Timing of Movement-Related Decision Processes in Clay-Pigeon Shooters as Assessed by Event-Related Brain Potentials and Reaction Times

BRUNA ROSSI * and ALBERTO ZANI **

* Istituto Superiore di Educazione Fisica, Rome, Italy.
** Istituto di Psicologia del CNR, Rome, Italy.

The present study attempts to shed some light on the temporal aspects of Information Processing (I.P.) in clay-pigeon shooters and to confirm the existence of an attentional «style» strictly bound to the practice of the two specialties of this sport: skeet and trap.

Eight Olympic athletes were subjected to an experimental psychophysiological paradigm in which the latency of the N2 and P300 components of Event-related Potentials and RT were recorded during an auditory discrimination task with two different levels of difficulty.

The results suggest that the motor performance of these athletes is subserved by a different timing of the processing mechanisms. It is proposed that this might be due to the adoption of two different modes of I.P. to cope with the experimental conditions. More in detail, a strategy primarily based on "knowledge" might explain the performance decrease of the skeet shooters in the difficult task in comparison with the easy task. Conversely, the great stability shown in the two difficult levels of the task by the trap shooters may be sustained by a primarily «data-driven» processing strategy.

Recently sport psychologists have devoted a great deal of effort to studying athletic performance from the human information processing viewpoint. Interest has grown in the way skilled performers handle information in perception, decision and organization of motor actions according to task demand (Marteniuk, 1976; Kelso, 1982; Saibene, Rossi & Cortili, 1986). This interest has been motivated by the conviction that the investigation of

Address for correspondence: Bruna Rossi, Istituto Superiore di Educazione Fisica, Piazza Lauro De Bosis 15, 00194 Roma (Italia).
these mechanisms may help, on one hand, to better understand athletes' performance and, on the other, to improve it.

In this theoretical framework, experimental research has mainly focused on attentional and cognitive processing in top-level athletes, and on the possible interindividual differences between the various sport disciplines (Alain & Procteau, 1980; Nougier, Ripoll, & Stein, 1989; Aherney, 1987; Zani & Rossi, 1987; 1990).

Clay-pigeon shooting is a sport discipline that has been conceptualized as requiring high attentional control of information processing or, in other terms, high attentional resource expenditure. In spite of this conceptualization, to our knowledge no information has been offered by sport scientists on the level of mental load required by the sport task performed by these athletes. Furthermore, not much knowledge is available on the processes underlying information processing and performance in the two specialities, i.e. Skeet and Trap, of this sport discipline.

Conceivably, current research on skills and skill acquisition may provide us with a framework for analyzing these processes. This research, in fact, showed that skilled performance occurs as specialized and automatized procedures compiled on the basis of the relevant aspects of the specific task performed (Anderson, 1982). These procedures may be understood only when these relevant specific-content aspects are taken into account. In this regard, different features characterize the two specialities of clay-pigeon shooting. In Skeet competition, on each trial the clay-pigeon follows a known trajectory, even if it may be randomly pulled with a delay ranging from 0 to 3 sec, from the athlete's call. In spite of this temporal uncertainty, however, in various competitions the task remains identical. Conversely, in the Trap competition the clay-pigeon is randomly pulled without any delay from the athlete's call toward one out of three different directions (i.e., left, center, or right) with one out of several possible slopes (i.e. 0-45°) to the ground. Thus, this speciality is characterized by high spatial uncertainty and high inconsistency across competitions.

In light of these task differences and the high skill acquired with many years of practice by top-level Olympic clay-pigeon shooters, it may be speculated that athletes in these different specialities may have automatized two different cognitive or attention styles, i.e. two consistent and characteristic manners of processing and organizing the incoming information specific to their particular athletic tasks. In fact, it seems reasonable to think that trap-shooters' performance should be mainly based on a bottom-up or data-driven processing mode related to stimulus detection and identification. Conversely, skeet-shooters should make mainly use of a top-down or knowledge-
driven processing mode related to a whole stimulus evaluation, based on encoding, identification and categorization operations. In addition, in the light of Ackerman and Schneider's (1985) model of individual differences in attentional processing, it may also be speculated that these automatic attentional styles are generalized and automatically transferred to cope with other general attention-demanding tasks.

