New Trends and Advanced Techniques in Clinical Neurophysiology (EEG Suppl. 41)
Editors: P.M. Rossini and F. Mauguière

The Skilled Performance Positivity after Learning a Skilled Task

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The effect of an intensive training period and that of a time-distributed training on skilled performance positivity (SPP) have been studied. SPP is a potential associated with knowledge and evaluation of the results of a goal-directed bimanual self-paced task requiring particular ability. Nine subjects with average intelligence but with some difficulties in the motor-perceptive sphere were studied. The task consisted of initiating the sweep of an oscilloscope with a self-paced movement and terminating it within 50 msec ± 10 msec. The subjects had to repeat this task several times at various time intervals. The electrical activity was recorded from Fpz, Fz, Cz, Pz, P4, P3 and the right/left precentral areas. For each performance, performance time, performance shift taken as the accuracy index, as well as the percentage of target performances were evaluated. Motor performances improved with both distributed and intensive practice. Only distributed practice had a significant effect on SPP latency and amplitude. SPP latency decreased in all brain areas, whereas amplitude increased in the prefrontal, frontal and left precentral areas. These results seem to suggest that the performance evaluation processes take place more quickly and efficiently through distributed practice.

Introduction

The execution of a motor act is known to be preceded on the scalp by a negative phasic potential called the Bereitschaftspotential (BP) (Kornhuber and Deecke 1965). The amplitude of this potential is proportional to the complexity of the motor action, which is greater during skilled than unskilled tasks (Papakostopoulos 1978a; Chiarenza et al. 1980). Besides, it has recently been demonstrated that, when the motor task has been learned after long exercise, the motor performances remain unvaried and the BP is reduced in onset and amplitude (Villa et al. 1989).

After the subject has carried out a skilled task and is expecting and receiving on-line information updating him about the result of his action, a positive potential appears on the scalp, defined as the skilled performance positivity (SPP), in both adults (Papakostopoulos 1978b, 1980) and children (Chiarenza et al. 1983). This potential has been correlated with knowledge and appraisal of the results which can be used to influence future action, once they have been memorized. According to Papakostopoulos (1980), this potential does not depend on either stimulus, response or task, as these factors are necessary but insufficient to produce SPP.

Distributed practice is known to be more useful than intensive practice in learning and memorizing psychomotor skills.

The aim of this paper is to evaluate SPP changes after lengthy practice and possible differences between intensive and distributed practice.

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Materials and method

The peculiar characteristics of the motor perceptual task used in this experiment suggested selecting subjects with difficulties in motor perceptual function in order to observe the effect of distributed practice clearly. The tested subjects came from the same secondary school of a Milan suburb and had been sent for diagnostic testing concerning learning difficulties. Nine right-handed subjects, 7 males and 2 females, of ages ranging from 113 to 170 months (mean age 151.7

months) were tested. To an extensive clinical and psychological test battery all subjects were of normal intelligence according to Wechsler's test (1976) (IQ = 94.56, S.D. = 7.14), without neurological and personality disorders and showed motor-perceptual disturbances revealed by the Bender Visual Motor Gestalt test (Koppitz 1964), Draw a Man test and Rey's complex figure test (Rey 1969).

Each subject sat in a comfortable chair facing the 10 cm screen of a CRT at a 70 cm distance. The motor-perceptual task consisted of initiating a single sweep of the oscilloscope trace by pressing a button with the left thumb and stopping the sweep after 50 msec ± 10 by pressing another button with the right thumb. The speed of the trace was 1 mm/sec (Papakostopoulos 1978a). The interval between the left and right thumb pressings was defined as the 'performance time.' The distance from the ideal target interval (40–60 msec) was referred to as the 'performance shift' and this value was taken as the accuracy index. The percentage of performances in the 40–60 msec interval was calculated and referred to as 'target performance.'

Ag/AgCl electrodes were placed at Fpz, Fz, Cz, Pz, P4, P3 as well as the left (LPC) and right precentral (RPC) areas. Each electrode was referred to linked mastoid electrodes. A bipolar EOG was also recorded from above and below the right eye to monitor blinking and eye movements. The surface EMG was recorded from the left and right forearm flexor muscles. The impedance of the electrodes was less than 3 kΩ. The preamplifier bandpass was 0.02–30 Hz for the EEG and 0.03–1600 Hz for the EMG. On-line data acquisition started with sampling a ± 20 μV square wave for calibration on each channel. A trigger pulse, generated by pressing the left-hand button, began a 3.2 sec EEG epoch which was sampled at 250 Hz. The average of the first 250 samples was used to establish the baseline from which the various measurements of the SPP were taken. The mean amplitude of the SPP was taken as the average value from the baseline over 200 msec centred around the main positive (SPP) peak in the latency band between 350 and 850 msec. The SPP latency was measured from the trigger pulse. Trials contaminated by obvious eye movements or blinking were rejected from the analysis.

