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# The Effectiveness of Collaborative Problem Solving by Junior University Students in The 'PL-Modified' Computer Game System

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The present study is aimed at examining the problem framed by the team of authors in the past research papers (2018, 2020, 2021) and assessing the level of the general learning actions of analysis, planning and reflection as the main components of theoretical thinking in students in the individual and collaborative (paired with a partner) problem solving conditions by the 'PL-modified' computer game system. General intelligence was separately evaluated and controlled. 138 students of the Faculty of Psychology of Education of MSUPE participated in this study. The results show that: 1) the main indicators of game performance were higher in collaborative problem solving, however, 2) depend on the intellectual capabilities of two players in a pair. The data obtained are analyzed in accordance with the effects revealed in past studies and discussed in terms of the further prospects for using the 'PL-modified' computer system as an additional tool for the assessment of the general learning actions of students of different ages and cognitive potential.

***Keywords:*** 'PL-modified' computer game system, general learning actions, collaborative problem solving, general and social intelligence, junior students.

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# Успешность совместного решения задач студентами младших курсов вуза в игровой компьютерной системе «PL-modified»

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Представлены результаты исследования, связанного с решением цикла задач, сформированных коллективом авторов в прошлых исследовательских работах (2018, 2020, 2021), которые направлены на оценку степени сформированности универсальных учебных действий анализа, планирования и рефлексии как основных компонентов теоретического мышления у учащихся в условиях индивидуального и совместного (в паре с партнером) решения игровых задач с помощью разработанной компьютерной игровой системы «PL-modified». Отдельно оценивались и контролировались общие интеллектуальные способности. В исследовании принимали участие студенты факультета психологии образования МГППУ (138 человек). Полученные данные показывают, что: 1) показатели игровой результативности оказались выше в условиях совместного решения задач, 2) тем не менее, они зависят от интеллектуальных возможностей двух игроков в паре. Полученные данные анализируются в соответствии с эффектами, полученными в прошлых исследованиях, и обсуждаются с точки зрения дальнейших перспектив использования компьютерной системы «PL-modified» в качестве инструмента диагностики универсальных учебных действий учащихся разного возраста и когнитивного потенциала.

***Ключевые слова:*** компьютерная игровая система «PL-modified», универсальные учебные действия, совместное решение задач, общий и социальный интеллект, студенты младших курсов.

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## Introduction

The pace of digitalization in education is steadily increasing nowadays. In addition to new curricula, courses, subjects, and methods that have been digitalized in whole or in part, digital methods of assessing knowledge and competencies are widely distributed. Although the process of digitalization is quite active in the field of education itself, there are not so many digital diagnostic tools in the psychology of education. The existing methods can be divided into two groups in terms of their diagnostic purposes and the content of the stimuli. The first group includes standard psychological tests and questionnaires submitted in electronic form. They are no different in content from their blank versions. At the same time, the digital format gives them a number of advantages in the form of low time and physical resources associated with diagnostics and data processing. Nevertheless, the electronic version of recognized tests is usually aimed at evaluating individual, specific, psychological constructs, so each new psychological characteristic requires a new measurement tool, which, accordingly, increases the diagnostic procedure.

The second group of methods consists of tests designed in the form of popular computer games with specially developed (more often non-verbal) material. These are so-called gamified diagnostic techniques. The question of the possibilities of using computer games as diagnostic tools, primarily cognitive abilities, has been discussed by researchers for quite a long time and does not allow us to come to a single solution at the moment. On the one hand, a sufficient amount of data has been accumulated confirming the high psychometric properties of individual computer games, which have proven themselves as an alternative tool for intelligence and creativity assessing. For example, some empirical studies were conducted under the leadership of Foruga [18], where a test of 15 puzzles of the popular video game Portal-2 was assessed. This test is evaluated to assess fluid intelligence. The results demonstrated high reliability rates with Advanced Raven matrices. Later with the same game, it was proved that video game experience had a significant positive effect on the indicators of psychometric creativity and spatial abilities. These effects were especially evident in those subjects who were actively engaged in the study of natural sciences [19]. On the other hand, the results of such studies are hard to overestimate for several reasons, such as the tendency to publish studies with exclusively confirmed data and often the lack of stable reproduction of the effects obtained. In this regard, the diagnostic capabilities of computer games are inferior to many proven ability tests, in particular, Standard Raven matrices, which have sufficiently high indicators of validity and reliability. Therefore, the issue of gamified techniques usage continues to be a matter of dispute for many researchers and at the same time is more relevant than ever, given the increasingly active penetration of the digitalization process into psychology and pedagogy and opens up new research prospects.

