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Temporal Characteristics of Students as Cognitive Diagnostic Characteristics: The Context of Adaptive Education

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Abstract
Introduction. The article presents the results of an experimental study of the individual temporal characteristics of cognitive space management in students while solving problems.
Methods. The methodological tools are briefly described, including traditional test questionnaires for identifying temporal features of subjective perception of time ('Semantic Time Differential', 'Time Perspective'), as well as modified and original research methods for identifying temporal characteristics of the cognitive activity of subjects in solving spatial problems in a laboratory experiment ('Mental rotation', 'Accuracy').
Results. In a series of laboratory experiments, new research data were obtained on the temporal specificity of the process of constructing a personal cognitive space in students. Using prognostic modeling procedures, we were able to record the presence of structural relationships between the time perception, cognitive characteristics of problem-solving, and stability of academic performance. It was experimentally proved that characteristics of time reaction and effectiveness in completing accuracy tasks and mental rotation tasks act as temporal predictors of levels of students' academic performance.
Discussion. The study revealed the fact that students with a dominant temporal orientation toward the present situation, looking constantly for new stimuli and feelings in the current time, had quite pronounced deficits in the choice of educational strategies based on more long-term and well-defined objective in the future. It was noted, as an important aspect in the personalization of studying, that students must be aware of their own temporal, cognitive and other characteristics of the information processing, and manage on their own their educational environments as appropriate. The possibilities are discussed in using cognitive diagnostic characteristics to predict and timely correct individual trajectories of students' educational paths as part of the adaptive approach to education.

Keywords
temporality, predictor, subjective perception, time perception, academic performance, temporal perspective, cognitive tasks, mental rotation, time of reaction, cognitive strategies

Highlights

➢ Individual originality of the students' temporal management of the cognitive space (characteristics of time of reaction and effectiveness of the cognitive tasks performance) serves as a cognitive diagnostic pattern of the individual behavior adequacy to the temporal space of cognitive environment and its specified requirements.

➢ Students with typological differences in the dominant temporal orientation and cognitive strategies choice in a real situation of solving spatial problems are pronouncedly different in their academic performance stability.

➢ Temporal differences in subjects of the educational process can be considered as a significant basis for the need for a variety of temporal options in educational technologies, especially in the context of exploding digitalization in modern education.

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Introduction

According to experts, effective implementation of innovative educational technologies in a modern university implies the building of individual trajectories of students' professional training along with other flexible changes in the organization of the educational process. To a large extent, the effectiveness of teaching modern students depends on the development of such meta-professional competencies as the willingness and ability to self-organize their own activities, the ability to choose optimal cognitive strategies in research, educational, and scientific activities. Today it is clear that in the development of individual educational trajectories, the cognitive characteristics of a person cannot be ignored, such as temporal features reflecting the details of time structures and the chronotopic orientation in the person's life. (Bredun, Krasnoryadtseva, & Shcheglova, 2018). Many interesting details have been reported about the psychological nature of a phenomenon of subjective perception of time, since the term 'temporary perspective' has been firstly used by L. Frank (Frank, 1939). The authors of the article do not purport to present a rigorous transspective analysis of the genesis of ideas about this phenomenon in psychological science. However, researchers should be mentioned, who's work allowed the authors to determine the research focus in their conception of the temporal orientation structure. Those are classic works by P. G. Zimbardo, who defined a phenomenon of the perspective as a personality construct depending on the attitude to time (Zimbardo & Boyd, 2010; Zimbardo & Boyd, 1999). In recent investigation very interesting findings were obtained, that is:

– The relationship between the accuracy of temporary solutions and the ability to synchronize the internal rhythm with the rhythm that the environment offers (Grondin, 2010; Wearden, 2003; Wittmann, Dinich, Merrow, & Roenneberg, 2006).

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– The relationship between subjective time and perception, attention, and memory has been established (Matthews & Meck, 2016).

– Some age- and interindividual differences in manifestations of temporality were determined (Droit-Volet, Wearden, & Zélanti, 2015; van Heerden, 2016).

