BRAIN. Broad Research in Artificial Intelligence and Neuroscience
ISSN: 2068-0473 | e-ISSN: 2067-3957
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2022, Volume 13, Issue 2, pages: 01-21 | https://doi.org/10.18662/brain/13.2/328
Submitted: January 25th, 2022 | *Accepted for publication:* February 24th, 2022

Anticipatory Resource of Temporary Regulation of Sensorimotor Action

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Abstract: *The aim of the study is to determine the composition and functional significance of anticipatory resources in the process of temporal regulation of sensorimotor action.*

Materials and methods. *The subjects were male (35 people) and female (31 people) students. The tasks of a simple sensory response, a choice reaction (three alternatives), and a “double choice” were implemented in a computer version of the experiment. In the “double choice” task, the stimulation variation was first provided (possible stimuli: one or three), and then a stimulus for a fast motor response was presented after some time, the orientation time (independent variable).*

Results. *The participants’ initial reaction to the option with three alternative stimuli in the “double choice” task was negative. The time of the motor response falls linearly as the orientation time increases in both the male and female groups for the variant with one possible stimulus and the frequency of anticipatory effects and premature actions increases in a quadratic pattern. It must be noted that with enough orientation time, determining the expected duration of the sensorimotor action is quite straightforward. It was demonstrated that, in the presence of a margin of orientation time, operational estimates and revisions of the time required to accomplish an action dramatically improve the likelihood of anticipatory effects.*

Conclusions. *Actualization of the anticipatory resource (which includes temporary memory standards, the ability to accurately determine and correlate the durations of processes and time intervals, time estimation skills, and individual characteristics that influence decision making) ensures the determination of the total duration of a sensorimotor action, prompt correction of its implementation, and a significant reduction in the time it takes to respond to a motor stimulus.*

Keywords: *Duration of action, temporal sequence, temporary memory standard, attitude, anticipatory effect.*

How to cite: Plokhikh, V., Popovych, I., Koval, I., Stepanenko, L., Nosov, P., Zinchenko, S., Boiaryn, L., & Zavatskyi, V. (2022). Anticipatory Resource of Temporary Regulation of Sensorimotor Action. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 13*(2), 01-21. https://doi.org/10.18662/brain/13.2/328

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1. Introduction

A modern person's vital activity is inextricably linked to a plethora of complicated, highly dynamic, and information-rich systems. In these conditions, it is clear that simply reacting to the subject's current circumstances is insufficient to assure high action efficiency. An examination of the activities of pilots, vehicle drivers, navigators, and operators in a variety of high-tech businesses reveals that accomplishing final results is only achievable if the required actions are performed with some spatiotemporal anticipation of the expected events (Plokhikh et al., 2019; Strelkov, 2008). The estimation of the dynamics of changes in the situation, the actualization of the necessary resources, and the implementation of the right expedient activity are all primarily given by psychological mechanisms of anticipation in the structure of action at any level of complexity (Konopkin, 1980; Lomov & Surkov, 1980; Zavalova, Lomov, & Ponomarenko, 1986).

According to research, the temporal and spatial parameters of a subject's actions can be considered separately (Ahrens et al., 2015; Plokhikh et al., 2021). Furthermore, the content and spatial aspects of anticipation have previously attracted some attention, particularly in regard to quite gradual external changes (Lomov & Surkov, 1980). The study of the temporal component of anticipation in the planning of actions was largely confined to examining the correspondence of the moment of getting the desired results to the constraints set in terms of commonly accepted physical time (Nosov et al., 2019; 2020a). At the same time, the structure of psychological time, which is important for activity in the context of significant, unexpected changes in the situation, is inadequately highlighted.

Any action proceeding from some initial conditions and oriented through the implementation of a planned sequence of operations to achieve a goal set in the future is a specific process and, as such, has a corresponding duration. With the subject's acceptance of the goal under particular conditions and the available resource support, a certain time frame for reaching the desired solution is instantly assumed (Nosov et al., 2020b; Zinchenko et al., 2020a). At the same time, the content features of the implemented action should be most closely linked to the time it would take to complete. The duration of a holistic action, on the other hand, might be thought of as its fundamental subjective transitory measure (Plokhikh et al., 2021).

