

Physiological Patterning of Short Badminton Serve: A Psychophysiological Perspective to Vigilance and Arousal

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Abstract: Previous research has revealed a heart rate (HR) deceleration due to an external focus of attention (vigilance) prior to a skilled performance; the effects of shifts in arousal however, may produce the same response. To separate out effects of these two different state constructs, HR and skin conductance level (SCL) were both measured as indices of vigilance and arousal, respectively. Twenty elite and twenty novice badminton players performed 30 short services while their HR and SCL were constantly recorded during 10s before and 10s after each service. Immediately prior to action, elites demonstrated a non significant decrease in SCL and a significant decrease in HR which was followed by a rebound increase. This pre-action decrease was not found in novices. For elites, linear decrease in SCL prior to action did not differ between best and worst serves. The best serves showed significantly lower HR levels prior to action. Results were discussed in relation to the hypotheses explaining the relationship between arousal and vigilance with performance.

Key words: Vigilance • Arousal • Heart rate • Skin conductance level • Short badminton serve

INTRODUCTION

One of the more critical components of skilled motor performance is the 5-10 s period immediately before the execution of the task. It is during this "preparatory" period that performers make final adjustments in their arousal/attentional sets [1]. Anticipatory cardiac deceleration has been observed to develop several seconds immediately before an expected event requiring attentional processing [2]. This phenomenon was first described by Lacey (1967) and Lacey & Lacey (1970). In order to explain the relationship between HR and attention, Lacey (1964) put forward the intake-rejection hypothesis according to which intake of stimulus was associated with reduction and rejection of stimulus was accompanied by increase in HR. On the other hand Obrist (1981) stated that HR changes are not directly attributable to attention but rather an indirect effect of reduction in motor activity.

Even though the views of Lacey on cardiac activity stress on the role of attentional processing and the views of Obrist emphasize motor preparation, there exists evidence in support of a middle ground argument. In other

words, the assertion that attentional processing and motor preparation are involved in a skilled performance such as a badminton serve does not seem unreasonable. Studies that have investigated the relationship between cardiac activity and attention in a few seconds before a sport performance have basically put the emphasis on self-initiated skilled performances, e.g. bowling, rifle shooting [4, 5] and golf [6, 7, 8]. A number of these investigations have failed to achieve clear findings. They have sufficed to measure HR and none has included a suitable physiological index for measuring arousal which is a potentially complex state parameter. It seems that changes in arousal level may obscure interpretation of attentional effects in such research studies.

As a historical point of view, psychophysiologicalists have initially used various measures such as skin conductance level, HR, blood pressure etc... as indices of arousal. But in view of the fact that these measures do not covary well in different situations and show "situational specificity" [9], extensive confusion arose about the concept and measurement of arousal in the literature of psychophysiology until Barry (1996) suggested that HR and SCL are not both indices for arousal measurement

and must be studied separately. Tremayne and Barry (2001) regarded the SCL as an index of arousal and the HR as an index of vigilance and have studied these two functions during the skilled performance of pistol shooters. SCL as the “gold standard” in the measurement of arousal has a long history in psychophysiology [10], indicating the electrical changes related to the activities of sweat glands (which are mostly concentrated in the palm of the hands and feet). In the present study, which is an endeavor in line with the research carried out by Tremayne and Barry (2001) to investigate the patterns of physiological changes in the skill of badminton short serve (with different physical and perceptual/cognitive demands), attentional requirements of the task as well as its muscular requirements has been emphasized. Therefore, the findings of this research have great importance in the completion and expansion of the present knowledge with regards to the relationship between cardiac function and electrical function of the skin.

Therefore, the aim of the present research was to examine 1) HR changes, as an index of vigilance and SCL changes, as an index of arousal, pre and post badminton serve, 2) the differences in the physiological profiles of badminton players by their skill levels and 3) the relationship between the physiological profiles and the performance of the players.

MATERIALS AND METHODS

The statistical population of experts included members of the national team and the country's badminton premier league in 2009/2010 totaling 49 individuals, aged from 18-26 years (mean age 22.05, S.D. 1.904) who had played for 6 years on average in the premier league and the novice population included non athletes university students in the academic year 2008-2009 totaling 550 in numbers, aged from 19-25 years (mean age 20.80, S.D. 1.239). From each population a group of 20 (10 women and 10 men) voluntarily participated in this study.