The authors of the article paid special attention to the studies where various aspects of the influence of social time on human life were investigated (Thomas, Didierjean, Maquestiaux, & Goujon, 2018; Arstila & Lloyd, 2014; Bolotova, 2006; Gorobets, 2011; Gorkaya, 2014; Khmelevskaya, 2012).

Thus, the analysis of the current state and exploration trends in the investigations of temporal characteristics of the human lifeworld made it possible to pose a research task to identify possible temporal predictors of the level of academic performance at a student age. In adolescence the time perspective is closely related to the student's real and educational achievements, since it includes professional self-determination, future achievements, setting educational and professional goals and tasks. Of particular interest are research data obtained by N. D. Gordeeva, suggesting that in subjects focused more on the speed of execution than on accuracy when solving cognitive problems, cognitive processes tend to slow down (Gordeeva, 1995). Based on this fact we postulated a research hypothesis that the speed of cognitive problems solving could serve as a temporal predictor of academic performance. The results of the verification of this hypothesis are presented in this article.

Methods

We evaluated the temporal characteristics of subjective perception of time using such methods as 'Semantic Time Differential' (Vasserman, Trifonova, & Chervinskaya, 2009), and the test 'Temporal Perspective' (Zimbardo Time Perspective Inventory – ZPTI) F. Zimbardo (Zimbardo & Boyd, 2010). The chosen methods allow to study cognitive, emotional components of time and the duration of experienced subjective phenomena of time (Zimbardo & Boyd, 1999).

To identify the temporal characteristics of the cognitive activity of subjects in spatial problems solving, the method 'Mental rotation' was used as described by R. N. Shepard and J. Metzler (Cooper & Shepard, 1973; Shepard & Metzler, 1971) in the modification of D. Yu. Balanev (Klochko, Krasnoryadtseva, & Balanev, 2016). This version of the technique gives a possibility to build perceptual space not on a 2D plane but in the three-dimensional space, using a 3D modeling technology, which permits to display a mental movement as a spatial motion. This procedure is aimed to assess the spatiotemporal characteristics of the process of solving a cognitive task.

The experimental procedure involves displaying a series of paired stimuli on a computer screen. In each pair of objects, one is slewed around the other, and research subjects must decide if stimulus objects were identical or not and using a graphic pen check one of two answers: 'different' or 'identical'. Each participant must solve a total of 96 tasks.

A technique *Accuracy* (Klochko et al., 2016) is an experimental procedure, aimed to identify the relationship between the spent time and accuracy in solving experimental problems. The purpose of the procedure is to measure the spatial and temporal characteristics of the procedural and cognitive activity of a person.

The procedure involves displaying a series of stimuli that represent ellipses characterized with different positions in the screen space, different diameters, and different center locations. Research subjects are instructed to indicate as accurately as possible the center of stimulus figures on the screen with a pen. The experimental procedure takes 20 minutes.

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As the academic performance index an arithmetic average of grade scores in disciplines mastered by bachelor students during at least 3 years of study (average grade score).

The experimental group consisted of 150 students Tomsk State University, studying at the Faculty of Historical and Political Sciences, at the Institute of Applied Mathematics and Computer Science, and at the Biological Institute.

Results

Based on empirical data and using prognostic modeling procedures, we hypothesized structural relationships between the time perception, cognitive characteristics of problem-solving, and academic performance.

To build a predictive model that describes the influence of time perception on university academic performance, we have carried out a multiple regression analysis. The average student performance grade, which was calculated as the arithmetic mean of the grade scores received by students for exams during their studies at the university, was a dependent variable. The parameters measured by the Semantic Time Differential and Temporal Perspective methods (N = 20) were chosen as independent variables. The algorithm for including independent variables in the regression equation was realized using a step-by-step method of 'exception'. As a result, a regression model was obtained (p = 0.003), which included 8 predictors (Tables 1, 2, 3). According to the obtained model, 44 % of the variance of the average grade score variable is accounted for the influence of such predictors as 'future', 'perceptibility of the past time', 'activity in the present time', 'structure of the present time', 'perception of the present time', 'emotions for the future time', 'the scale of the future time', and 'the perceptibility of the future time'. Regression coefficients (Table 3) show that predictors 'future', 'scale of the future time', 'structure of the present time', 'perceptibility of the present time' correlate positively with the dependent variable 'average grade score', while such predictors as 'perceptibility of the past time', 'activity in the present time', 'emotions for the future time', and 'perceptibility of the future time' correlated negatively.