In order to shed some light on these processes, we began a research project from the cognitive psychophysiological point of view. The mechanisms and timing of the flow of information processing are, in fact, central issues in cognitive psychophysiology, as they are in cognitive psychology and mental chronometry. In this regard, the main assumptions of this theoretical framework are that (1) information processing activities are implemented in the nervous system by means of physiological changes, and (2) these physiological changes may be taken as manifestations of these processing activities. On the basis of these assumptions, it seems to us that cognitive psychophysiology may be used as a fruitful interface between sport and cognitive psychology in the investigation of athletes' neuropsychological mechanisms of information processing (Zani & Rossi, in press).

Within this framework, our investigation was carried out by recording both behavioural responses and brain electrical potentials associated with stimulus and cognitive events, i.e., Event-related brain potentials, or ERPs. At present there is substantial evidence that the concurrent recording of these measures illuminates the operations underlying the processing of information more fully than is possible using either measure alone (Näätänen, Alho, & Sams, 1985; Donchin, Karis, Bashore, Coles, & Gratton, 1986; Zani, 1988). In fact, because of their direct access to sensory and cognitive channels, the amplitude and latency of the ERP components have been shown to provide direct information on, respectively (1) the dynamics of sensory and cognitive events elicited by stimulus information in an individual while he/she is engaged in a psychomotor task, and the specific workload required by these events, and (2) the timing of the events, i.e., processes, intervening between stimulus and response, i.e., product (Kutas, McCarthy, & Donchin, 1977; McCarthy & Donchin, 1981). In this regard, the latency of the N2 and P300 components has been related to different processes underlying the motor output. In studies based on trial-by-trial analyses, in fact, evidence shows that the latency of the N2 recorded from the central scalp locations always closely precedes the reaction time, and that the two indexes are closely correlated. This has suggested that the latency of the N2 component may reflect the timing of a decision process related to a sensory discrimination relevant to the motor response (Ritter,
Simson, Vaughan, & Friedman, 1979; Renault, Ragot, & Remond, 1982). Conversely, experimental findings suggest that the P300 latency may index the relative timing of stimulus evaluation between experimental conditions. This index would be affected by the complete stimulus encoding, identification, and categorization operations required for a full stimulus evaluation, but not by the processes involved in response selection and execution. The latter view has been suggested by results revealing that stimulus-response compatibility conditions affect subject's reaction time (RT), but not P300 latency (Magliero, Bashore, Coles, & Donchin, 1984); or that when a speeded response is required, the P300 latency follows the RT; whereas when response accuracy is stressed the P300 latency precedes the RT and is closely related to it (Kutas, McCarthy, & Donchin, 1977).

Based on this theoretical framework and electrophysiological methodology, a first study aimed at giving support to our speculation of two different information processing styles in clay-pigeon shooters was carried out. Athletes were presented with streams of auditory stimuli, belonging to one of two categories. The probability was low (20%) that a stimulus belonged to one of the categories and correspondingly high (80%) that it belonged to the other category. The same series of stimuli were administered in random order in three randomized successive runs with different behavioural instructions: a passive listening task and two go/no-go RT tasks. In the two RT tasks, the athletes had to press a button as fast as possible for the measurement of their reaction times to the stimuli belonging to the low-probability category and to hold the response to the high-probability category. In one case they used their right hand, in the other, the left. The amplitude of the N2 and P300 components elicited by both the rare stimuli, and the frequent stimuli immediately preceding and following the rare ones were monitored and measured. Statistical analyses showed that trap-shooters attained consistently larger rare-stimulus-related N2 amplitudes than the skeet-shooters. Conversely, the skeet-shooters showed larger P300 amplitudes than the trap-shooters as a whole. However, this resulted true only for the two active tasks, suggesting that these results depended on the voluntary adoption of processing strategies aimed at coping with these attention-demanding tasks. Furthermore, they suggested that whereas trap-shooters mainly allocated their attentional resources to the relatively early-latency sensory discrimination processes relevant for motor stages of information processing, skeet-shooters mainly allocated their processing resources to the late latency cognitive evaluation of incoming information. Thus, these psychophysiological data seem to give support to our hypothesis of two different information processing or attentional styles in the two specialities of clay-
pigeon shooting, presumably strictly bound to their different sport skills acquired performing their different specific tasks (Zani & Rossi, 1990).