The portable device used for recording data was Biograph Infiniti manufactured by Thought Technology (Canada) Ltd. For measuring electrocardiogram, the EKG-Flex/Pro sensor was used. For recording SCL, the SC-Flex/Pro sensor was used. This sensor has two electrodes which were fixed to the inside of the large arch of the non-preferred feet of the participant, two and a half centimeters away from each other.

In order to control the mood states of participants, the Brunel Mood Scale (BRUMS) was used [11]. In order to measure the anxiety parameter, the State Trait Anxiety Inventory (STAI Form Y-2) was used [12].

The task was performing a back-hand short badminton service. The novice participants practiced a session consisting of 5 blocks of 15 trials. The test which included 30 consecutive self-paced short serve was conducted on the following day. The practice and test of short serve were taken from a method adopted by Goode and Magill (1986), which is as follows: in the right service court, markings were drawn 10 centimeters width and in arch form at 10, 20, 30, 40 and 50 centimeter intervals from the intersection of the centre line and the short service line and a score of 1, 2, 3, 4 and 5 was considered for each of these. Any shuttle landing on the line received a higher score and each shuttle landing outside the target area received a zero score.

While the participant was standing in the proper position for serving, electrodes were fixed to his body. The participant was given ten minutes to get used to the electrodes. During this time the STAI Form Y-2 and the BRUMS were completed by the participant and in order to warm up and become familiar with the exercise, 5 practice serves were hit. With the announcement of the start of recording of the data, the participant executed 30 consecutive self-initiated short serves. Data relating to SCL and HR with a frequency of 256 Hertz were collected and were used with a 32 Hertz frequency for statistical analysis. The scores of 4 and 5 were used as the best scores and the scores of zero and 1 were considered as the worst ones.

For statistical analysis, for each serve, the mean SCL and HR values during each half second interval for 10 seconds before and 10 seconds after the action was calculated and the mean of these physiological levels during the thirty serves were analyzed using ANOVA. The analysis was indicative of pre action and post action patterns separately for expert and novice participants. This method prevents the nonhomogeneity problems related to the variance/covariance matrix which commonly accompanies repeated measurements of variance analysis of physiological data. This analysis included selected orthogonal trends on repeated measurements. The data of the experts were divided into two groups of the best and the worst serves over time and each group of data were analyzed by repeated measures ANOVA, indicating patterns of HR and SCL levels pre and post action separately. In all tests, $\alpha \leq 0.05$ was presumed.

RESULTS

Psychological Variables: Using the STAI Form Y-2, the mean raw score of trait anxiety of the participants was 32.6, with the minimum score of 23 and the maximum score of 42, which based on the published norms was considered low to relatively low. Using the BRUMS, the mean score of the participants in the 'anger' component was equal to 0.275, in the 'confusion' component was equal to 0.55, in the 'depression' component was equal to 1.0, in the 'tension' component was equal to 0.65 and in the 'vigour' component was equal to 11.30. Based on published norms, all the negative mood states scores were less than the 50th percentile, indicating a normal state as far as the anxiety and mood was concerned. The score of positive mood of 'vitality' was more than the 50th percentile which was expected.

Electrodermal Activity: Figure 1 illustrates the mean SCL in experts (mean 11.718, S.D. 2.525 micro-Siemens) and novices (mean 11.760, S.D. 2.598 micro-Siemens).

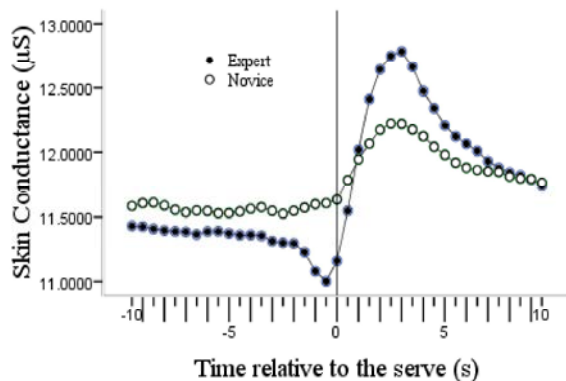


Fig. 1: Mean SCL at half second intervals starting 10 seconds before and ending 10 seconds after the action. The vertical line in the middle of the figure shows the time the service has been hit. The linear reduction in SCL from five seconds to one half of a second prior to the action and its immediate rebound within three seconds after the action in experts can be observed. In novices, no reduction is observed prior to the action but afterwards an increase is observed within three seconds.