## Theoretical background and purpose of the study

The study continues the research series of gamification methods as tools for measuring psychological constructs. An example of such a tool is the computer game

system 'PL-modified', aimed at assessing the level of universal educational actions (hereinafter UEA) of secondary school-age students. The diagnostic capabilities of the technique were studied in previous studies of the authors' team [7; 8; 9] and confirmed its high validity indicators. The present study is aimed at evaluating the effectiveness of solving game problems by young students — undergraduate and graduate students of the MSUPE Faculty of Education— under two game conditions: individually and paired with a partner.

The methodological background of the research is represented by L.S. Vygotsky's cultural-historical theory [1], A. Leontyev's theory of activity [5], and V.V. Davydov's theory of developmental learning [16; 4], which postulate that the mental development of a person is determined by the interiorization of generalized ways of action that occurs in the process of communication between a child and an adult.

Joint activity realized through communication contributes to the active position of the subject and triggers the development of his mental actions formed on the basis of theoretical thinking. Davydov [4] identified three key components of theoretical thinking, or higher mental actions, such as analysis, planning, and reflection. The formal-theoretical level of analysis (as opposed to the empirical one) is aimed at identifying internal, essential features in the phenomenon under study, allowing the object to be attributed to a certain class. The mental action of planning as part of a more general ability to act "in the mind" is interpreted as the ability to predict what will happen to an object if certain transformations are made [17]. Reflection as the ability to see the origins of one's own way of acting is the ability to distinguish between universal relations in the studied object.

These three universal educational actions make a significant contribution to high achievements in education and create the basis for a deep understanding of the main school disciplines, the ability to successfully solve educational tasks, and realize the effectiveness of their own educational actions. Moreover, cooperation and any other form of children's joint activity plays a key role in the development of mental actions. In a number of modern studies, it has been shown that those preschoolers and schoolchildren who have fairly good skills of interaction in small groups and joint games develop conceptual thinking and improve academic performance [3; 2; 4; 11; 9; 13; 14]. Despite the fact that universal educational actions are studied mainly by students at the stage of graduation from primary school, properly formed UEA are invariant for the entire educational process, which continues, including at the stage of higher education. Thus, the Federal State Educational Standard of Secondary General Education sets requirements for the development of personal, regulatory, communicative, and cognitive universal educational actions by students. Nevertheless, according to some researchers, individual UEA can also be formed in the first years of higher education [15]. Universal learning activities contribute to the multi-level of knowledge, skills, and competencies in certain areas of knowledge that underlie professional activity. Thus, the study of UEA not only among schoolchildren but also students is an urgent task of modern psychological science.

The presented study solves several problems. First, it is aimed at assessing the level of students' mental actions through the indicators of the game performance in two conditions of solving problems — individually and paired with a partner, which will allow to share the contribution of specific mental actions and individual characteristics to the effectiveness of the studied activity. Secondly, taking into account the previous empirical facts, the new data will provide additional information about the

psychometric properties of the computer system itself (in particular, its reliability), which will increase its diagnostic potential in the future.

