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TEMPORAL DIMENSIONS OF MENTAL EFFORT IN DIFFERENT SPORTS

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In the experiments reported in this study the secondary-task interference procedure was employed to assess the time course of mental effort (i.e., allocation of attentional resources) in different sports. The sports investigated were volleyball, 100m-dash, 110m-hurdles and tennis. These were the primary tasks. The secondary task was always the same: to emit, as quickly as possible, a verbal response to an acoustic signal. According to the logic of the secondary-task interference, speed of response to the acoustic signal should be inversely related to the resource demands of the primary task at a given moment. The acoustic signal was presented at different times while the athlete was performing, in order to estimate the time course of resource allocation. The results showed that allocation of resources varies as a function of a) the moment in which the acoustic signal is presented; b) the type of performance; and c) the degree of performance difficulty.

Human attention may be divided in different components, one of which is mental effort (*). Kahneman (1973) suggests that only a single reservoir of undifferentiated attentional resources exists within the human processing system. These resources are equally available to all stages of processing or mental operations. The subject can modulate the supply of resources (i.e., mental effort) between different tasks in order to obtain the desired levels of differential performance. In turn, the quality of performance is a monotonically nondecreasing function of the resources invested in a task. If the mental effort necessary to perform two simultaneous tasks is more

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(*) In sports the effort component of attention is often called «concentration». To concentrate oneself on an athletic performance means assigning to it the necessary amount of mental effort, so that interferences, which might render performance less efficient, can be avoided. For example, a tennis player who is paying too much attention to the spectators does not pay enough attention to the stroke which is about to make, and his performance will not be optimal. By contrast, if the mental effort devoted to the stroke is too high, it might become impossible to resort to the most favorable game tactics.

than the total amount available, there will be interference (see also Keele, 1973).

The relation between performance and resources is more easily measured under a dual-task condition. When a subject performs two tasks concurrently, and is required to allocate attention disproportionately in favor of one task or the other, performance is observed to vary as a function of the instructions (Wickens, 1984). Imposing the secondary task as a measure of residual resources not utilized in the primary task is a technique often employed to assess the effort required by the primary task (see e.g., Ogden, Levine & Eisner, 1979; Rolfe, 1971). Rather than «absorbing» resources by increasing the difficulty of the primary task, residual resources are absorbed by a new activity, the secondary task. Secondary-task performance can thus be taken to be inversely proportional to the primary-task resource demands (i.e., mental effort).

However, the use of this procedure can be problematic due to structural interference. This is because interference between two tasks can also arise if they compete for common mechanisms or structures. For example, solving a puzzle will be more disrupted by the simultaneous requirement of reading a text (which also demands the processing of visual information) than of listening to the same text instead, which involves the auditory channel. One of the solutions offered to this problem is to choose secondary tasks that are dissimilar from the primary task so that structural interference is reduced to a minimum, or altogether avoided (Ödgen et al., 1979).

In the present study, the secondary-task procedure was employed to evaluate the resource demands of volleyball, 100m-dash, 110m-hurdles and tennis.

Experiment 1: Volleyball

In this experiment the fundamental of reception was studied. To perform a correct reception the type of serve (floating or jump) must be inferred on the basis of cues conveyed by the opponent who is serving. The speed and trajectory of the ball must be computed and also the position of the other players must be evaluated. Even though some of these mental operations can be automatized in an expert player, the overall process must be controlled and therefore demands attentional resources (for a distinction between automatic and controlled processing see, e.g., Schneider, Dumais & Shiffrin, 1984).

The aim of the experiment was that of elucidating the time course

of resource demands while a player is performing a reception. To this end, we considered two types of serve (floating and jump) and three different positions of the ball (while the opponent was serving, when the ball was above the net and when the receiving player was about to hit the ball).

Of course, reception was the primary task. As the secondary task, a simple vocal response to an acoustic signal was chosen, so that to minimize structural interference. The logic of the procedure was that the latency of the vocal response should be inversely related to the resource demands of the various stages of the primary task.

Method

SUBJECTS

Ten professional athletes between the ages of 18 and 29, from a first division team, took part in the experiment. All were naive as to the purpose of the experiment.

APPARATUS AND PROCEDURE

The athletes wore an anatomic helmet equipped with a transmitting-receiving device, which was connected, through aerials, to an Apple IIe personal computer.