In experts, up to nearly 5 seconds before the action, SCL levels had a slight change and followed by a linear reduction over time which lasted up to half a second before the action and approached a significant level ($F_{1,19} = 3.442$, $P < 0.079$). In novices a slight change in electrodermal activity was observed in 10 seconds prior to the action ($F < 1$). Half a second before the action, an

increase in SCL levels of experts was observed which reached its peak within 3 seconds after the action (12.787 micro-Siemens) and subsequently approached pre-action levels. These changes were represented by a significant linear trend ($F_{1,19} = 31.815$, $P < 0.000$), quadratic trend ($F_{1,19} = 43.593$, $P < 0.000$) and cubic trend ($F_{1,19} = 58.367$, $P < 0.000$). In novices the increase in SCL levels was observed from the moment of the action and peaked to its maximum within 3 seconds (12.222 micro-Siemens) and it subsequently reduced. These changes were observed as a significant linear trend ($F_{1,19} = 6.246$, $P < 0.000$), quadratic trend ($F_{1,19} = 25.950$, $P < 0.000$) and cubic trend ($F_{1,19} = 13.528$, $P < 0.002$).

Figure 2 indicates the data relating to the SCL levels in experts for the best/worst serves. In general, the best serves were associated with a lower level of electrodermal activity (mean 11.570, S.D. 2.568 micro-Siemens and mean 11.863, S.D. 2.528 micro-Siemens, respectively). No significant difference was observed in the linear reduction in skin conductance level before the action between best and worst serves ($F_{1,19} = 2.870$, $P < 0.099$).

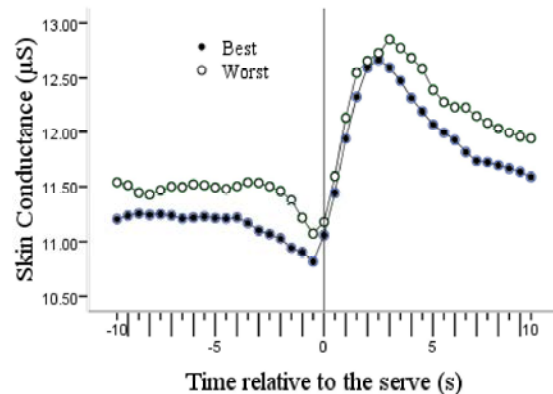


Fig. 2: Skin conductance level profiles for the best/worst badminton serves in experts. A gradual decrease prior to the action and afterwards a sudden increase is seen in both groups. The reduction in SCL before the best serves compared with the worst serves was not significantly different

Cardiac Activity: Figure 3 shows the mean HR in experts (mean 90.809, S.D. 9.4175 beats / minute) and novices (mean 92.934, S.D. 6.2047 beats / minute). From about 8 seconds to 3.5 seconds before the action, a reduction in HR levels of experts as a significant linear trend was observed ($F_{1,19} = 10.605$, $P < 0.004$). In novices no evidence of a reduction in HR prior to the action was found. In experts, the increase in HR started from about 3.5 seconds before the action and peaked to its maximum (93.79 beats / minute) approximately a half of one second

after the action and immediately decreased and within 9-10 seconds returned to approximately pre-action levels. These changes were represented by a significant linear trend ($F_{1,19} = 4.882, P < 0.041$), quadratic trend ($F_{1,19} = 8.383, P < 0.009$) and cubic trend ($F_{1,19} = 41.346, P < 0.000$). In novices, from about 7.5 seconds before the action, an increase in HR occurred which lasted roughly until about the moment of the action and peaked to its maximum (97.34 beats / minute). It later decreased until it approached pre-action levels within 10 seconds after the action. These changes were represented by a significant linear trend ($F_{1,19} = 15.265, P < 0.001$), a significant quadratic trend ($F_{1,19} = 18.171, P < 0.001$) and a cubic trend ($F_{1,19} = 30.637, P < 0.000$).