## Method

### Research methods

*The 'PL-modified' computer game system, calculating methods of game indicators and the design of the study*

The study used a modified version of the 'PL-modified' computer game system. The overall structure repeated the design of the previous two versions of the game, developed for research in 2018—2021. The ''working" screen of the game system is shown in Figure 1 and is a field of 9×9 cells. Colored balls appear on this field according to certain rules ("patterns"). The player's goal is to build lines of balls of the same color, gaining points. Understanding the rules of the appearance of balls should contribute to a more effective game, manifested, in particular, in more points. The specific parameters of the game — the rules understanding and using in the game — are diagnostic indicators of specific mental actions — analysis, planning, and reflection. Thus, the mental action (hereinafter referred to as the MA) of the analysis was calculated by the number of correctly identified patterns (in each game set and throughout the game), the planning MA was estimated as the total number of game points, the reflection MA was estimated by the number of balls on the playing field at the last turn of the game[1]. In addition, regard to the planning markers it is important to note that the statistical analysis did not use the "raw" points that the players received at the end of each game set and the entire game. A certain coefficient was calculated, which was determined as follows: X0 = X1/X2, where X0 is the total coefficient of the game (= planning time), X1 is the total number of points scored during the game, X2 is the number of moves made during the game. The calculation was made taking into account the logic that one player in any case will make more moves per game than two players. At the same time, the quality of the moves may differ, so the selected coefficient maximally equalizes the gaming capabilities of the two-game conditions, despite the technical differences.

The design of the study also included two stages. The first stage — "individual" — is aimed at assessing the mental actions of students through the effectiveness of game actions in the process of individual work in the system (Figure 2). The second stage involved the work of students in pairs when each game move is made in turn by each participant of the game. In this case, any move is confirmed or rejected by the partner in the game (Figure 2). It is assumed that the proposed format of the game in the form of a dialogue initiates the mental activity of students, activating the use of mental actions for the successful completion of the task. This version of the system included three games with prepared rules for the appearance of balls for each game stage.

The study objectives were to: 1) compare the main indicators of game performance in two game conditions: an individual format and the form of an active dialogue between the participants; 2) analyze the main indicators of the game at each stage; 3) analyze the main indicators of game performance and the patterns of relations

[1] The variable "reflection" was calculated in this way only for individual game conditions. The same variable in the collaborative game conditions will be assessed as the number of expressions of a certain category in the process of communication between players, which will be discussed later in the article.

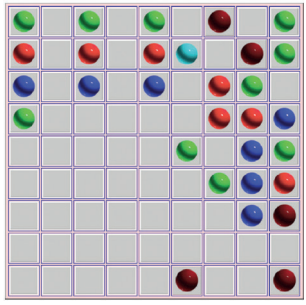

*Fig. 1.* The playing field of the 'PL-modified' system for individual game

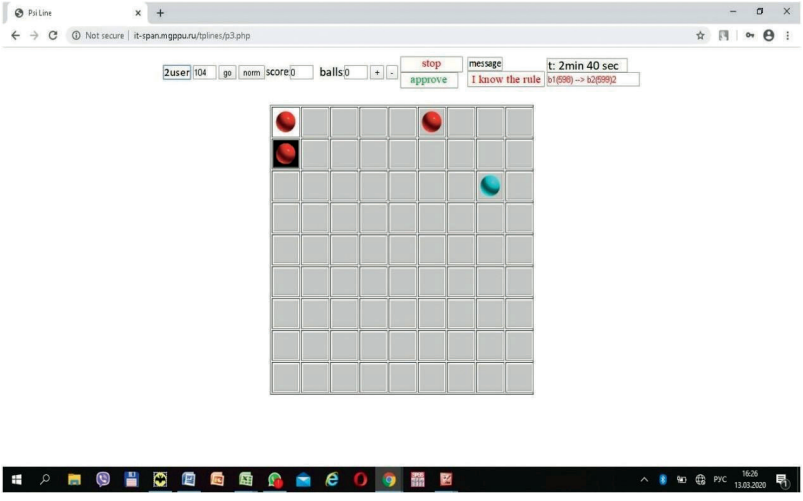


*Fig. 2.* An example of the game version when interacting with a partner with examples of the presentation of balls of permission / prohibition of the step

between them in the conditions of the game paired with a partner, taking into account the individual psychological characteristics of the two players in a couple.