Table 1
Results of the regression analysis

Revise for the model				
Model	R	R-square	Adjusted R-square	Standard error of estimate
1	0.663[a]	0.440	0.319	0.61493

a. Predictors: (constant), the perceptibility of the future time, the perceptibility of the present time, the future, the structure of the present time, the scale of the future time, the perceptibility of the past time, the activity in the present time, the emotions for the future time.

Table 2
Results of the regression analysis

ANOVA[a]						
Model		Sum of squares	D. of ass.	Mean Square	F	*P value*
	Regression	10.997	8	1.375	3.635	0.003[b]
1	Rest	13.991	37	0.378		
	Total	24.988	45			

a. Dependable variable: average grade score;

b. Predictors: (constant), the perceptibility of the future time, the perceptibility of the present time, the future, the structure of the present time, the scale of the future time, the perceptibility of the past time, the activity in the present time, the emotions for the future time.

The obtained prognostic model shows that respondents who structure their present from the perspective of a future-orientated position can be more successful in learning, as a rule (with better academic performance). While students who are more focused on the present time or future, prone to abstract images full of emotions rather than to specific goals and actions, will be less successful in learning (lower academic performance).

Since the assessment of the studying achievements includes not only a general grade score but the stability of academic performance grades, as well, we divided the students in this study into 7 groups according to the results of the total of examinations depending on the stability/instability of academic achievements: group 1 – different ways of instability; group 2 – unstably successful (‘5’, ‘4’ or non-appearance); group 3 – stably unsuccessful; group 4 – a steady decline in success; group 5 – stably mediocre; group 6 – a steady increase in success; group 7 – stably successful.

To study the influence of cognitive abilities demonstrated in solving mental rotation problems on the stability of students' academic performance, a regression analysis was performed, where the stability variable played the role of a dependent variable (response), and the speed and accuracy indicators recorded in a time of mental rotation problems solving were predictors. As a result, a regression model was obtained ($p = 0.000$), which characterizes the quadratic dependence of the stability of academic performance on the accuracy of performing mental rotation tasks (Table 4 and Fig. 1).

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Table 3
Results of the regression analysis

Coefficients[a]

Model		Non-standardized rates B	Non-standardized rates Standard Error	Standardized rates Beta	t	*P value*
1	(Constants)	3.802	0.889		4.278	0.000
	Future	0.507	0.208	0.330	2.438	0.020
	Perceptibility of the Past	–0.244	0.138	–0.365	–1.768	0.085
	The Present Activity	–0.385	0.140	–0.727	–2.752	0.009
	The Present Structure	0.229	0.117	0.320	1.954	0.058
	Perceptibility of the Present	0.424	0.156	0.760	2.716	0.010
	Emotions of the Future	–0.391	0.142	–0.816	–2.750	0.009
	Scale of the Future	0.315	0.131	0.664	2.407	0.021
	Perceptibility of the Futureы	–0.351	0.116	–0.433	–3.026	0.004

a. Dependent variable: average grade score.

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Table 4
Revise for the model and parameters estimates

Dependent variable: stability								
	Revise of the model					Parameter estimates		
Equation	R-square	F	D. of ass. 1	D. of ass. 2	*P value*	Constant	b1	b2
Square	0.143	10.976	2	132	0.000	5.062	–2.688E–7	6.473E–15

Independent variable – accuracy.