As a first approximation, the timeliness of achieving the goal is determined by the accuracy of the subject's correlation of the duration of the action with the durations of significant objective changes and with the total duration of the implementation of the sequence of necessary operations in the anticipatory process. Problems with determining the realistically possible duration of the planned action under conditions of a strict time limit become an essential prerequisite for the emergence of regimes of acute and total lack of time. In the latter scenario, the subject chooses to act in a particular way, even if it is obvious from the start that achieving the final result by the deadline is nearly impossible (Plokhikh, 2019; Strelkov, 2008).

At the sensorimotor level of anticipation, the action is realized at intervals of tenths of a second (Gellershteyn, 1958; Lomov & Surkov, 1980). Conscious control over both the execution of an action and the lapse of time is severely limited or impossible in such circumstances (Nosov et al., 2020c; Zinchenko et al., 2020b). As a result, the subject is compelled to refer to previously memorized time standards as well as urgent information (Carboch et al., 2014; Cravo et al., 2017; Lomov & Surkov, 1980). The variety and accessibility of standards found in experience and swiftly generated in short-term memory, as well as the ability to notice substantial changes, might be considered a resource for anticipating activity structuring. In this case, the ways of integrating significant information about current changes into the duration of the action learned by the subject can also be a resource (Shevchenko et al., 2020).

The duration of an activity is generally selected by the subject as a previous assessment of the temporal perspective of the accompanying expedient efforts. The situation alters in some way while the sequence of activities continues, and these changes can be important and should be factored into ongoing corrections.

As a complex system formation, the action structure includes a number of feedback loops that provide anticipation and self-regulation processes (Konopkin, 1980; Prohorov, 2020). The most general feedback loop is concerned with determining whether the result parameters are in accordance with the requirements for achieving the goal. All at the same, intrasystem local feedbacks are tuned to control and correct sequential operation execution (Nosov et al., 2021a). In this regard, N. Bernstein's (2004) studies of movement construction revealed that at any level of movement organization, the implementation of any operation, despite being based on the corresponding subjective motor standard, is always unique. In this case, the so-called principle of "repetition without repetition" is effective. According to this principle, each subsequent execution of a motor operation promptly adjusts to any, even consciously indistinguishable, changes in the situation through verified corrections (Nosov et al., 2021b). Concurrently, the correction of operations in the optimal variant is carried out ahead of the expected undesirable consequences and violations in the movement's execution. The sequence of operations that is controlled in this manner is only temporary. And this sequence of operations should roughly correspond to the duration of the movement. In this case, the corresponding standards fixed through repeated repetitions in memory, methods for assessing afferent information, and methods for correcting performance serve as a basis for coordinating the structural elements of the actions being implemented and the current changes in the situation (Cravo et al., 2017; Plokhikh et al., 2021).

The unconscious level of mental regulation plays a significant role in the performance of sensorimotor actions. At once, many previously learned operations and methods for their control and correction are implemented automatically in a fraction of a second. However, even in such circumstances, S. Gellershteyn (1958) proposed using physical time measures to improve subjects' conscious regulation and reduce sensorimotor response time. The author's consistent results indicated a reliable fixation in the subjects' experience of more advanced methods for assessing the course of psychological time with the expansion of the scope of their practical application.

Studies of the development of sensorimotor actions at the level of the most basic conditioned reflexes reveal the importance of anticipatory mechanisms in the process of their implementation at all levels of mental activity (Pavlov, 2004). When a conditioned stimulus occurs, the memory standards formed during the process of developing conditioned reflexes, with a time-determined lead, initiate the corresponding activity of the organism. As a result, the regulation of both simple and complex actions necessitates a mandatory assessment and correction of the total duration and temporal sequence of implementations. The anticipatory process's ability to provide appropriate resources is critical for the effectiveness of the sensorimotor response.

The process of temporal regulation of sensorimotor action is the *subject* of the research.