Spearman's rank correlation coefficient, Wilcoxon's t-criterion, Mann-Whitney U-criterion, and descriptive statistics were used for statistical data analysis. The SPSS Statistics program (version 23) was used.

**Sample, research structure, and other psychological points**

The study involved junior students of the Faculty of Educational Psychology of MSUPE (N = 138; 85% women).

Working with a computer game system included 2 academic hours. First, an individual stage was held. Each participant worked while sitting at their own computer/laptop. The game consisted of 3 game sets of 8 minutes each. After each game set, the subjects were presented with a list of rules with a description of correct and deliberately false rules. The task was to choose the rules that are observed when presenting balls in a particular game set.

In the next lesson, the stage of playing in a pair with a partner began. The students were divided into pairs in advance according to the alphabetical principle. The condi-

tions of the new game were explained to the students: first, one participant makes a step, which is simultaneously displayed on two computers — the one who made the step and his partner. The task of the second participant is to evaluate this step from the point of view of its expediency for the main task — to build a line of balls and get points. Therefore, the second participant can either approve this step or prohibit it. After the approval of the desired step, the initiative passes to the second player.

The following two classes were used to diagnose other individual psychological characteristics of students: general and social intelligence, as well as motivation[2]. To assess intellectual abilities, the psychological test "Standard Progressive Matrices" by J. Raven was used [10; 12], which includes 12 abstract matrices. In the case of a sample of students, before testing, a special lesson was held on the structure of cognitive abilities and modern methods of their diagnosis, for some students, diagnostics took place in a blank format, and for some online using an electronic resource https://www.psytoolkit.org [20; 21].

## Results

The results are divided into three groups of data. There are: 1) the main data of the game performance in two different research conditions; 2) the data of the game performance at every stage of the game; 3) the main data about the patterns of the interactions between the researched variables depending on the individual (intellectual differences). We used ranking scales and nonparametric criteria for the analysis because of the abnormal distribution of some data.

*The main indicators of game efficiency in various game conditions: general data and game stages.* The mean data as the indicators of analysis, planning, and reflection are presented in *Table 1.*

All means were counted and compared for all variables in two game conditions. A Wilcoxon Test was made on the comparison of the means[3]. The data showed the advantages in means of planning between two games in favor of collaborative conditions. For more precise analysis the means at every game stage were compared. The results are displayed in *Figure 3.*

The revealed data show opposite patterns in the case of analysis and planning for different game conditions. The indicators of analysis quantitatively grow at each new game stage under individual game conditions. It means that participants understand more rules by playing further. But these advantages don't have an impact on the total game score. These data — in the

Table 1

**The main differences in means by comparison of two game conditions (SD are displayed in parentheses)**

| Measure | Game conditions | |
|---|---|---|
| | Individual game (N=137) | Collaborative game (N=138) |
| 'Analysis' *(No. of correct rules)* | 5.13 (2) | 4.64 (2.11) |
| 'Planning' *(X-parameter of game performance)* | 5.85 (1.90) | 7.60 (3.85)* |
| 'Reflection' *(free cells on the last game step)* | 137.51 (31.46) | 78.23 (21.42) |

*Note: differences are significant at the p = 0.05 level

[2] The measurements for motivation and social intelligence were aimed for the other purposes and are not presented in this study.

[3] Only two variables — analysis and planning — were compared for Table 1.

case of planning — grow only under collaborative game conditions. We presume that such empirical facts can be explained in terms of technical calculations of the variable of analysis. Participants had to choose the rules on their own no matter in which conditions they were playing (even collaborative). We will definitely try to modify and equalize the calculations for each experimental condition further. Anyway, the present data underline the main empirical fact showing the advantages of game efficiency in total scores and means at every game stage in collaborative game conditions.