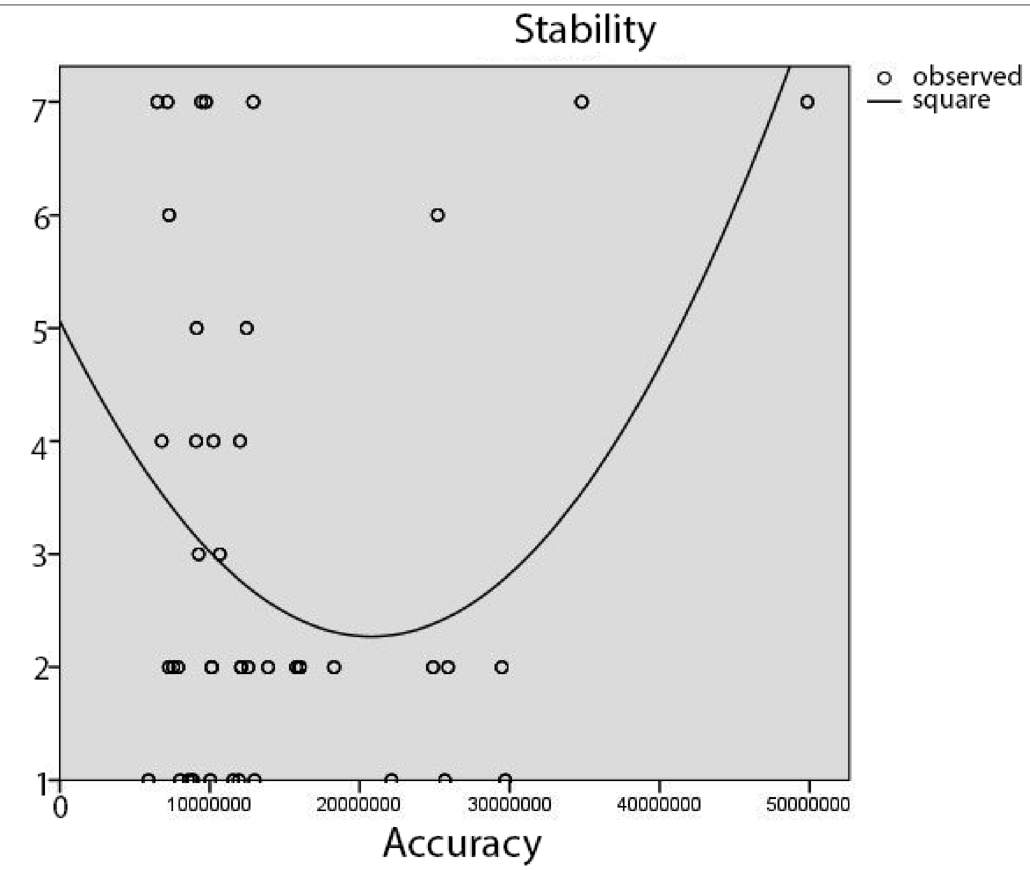

Figure 1. Regression model characterizing the dependence of the stability of academic performance on the accuracy of the mental rotation tasks completing

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The obtained regression model suggests that students with stable academic performance demonstrated low or high accuracy in tasks completing, while an average accuracy in tasks completing was characteristic for students with academic performance instability and unsteady results in examinations.

A detailed analysis of the results of laboratory experiments in selected groups of students with different academic performance stability revealed that cognitive characteristics tend to influence the academic performance of students and, in particular, the apparent learning stability. The results of this analysis, specific features in the mental rotation tasks completing (speed and accuracy characteristics), demonstrated by students with different academic performance stability are presented in diagrams (Figures 2, 3, 4).