The experiment was performed while each athlete was practicing reception in three different zones. The serve was executed by another athlete. The different types of serve were jump and floating and the latter took place either near or far from the base-line. Every athlete received 50 serves in each of three zones of the court: 10 jump serves, 20 floating serves near the base-line and 20 floating serves far from the base-line.

The secondary task was to emit a vocal response to an acoustic signal produced by the computer and delivered, through the aerials, to loudspeakers fastened to the helmet. The signal lasted 50 msec and the athlete had to utter, in response to it, the sound «hop» as soon as possible. The latency of the vocal response was measured by the computer to the nearest millisecond.

One of the experimenters watched the two players and operated the computer so that the acoustic signal was presented three times during the execution of every serve. First, when the ball was about to be served, then when the ball was above the net, and finally when the athlete was about to receive it.

Before the experimental session the athletes performed in a control session during which reaction times (RTs) to the acoustic signal were measured in the absence of the primary task.

Results and Discussion

Vocal responses emitted before the acoustic signal or with a delay of 2 sec or longer were considered as errors. They were very few (about 2%)

and were not analyzed. A first analysis of variance was conducted to compare RTs in the control condition and RTs collected while the player was receiving. In it there was only one within-subjects factor. It showed that response latencies were faster in the control condition (212 vs 256 msec), $F(1,9) = 36.451$, $p < 0.001$. Correct RTs collected in the experimental condition were submitted to a two-way within-subjects analysis of variance. The factors were type of serve (jump or floating) and position of the ball (when the opponent was serving, while the ball was above the net and when the ball was close to the receiving player; for sake of brevity: times 1, 2 and 3).

The main effect type of serve was significant, $F(1,9) = 31.013$, $p < 0.001$. It showed that the stimuli were responded to faster in the case of a jump than of a floating serve (236 vs 268 msec). This finding means that more attentional resources were available for the secondary task during a jump serve. Stated in another way, mental effort was greater when the player was in the process of receiving a floating than a jump serve.

When the serve is of the jump type, the player who is receiving must evaluate the trajectory of the ball in order to meet it in the proper way and thus reduce the strength of the serve. In the case of a floating serve the player's task is more complex and likely more resource demanding since many other parameters must be evaluated because the ball does not follow a straight trajectory. In other words, for a jump serve the primary information is the trajectory of the ball. Once this is determined, a motor response can be rapidly programmed and executed. For a floating serve the trajectory of the ball changes unpredictably and the motor program must undergo continuous modifications. This is likely to be the reason why the reception to a floating serve requires a greater amount of attentional resources.

Also the main effect position of the ball and the interaction between type of serve and position of the ball were significant, $F(2,18) = 49.064$, $p < 0.001$ and $F(2,18) = 3.536$, $p < 0.5$, respectively. As shown in Figure 1, RTs were fastest when the ball was served, intermediate when the ball was above the net and slowest when the ball was near the receiving player (218, 260 and 279 msec). The interaction showed that RTs were very similar for the two types of serve when the ball was served but differed markedly in the other two conditions (see again Figure 1). These differences were significant when tested with the Neumann-Keuls method ($p < 0.05$).

If one accepts the notion that speed of response to the acoustic signal is inversely related to the resource demands of the primary task at a given moment, it is apparent that the receiving player's mental effort changes

during the trajectory of the ball. It is at a minimum when the player is watching the serve. Actually, in this condition RTs are more or less as fast as in the control condition (212 vs 210 msec). Mental effort increases when the ball passes the net and reaches a maximum when the ball is about to be received.

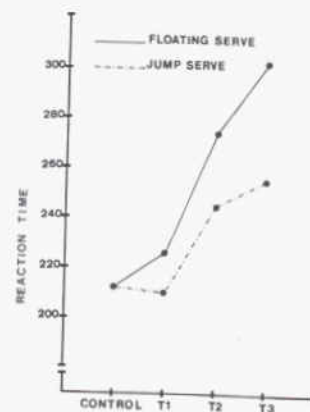


Figure 1. - Speed of response to the acoustic signal (secondary task) as a function of time; reception in volleyball (primary task). RTs in milliseconds.

Perhaps even more interesting is the information provided by the interaction. It shows that the time course of mental effort differs as a function of the type of serve. Overall, receiving a floating serve requires more effort than receiving a jump serve (this is shown also by the main effect type of serve). However, whereas the difference is rather small (and not significant) when the player is watching the serve, it becomes larger when the ball is travelling above the net and increases even more when the player is about to receive the ball.