The correlation analysis with the usage of Spearman criterion was additionally applied to measure the interactions between the variables of analysis and planning. For each game condition the coefficient was 0.2 with its significance at p = 0.05 level. It is worth of notion that such effects repeat those revealed on the sample of middle-school students in the last study[4]. Thus the main patterns of the relations between the game parameters representing the mental actions of theoretical thinking are replicated.

*The main effects and patterns of the interactions between game indicators: the impact of the individual differences.* At the next step the interactions between three researched variables — analysis, planning, and reflection — were analyzed. As was noticed before, the variable reflection is not to be calculated as a number of free cells on the last game step for collaborative conditions. Thus, this variable was assessed by analyzing participants' dialogues in a collaborative game. All of them were transformed into written texts after being listened. The text was prepared for every student and for each game set. All expressions were written without being skipped for a detailed analysis. After that, the phrases were divided into six categories by the criterion of the participant's attitude to the game and to his / her partner. In the end, each phrase was awarded one point for a concrete category. The categories and expressions examples are presented in Table 2.

Every category reflects the attitude (or its absence) of participants to the current game situation. The previous results

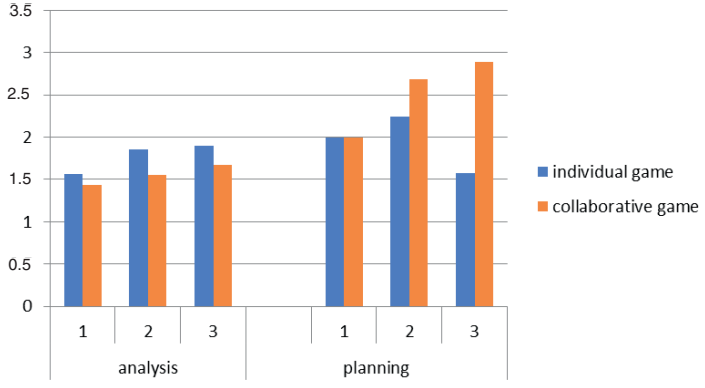


*Fig. 3.* Means of game performance at every game stage.
Along the abscissa is No. of the game, along the axis are means of game performance

[4] Correlation coefficients between the variables of analysis and planning were r = 0,22 (p = 0.01) for individual game and r = 0.17 (p = 0.08) for collaborative game. These results are described in the "Cultural-Historical Psychology" Journal. V.17, №2, 2021.

Table 2

**The list of the categories with concrete phrases examples**

| Category | Expressions |
|---|---|
| **1. Neutral** *(doesn't change behavior of a participant)* | "Shall we begin",<br>"What's that?",<br>"I can't",<br>"Have you moved in this way?",<br>"Where are you moving!" |
| **2. Neutral-motivational** *(it is not the participant's behavior in general, but it brings emotional/motivational investment in the dynamic of the game)* | "Come on, move on!",<br>"Please, approve",<br>"Hurry up, we're just running out of time",<br>"Come on!",<br>"Ah! All right!",<br>"Yes, let's make it this way" |
| **3. Individually intended** *(when the partner talks about his actions or asks his partner to pay attention to his actions)* | "I'm making vertical line",<br>"I'm making horizontal line",<br>"I'm making horizontal line",<br>"Amid / cancel my move". |
| **4. Collaborative intended** *(when the participant talks to his partner about his moves or their collaborative actions and plans)* | "Make it again",<br>"Let's build this line together",<br>"Better to take this ball",<br>"Take balls of the other color"<br>("take balls from this angle… green…blue" etc.),<br>"We need to clear the field",<br>"We need to try this". |
| **5. Agreeing** *(the participant agrees with his partner and accepts his move or cancels his own move, but understands the reason)* | "Generally, yes, it is so",<br>"Yes, we take the green one",<br>"I accept",<br>"Yes, I agree, we move in this way",<br>"Yes, all right". |
| **6. Changing** (objecting) *(an attempt to change partner's behavior with concrete arguments or statements about the game rules)* | "We can't build a line in this way",<br>"This move is useful",<br>"This move doesn't bring anything",<br>"This move will destroy a line",<br>"Diagonals are coming this way",<br>"We could get more points in such a manner",<br>"It's easier",<br>"Three blue balls are arriving one after another", etc. |

(2021) showed the importance of category 6 for the assessment of the reflection variable. Thus, this parameter was mainly used for further analysis. Since some classes were held in an online format because of coronavirus restrictions the next data with dialogues were measured only by those participants who could be present in person (N = 100). Table 3 with means for each category is presented below.