The aim of the research was to determine the composition and functional significance of anticipatory resources in the process of temporal regulation of sensorimotor action.

***Hypothesis*:** Full-fledged actualization of the anticipatory resource during the temporary regulation of sensorimotor action contributes to pronounced anticipatory effects and a significant reduction in the time of the motor response to stimulation.

Research tasks were:

1) To substantiate theoretically and to confirm empirically the actualization of anticipatory resources in the components of the process of temporal regulation in the structure of sensorimotor action.

2) To establish experimentally the composition and features of the use of anticipatory resources in determining the duration of the sensorimotor action.

3) On the basis of experimental data, to show the value of anticipatory resources for the current operational regulation of the time of performing a sensorimotor action.

2. Materials and methods

The study included 66 students, both male and female. The male group had 35 people (age: Me = 20, min = 17, max = 25) and the female group had 31 people (age: Me = 20, min = 17, max = 23).

The design of experimental tasks was based on schemes of a simple sensorimotor reaction and a choice reaction (Jain et al., 2015; Shoshol, 1978; Silverman, 2010). The response scheme was used in the research methodology, with a warning (indicative) signal indicating the appearance of the main stimulus for the motor response after a certain time interval. The implementation of this scheme reinforces the reflex connection between the conditioned stimulus and the reaction in the simplest variant of the response (Pavlov, 2004). The experience of constructing an empirical and experimental picture in studies of temporality (Popovych et al., 2021a), social expectations (Popovych et al., 2021b; Semenov et al., 2021), adaptive processes (Blynova et al., 2020; Halian et al., 2021), individual self-regulation ability (Hudimova, 2021; Hudimova et al., 2021; Khmiliar et al., 2020), and psychological patterns of the age range of respondents (Kuzikova et al., 2021; Popovych et al., 2021c) was taken into account when developing the research methodology.

The methodology also implemented the effects described by Hick's law, which manifested itself in the fact that as the number of possible stimuli alternatives increases, so does the reaction time of choice (Shoshol, 1978). The "double choice" problem was based on the aforementioned grounds. In this task, a stimulus was presented in accordance with one of two options in the following trial: one possible stimulus for presentation (1_PS); three possible stimuli for presentation (3_PS). The stimulus in variant 1_PS was one of three possible stimuli in variant 3_PS. The subject's stimulation option for the follow-up trial was initially unknown. We organized the experimental task with the understanding that in a situation of uncertainty in the prospects for action, a person attempts to focus on the most extensive set of current circumstances, with their subsequent admissible concretization and formation of the necessary information basis for action (Konopkin, 1980; Plokhikh et al., 2021; Shoshol, 1978). A change in orientation to the perceived situation is, first and foremost, a change in the apperceptive scheme, followed by a change in the system of action, which takes time (Gordeeva, 2000).

The subjects in the experiment completed five test series of trials that differed in the task conditions, each of which was preceded by a number of training trials. The experimental task had a software implementation and was made available to the subjects for computer-based completion. The subject had to respond to the appearance of a stimulus on the monitor screen as quickly as possible in all variants of the experimental task (a square colored burgundy). The square was displayed in the center of the screen in the task of simple sensorimotor response (variant 1_PS) (series 1). The square was presented on the screen in one of three possible locations in the choice reaction task (variant 3_PS): in the center, to the right of the center, or to the left of the center (series 2). When the stimulus was presented, the subject was required to press the appropriate key on the keyboard. The "↓" key was used for a simple sensorimotor response. The function keys for the selection reaction in variant 3_PS were as follows: the square on the left is the "←" key; the square in the center is the "↓" key; and the square on the right is the "→" key.

In the "double choice" (DC) task, the variant of the proposed task was preliminarily indicated on the monitor screen some time before the appearance of the stimulus: 1_PS or 3_ PS. The time of orientation was measured from the preliminary indication of the updated version of the task to the moment the stimulus was presented. The task variant was indicated by displaying small burgundy circles on the screen above the locations where the stimulus could appear. In order to solve the DC problem, the subject had to, after the presentation of the square stimulus, press the corresponding key on the keyboard as quickly as possible, taking into account the possible locations of appearance of the stimulus previously marked with circles.