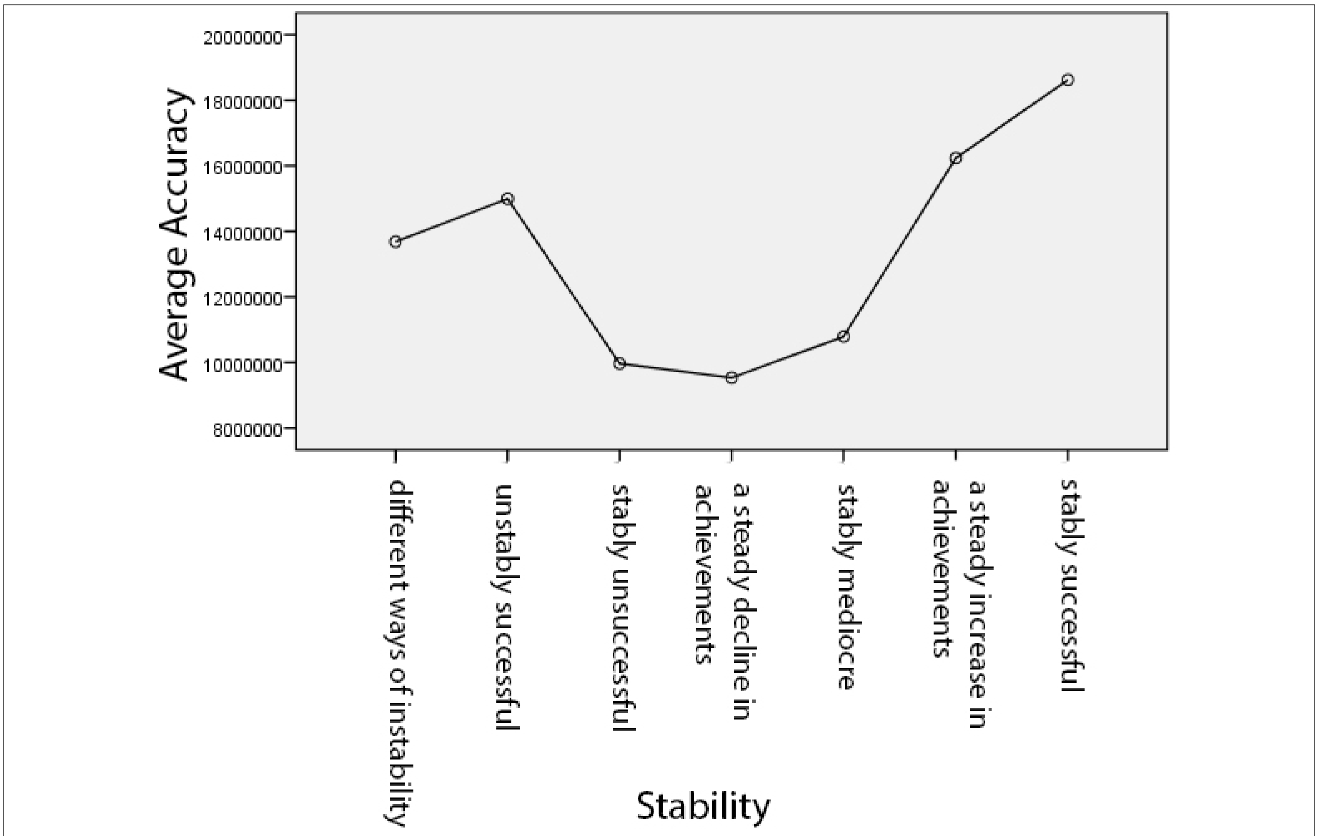

Figure 2. Results of the average speed of accuracy cognitive tasks completing in groups of students with different academic performance stability

The obtained data (Fig. 4) suggest that respondents assigned to the groups of steadily declining performance, stably unsuccessful, and stably mediocre academic performance spent significantly less time on cognitive tasks compared to other respondents. It should also be noted, that students with consistent ‘excellent’ or ‘good’ grades (stably successful) performed the proposed accuracy tasks the most slowly of all students.

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When the more complicated on cognitive mental rotation tasks were offered, the results turned out to be somewhat different.