The experimental design was the following: the first 'phase' consisted of one 'set' of 100 performances repeated after 1 h and after 2 weeks. After 1 month, the second phase started with the same modalities as the first. A 100 trials were averaged in 4 blocks of 25 each. The analysis of the data was based on multiple linear regression analysis. The phases, sets and blocks were the independent variables and the performances and SPP latency and amplitude the dependent variables. The variance analysis was performed to test the significance of multiple regression, yielding F values, and the significance of the individual regression coefficients, yielding t values.

Results

All the children understood the verbal explanation of the task and completed all the experimental procedures. The multiple linear regression analysis showed a significant decrease in performance time and performance shift and a significant increase in percentage of target performances with both distributed (i.e., phase

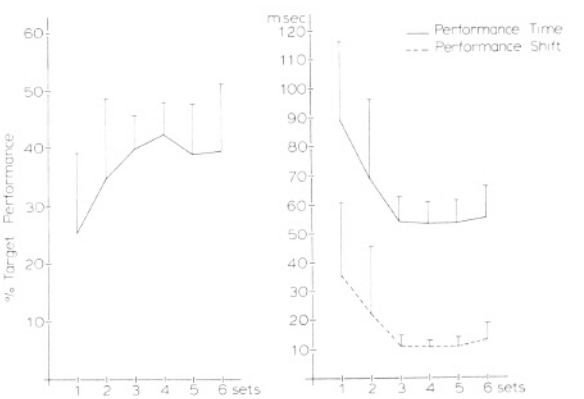

Fig. 1. Means and S.D. of performances for all subjects in the various sets.

TABLE I

SUMMARY OF VARIANCE ANALYSIS FOR THE MULTIPLE LINEAR REGRESSION OF PERFORMANCE RELATED TO PHASES, SETS AND BLOCKS

For each performance parameter the t value is computed in relation to phases, sets and blocks.

	Phase	Sets	Blocks
Performance time	-4.82^{**}	-3.74^{**}	-3.97^{**}
Performance shift	-3.89^{**}	-3.06^{**}	-3.39^{**}
% target performance	3.63^{**}	2.48^{**}	2.35^{*}

$^{*}P<0.05$; $^{**}P<0.01$.

TABLE II

SUMMARY OF THE MULTIPLE LINEAR REGRESSION ANALYSIS OF SPP RELATED TO PHASES, SETS AND BLOCKS

For each parameter of SPP in each location the t value is computed in relation to phases, sets and blocks.

		Fpz	Fz	Cz	Pz	RPC	LPC	P4	P3
Lat. SPP	Phases	−1.22	−2.70**	−4.33**	−2.21*	−3.68**	−4.09**	−2.10**	−2.39**
	Sets	0.45	−1.45	−0.54	−0.89	−1.34	−1.15	−1.00	−0.76
	Blocks	−1.24	0.50	−0.98	1.82	−0.42	−0.35	1.18	1.04
Amp. SPP	Phases	2.95**	2.91**	0.69	−1.32	−1.57	3.97**	0.10	0.08
	Sets	1.45	0.66	−0.20	0.44	0.77	−0.23	0.00	−0.53
	Blocks	0.05	−0.09	0.30	0.35	0.34	0.21	1.36	1.29

*$P<0.05$; **$P<0.01$.

and sets) and intensive practice (i.e., blocks; Fig. 1 and Table I).

Intensive practice (i.e., blocks) did not significantly alter SPP latency or amplitude. Distributed practice had no effect on SPP latency or amplitude when the various sets were analysed, while it had a significant effect when the two phases were compared (Table II). During the second phase, SPP latency was significantly reduced in all brain areas except Fpz. SPP amplitude increased significantly in the prefrontal, frontal and left precentral areas. In the remaining areas, SPP amplitudes were similar (Fig. 2).