Variants of the DC experimental problem differed in how they changed the orientation time while running a series of trials. Three different fixed values of the possible orientation time were set in series 3 and 4. A random number generator was used to choose one of the three orientation time values for the next sample. The orientation time from sample to sample in series 5 changed automatically in accordance with the specified algorithm. The indication for changing the duration of orientation in the next trial was the result of a software comparison of the motor response time in the current trial in variant 1_PS and previously, before the start of the series, the value of the median value of the subject's simple reaction time in series 1 (criterion for changing the orientation time) set under computer program conditions. If the motor response time value was greater than the criterion value, the orientation time for the next trial was increased by .05 s; otherwise, the orientation time was decreased by .05 s.

The current version of the DC task and the location on the screen where the stimulus for the reaction appeared in the next trial was determined using a random number generator. The time interval between samples in the series was changed at random within 1.7÷2.3 s. And after each trial, data about the conditions and outcomes of its implementation were automatically recorded in the program data array. Following the completion of a series of trials, the data array was pre-processed and entered into the test results file.

Our previous works contain a detailed description of the experimental study's methodology as well as instructions for the subjects (Plokhikh, 2021; Plokhikh et al., 2021).

In series 1, subjects performed a simple sensorimotor reaction (5–7 training trials and 25 test trials). The choice reaction was performed in variant 3_PS in series 2 (5–7 training and 25 test trials). Subjects in series 3 and 4 solved the DC issue with fixed orientation time options (7–10 training and 65 test trials each). The orientation time options in series 3 were .05 s, .15 s, and .25 s. The orientation time options in series 4 were .10 s, .20 s, and .30 s. When the results of series 3 and 4 were combined, the orientation time in them ranged from .05 s to .30 s, with a "step" of .05 s. 7–8 training and 50 test trials were carried out in series 5 with automatic change in orientation time.

In the course of processing the experimental data, pronounced effects of anticipation in the reactions of the subjects were discovered. These effects were observed when the subject's response time to the stimulus in the 1_PS variant was less than the minimum reference value for a simple reaction to a visual signal (.150 s) (Boyko, 2002). The probability of anticipation in the series was calculated as the ratio of the number of pronounced anticipatory effects to the total number of samples in the series for all subjects in the group for variant 1_PS. The probability of premature action was also calculated as the ratio of the number of noted hasty reactions (reactions prior to the appearance of the stimulus) to the number of trials in the series for the variant 1_PS combined for all subjects in the group.

Thereby, the time of orientation and the proposed version of the task for the sensorimotor response (1_PS or 3_PS) were the independent variables in the experimental series. The dependent variables of this research were motor response time, anticipation probability, and premature action probability. The following statistical criteria were used to process experimental data: the Kolmogorov–Smirnov criterion; the Wilcoxon signed-rank test; the Student's t-test; the χ^2r – Friedman criterion; and the Fisher φ^* – criterion. The statistical package IBM SPSS Statistics v. 20 was used.

3. Results

The distribution of motor response time in all series, as well as orientation time in series 5, was analyzed in subject groups for compliance with normal law (Kolmogorov-Smirnov statistical test). A positive result of compliance was established in most cases, with the exception of the simple reaction time in series 1 in both groups of subjects, but with a central trend in the distributions of sample data. For the male and female groups, the parameters of the distributions of the simple reaction time in series 1 were calculated (males: Me = .220 s, min = .150 s, max = .260 s; females: Me = .220 s, min = .190 s, max = .280 s) and reaction time of choosing from three signal alternatives in series 2 (males: Me = .320 s, min = .260 s, max = .410 s; females: Me = .340 s, min = .290 s , max = .420 s). Statistical comparison of simple reaction time and choice reaction time in series 1 and 2 (Wilcoxon signed-rank test) revealed significant differences for both male ($Z=5.169$; $p<.001$) and female ($Z=4.870$; $p<.001$) groups.