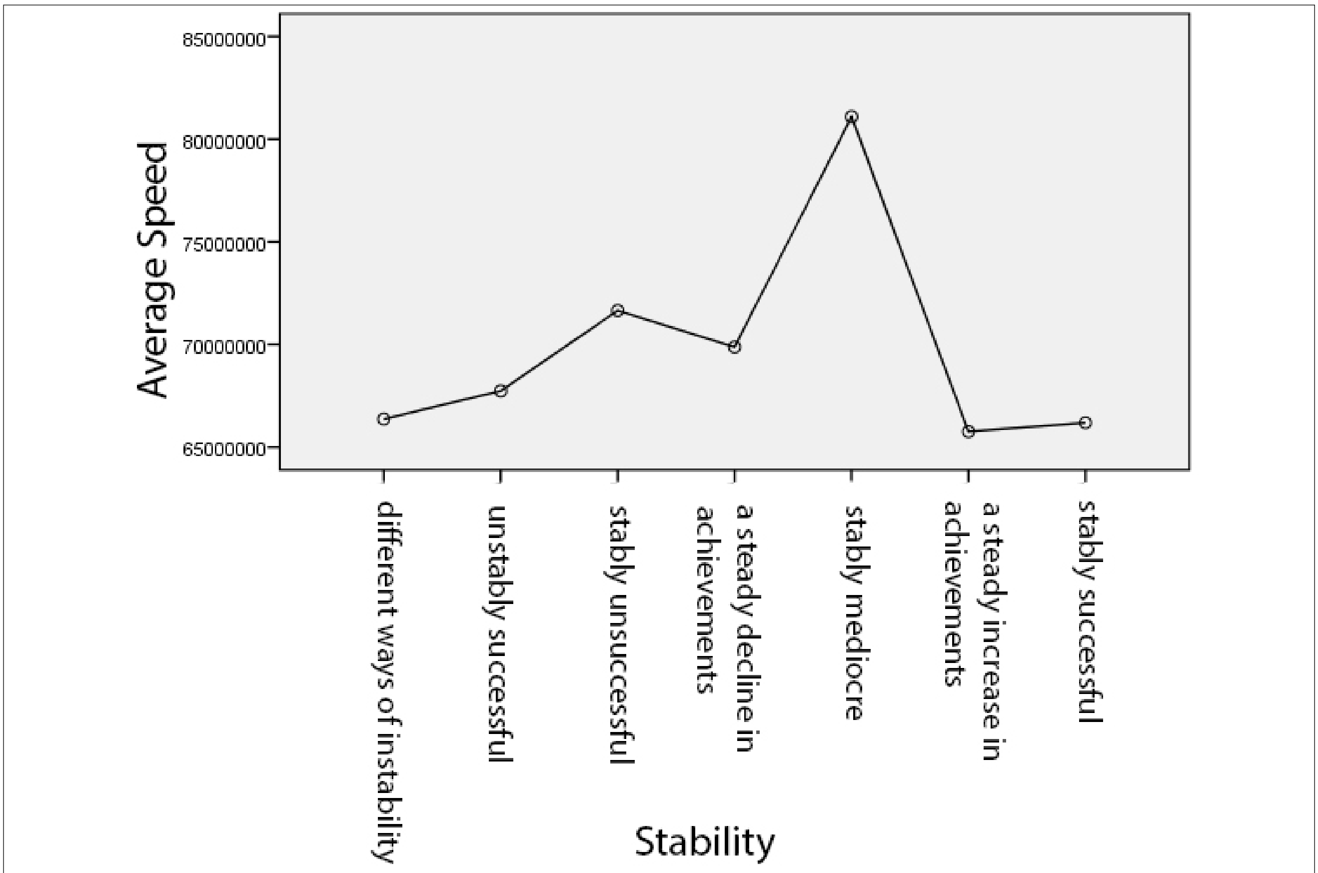

Figure 3. Average speed of cognitive mental rotation tasks completion in groups of students depending on the academic performance stability

The analysis of obtained data suggested that students with the stably mediocre academic performance throughout the entire period of studying at the university spent much more time to complete cognitive mental rotation tasks compared to students assigned to other groups (stably successful, unstably successful, different ways of instability, and with a steady increase in success). At the same time, the students with stably mediocre performance make very few errors compared to other groups, with the exception of students who demonstrate a decrease in performance (Fig. 4). Respondents whose academic performance decreases over time had also few errors in cognitive mental rotation tasks, compared to students of other groups. The most number of errors in cognitive mental rotation task, compared to the other groups, made those students who demonstrated instability in studying and received various grades on exams (from 'unsatisfactory' to 'excellent'), as well as students who passed all exams with only 'excellent' (rarely 'good') grades, or did not appear at an exam when they were not firmly confident in their preparedness (Fig. 4).