The present investigation is concerned with the timing of movement-related processing in these athletes. Because of their differential relationships with this processing, the N2 and P300 latencies have been monitored in a task with two levels of stimulus discrimination difficulty, in the attempt to generate a differential strategical speed-accuracy trade-off in these athletes. It was our opinion that if, as speculated and supported by our N2 and P300 amplitude data reviewed above, skeet-shooters actually adopted a knowledge-driven processing mode, the uncertainty left by the difficult discrimination task should have induced in these athletes a trade-off from speed to accuracy which should have slowed down their movements related processing and RTs. Instead, the data-driven trap-shooters should have been only relatively affected by task difficulty. To be able to demonstrate that these contexts would produce differential effects in the timing of motor decision of the two specialties would strengthen the view of two different information processing styles in these specialties.

Method

Four skeet- and 4 trap-shooters from the Italian National Olympic Team volunteered for this study. They were all right handed. The laboratory task consisted of two experimental conditions controlled by an Apple IIe microcomputer: "easy" and "difficult" auditory discrimination. An "easy" run consisted of a randomized sequence of 65 dB SPL, 1000 Hz (low pitch) and 2000 Hz (high pitch) tone bursts, whereas a "difficult" run consisted of a sequence of 65 dB SPL, 1000 Hz (low pitch) and 1050 Hz (high pitch) tone bursts, delivered binaurally through headphones at a rate of one every 1650 msec. In both conditions, high pitch stimuli occurrence probability was 20%. The subjects' task was to press a lever as fast as possible with their right hand in response to high pitched tones to measure of their reaction times.

High pitch tone related brain potentials were recorded by means of an Ag/AgCl electrode referred to linked earlobes and grounded at the forehead placed on the Vertex of the scalp according to the International 10-20 system (Jasper, 1958). A second pair of electrodes was placed above and below the right eye for the rejection of trials contaminated by eye movement and blinking. Selected 1.6 sec epochs of EEG data were sampled at a rate of 4 msec/pt. Stimulus onset occurred 0.8 sec after the start of each sampled epoch. Each run continued until 20 artifact-free target-related EEG epochs had been recorded and averaged. Both the RT and ERPs were recorded on disks for off-line analysis.

Because of technical problems related to the eye-electrode impedance, the recordings relative to the difficult run of one trap athlete had to be discarded. Then, in order to
have samples of the same size, one out of the 4 skeet-athletes was drawn by lots and discarded. Thus, 3 skeet- and 3 trap shooters were compared.

The peak latencies for the N2 and P300 components were measured in fixed latency ranges. Because of the inter-individual and intra-individual latency variability across the tasks, on the basis of visual inspection of individual ERPs and of automatic cursor alignment on the microcomputer monitor display, peak latency criteria were fixed allowing measurement reliability for all the athletes' waveforms. These criteria were 200-300 msec for N2 and 250-500 msec for P300.

Results

Both reaction time and N2 and P300 latency measures were submitted to a two-way repeated measures analysis of variance (ANOVA) with specialty (skeet vs trap) as between factor and task difficulty (easy vs difficult) as within factor.

The ANOVA revealed that skeet-shooters attained consistently earlier latencies than trap-shooters for both the N2, F(1,4) = 8.475, p < 0.0005, and P300, F(1,4) = 7.81; p < 0.05 components, as can be clearly seen in Fig. 1. In addition, a significant interaction between specialty and task difficulty F(1,4) = 16.62; p < 0.01, was obtained for the RTs.

Fig. 1. - N2, P300 and RT latencies for skeet and trap shooters as a function of the difficulty (E = Easy and D = Difficult) of the auditory discrimination task.
Tests for simple effects showed that the difficulty of the auditory discrimination task slowed down the reaction times of skeet. \( F(1, 4) = 22.98; \ p < 0.01 \) but not of trap-shooters.

Further tests clearly showed that whereas the easy task did not yield significant differences in the RT speed between the two specialties, the difficult task induced significantly slower RT, in skeet \( F(1, 4) = 13.47; \ p < 0.025 \), than in trap-shooters.