The probabilities of anticipation and premature action were determined in male ($p= .048$ and $p= .051$; $n=827$) and female ($p= .014$ and $p= .049$; $n=715$) groups for a series of simple reactions with the obtained number of observations (n).

Tables 1 and 2 show the response parameters of the test groups to the stimulus in variant 1_PS series 3, 4, and 5. The probabilities of anticipation and premature action for variant 1_PS in series 5 were calculated using the following numbers of observations (n): n = 911 for the male group and n = 763 for the female group.

Table 1. Parameters of the motor response to the signal in the case of one stimulation variant in series 3 and 4 with different orientation times in the groups of subjects

Group	Motor response parameter	Orientation time, s					
		.050	.100	.150	.200	.250	.300
Males	Time ($\overline{M}$), s	.331	.291	.268	.219	.191	.135
	Time (SD), s	.041	.038	.048	.045	.063	.064
	Probability of anticipation	.000	.000	.014	.113	.282	.499
	Probability of premature action	.012	.004	.006	.010	.009	.042
Females	Time ($\overline{M}$), s	.340	.308	.273	.237	.197	.154
	Time (SD), s	.048	.040	.044	.057	.063	.075
	Probability of anticipation	.000	.000	.016	.088	.249	.459
	Probability of premature action	.010	.029	.010	.015	.041	.057

Table 2. Motor response parameters in the "double choice" task in series 5 to a signal in the case of one stimulation option in groups of subjects

Group	Motor response parameter					
	Time, s		Orientation time, s		Probability of anticipation	Probability of premature action
	$\overline{M}$	SD	$\overline{M}$	SD		
Males	.217	.028	.184	.059	.128	.016
Females	.234	.026	.206	.064	.108	.025

Statistical analysis (Wilcoxon signed-rank test) revealed that the simple reaction time in series 1 did not differ significantly from the motor response time in the variant 1_PS in series 5 in the male group ($Z=1.347$; $p=.178$). The time of a simple reaction in series 1 in the female group is slightly less than the time of motor response in the variant 1_PS in series 5 ($Z=2.401$; $p=.016$).

In the “double choice” task in series 5, the values of statistical indicators for the motor response time to the stimulus in the 3_PS variant were determined for males ($\overline{M}$ = .299 s, SD = .030 s) and females ($\overline{M}$ = .310 s, SD = .027 s). The comparison (Student’s t-test) of the given values of the motor response time to the stimulus in the 1_PS and 3_PS variants in series 5, similar to the comparison of the results of series 1 and 2, revealed a significant excess of response time for the 3_PS variant and in the male ($t=14.520$; $p<.001$), and female ($t=13.648$; $p<.001$) groups.

Comparison of the values of the motor response time to the stimulus in the 1_PS variant, corresponding to different orientation times in series 3 and 4 (see Table 1), using the Friedman χ^2r test, made it possible to establish significant differences for the male (χ^2r = 160.033 at $p<.001$), and for female (χ^2r =141.659 at $p<.001$) groups. Changes in the time of motor response, as well as changes in the probabilities of anticipation and premature actions, occur in accordance with certain trends as the time of orientation increases. The parameters of mathematical models closest to the trends in empirical data in the variant 1_PS in series 3 and 4 were calculated (“curve fitting method”) for the dependences of the following variables on orientation time: motor response time (linear model), anticipation probability (quadratic model), and probabilities of premature actions (quadratic model) (Table 3).

Table 3. Parameters of mathematical models depending on the orientation time of the motor response time (linear model), the probability of anticipation (quadratic model), the probability of premature action (quadratic model) in the case of one stimulation option in groups of subjects in series 3 and 4 of the “double choice” task

Group	Motor response parameter	Model’s parameters			Characteristic	
		Constant	**Coefficient 1**	**Coefficient 2**	^{2}	**p**
Males	Time	.372	- .759	–	R 988	<.001
	PA	.092	-2.297	12.179	.998	<.001
	CPA	.029	-.386	1.379	.858	.054
Females	Time	.382	- .748	–	.997	.000
	PA	.096	-2.296	11.643	.999	.001
	CPA	.027	-.255	1.179	.775	.107

Note: PA – probability of anticipation; CPA – chance of premature action; p – significance level; R^2 – proportion of reaction time variance due to orientation time.