As suggested above, the reason for the difference becomes apparent if one takes into consideration the features of the two serves. The main feature of the jump serve is the speed of the ball, whereas the trajectory can be estimated rather easily. Therefore, the receiving player does not have to perform much processing after the ball has been put into motion. By contrast, in a floating serve the speed of the ball is comparatively low, but the trajectory is rather difficult to determine. Therefore, the receiving player must perform much computation while the ball is approaching him.

Experiments 2: Race

In this experiment we have applied the secondary-task procedure to analyze the time course of mental effort in two speed races, that is 100m-dash and 110m hurdles.

Method

SUBJECTS

Sixteen expert athletes between the ages of 18 and 27, 8 sprinters and 8 hurdlers, participated. All were naive as to the purpose of the experiment.

APPARATUS AND PROCEDURE

The apparatus was the one described for Experiment 1. The experiment took place while the athlete was practicing in some trials in the form of «repetitions». Each athlete performed four times in four different days, so that there were 16 trials for every subject. Of course, the primary task was that of running as fast as possible. The secondary task was that of Experiment 1. It is important to keep in mind that the primary task was rather realistic because the athlete under investigation ran along with other 7 athletes.

For the sprinters the acoustic signal was presented four times, that is, at the start (just after the command «get»), immediately after the coming out from the blocks, at the 50m mark, and finally at the moment of the last thrust. For sake of brevity we will use the terms times 1, 2, 3 and 4 to indicate these successive moments in the race.

For the hurdlers the acoustic signal was presented five times: at the start, when the athlete was about to jump over the first hurdle, at the 50m mark, when the athlete was about to jump over the last hurdle, and at the moment of the last thrust. Again, we will refer to those moments in the race by using the terms times 1, 2, 3, 4 and 5.

At the beginning of every experimental session, the athlete performed in a control condition in which RTs to the acoustic signal were measured in the absence of the primary task.

Results and Discussion

There were virtually no errors and therefore they were not analyzed. The correct RTs were entered into two analyses. The only within-subjects factor was time, that is times 1-4 for the sprinters and times 1-5 for the hurdlers. Both analyses had another level, that is control condition. The results are shown in Figure 2. The main effect of time was significant for both the sprinters and the hurdlers, $F(4,28) = 104.623$, $p < 0.001$ and $F(5,35) = 34.979$, $p < 0.001$, respectively.

RTs were much slower (by a factor of about four times) at any moment of the race than in the control condition. That happened for both groups. Also the pattern of RTs collected during the race is similar in the two groups: RTs were slower at the beginning and at the end of the race than at the intermediate times (times 1 and 4 vs times 2 and 3 for the sprinters and times 1 and 5 vs times 2, 3 and 4 for the hurdlers) (see Figure 2). The reliability of these differences was confirmed by the Neumann-Keuls method, which yielded $p < 0.01$. In the case of the hurdlers, another difference was significant ($p < 0.001$), that is that between time 2 (first hurdle) and time 3 (50m mark).

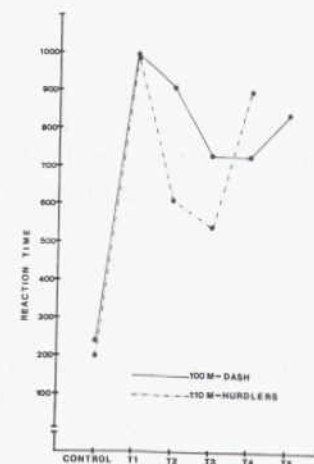


Figure 2. - Speed of response to the acoustic signal (secondary task) as a function of time; 100m-dash and 110m-hurdles (primary tasks). Time 4 for the sprinters and Time 5 for the hurdlers correspond to the moment of the last thrust. RTs in milliseconds.

A further analysis of variance was carried out to compare those times that were common to both groups. The group was a between-subjects factor (sprinters vs hurdlers) and time was a within-subjects factor (control, start, 50m mark and end). Note that the 50m mark is time 3 for both groups whereas end is time 4 for the sprinters and time 5 for the hurdlers. In this analysis the only significant source of variability was the interaction, $F(3,42) = 3.375$, $p < 0.05$. It showed that response latency was equivalent for the two groups at the start and at the end of the race,

whereas at the 50m mark hurdlers were slower than sprinters in responding to the acoustic signal.