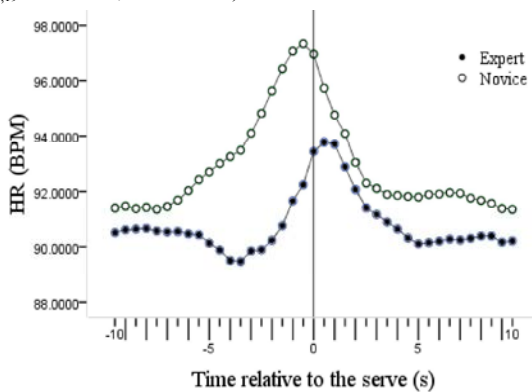


Fig. 3: Mean HR levels in half second intervals from 10 seconds before the action to 10 seconds after the action in expert and novice groups. In experts, a significant reduction in HR levels was observed prior to the action which was accompanied by a rebound. In novices, no reduction in HR was observed before the action; but a sudden increase up to the pre-action levels was observed at the moment of the action

Data relating to the HR of experts for best and worst serves is illustrated in Figure 4.

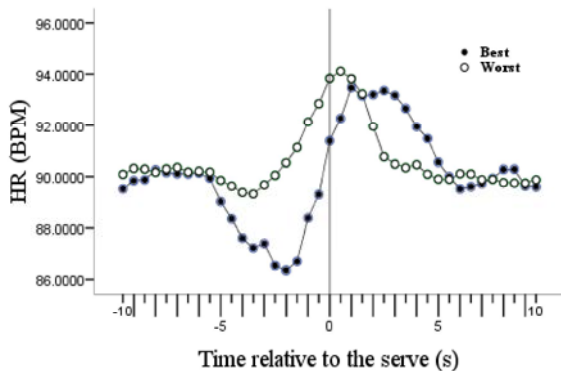


Fig. 4: HR profiles for best and worst serves in experts. The reduction in HR before the best serves was significantly higher

In general, the HR in the best serves (mean 90.052, S.D. 9.628 beats / minute) was relatively lower than the worst serves (mean 90.629, S.D. 9.442 beats / minute). The difference in linear reduction of HR levels prior to the action between best/worst serves was significant ($F_{1,38} = 6.816, P < 0.013$), with a higher reduction in best serves.

DISCUSSION

The results of the self-report measures of STAI Form Y-2 indicated low anxiety in participants. Likewise, the BRUMS results indicated that the mood states of the participants were normal. The above findings are important because high levels of anxiety and mood changes might have increased arousal levels which make the interpretation of the data difficult and reduce the generalizability of findings.

In this research, arousal has been considered as the energetic state at that moment, measured by SCL [13-18]. Considering Figure 1, a reduction in arousal before the action in experts was observed which approached significance. This pattern followed by a rebound to the base level. There was no evidence of reduction in arousal levels prior to the action for novices; however after the action, it was followed by a rebound to the base level. In the present study, experts demonstrated a decrease in electrodermal activity prior to the action which approached significance; therefore the findings of the present study to some extent confirm the findings of Tremayne and Barry (2001) which presented a picture of arousal decrement prior to the performance execution in experts and absence of this pattern in novices. It appears that the difference can be attributed to the physical demands in the two tasks. Tremayne and Barry (2001) claimed that the general reduction in arousal before the shot might be associated with quietening and stillness before execution of the shot by skilled shooters. Based on this interpretation, it seems that since badminton serve does not require a quietening and stillness of the body in the moments prior to the action in the way that is necessary in shooting, the reduction in the SCL levels of skilled players was not significant. In the present research, from the moment of the action a sudden increase in SCL levels of both groups was observed which was not consistent with the results of Tremayne and Barry (2001), as this pattern was not apparent in the novice shooters. It appears that the physical requirements and body movements in the two tasks underlie the difference of the findings. The shooter requires the minimum of effort and body movements at the moment of the shot, therefore the rebound increase in physiological patterns reflects

psychological factors, whilst at the time a badminton serve is hit, body movements have a role in the increase of physiological patterns as well [19-21].