The theoretical values of the expected duration of orientation required to achieve a high criterion of response efficiency (median of a simple reaction in series 1) for male and female groups in series 5 were calculated using the obtained mathematical models of the dependence of the time of the motor response to the stimulus in the variant 1_PS on the time of orientation (respectively: for the male group – .200 s; for the female group – .217 s) (see Table 3). Using a one-sample t-test, it was found that the orientation time in the "double choice" task in series 5 (see Table 2) was not statistically different from the estimated expected orientation time for the male ($t=1.606$; $p=.117$), and for female ($t=.915$; $p=.368$) groups.

The expected values of the motor response time, the probability of anticipation, and the probability of premature action in the 1_PS variant were calculated using the obtained mathematical models and based on the average values of the orientation time in the male and female groups established in the empirical study in series 5 (Table 4). The calculated results were compared to empirical results in series 5, as well as series 3 and 4.

Table 4. Expected values of sensorimotor action parameters, in series 5 ("double choice" task) for the case with one stimulation option, calculated using mathematical models for male (n=911) and female (n=763) groups

Group	Calculated parameter of sensorimotor action		
	motor response time, s	**probability of anticipation**	**chance of premature action**
Males (35)	.232	.082	.005
Females (31)	.228	.117	.025

Using a one-sample t-test, it was found that the motor response time in variant 1_PS of the "double choice" task in series 5 (see Table 2), when compared to the calculated time (see Table 4) is statistically different for the male group ($t=3.276$; $p=.002$) but not for the female group ($t=1.256$; $p=.219$).

The probabilities of anticipation and premature actions were statistically compared (Fisher's φ*-test) in series 1 (simple reaction) and series 5 ("double choice" task) (see Table 2). In the male ($\varphi^*=6.038$; $p<.001$) and female ($\varphi^*=8.319$; $p<.001$) groups, there was a significant excess of the probability of anticipation in series 5 compared to series 1. Premature actions, on the other hand, were more likely in series 1 for both male ($\varphi^*=4.206$; $p<.001$), and female ($\varphi^*=2.459$; $p=.006$) groups.

4. Discussion

The calculated values of the indicators of the probability of anticipation and the probability of premature actions for the DC task (see Table 4) differed from the empirical data in some ways (see Table 2). All at the same, they were quite consistent with the corresponding trends in real changes in these indicators when the orientation time in series 3 and 4 changes (see Table 1). Some discrepancies in the calculations and experimental results can be explained by the male group's subjects' reorientation in the DC task from variant 3_PS to variant 1_PS being particularly quick in comparison, for example, to the results in our other experiment (Plokhikh et al., 2021). Furthermore, the results of another experiment with different participant compositions of male and female groups were quite consistent with the theoretical trends presented above (see Table 3).

Both the experimental and calculated values of the orientation time required for the subjects' complete reorientation to the 1_PS option in solving the DC task fell into that section of the dependences of the anticipation probability and the probability of premature action on the orientation time, which marked the beginning of a pronounced change in the values of these indicators (see Tables 1 and 3) Such drastic changes in the dynamics of system implementation are typically associated with the qualitative restructuring of system processes (Konopkin, 1980). In other words, the organization and implementation of the sensorimotor action in the DC task differed significantly for short and long orientation times. Furthermore, the functioning of anticipation mechanisms included in the action structure varied under these conditions.