The first thing to note is the huge lengthening of RT from the control condition to any experimental condition. This finding is likely to be artifactual, that is attributable to a sort of structural interference. While running very short races, athletes do not breath normally and this can affect the speed with which the vocal response is emitted. Note, however, that this problem does not affect the reliability of the comparisons among different stages of the race.

For sake of simplicity it is preferable to discuss together the results for the sprinters and the hurdlers. In both groups RT was comparatively slower at the start (time 1) and just before the end of the race (times 4 and 5). In the first condition the decrease in speed of response to the acoustic signal can be attributed to the fact that attentional resources are almost entirely devoted to the detection of the start signal or, more likely, to the preparation of the motor response to it. More puzzling is the delay observed when the race is approaching the end. One could argue that at that stage the athlete, besides allocating most of his attentional resources to perform the last thrust, must also monitor his distance from the finish line and the relative positions of his opponents.

At the intermediate stages (times 2 and 3 for the sprinters and times 2, 3 and 4 for the hurdlers) there is a clear decrease of resource demands, as indicated by the speed of response to the acoustic signal. In the case of the sprinters this is not surprising because there can be little doubt that these are the stages in which a comparatively smaller amount of attentional resources is required. One would instead suppose that negotiating the hurdles should require a fair amount of attentional resources. Our results are in keeping with this predictions because RT at the intermediate stages was slower for the hurdlers than for the sprinters (see Figure 2). It is also interesting to note that RT was slower at time 2, that is when the athlete was about to negotiate the first hurdle. It seems therefore that for the athletes under investigation in our study, the act of preparing to jump over the hurdles was not fully automatized and, therefore, required the allocation of a certain amount of attentional resources.

Experiment 3: Tennis

In this experiment, the serve return in tennis was studied. As usual, the aim of the study was that of elucidating the time course of resource demands while the athlete was performing the return. The logic and the procedure were those already explained for the previous experiments.

Method

SUBJECTS

Eight professional players between the ages of 18 and 25 took part in the experiment. All were naive as to the purpose of the experiment.

Apparatus and Procedure

The apparatus was the one already described. The experiment was performed while the player was practicing the return. The primary task was to perform it as efficiently as possible. The secondary task was identical to that of the other experiments. The acoustic signal was presented 4 times during every serve, that is, when the opponent was about to serve (time 1), when the ball was above the net (time 2), when the ball hit the court (time 3) and when the player was performing the return (time 4). The experiment comprised two experimental sessions with a rest period of about 2 h in between. In each session there were 20 returns.

Before the first session the player performed in a control session during which he was asked to respond as fast as possible to the acoustic signal in the absence of the primary task.

Results and Discussion

Errors (about 1%) were not analyzed. The correct mean RTs were submitted to a one-way within-subjects analysis of variance in which the factor was condition (control and times 1-4). The main factor was significant, $F(4,28) = 52.25$, $p < 0.001$ (Figure 3). Pair-wise comparisons with the Neumann-Keuls method showed the reliability of all differences ($p < 0.01$), with the exception of that between times 1 and 2.

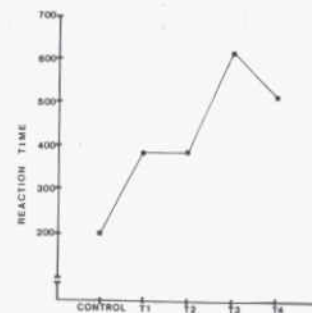


Figure 3. - Speed of response to the acoustic signal (secondary task) as a function of time; return to serve in tennis (primary task). RTs in milliseconds.

It is clear that all stages of the return we considered are resource demanding. This is shown by the increase in RT with respect to the control condition. Time 3, that is when the ball was hitting the court, appears to be the most demanding condition of all. Why this is so becomes clear if one considers that this is the moment in which the player must evaluate the speed and trajectory of the ball and prepare the motor program for performing the return. Time 4 is less demanding, probably because at that stage the player has already begun the movement, which is likely to be ballistic and, therefore, requires a small amount of attentional resources. Times 1 and 2 are the least demanding. This finding confirms what was found for volleyball (see Figure 1), in which times 1 and 2 required comparatively fewer resources.

Conclusion

The main purpose of the experiments reported in this study was that of assessing the time course of resource demands of athletic performance in some sports. The experiments were based on the logic of the secondary-task interference. The athletes were required to perform a secondary-task consisting in a vocal response to an acoustic signal, while performing as the primary task the athletic performance under investigation. The basic idea was that the speed of the response to the acoustic signal should be inversely related to the resource demands at a given time of the athletic performance.