Discussion

As a whole, these results suggest the existence of interindividual differences in the timing of movement-related decision making between skeet- and trap-shooters. In addition, differences in latency of motor output are also suggested. The latter differences, however, give the impression of being dependent on the task dealt with. In the easy task, in fact, skeet-athletes attained behavioural responses which were not significantly different from those of trap-athletes, even if a tendency to faster RTs can be discriminated. However, their N2 latency resulted significantly shorter than that attained by trap-shooters. This would suggest that the processes on which the motor response is based in skeet-athletes may be more automatized. The view of a more automatic mode of movement-related information processing in the latter athletes during the easy task seems to be also supported by the fact that their P300s follow the RTs closely enough. However, it seems that this automatic processing mode preceding the motor response may be possible only when the stimulus category discrimination is effortless (easy task). In fact, when the stimulus discrimination was made difficult (difficult task), skeet-athletes showed a nonsignificant tendency to a delay in N2 and P300 latency. More importantly, they showed a significant and dramatic increase in RTs. As a consequence of this increase in RTs, in the difficult task skeet-athletes’ RTs followed the P300-peak latency and were remarkably shorter than those of trap-athletes. This is worth noting since in the easy task the RTs of skeet-athletes preceded the P300-peak latency. Although remarkable, the results obtained in these athletes are in strict agreement with the findings reported by Ritter et al. (1979) and Ragot et al. (1982) in non-athlete subjects, i.e., in an easy stimulus discrimination task the RTs preceded the P300, whereas in a difficult discrimination task the RTs followed the P300. It is possible that these results depend on subjects’ speed-accuracy trade-off as suggested by Kutas’ et al. (1977) findings. As a whole our findings suggest that it is probable that skeet-athletes adopted a knowledge-driven processing strategy to cope with the tasks administered. This seems to have compelled them to trade speed with
accuracy when the discrimination of the stimulus categories was made difficult. In this condition, in fact, the a posteriori uncertainty about the nature of the stimulus remains high and for this reason it is reasonable to think that skeet-shooters' slower RTs may be explained by a fuller stimulus evaluation, i.e., encoding, identification and categorization, made by these athletes before the emission of their responses.

Interestingly enough, trap-shooters did not follow the same trend as the skeet-shooters. In fact, they seem to be characterized by a more controlled movement-related processing mode, as suggested by the significantly slower latencies of both N2 and P300 components attained by these athletes. This appears to be true not only in the easy task, where their RTs are similar to those of skeet-shooters, but also in the difficult task, where their RTs resulted significantly faster than those of skeet-shooters. This, however, was because their RTs did not increase in this task. On the contrary, although not significant, this group showed a tendency to attain slightly faster latencies for both RTs and ERP N2 and P300 components when engaged in the difficult discrimination task. These data and the fact that in both tasks the RTs of these Olympic athletes result strictly related to the N2-peak latency and clearly precede the P300-peak latency suggest that their motor responses were mainly based on the processes indexed by the N2. Consequently, it may be thought that these athletes made mainly use of a data-driven processing strategy very likely based on stimulus encoding and identification operations. Thus, independent of task difficulty, it might have been the use of this strategy that allowed them to obtain a constant output in terms of RTs, and permitted them to respect overall the instruction of speed in both tasks.

On the basis of results, some general points can be raised. First, it is interesting to note that also when both groups showed the same RTs, as in the easy task, their motor output was subserved by a different timing of the processing mechanisms. It is worth noting that these differences were demonstrated by means of the concurrent recording of ERP measures and RTs, thus confirming that these electrophysiological measures may be fruitfully used to investigate specific information processing in the sport field, as has already been shown in more general areas. Second, it must be underlined that the differences shown in athletes with different specific sport skills may be important not only in sport sciences but also for the construction up of a general theory of interindividual differences in human information processing and skill acquisition. Finally, a more specific topic must be considered. In fact, our present findings of interindividual differences in the timing of motor response and information processing be-
tween the two specialties of clay-pigeon shooting seem to give further support for our hypothesis of two different information processing styles in these athletes. Since some support to our hypothesis had already been provided by the N2 and P300 amplitude data measured in a previous study (Zani & Rossi, 1990), it is reasonable to assume that this hypothesis is sound, and particularly suited for future investigation of sport skills in these specialties.

Acknowledgements

This research was supported by CONI-Educational Ministry research grants. We are grateful to the Italian Clay-pigeon shooting Sport Federation and the Olympic athletes who volunteered.

RESUMÉ

Ce travail est destiné à étudier les aspects temporels du processus d’élaboration de l’information chez les athlètes de l’équipe italienne de Tir au pigeon d’argile et à confirmer l’existence d’un «style» attentionnel différent, lié à la pratique de ces deux disciplines, le skeet et le trap.