The presented results of the table show the frequent use of expressions of the neutral-motivational category, which is predictable. Such data are consistent both with the results of the previous study and with the emotional component of the category itself. This type of line may not have much of an effect on the flow of the game, but it does set the overall pace and mood, which also matters. On the other hand, the sixth category is an important indicator, and is on the second place of the frequently used "reflective" expressions in the course of the dialogue.

Table 3

**Means of all categories**

| Category | M | SD |
|---|---|---|
| **1. Neutral** | 3.76 | 3.62 |
| **2. Neutral-motivational** | 12.58 | 6.74 |
| **3. Individually intended** | 3.33 | 3.42 |
| **4. Collaborative intended** | 6.68 | 5.35 |
| **5. Agreeing** | 2.1 | 1.08 |
| **6. Changing (objecting)** | 7.77 | 3.61 |

The correlation analysis, however, did not allow us to find significant correlation coefficients between the analysis/planning indicators, on the one hand, and the average number of used expressions of each category, on the other. In this regard, the sample of subjects (those whose dialogues were recorded and analyzed further) was divided into two groups in accordance with the intellectual differences of participants. In past studies, it was important to for two partners to work in a pair , taking into account their intellectual abilities — the same or different. Therefore, this time two types of groups were also identified.

Group 1 consisted of the players with the same (near) level of intelligence, and group 2 included the players with different intellectual test performances[5]. Below is Figure 4 which represents game performance depending on the group. As one can see, both the analysis and planning indicators are higher in the second group of players who demonstrate differences in the intellectual level[6].

At the next stage, a correlation analysis was carried out between the indicators of planning, analysis and all types of categories (in particular, category 6, reflection) in each group. The data are shown in Table 4.

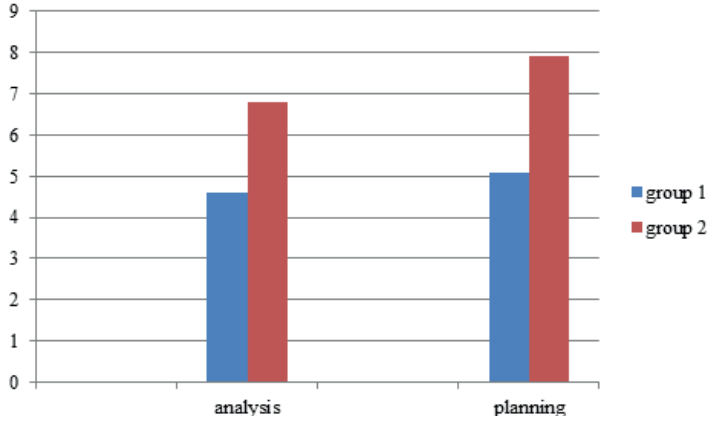


Fig. 4. Means of game performance compared in two groups

[5] As before, the results of each subject were labeled as follows: higher than 66.7% of the sample (high level), in the range from 33.3 to 66.7% of the sample (average level), or lower than 33.3% of the sample (low level).

[6] The means of the analysis and planning variables were compared in both conditions using the Mann-Whitney U-test for two independent samples and allowed us to establish significant differences ($p = 0.05$).