When the orientation time in the DC task is small, the subject is gradually reoriented to a new situation and a new variant of the action system's organization. The results clearly showed that when the variant 1_PS is updated, the initial setting of the subject to the variant 3_PS changed. All at the same, the executive link structure and the apperceptive scheme tuned to the expectation of perception of the corresponding stimuli change. The presentation of a stimulus in the experimental DC task was a significant simplification of the scheme of a more complex task in the 3_PS variant, implying a significant reduction in the amount of information processed. And it appears that a sharp restriction of the information flow and simplification of the response should immediately increase the subject's motor response speed. However, as the experiment results showed, there was a radical restructuring of the structure of the entire action, and this restructuring occurred gradually (see Table 1). The restructuring took about two-tenths of a second in the DC problem. Naturally, the time required for emergency updating of an action system with a more complex structural organization and in more difficult circumstances (for example, in operator or sports activities, and in extreme situations) increases significantly (Konopkin, 1980; Zavalova et al., 1986).

Any action, as previously stated, has a corresponding duration. As a result, when the subject was reoriented to option 1_PS, the structure of the action in the DC task was restructured, as was the duration of achieving the goal. Deficiencies in the content of the action structure, as a stable holistic systemic organization, are reflected in a decrease in the certainty in the assessment of duration, as well as in the assessment of the sufficiency of this duration to achieve the desired result under changing conditions. In our previous study of anticipating the location of a uniformly moving object with partial occlusion of the motion trajectory, the stages of determining the duration of an action in the process of reorienting the subjects to the 1_PS option in the DC task fully corresponded to the states of the activity system in the modes of total and acute time deficit (Plokhikh, 2006).

Naturally, when the structure of an action of any complexity is changed, the feedback loops are rebuilt, providing current corrections at various structural levels of the organization (Bernstein, 2004). It is extremely difficult to assess the dynamics of current circumstances and the necessary operational changes in the time parameters of ongoing operations with incompletely formed feedback loops, particularly the main loop for controlling the duration of action. The latter was manifested by a slower response time and a low probability of anticipation for small values of orientation time in the DC task (see Table 1).

At the same time, mere completion of the system of action formation is insufficient for successful anticipation. This was based on a comparison of the simple sensorimotor reaction in terms of the “probability of anticipation” parameter (series 1) with motor responses in the 1_PS variant (series 5) and the calculated values for both male and female groups (see Tables 2 and 4). An appropriate time reference, which became the moment of the appearance of the indicative signal, was required for anticipation in the DC problem. The most accurate estimated correlation of the duration of action with the time interval between the orienting signal and the expected moment of the appearance of the stimulus determined the start of motor response realization not after, but simultaneously with the appearance of stimulation. In the series of the DC task, such a verified combination of the onset of action with the appearance of a stimulus actually provided anticipation and a significant reduction in the time of the motor response. And in this aspect, it should be noted that if N. Gordeeva

(2000) considered a sequential change in the forms of sensitivity in the microstructure of action with a reorientation of executive functions to perceptual ones and vice versa, then in the variant we were considering, these functions were integrated into a certain coordinated unity at the final stage. The latter is quite consistent with the findings of J. Carboch et al. (2014) in a study of the importance of tennis players observing various sections (particularly the final section) of the ball's flight path.

The subjects' ability to maintain orientation time in series 5 of the DC task indicated the formation and retention in operative memory of a temporary standard of the required duration of action (see Table 2). The action was under control thanks to this standard. Furthermore, the time standard was implemented in a series of samples quite flexibly and in response to known variations in the orientation time (.05 s.). Subjects discovered the ability to account for current changes in the time of appearance of the stimulus for a response and combined it with a motor response, resulting in anticipatory effects.

As can be seen, the resources in the process of temporal regulation at the stage of reorganization of the structure of the sensorimotor action are ways to improve the accuracy of highlighting the expected duration of action; ways to improve the accuracy of assessing the prospects for significant objective changes; skills of correlating the moment of motor response with the expected event in the future. Of course, the faster the required system of action is established, the more fully the resource support for the functioning of the sensorimotor level's anticipatory mechanisms is actualized.

The anticipated scheme is presented in the study in its most basic form, which is typical of the construction of conditioned reflexes. The time interval between the conditioned stimulus and the previously reinforced subsequent reaction is critical in conditioned reflexes (Pavlov, 2004). However, intrasystem feedbacks are significant even in this variant, as evidenced by the unique dynamics of the processes of excitation and inhibition of active parts of the nervous system.