Huit athlètes olympiques ont été soumis à un paradigme expérimental de type psychophysiologique dans lequel composantes N2 et P300 de Potentiels Liés aux Événements étaient enregistrées dans une tâche de discrimination auditive à différents degrés de difficulté.

Les résultats suggèrent que la performance motrice de ces athlètes est sous-tendue par un décours temporel différent du Processus de Traitement de l’Information et confortent la présence de différences inter-individuelles, liées à la discipline pratiquée, dans le style attentionnel des deux groupes d’athlètes.

En particulier, chez les tireurs de skeet, une stratégie essentiellement basée sur la «connaissance» expliquerait la chute de la performance enregistrée dans la condition «difficile» par rapport à la condition «facile». Chez les tireurs de trap, la stabilité de la performance observée dans les deux conditions serait soutenue par une stratégie de traitement basée préférentiellement sur les «données».

RESUMEN

Este ensayo tiene que estudiar los aspectos temporales del proceso de elaboración del informe por los atletas de la Nacional Italiana de tiro al plato y de averiguar la existencia de un «Estilo» de atención diferente junto a la práctica de dos particularidades (TRAP, SKEET).

Para este objeto 8 atletas olímpicos se han sometido a un cuadro experimental de tipo psicológico donde se registraban los elementos N2 e P300 de los Potenciales Juntos
al Acontecimiento (ERPs) y los Tiempos de reacción donde se encontraban estímulos auditivos con dos diferentes niveles de dificultad. Los resultados sugieren que la prestación motora de estos atletas está determinada por un diferente discurso temporal de los mecanismos de elaboración del informe.

Esto parece aseverar la presencia de diferenciaciones interpersonales, juntas a la especialidad practicada, en el estilo atencional de los dos grupos de atletas. En particular, en los punteros de skeet, una estrategia basada preferentemente sobre un «conocimiento» podría explicar el empeoramiento indicado durante sus prestaciones en la tarea «difícil» respecto a la «fácil». Entre los punteros de trap la perseverancia en las prestaciones observadas en los dos niveles de dificultad de la tarea sería apoyada de una estrategia preferentemente fundada sobre los datos.

ZUSAMMENFASSUNG

Das Ziel dieser Arbeit ist, die zeitlichen Aspekte des Ausarbeitungsprozesses der Information der Athleten der italienischen Nationalmannschaft des Schießens auf ein beweglicheres Ziel zu untersuchen und das Vorhandensein eines verschiedenen «Aufmerksamkeitsstiles», der mit den zwei Disziplinen (Trap und Skeet) verbunden ist, zu bestätigen.

Zu diesem Zweck haben acht olympische Athleten einen psychophysiologischen Experimentsplan gemacht, in dem die Elemente N2 und P300 der Potenziale von Korrelation für Ereignisse und die Reaktionszeiten in einer Übung von Gehörreizen auf zwei verschiedenen Ebenen von Schwierigkeiten registriert wurden.

Die Ergebnisse beweisen, daß die verschiedenen Zeiten für die Informationsausarbeitung die Bewegungsleistungen dieser Athleten beeinflussen. Das scheint, das Vorhandensein von interindividuellen Unterschieden, die mit der betriebenen Disziplin verbunden sind, in dem Aufmerksamkeitsstil der zwei Gruppen von Athleten zu Bestätigen.


RIASSUNTO

Il presente lavoro si prefigge di studiare gli aspetti temporali del processo d'elaborazione dell'informazione in atleti della Nazionale Italiana di Tiro a Volo e di confermare l'esistenza di una «Stile» atenzionale diverso legato alla pratica delle due specialità (Trap e Skeet). A questo scopo 8 atleti olimpici sono stati sottoposti ad un paradigma sperimentale di tipo psicofisiologico nel quale venivano registrate le componenti N2 e P300 dei Potenziali Correlati ad Evento (ERPs) ed i Tempi di Reazione in un compito discriminativo di stimoli uditive a due diversi livelli di difficoltà.

I risultati suggeriscono che la prestazione motora di questi atleti è sottesa da una differente temporizzazione dei meccanismi di elaborazione dell'informazione. Ciò sembra confermare la presenza di differenze inter-individuali, legate alla specialità praticata, nello stile attenzionale dei due gruppi di atleti.
REFERENCES


Manuscript submitted January 1990. Accepted for publication October 1990.