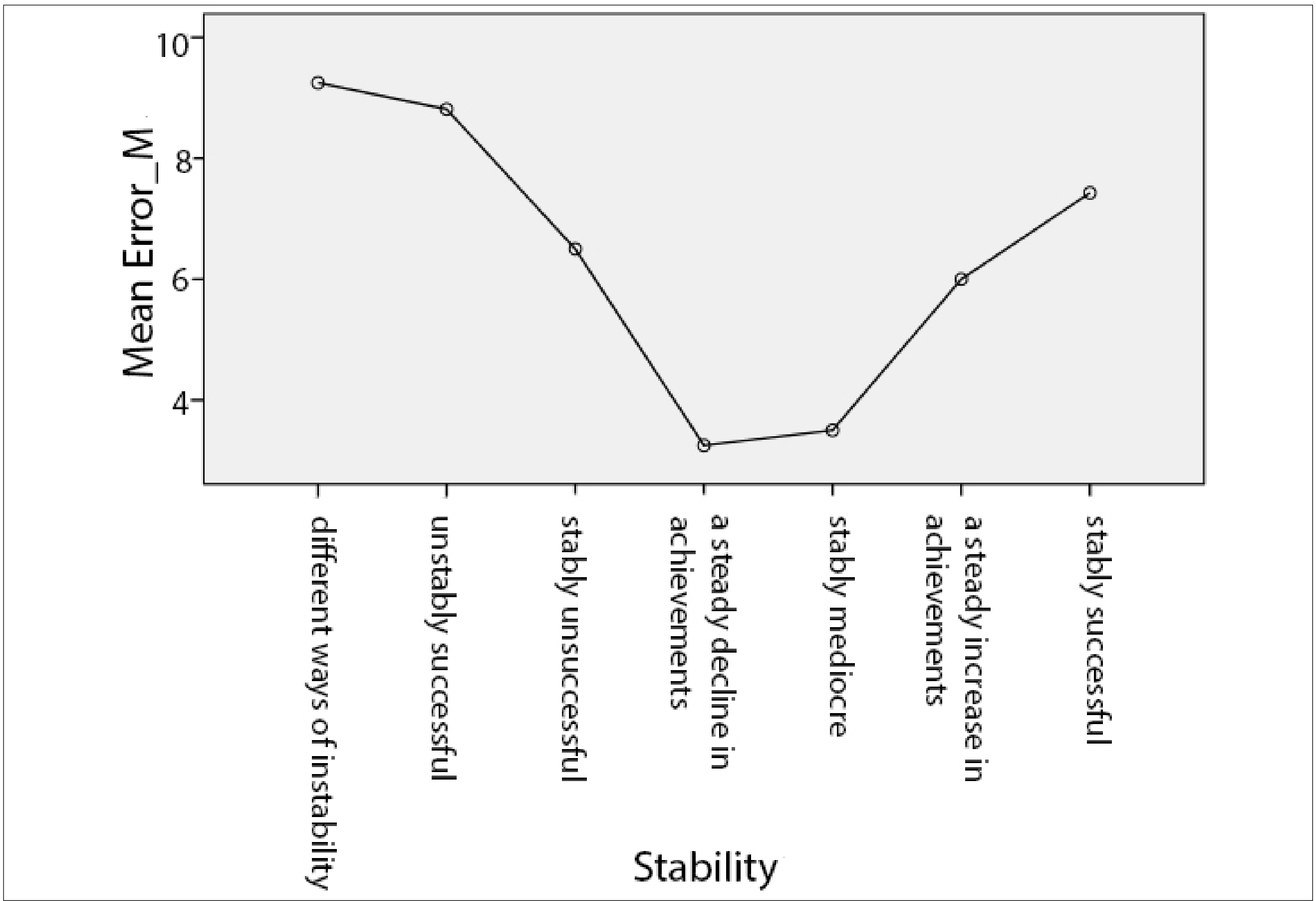

Figure 4. Number of errors while completing cognitive mental rotation tasks in groups of students with different academic performance stability

Thus, solving more complicated cognitive tasks (mental rotation tasks, which are more complicated compared to accuracy tasks) respondents, assigned to groups of low academic performance, spent more time to complete the task. Respondents, assigned to groups with higher academic performance, on the contrary, needed less time to solve mental rotation tasks and more time, in comparison with other groups, to solve accuracy tasks. Moreover, the group of 'ubstably successful' made the most number of errors, while the least academically successful and 'stably mediocre' successful respondents coped with the mental rotation tasks best of all.