In the DC task, increasing the orientation time beyond what was required for full action system actualization in the 1_PS variant increased the probability of anticipation almost exponentially for both the male and female groups (see Tables 1 and 3). It is reasonable to assume that this effect was simply the result of further improvements in the comparison of the total duration of action with the expected time for changes in objective circumstances. However, in the cases where the orientation time in series 3 and 4 was the longest (.25 s and.30 s), and the duration of the processes estimated by the subjects were equally certain, the corresponding probabilities of anticipation should not have differed significantly. Meanwhile, for the considered time regimes, with an increase in the orientation time by only fifty milliseconds, the probability of anticipation sharply increases almost twice (see Table 1). This effect was due to a significant improvement in successive intermediate time estimates and the corresponding current corrections of operations via the actualization of internal feedback loops in the established sensorimotor action system. This result fully corresponded to N. Bernstein's (2004) identified peculiarities of movement construction at the spatial field level, as well as the results of S. Gellershteyn's (1958) formative experiments. In this case, the relevant time standards assimilated in preliminary samples became an important resource for anticipating operation execution moments. Along with this, the subjects' ability to accurately estimate and correct the time of performing operations was rapidly improving. Other studies of the regulation of highly coordinated movements in hitting targets and sports activities found a similar effect (Cheban et al., 2020a; 2020b; Kiparenko & Kremenchutska, 2021).

Another empirical fact indicates an increase in the fundamental importance of operational time estimates in solving the DC problem. It is characterized by the fact that as the probability of anticipation increases, so does the probability of premature action (see Table 1). In other words, while carrying out a sensorimotor action, the subjects were given the option of either reacting immediately or delaying their reaction in order not to get ahead of events (Carlsen et al., 2008). Fears of reacting too quickly have an impact on decision-making confidence. The latter, as a limiting factor, can explain why the motor response time in the 1_PS variant decreased linearly as the orientation time increased, whereas the probability of anticipation increased in a quadratic pattern (see Table 3). The same fact confirms the significance of operational time interval estimation accuracy in facilitating timely decision-making. And in this case, as a resource for sensorimotor level anticipation, there are time interval standards stored in memory, learned schemes for differentiating time intervals, and time estimation skills. Individual characteristics of the subject associated with the mobility of nervous processes, as well as character traits that affect the accuracy, validity, and decisiveness of actions, should be added to the proposed resource provision.

5. Conclusions

1. A full-fledged actualization of the anticipatory resource of the sensorimotor action system, performed in the unity of the implementation of the mechanism for the attitudinal determination of the expected duration of action (in the simplest version, the duration of the implementation of the conditioned reflex connection) and the psychological mechanism for clarifying the operational estimation of time intervals, significantly increases the subject's motor response.

2. If the system of action is completely organized, and there is preliminary tentative information about the possible moment in time for the realization of a motor response in the future, the mechanism for setting the expected duration of the realization of a sensorimotor action is sufficiently activated. The ability to accurately determine the expected duration of action; the ability to accurately estimate the time of significant objective changes; skills to correlate the expected duration of action with the expected duration of significant external changes; high speed of formation and significant definiteness of the system of action act as anticipatory resources in this case.

3. In a fully functioning system of action, the anticipatory resource of the sensorimotor action is updated if there is a margin of time for the corresponding estimation, which is associated with an increase in the effectiveness of the psychological mechanism for clarifying the estimation of time intervals and the moment of the motor response. The probability of anticipatory effects increases sharply as the margin of time increases (within the limits of the implementation of the sensorimotor level of anticipation), as does the effectiveness of the action, but so does the probability of a premature response. An increase in the probability of a premature motor response limits the possibilities for anticipation in action organization. The resources of anticipation in clarifying the temporal characteristics of operations in the structure of sensorimotor action are: time interval standards stored in memory; mastered schemes of differentiation of time intervals; time estimation skills; individual characteristics associated with nervous process mobility; personal qualities that ensure quick and effective decision making.

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