In experts, the difference in decrement of arousal levels prior to the action was not significant between best and worst serves. These findings were consistent with the results of Tremayne and Barry (2001). In the most recent studies investigating the relationship between arousal levels with performance, the change in arousal from a resting baseline to the task situation has been called "activation" [14-17]. According to these studies it seems that activation is a predictor of behavior not arousal.

As was expected, based on the studies conducted by Lacey [19] a significant reduction in the HR of experts was observed prior to the action. Vigilance, in the context of the present study, refers to the attentive state of an individual concentrating on an external stimulus. In this research, it can be considered as the focussing of the sight on the target area which had been marked in the right service area. This result is consistent with other research findings such as those conducted by Lacey & Lacey (1978), Stern (1976), Brunia (1984), Landers *et al.*, (1994), Molander & Backman (1989), Boutcher and Zinsser (1990) and Neumann & Thomas (2009) which reported a reduction in HR before the relevant stimulus. Tremayne and Barry (2001) asserted that when the preparatory stage does not involve major physical demands, such as golf putting and sprint start, cardiac deceleration is indicative of attention and when physical endeavor plays a greater role, HR deceleration does not occur. In their research they observed the anticipatory cardiac deceleration from 15 seconds prior to the shot which lasted up to the moment the shot was fired. The short back-hand serve in badminton is one of the tasks which have some of the attributes of self-initiating skills and is dependent upon the effectiveness of perceptual/cognitive evaluating of environmental stimuli, therefore based on Lacey's intake-rejection hypothesis (1967), the existence of anticipatory cardiac deceleration was expected in the present study. Continuation of HR deceleration up to 3.5 seconds before the action in experts (in comparison to the research carried out by Tremayne and Barry, 2001, which lasted until the shot) confirms the assertion. The findings of Landers *et al.*, (1994) also support the interpretation of the present study since a significant cardiac reduction was found prior to arrow release in archers who draw a lighter bow (10-12 kg).

It seems that the reduction in HR as an index of vigilance in the present study is indicative of narrowing in attentional focusing of skilled players, facilitating by HR. Because this pattern was not observed in the novice

players, it appears that HR patterns reflect skill-dependent aspects of the preparation stages of readiness for execution of badminton serve.

The rebound in HR in both groups occurred about 3 seconds prior to the action. As this cardiac pattern was observed in both groups, we interpret it in terms of mechanical effect due to motoric activity and task execution rather than the skill level; hence the claim made by Tremayne and Barry (2001) which attributed the cardiac pattern to the skilled performance was not confirmed by the present study. It seems that the difference between physical demands and the body movements of the two tasks underlie the interpretation of this finding.

As was seen, the reduction in HR in best serves in experts was significantly higher which may reflect a more efficient narrowing in focusing of attention before the serve in best serves and indicate a connection between efficiency of this process and the result of the performance.

The findings of other studies such as Molander & Backman (1989), Boutcher and Zinsser (1990), Tremayne and Barry (2001), reporting a higher decrement of HR associated with better performance, were consistent with the findings of the present study. Konttinen & Lyytinen (1992) found no significant differences in HR between high and low score shots in the post-test that might be due to the small number of subjects in their study. Cottyn *et al.*, (2009) associated the poor performance of adolescent participants on balance beam with HR deceleration. Although it seems that their findings conflict with the literature connecting anticipatory cardiac deceleration to better performance, the interpretation of these findings in terms of attentional focussing support the intake-rejection hypothesis. In other words, since cardiac deceleration during the preparatory period of performance was a reflection of external focus of attention, the poor performance indicated that the skill had not benefited from external focus of attention [22-25]. Despite, the findings of Cottyn *et al.*, (2009) cannot be compared with the findings of the current study from a psychological point of view. Using non-adult participants in their study, has limited the generalizability of the findings. (The mean age of the participants in their study was 13.2 years).

In summary, the findings of the present study, emphasizing the different attentional and physical demands of the task, confirm the distinction between the two construct states of arousal and vigilance based on the research conducted by Tremayne and Barry (2001) and regards SCL as the index of arousal and HR as the

index of vigilance. The possible interaction between these two systems is not within the bounds of the current study and perhaps it would be a fruitful suggestion to investigate this interaction. The findings of this study help elucidate the complex perceptual/cognitive processes in short badminton serve and show the importance of the psychophysiological aspects in sport psychology [26-28].

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