EFFECT OF PREPARATION DURATION DIMINUTION IN SHOT PUT THROUGH NEUROVEGETATIVE ACTIVITY

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Abstract. Recently, time allocated to athletes concentration has been reduced to 1 minute. Increased activation and focused attention are thought to be important operations which influence performance during preparation. The aim of the study was to test whether reducing preparation time has an effect on subjects' mental activity and consequently on performance. Ten subjects took part in the experiment. Each subject had to perform 14 throws: a) 7 with preparation b) 7 with no preparation. Autonomic nervous system activity was continuously recorded through six variables (2 electrodermal, 2 thermovascular and 2 cardiorespiratory variables). Performance was comparable in preparation and non-preparation modalities. Subjects increase their activation before throwing, however more rapidly without preparation time. Thus, performance was obtained through the same activation level whatever the time allocated to prepare. Shot-put performance seems to be dependent upon execution quality but also on reaching an optimal activation level. Phasic autonomic responses (related to focused attention and movement programming) were recorded during preparation and execution. Only a weak relationship was evidenced between vegetative responses in preparation and execution phases. Thus, vegetative responses during the preparation phase did not attest mental operations such as focusing attention on a technical aspect.

(Biol.Sport 20:289-301, 2003)

Keywords: Autonomic nervous system - Activation - Preparation - Sport

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Introduction

Until 1978 the time allocated to shot putters for preparation was two minutes. This was reduced to one minute in 1998. The effect of such a reduction on the shot putter's preparation phase and thus on his performance may be discussed. Time before throwing may be thought to have two main functions: a) physiological activation and b) attentional processes.

Activation is defined as a set of processes required to improve the aptitude of an organism to process information and to carry out an action [15]. Activation changes may be attested by tonic activity of cerebral structures under the dependence of reticular formation. Sensorial afferences are known to emphasise physiological activation. Tonic activity of muscular and neurovegetative effectors is increased simultaneously through reticulospinal pathways when motor activity is prepared. Findings related to Autonomic Nervous System (ANS) functions have led to consider that vegetative activity reflects some brain functions, e.g. physiological activation [10]. Multiparametric recordings through sensitive micro sensors and new indices of ANS activity quantification have brought new concepts to ANS physiological functioning [5]. Simultaneous and continuous measurement of ANS activity during motor preparation might lead to a better understanding of such mental processes. Consequently, ANS response analysis may offer a reliable method in studying athletes' preparation periods.

A relationship between activation and performance was evidenced by Yerkes and Dodson [21]. Performance was shown to evolve in the form of an inverted U curve as activation continued to increase. Performance was thus maximal when activation was optimal. Although these data were obtained mainly in studying animal behavior, they could be generalized to the human being. However, the inverted-U law had to be modulated with regard to requirements on physical activities: these, e.g. weightlifting, need a high activation level whereas others only need a low activation level, e.g. golf [13]. In the same way, optimal activation level is related to features of the individual [12]. Furthermore, performance has been shown to be dependent upon execution factors, i.e. skill requirements. When execution requires to be skilled, activation seems to be less important [4]. Moreover, activation level depends upon the context of performance production [8].

Thus, action preparation requires an increase in activation. However, according to Näätänen [14], "direction" vs "intensity" should be considered determinants of performance. The preparation phase is probably also used by athletes to process information i.e. to focus attention on particular technical aspects of movement

execution. Mental processes during motor preparation should be thus questioned especially when time allocated to prepare is reduced and even suppressed.
During the preparation phase, it could be hypothesized that :

Each thrower goes through self-activation.

Each thrower focuses on technical features of his movement.

Tonic activity (slow variation) is known to be related to changes in activation level. Phasic responses (sudden variations) are recorded in response to various stimuli and have been shown to accompany behavior [18] and to reflect information-processing [3], e.g. focused attention. It may consequently be supposed that suppressing this preparation phase will alter activation (the “intensive” aspect of preparation) as well as focusing attention (the “directional” aspect of preparation) and probably lead to a decrease in performance.

Material and Methods

Subjects were voluntary and were provided informed consent. They were divided into two groups according to their level of performance. The first group was made up of 5 athletes who specialised in the shot-put event (aged from 21 to 26, mean 23 years). Each best performance was between 13 and 18 meters (i.e. confirmed level). The second group was composed of 5 novices (aged from 20 to 24, mean 21 years) whose personal best was below 10 meters (i.e. novices). The weight was 7 kg.
Two throwing conditions were to be tested:

Standing throw according to field rules, i.e. within a minute.