Table 4

**The patterns of the interactions between means of the expressions in each category and indicators of analysis and planning**

| Category | Group 1 (N=70) | | Group 2 (N=46) | |
|---|---|---|---|---|
| | Analysis | Planning | Analysis | Planning |
| **1. Neutral** | 0.24 | -0.44 ** | 0.01 | 0.68** |
| **2. Neutral-motivational** | -0.16 | 0.48* | 0.24 | -0.49* |
| **3. Individually intended** | -0.1 | -0.42* | 0.04 | 0.72** |
| **4. Collaborative intended** | -0.03 | 0 | 0.2 | 0.1 |
| **5. Agreeing** | -0.3 | -0.5* | 0.76** | 0 |
| **6. Changing (objecting)** | 0.35* | 0.12 | 0.58* | 0.64* |

*Note: significant at the p = 0.05 level; **significant at the p = 0.000 level.

The results mean that the more frequent is the use of neutral-motivational expressions in a group of pairs of players with the same level of intellectual abilities, the higher are their planning indicators, while this relationship is inverse for pairs with different levels of intelligence — the more frequent are such expressions, the lower are their planning indicators. The number of expressions of the changing type turned out to be significantly positively related to the indicators of analysis in both groups of players and to the indicator of planning in the group of players with different levels of intelligence. The number of agreeing expressions is negatively related to planning scores among players with equal intellectual abilities and positively to analysis scores in pairs with different levels of intelligence.

The results show several effects. First, positive correlations between the main game indicators and the expressions of the sixth category are to be observed in both groups. Thus, the connection between the three key mental actions measured by using a computer game system is obvious. On the other hand, it is group 2 where the main significant and strong effects are manifested, while the effects in group 1 are either weakly expressed or significantly negative. Such results emphasize the importance of individual differences between the subjects for the game performance. In the case of school students, there were pairs with the same intellectual level that demonstrated higher game performance. Then the reverse effect is observed in the case of students. Pairs of players with different intellectual abilities are more successful. This can be seen both in the average game indicators and in the correlation of these indicators with different categories. Thus, the measurement of the key mental actions needs to take various factors both external (game conditions) and internal (intellectual abilities) into account.

## Conclusion

The presented study was aimed at assessing the level of mental actions of analysis, planning, and reflection of junior students in different conditions of game problem solving. The PL-modified computer game system was used as a diagnostic tool, which has already been used by the authors to evaluate mental actions in schoolchildren. The results of the study allow to draw some significant conclusions.

First, the level of mental actions of analysis, planning, and reflection of students, as well as the patterns of relationships between them are mediated by two factors: the conditions of the game (individually /in pairs) and cognitive resources

(equal/unequal intellectual capabilities). So, the indicators of the MA of analysis are approximately equal in both games, while the MA of planning is in the conditions of playing in pairs. These results are saved both for the overall game and for each game set. The dynamics of the game in pairs (the change from one game set to another) also increases with respect to the planning indicator. Thus, the playing conditions in pairs contribute to a more productive game.

At the same time, it is important to note that the key indicators of the game — quantitatively and qualitatively — depend on the psychological conditions of the interaction of partners in a pair. In general, pairs made up of students with different intellectual abilities play more effectively compared to players with an equal level of intelligence. This effect is expressed both in higher average game indicators and in significant positive patterns of interrelations between the main indicators of the studied mental operations — analysis, planning, and reflection. It is important to compare these data with the reverse effects obtained on a sample of secondary school age students, when players with equal intellectual indicators demonstrated high game performance [6]. It is obvious that such results are influenced by the age of the subjects themselves. Younger students (compared to students), apparently, are more comfortable playing with peers who are close in level. In addition, it is worth taking into account that the main level of secondary school age is communication [5; 16], when children unite in a circle of interests and build contacts with peers with similar internal attitudes. This thesis is equally a characteristic of cognitive abilities. Therefore, higher game performance in pairs of players who are equal in intelligence level corresponds to the age-related features of development described by Russian researchers.

In relation to the student sample, a slightly different picture is observed. It is important to understand that even junior students are already practically formed personalities who use the learning process for their further realization. Therefore, the range of their interaction is wider, requiring adaptation to completely different people with different abilities, traits and attitudes. This partly explains the different effects of different groups of players working together. Of course, many other factors can influence game performance, in particular, related to social intelligence, motivational components, and personality characteristics. In any case, at this stage, it is important to conclude that we should not expect obviously simple links between the indicators of game performance without taking into account various external and internal factors. A joint game a priori does not lead to a qualitative result but forms many opportunities for the deployment of the potential of its players.