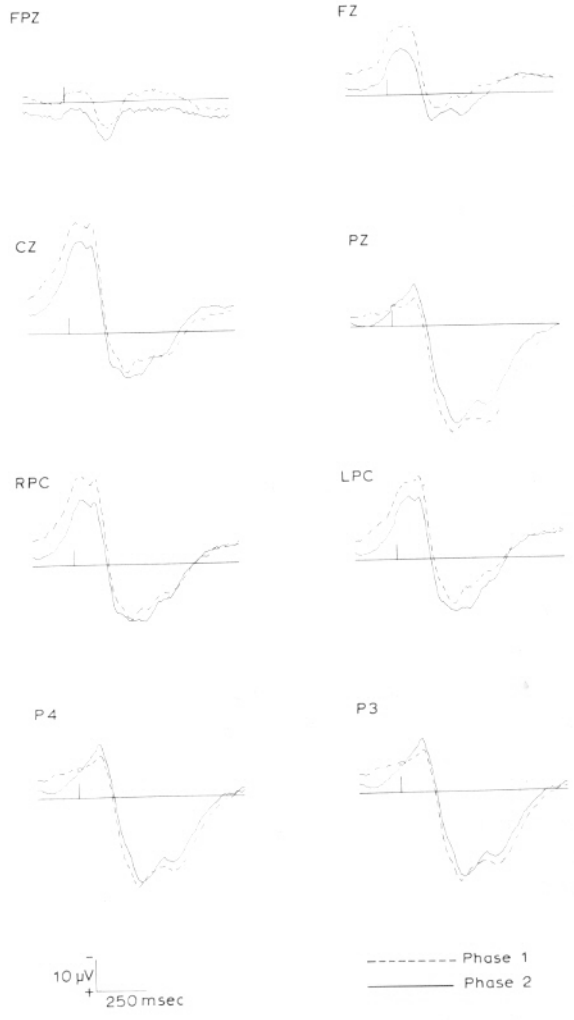

Fig. 2. The SPP grand average for all subjects. Note the increased amplitude of SPP in Fpz, Fz and RPC during phase 2.

Discussion

Both distributed and intensive practices are the important conditions for learning complex motor skills. Practice is in fact necessary for rehearsing those particular subtasks which are only partially learned; coordinating the subtasks so that they are performed in the proper sequence and with appropriate timing; preventing extinguishing and forgetting the subtasks; developing the skill to the autonomous stage of learning. The trend of the performances throughout the 6 sets shows that our subjects reached and kept a certain level of accuracy and target performance: 40% approx. after 300 trials. This level of performance is comparable to that obtained by adult subjects involved in the same task (Papakostopoulos 1978a); thus this result ought to be considered as optimal.

The attainment of this level of performance after the third set proceeds with changes in SPP latency and amplitude. In fact, comparing the two phases, SPP amplitude increases in the prefrontal, frontal and left precentral areas during the second phase, and latency is reduced in all brain areas. This phenomenon

may be interpreted as the effect of better synchronization of the systems involved in result appraisal. It has been demonstrated that learning alters the state of certain synapses and increases their conductivity and sensitivity to acetylcholine stimulation (Deutsch 1983). Marczynski (1978) hypothesized that thalamocortical reverberating circuits of a cholinergic nature are involved in the generation of scalp positive potentials. SPP is supposed to result from the rhythmic phasic activity of hyperpolarizing cholinergic neurones. The changes in SPP only after a fortnight's interval could be explained by the need of the mnesic trace for a period of consolidation which is caused by acetylcholinic reverberating circuits. At present, specific storage of mnesic traces is thought to occur near the specific cortical areas involved in the processing of the material to be stored (Mishkin and Appenzeller 1987). This could explain why changes in SPP amplitude are mainly found in those brain areas which are the most directly concerned with producing and maintaining the 'motor engram' (Bernstein 1967), i.e., the frontal and precentral areas.

The effect of training has mainly been studied with externally paced odd-ball type paradigms in order to elicit P300. The repetition of the stimulus induces different changes following the presentation of target and non-target stimuli. P300 to target stimuli remains stable in amplitude, while non-target P300 shows a decrease (Roth and Koppell 1973; Courchesne 1978, 1983; Woods and Elmasian 1986). Target P300 shows reductions only when the stimuli are repeated in hundreds or thousands of trials (Woods et al. 1980). Unlike P300, SPPs increase in amplitude with exercise.

From a psychological point of view, it has been suggested that cognitive operations are characterized as 'controlled' and 'automatic' (Shiffrin and Schneider 1977) or 'scopeutic' and 'categoric' (Cooper et al. 1979). Cooper et al. (1979) suggest that the scopeutic or controlled mode of action is used in those circumstances in which there is an 'involvement of the subject, continuous interaction with the environment and an end result.' Conversely, the categoric or automatic mode is used when a subject 'performs a task in an automatic and unthinking manner, but with the ability to maintain a good level of performance.' In our study, the observation that performance reached an optimum level after a certain time and maintained it could make one assume that the subjects operate on the basis of a categoric model, but the reduced SPP latency and increased SPP amplitude, which do not remain stable nor decrease as P300 does, supports the hypothesis of a scopeutic mode.

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