Standing throw immediately after having been called.

Each athlete was to make 14 randomly ordered throws, 7 under each condition. Actual throwing had to reach a distance equivalent to 90% of the best personal mark. The experiment took place in a closed gymnasium where ambient temperature and humidity remained constant. Particularly, ambient temperature was maintained between 16 and 18 °C as it may affect electrodermal activity. Performance and ANS responses were considered the dependent variables, throwing conditions being considered the independent variable.

ANS activity was continuously recorded from sensors placed on the non-dominant hand. Tonic variations evolved simultaneously with subjects’ activation. These were quantified between two easily observable events: the athlete being called to throw and actual throwing. The duration of preparation was measured between these two events. Phasic responses were expected to occur in relation with mental events such as increasing attention, during the preparation phase, mainly.

ANS recordings: Six ANS parameters were selected: electrodermal responses (skin resistance and potential), thermovascular responses (skin blood flow and skin temperature) and cardio-respiratory parameters (instantaneous heart rate and respiratory frequency).

Resistance responses: The constant voltage method is usually used. However, the constant current method was chosen as this requires less amplification, which is especially advantageous in the case of multiparametric recordings [2]. Skin resistance was recorded using 50 mm² unpolarizable round Capsulex electrodes held by adhesive tape and placed on the second phalanx of the index and of the third digit of the non-dominant hand. It was measured with 15 μA DC current. A new temporal index was defined [17] as response amplitude depends on the prestimulation value [20]. To eliminate any interference between skin potential and resistance and other artefacts, parameters were recorded by means of a high-rate common-rejection mode differential "isolation" amplifier (Analog Devices AD 293 B). Likewise, recorder inputs were in a different mode, and resistance circuit supply was of the floating type. Skin resistance measurement current passed between the index and the third digit, while skin potential was measured between the hypothenar eminence and the innerside of the forearm [16].

Potential responses: Skin potential was recorded using Beckman self-adhesive 78 mm² electrodes. Electrode positioning was in compliance with traditional recommendations [9]. The active electrode was placed on the hypothenar eminence of the subject's non dominant hand, after alcohol-ether cleaning of the skin. The reference electrode was placed 10 cm higher on the wrist. Signal processing for electrodermal potential responses was carried out using the SYDER code [7], which permitted classification of elementary responses, according to their form.

Superficial skin blood flow: This was assessed using the original Hematron patented sensor (Dittmar, C.N.R.S/A.N.V.A.R., 1985, Brevet 85 15932). The non-invasive sensor was placed on the skin with adhesive tape, on the thenar eminence of the non-dominant hand. The transducer consisted of a disc 25 mm in diameter and 4 mm thick. The measuring surface in contact with the skin was made up of two parts: the reference area at the periphery of the disc and the measurement area, at the center of the disc. The temperature difference between these two areas was measured using 16 thermocouple junctions. A very low thermal-inertia flat heater was located in the central part of the disc. A proportional, integral, and derivative device controlled the heating power in order to maintain a constant temperature difference of 2°C between the central area and the periphery. The size and shape of the heater were designed in such a manner that a thermal field was induced in the capillary network. The power necessary to maintain the temperature difference constant depends on skin blood flow: heat was transferred through the skin and washed out by the blood flow. Skin blood flow variations were measured by the difference (positive or negative) between the pre- and post-stimulation values expressed in mW/cm/°C and by the duration of the oscillation perturbation expressed in seconds.

Superficial skin temperature: This was measured by a low inertia thermistor (10 K3 MC D2 Betatherm). A 4 mm² sensor was placed on the middle of the palm of the non-dominant hand with non-caustic glue. A phasic variation of less than one-hundredth of a degree can be detected under such conditions independently of tonic evolution resulting from outside conditions.

Instantaneous heart rate: This was recorded from three silver electrodes in the precordial position. The interval between two consecutive R waves was processed and delivered in the form of instantaneous heart frequency. The smallest appreciable variation was 0.5 of a beat per minute and the calibrated scale ranged from 0 to 200 beats per minute.

Instantaneous respiratory frequency: This was recorded from a low inertia thermistor (10 K3 MC D2 Betatherm), placed at the entrance of the left nostril with hypoallergenic adhesive tape. This thermistor was self-heated (several degrees above ambient temperature) by its measuring current (0.5 mA). The exhaled air cools the thermistor at each respiratory cycle. The same signal processing as that for heart rate was used for recording instantaneous respiratory frequency.