It is important to note that in both experimental procedures the speed of presenting tasks depended on the respondent himself so that they performed tasks in the rhythm the most convenient for them. Students who have low or mediocre academic performance spent as much time on solving cognitive tasks as they needed, analyzing each task at their own pace. This allowed them to achieve greater success compared to other respondents. In turn, academically successful students were focused more not on the result, but on the speed, on their ability to finish the task as fast as possible. Perhaps they have analyzed the tasks during the first rounds, and the solution to the subsequent ones was an integrative process when each subsequent stimulus was compared with those presented earlier. And therefore, the participant devoted little time to complete each problem, relying on the experience gained, which led to a large number of errors, since all the stimuli in this experiment had different cognitive loads.

Discussion

The use of experimental techniques made it possible to obtain factual research material that clearly illustrates the individual temporal identity in the process of organizing cognitive space by students in a situation of a real solution of spatial problems. The trends of the influence of temporal characteristics such as the speed and accuracy in completing cognitive tasks on the academic performance stability of students are revealed. Thus, it can be concluded that the temporal characteristics of students can be considered as prognostic cognitive diagnostic characteristics of academic performance.

It has been experimentally proved that having different temporal characteristics, students are not always able to meet the temporal space of the cognitive environment and the requirements that it imposes. The speed of information processing, the time spent on studying the material, or solving a problem can be one of the determining factors of academic performance. In this regard, it can be assumed that if a student spends as much time studying the material as he needs, he can demonstrate a higher level of success. Thus, facilitating the development of one's ability to structure their cognitive activity on their own is ineffective without taking into account their personal temporal characteristics.

Particularly noteworthy, from our point of view, is the fact that students with a dominant temporal orientation toward the present and characterized by their constant looking for new incentives and sensations in the current time have pronounced deficiencies in the choice of educational strategies based on long-term and well-determined goals for the future. It seems that the orientation of the main professional educational programs of students on the development of their readiness and ability to formulate and solve strategic tasks of their life (including professional) will increase students' self-organization in the current time.

The fact of temporal differences in the subjects of the educational process can be considered as another reason for the need for a variety of options for educational trajectories. Each type of educational technology implies a certain temporality, without taking into account the great variety of dominant modalities of the time subjective perception in students. In this regard, an important aspect of the personalization of education is the ability of a student to understand his/her own temporary, cognitive, and other peculiar characteristics of information processing to be able to organize an educational environment independently. Understanding of cognitive characteristics permits to identify individual differences in information processing, as well as to organize educational support to predict individual trajectories of students' educational paths. The more so, as the number of unsuccessful students, demonstrating a low ability for self-adjustment in the educational environment, continues to be rather high. One of the most promising areas of the practical application of the obtained research results is the adaptive approach to education, actively developed in the context of exploding digitalization of modern education (Borba et al., 2017; Gibson, 2017; Nguyen, Hsieh, & Allen, 2006; Zitter, De Bruijn, Simons, & Cate, 2011; Pavlov, 2017). Adaptive education could be understood as a tool able to improve the quality of educational experience through its personalization. Unlike traditional educational systems, adaptive education is a way to create a model that highlights individual differences of each student (Nakic, Granic, & Glavinic, 2015; Kochetkova & Kytmanov, 2016; Toktarova, 2017; Shershneva, Vainshtein, & Kochetkova, 2018). The expansion of personalized students' characteristics generated by analysis of psychological, temporal, cognitive, and other data will make it possible to reorient the educational process to real individualization and adjust individual educational trajectories of students taking into account indicators of the dynamics of cognitive characteristics.

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