The experiments were successful because it was found that resource demands change as a function of the moment in which they are probed, and these changes are related to the difficulty of performance. In our opinion, the procedure employed in this study can be profitably applied to a number of sports and can provide useful information about the relative difficulty of the various stages in which athletic performance can be subdivided.

Acknowledgement

The authors wish to thank Dr. G. Janelli for writing and implementing the computer programs. The study was supported by grants from the Consiglio Nazionale delle Ricerche and the Ministero della Pubblica Istruzione. Some of the results reported here were published in Castiello and Umiltà (1987) and in Castiello and Umiltà (1988).

RÉSUMÉ

En ce qui concerne l'attention, on peut identifier plusieurs composantes. L'une de celles-ci est l'engagement mental. La recherche expose l'application d'une technique pour mesurer l'engagement mental au cours de l'exécution des gestes caractérisant les différentes disciplines sportives.

Les sports pris en considération sont le volley-ball, 100 mètres, 110 mètres haies et tennis. Les résultats ont prouvé qu'il existe des variations dans l'engagement mental appliqué suivant le type de situation à laquelle l'athlète doit faire face.

RESUMEN

Se puede individualizar diferentes componentes en la atención. Una de éstas es el empeño mental. La investigación describe la aplicación de una técnica para medir el empeño mental durante la ejecución de gestos que caracterizan varias disciplinas deportivas.

Los deportes tomados en consideración son volibol, 100 metros, 110 con vallas y tenis. Los resultados han demostrado que existen variaciones en el empeño mental empleado según el tipo de situación a la cual el atleta debe enfrentarse.

ZUSAMMENFASSUNG

Verschiedene Komponenten kann man in der Anmerdung individualisieren. Eine davon ist jene der geistigen Anstrengung. Die Studie beschreibt die Anwendung einer Technik, um die geistige Anstrengung während der Ausführung von Gesten zu messen, welche die verschiedenen Disziplinen sportlicher Art kennzeichnen.

Die in Betracht gezogenen Sportarten sind Volley-Ball, 100 Meter Lauf, 110 m Hürdenlauf und Tennis. Die Ergebnisse haben gezeigt, dass Variationen in der geistigen Anstrengung existieren, verteilt auf die verschiedenen Situationsformen, denen der Athlet gegenübersteht.

RIASSUNTO

Nell'attenzione si possono individuare diverse componenti. Una di queste è quella dell'impegno mentale. La ricerca descrive l'applicazione di una tecnica per misurare l'impegno mentale durante l'esecuzione di gesti che caratterizzano varie discipline sportive.

Gli sports presi in considerazione sono pallavolo, 100 metri, 110 ostacoli e tennis. I risultati hanno dimostrato che esistono variazioni nell'impegno mentale erogato a seconda del tipo di situazione a cui l'atleta deve far fronte.

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WORRY AND EMOTIONALITY: ITS INFLUENCE ON THE PERFORMANCE OF A THROWING TASK

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This study was conducted to examine the effects of state anxiety and its sub-components, worry (cognitive anxiety) and emotionality (somatic anxiety), on the performance of a motor task, consisting of throwing tennis balls overhand at a target. Sixty male physical education students participated in the experiment. Anxiety was manipulated by selecting low, moderate, and high trait anxiety subjects and by giving specific task instructions.

No relation between any of the three anxiety measures and the accuracy in terms of scores indicating the place of hitting the target could be demonstrated. However, if the target was to be hit at a moment specified by the position of a small moving flag coinciding with the position of the bull's eye, moderate state anxiety subjects and moderate cognitive anxiety subjects showed better timing performance than the low and the high (state and cognitive) anxious subjects. Timing performance was independent of the level of emotionality.

Comparison of the performances of the 12 subjects rated highest, and the 12 subjects rated lowest on 'ball game proficiency' (these ratings being based on teacher's judgements), indicated that these groups only differed with respect to the timing aspect of throwing, the former group timing their throws significantly better than the latter one. This result was taken as evidence for the contention that only the timing aspect of throwing could be qualified as being «difficult», which was in concordance with the finding that only with respect to this aspect, effects of anxiety (state anxiety and cognitive anxiety) could be demonstrated.

Theories advanced to account for the curvilinear relationship between anxiety and task performance, also known as the Yerkes-Dodson Law, can be categorized into two broad classes. Physiological-based theories assume that all of the phenomena attributed to anxiety are in essence consequences

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