Recording apparatus: This was made up of a YTSE 460 type BBC (Brown Boveri) six-channel potentiometric DC recorder fitted with an event tracer, and an automatic synchronisation appliance which cancels out temporal differences between the six markers. A special software package was designed and developed for rapid analysis and processing of the recorded data. The interactive software makes it possible to calculate all indices. The software features other utilities such as amplification or attenuation of signals and zooming [16].

Taking into account the number of subjects in each group, only non-parametric statistical tests were used (Wilcoxon test in intra-group comparisons and Mann-Whitney test in inter-group comparisons).

Tonic values: Due to the great inter-subject difference in basal vegetative values, measurements are expressed through relative data: values recorded when subjects put the shot were divided by those recorded when they were called to throw. Thus, ratios are distributed around 1. Decreases in skin resistance, skin blood flow and skin temperature are related to increasing activation level. Increases in skin potential, instantaneous heart rate and respiratory frequency imply increasing activation. This method made inter-subject comparison possible. As skin potential values could be negative, the number of skin potential value increases (+) or decreases (-) were then taken into account between calling and throwing. Data were analysed with chi-square test.

Number of phasic responses between the preparation and execution periods: The number of neurovegetative phasic responses were taken into account between the preparation and execution phases. Data were analysed with chi-square test.

Results

Table 1
Preparation duration, performance and ANS tonic values (standard deviation) during preparation for the prepared (With) and immediate throws (Without)

	Confirmed				Novices			
	With	Without	Z or x^2	P	With	Without	Z or x^2	P
Preparation duration (s)	37.56 (14.43)	12.86 (3.03)	Z=-2.02	*	35.21 (9.42)	8.05 (0.84)	Z=-2.02	*
Performance (m)	11.87 (1.63)	11.66 (1.65)	Z=-1.48	NS	7.26 (1.45)	7.28 (1.43)	Z=-0.13	NS
Skin resistance (kΩ)	0.95 (0.04)	0.94 (0.05)	Z=-0.74	NS	0.89 (0.05)	0.92 (0.08)	Z=-1.22	NS
Skin potential (mV)	8+ 22-	8+ 26-	x^2=0	NS	5+ 30-	6+ 29-	x^2=0	NS
Skin blood flow (mW/cm/°C)	1.03 (0.27)	0.99 (0.06)	Z=-0.67	NS	0.98 (0.06)	1.01 (0.04)	Z=-0.67	NS
Skin temperature (°C)[1]	0.99 (0.005)	0.98 (0.02)	Z=-1.21	NS	0.97 (0.02)	0.95 (0.04)	Z=-0.94	NS
Heart rate (bpm)	1.36 (0.05)	1.27 (0.05)	Z=-1.75	NS	1.29 (0.16)	1.21 (0.14)	Z=-1.48	NS
Respiratory frequency (bpm)	1.11 (0.12)	1.11 (0.07)	Z=-0.4	NS	1.49 (0.4)	1.19 (0.3)	Z=-1.83	NS

ANS tonic values are expressed here through relative data, i. e. values recorded when subjects put the shot were divided by those recorded when they were called to throw. No difference appeared in performance and activation level (value when throwing/value when being called) as far as each variable was concerned.
NS: non significant; *P<0.05. [1]Example of neurovegetative recording in Fig. 1.

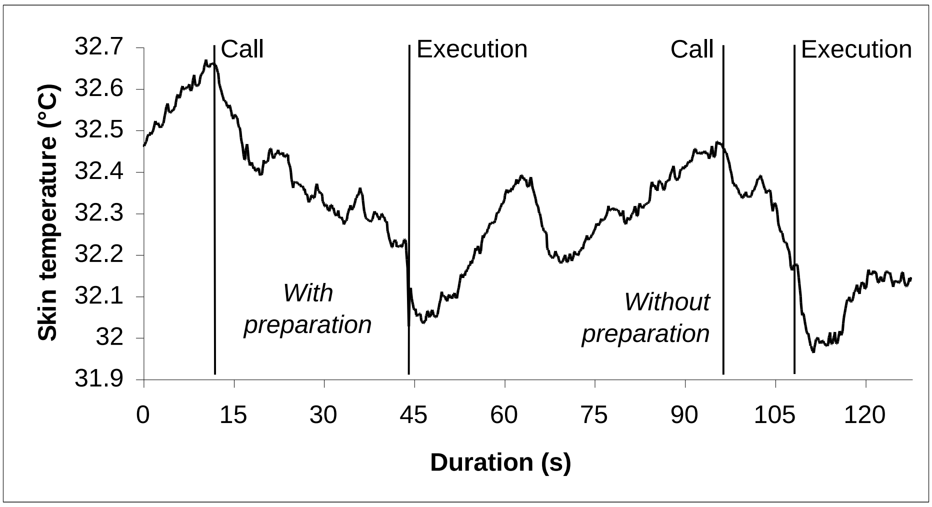

Fig. 1
Example of skin temperature recording during the preparation period (i.e. with and without preparation) in shot put. The first decrease was related to orienting response (i.e. name calling), then subject increased activation (i.e. decrease in skin temperature) before throwing, however more rapidly without preparation time. Finally, a phasic response finally occurred, accompanying execution.

