.87$ s) to perform the serve with the non-automated PPR in the dual-task condition in comparison to normal execution, $t(14) = 3.43, p = .004, d = .51$. Thus, the routine was likely not automated.

Performance

To control for potential differences between groups in the initial performance level an independent t test was conducted. No significant difference was found between the groups in the pre-test, low-pressure condition ($p = .944$), indicating equal ability levels at the start of the study.

As for performance, no main effects were found for condition ($p = .094$) and testing time ($p = .169$). However, a significant interaction effect was found for testing time and condition, $F(1, 27) = 4.558, p = .042, \eta^2 = .144$. Thus, two separate paired t tests, adjusting the significance level to .025, revealed that performance in the low-pressure condition differed between pre- and post-test. That is, participants performed significantly better in the low-pressure condition in the pre-test in comparison to the low-pressure condition in the post-test, $t(28) = 2.888, p = .007, d = 0.35$. Due to this interaction, which indicated a different level of baseline performance in pre- and post-test, further analyses were conducted to

compare means within the pre- and post-test phases. In the pre-test, performance decreased significantly in the intervention group, $t(14) = 3.302$, $p = .005$, $d = 0.52$, whereas no significant change in performance was shown in the control group ($p = .182$). During the post-test, performance did not change significantly for either group ($p_{intervention\ group} = .161$, $p_{control\ group} = .224$).

Discussion

The aim of the current study was to investigate the effects of a non-automated PPR on tennis serving performance in a high-pressure situation. Our results showed that the anxiety induction significantly increased subjective (i.e., higher VAS in high-pressure condition for pre- and post-test in both groups), but not objective, stress levels. The control group did not show any performance changes due to anxiety induction—neither in pre- nor post-test, whereas the experimental group performance decreased after the anxiety induction in the pre-test but was stable in the post-test, after learning the non-automated PPR. Thus, the use of the non-automated PPR kept performance under pressure consistent. Thereby, the results expand empirical evidence of the approach of theory-matched intervention for athletes that initially decrease performance under pressure (Mesagno, et al., 2008; Mesagno & Mullane-Grant, 2010) to a more applicable use of a PPR also for competitive settings.

Although the anxiety induction used in our study has increased salivary cortisol levels before (e.g., Laessle & Hansen-Springer, 2010), it was not the case in the current study. Studies that also report subjective increases in stress but no significant increases in cortisol argue that the hypothalamus-pituitary-adrenal axis of athletes is adapted because of repetitive stress of competitions (e.g., Hanton, Thomas, & Maynard, 2004; Strahler, Ehrlenspiel, Heene, & Brand, 2010). In addition, the level of physical fitness might also play a role. Stressing well-trained and untrained men with the TSST showed that these groups differ significantly in their cortisol response—being higher in untrained men (Rimmele et al., 2007).

Overall, an adaptation to psychosocial stress due to competitive settings or physical fitness of athletes might be the reason why cortisol did not increase in our study even though the anxiety induction increased stress on a subjective level, which is in line with previous research (e.g., Mesagno & Mullane-Grant, 2010).

Performance between the groups did not differ in the beginning (i.e., pre-test, low-pressure condition). After the anxiety induction in the pre-test, however, the control group did not change in performance, whereas the intervention group dropped performance significantly. In the low-pressure condition of the post-test, performance in both groups was significantly worse than in the low-pressure condition of the pre-test. As a result, the changes in performance within pre- and post-test were used for further analysis and showed that the use of the non-automated PPR helped the intervention group to keep their performance consistent in the high-pressure condition of the post-test. This finding is contrary to findings showing an increase in performance (i.e., Mesagno et al., 2008; Mesagno & Mullane-Grant, 2010). Considering that in our study, each athlete was given the identical routine, to ensure standardization in order to allow replication, the incorporation of individual needs, as suggested by many authors (e.g., Cotterill, 2010) was not installed. This could be the reason for finding a stabilization in performance, rather than an increase found by Mesagno et al. (2008) and Mesagno and Mullane-Grant (2010), who took the time to develop individual routines with each athlete.

This study presents methodological limitations that should be addressed in future research. External factors could be the reason for the surprising performance decrease throughout control and intervention group, as the study was conducted outdoors and the weather may have changed from pre- (i.e., sunny, no wind) to post-test (i.e., rainy, windy). Future research should be conducted in a tennis indoor facility. Additionally, a control group should get a control treatment in order to avoid social approval effects. Nevertheless, in

regard to our control group, there is little evidence suggesting that such social factors played a role.

From a theoretical perspective, it has been suggested that an increase in perceived control, due to a routine, in a high-pressure situation might be the reason for consistency (or increase) in performance under pressure (e.g., Cheng, Hardy, & Markland, 2009; Dale, 2004). It appears that control on performance direction (i.e., where should the ball land)—not movement processes—is to be gained due to the non-automated PPR, proposed in this study. Thereby, a distraction towards irrelevant stimuli (Baumeister & Showers, 1986) was prevented as well as an increased self-focus on the players' own movement processes (Beilock & Carr, 2001; Masters & Maxwell, 2008), as participants had to focus on the non-automated PPR that included functional elements for performance, in order to execute it. This study also supports research that investigated choking under pressure based on the distraction model of choking (e.g., Mesagno et al., 2008; Mesagno & Mullane-Grant, 2010), indicating that using a PPR improves performance under pressure.

Overall, the question whether to use a non-automated PPR that is trained longer (i.e., 4 weeks) in comparison to only shortly before the high-pressure situation has to be answered on different levels. On the one hand, performance with the longer non-automated PPR *only* allowed participants to maintain performance, whereas performance increased when learning it shortly before the high-pressure situation (e.g., Mesagno & Mullane-Grant, 2010). On the other hand, the use of a longer trained non-automated PPR is more realistic and possible to incorporate during actual competition. With this in mind, for athletes who experience decreases in performance in high-pressure situations, we would recommend using an individualized longer trained PPR (see also Hazell, Cotterill, & Hill, in press), to ensure the athlete is comfortable with using the routine.

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