Intra-groups comparisons

Preparation duration: Preparation duration of throwing was compared according to the two modalities (with and without time). A significant difference was evidenced in the confirmed group, preparation duration, with and without time, being 37.56 s and 12.86 s, respectively (Z=-2.02, P<0.05) and in the novice group (35.21 s and 8.05 s, respectively, Z=-2.02, P<0.05).

Performance: Performance was compared according to the two modalities (with and without time). No significant difference was evidenced in the confirmed group, performance, with and without time, being 11.87 m and 11.66 m, respectively (Z=-1.48, P>0.05) and in the novice group (7.26 m and 7.28 m, Z=-0.13, P>0.05).

Tonic variations: comparison between trials with and without preparation phase: Tonic variations were compared according to the two modalities (with and without time). No significant difference (P>0.05) was evidenced, as far as each variable and population were concerned.

Phasic responses: comparison between preparation and execution: Number of phasic responses were compared during preparation phase and in execution according to each modality (i.e. with and without preparation trials). Significant difference (P<0.001) was evidenced in confirmed population (x^2=40.12 and x^2=46.64, respectively with and without preparation trials) and in novice population (x^2=43.44 and x^2=49.95, respectively).

Table 2
Number of phasic responses between preparation (P) and execution (E) periods

	Confirmed						Novices					
	With			Without			With			Without		
	P	E	*p*	P	E	*p*	P	E	*p*	P	E	*p*
Phasic responses	5	32		6	37		13	41		4	37	
Absence of responses	36	5	***	33	2	***	32	0	***	37	4	***

Difference appeared in prepared (with) and unprepared execution (without). Phasic responses occurred systematically during execution and occasionally during the preparation phase; ***P<0.001

Inter-groups comparisons

Tonic variations: comparison between confirmed and novices for freely prepared trials: Tonic variations were compared according to the freely prepared modality. No significant difference (P>0.05) was evidenced in skin potential ($x^{2=0.87}$), skin blood flow (U=19) and heart rate (U=19). However, significant difference was evidenced in skin temperature (U=23, P<0.05). Moreover, skin resistance and respiratory frequency show a tendency (U=20.5, P=0.09 and U=3.5, P=0.06, respectively).

Table 3
ANS tonic values comparison (standard deviation) according to the expertise level

	With preparation			
	Confirmed	Novices	U or x^2	*p*
Skin resistance (kΩ)	0.95 (0.04)	0.89 (0.05)	U=20.5	NS (0.09)
Skin potential (mV)	8+22-	5+30-	$x^{2=0.87}$	NS
Skin blood flow (mW/cm/°C)	1.03 (0.27)	0.98 (0.06)	U=19	NS
Skin temperature (°C)	0.99 (0.005)	0.97 (0.02)	U=23	*
Heart rate (bpm)	1.36 (0.05)	1.29 (0.16)	U=19	NS
Respiratory frequency (bpm)	1.11 (0.12)	1.49 (0.4)	U=3.5	NS (0.06)

Tonic values are expressed here through relative data, i.e. values recorded when subjects put the shot were divided by those recorded when they were called to throw. No difference appeared in activation level except for skin temperature. Skin resistance and respiratory frequency showed a tendency.
NS: non significant; *P<0.05.

Discussion

Preparation duration: Preparation before throwing required about 35s in the two groups. Such a period of time is thought to be sufficient to pick up the shot and to place it against the neck. During this phase, athletes are thought to self-activate and concentrate. When subjects were required to put the shot immediately, they took about 10 s. As time was measured from when subjects were called to throw, placement in the area as well as picking up and placing the shot were included in this period. Thus, confirmed and novice shot putters were both shown to have thrown immediately. It can be considered that experimenters' instructions were respected. However, as confirmed took longer, they were perhaps more disturbed than novices. They had probably built up strong habits which had become automated. Thus it seemed more difficult for them to inhibit such a behavior.

Performance: Confirmed group performance was shown to be identical with or without preparation. Automatic processing does not require the focusing of attention resources on movement execution. Athletes build up a motor program of throwing which is memorised through multiple training sessions. Thus, information processing, such as recalling the appropriate motor program, is facilitated by direct access to a memorised plan. Automated movements are thus available even in situations with high temporal constraints. Memorisation is dependent upon cortical and sub-cortical (particularly basal ganglia) neural network functioning. Movement control is consequently simplified as degrees of freedom are reduced by automation [11]. Mental processes such as focusing attention are not required in controlling automated movements. The time required to access automated programs is thus reduced. With regard to the novice group, it may be supposed that they had built up their own automated gestures although they were not comparable to those of the confirmed. Automation is a process that begins simultaneously with learning. Novice athletes could act on the basis of automated movements which correspond to their own level of performance. Thus the same conclusion may be drawn in the confirmed and in the novice groups.

Neurovegetative variables: Tonic variations: Activation was identical when freely prepared action and immediate throwing were compared. For a long time, activation has been shown to influence performance. According to the well-known Yerkes and Dodson law [21], performance increases simultaneously with activation. An increase in physiological activation above the optimal level could elicit a decrease in performance. In shot putters, performance is not affected by the length of preparation. Activation could thus rapidly be obtained. When required, organism resources, controlled by ANS functioning (especially the orthosympathetic system) could be immediately involved. Research by Wallin and Fagius [19], based upon recordings of sympathetic unit activities with micro-electrodes, concluded that ANS is rapidly and selectively activated. Autonomic subdivisions are specialised in regulating organ functions in response to the changing demands of the internal and external milieu. The same activation level is obtained in the two experimental conditions; as memorised action planning was immediately available, even under high temporal constraints, performance was not affected.

However, a difference was evidenced in inter-group comparison: activation (skin resistance, skin temperature and respiratory frequency ratios) was higher among novice shot putters. Activation was observed through tonic variations in both groups but was higher in the novice group. It could thus be concluded that novice shot putters were slightly more activated than confirmed. Confirmed shot putters are used to competition throwing and have learned to inhibit excessive activation. The experimental situation was designed to place subjects in the same conditions as in competition. Novices were not used to shot putting competition. This may explain that their activation was higher.

Phasic variations: Phasic ANS responses during the preparation phase were thought to be related to mental activity [6]. As phasic responses were not systematically observed, mental activity (i.e. focused attention) seems to be reduced in shot putters during the preparation phase. The main role of preparation preceding throwing is related to increasing physiological activation. Focusing attention on one or several technical aspects of skill execution before action are not an essential pre-condition of success. This result is quite different from conclusions from previous studies of sporting activities. In air-rifle shooting, autonomic responses were systematically observed during the preparation phase and were shown to be highly correlated with those accompanying execution [6]. Mental representation of shooting appeared therefore to be fundamental. This could be characterised by fine adequation between a motor program recalled during preparation, and execution phases were thus shown to be quite identical. The closer the responses during these two phases, the better the shooting performance was. Such findings are not confirmed by present results. Only a weak relationship has been evidenced between responses recorded during the preparation phase and those of the execution phase. If such mental activity (i.e. focused attention) is necessary, it may take place before being called to perform.

Performance stability in the immediate throwing condition showed that focused attention on the forthcoming execution is not a determinant factor of performance during this phase. However, it may be supposed that shot putters can focus themselves during the phase preceding their being called to throw, the latter period being reserved for activation only. In a study involving weightlifters, it was shown that focused attention and activation periods were clearly separated. Subjects were shown to focus attention on technical aspects of movement as soon as they were called to the lifting area. Such mental activity appeared through recordings of ANS activity. From the time they put their hands on the bar, subjects auto-activated [1]. Thus, two different phases appeared in weightlifters' preparation. If shot putters use focusing attention, this mental activity does not take place in the phase following calling and preceding throwing.

Vegetative responses have been shown again to transcribe central nervous system activity at a peripheral level. It is well accepted that behavior results from interactions of neural networks responsible for action production and those controlling energy expenditure that accompany execution. Thus, vegetative response analysis should be considered an inferential model of central nervous system functioning [10]. A decrease in preparation duration in track and field events has been demonstrated to not affect performance dramatically. Present rules allow athletes one minute to prepare. With reference to present findings, this period of time could be diminished without affecting performance and would probably increase interest in track and field competitions by reducing "dead" times.

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Accepted for publication 26.05.2003