Secondly, the obtained correlation patterns — first of all, with respect to the significant positive relationship between analysis and planning — repeat the effects that were identified in previous studies. The presented effects are reproduced in both general data and data of different subgroups. This indicates the good psychometric properties of the developed computer gaming system ‘PL-modified’. As already mentioned in the introduction, the evaluation of a gamified technique as a diagnostic tool always poses great challenges to the specialist related to the exact procedure for developing parameters for registering the studied constructs and the process of diagnostics itself. Therefore, the reproducible effects emphasize the value of both the data itself and the computer technique, which allows to register various psychological constructs in several conditions for solving problems in the future, taking into account the age differences of the subjects.

***References***

1. Vygotskii L.S. Umstvennoe razvitie detei v protsesse obucheniya: Sbornik statei [Mental development of children in the learning process: A collection of articles.]. M.—L.: Gosudarstvennoe uchebno-pedagogicheskoe izdatel'stvo, 1935. 136 p. URL: http://psychlib.ru/inc/absid.php?absid=9980.

2. Gordeeva T.O., Sychev O.A., Lunkina M.V. Shkol'noe blagopoluchie mladshikh shkol'nikov: motivatsionnye i obrazovatel'nye prediktory [School well-being of younger students: motivational and educational predictors]. *Psikhologicheskaya nauka i obrazovanie = Psychological science and education*, 2019. Vol. 24, no. 3, pp. 32—42. DOI:10.17759/pse.2019240303

3. Guruzhapov V.A. Ehkspertiza uchebnogo protsessa v sisteme razvivayushchego obucheniya D.B. Ehl'konina — V.V. Davydova [Examination of the educational process in the D.B. Elkonin's — V.V. Davydov's system of developing education]. Moscow, 1999. 76 p.

4. Davydov V.V. Teoriya razvivayushchego obucheniya [Theory of developmental learning]. Moscow: INTOR, 1996. 544 p.

5. Leont'ev A.N. Problemy razvitiya psikhiki [Problems of mental development]. Moscow, 1959.

6. Margolis A.A., Gavrilova E.V., Kuravskii L.S., Shepeleva E.A., Voitov V.K., Ermakov S.S., Dumin P.N. Otsenka umstvennykh deistvii s pomoshch'yu komp'yuternoi sistemy v usloviyakh vzaimodeistviya s partnerom [Measuring Higher-Order Cognitive Skills in Collective Interactions with Computer Game]. *Kul'turno-istoricheskaya psikhologiya = Cultural-Historical Psychology*, 2021. Vol. 17, no. 2, pp. 90—104. DOI:10.17759/chp.2021170209

7. Margolis A.A., Kuravskii L.S., Shepeleva E.A., Gavrilova E.V., Petrova G.A., Voitov V.K., Yurkevich V.S., Ermakov S.S. Vozmozhnosti komp'yuternoi igry «Plines» kak instrumenta diagnostiki kompleksov kognitivnykh sposobnostei shkol'nikov [Capability of the "Plines" computer game as a diagnostic tool for complexes of cognitive abilities of schoolchildren] [Ehlektronnyi resurs]. *Sovremennaya zarubezhnaya psikhologiya = Journal of Modern Foreign Psychology*, 2018. Vol. 7, no. 3, pp. 38—52. DOI:10.17759/jmfp.2018070304

8. Margolis A.A., Kuravskii L.S., Voitov V.K., Gavrilova E.V., Ermakov S.S., Petrova G.A., Shepeleva E.A., Yurkevich V.S. Intellekt, kreativnost' i uspeshnost' resheniya zadach uchashchimisya srednego shkol'nogo vozrasta v komp'yuternoi igre «PLines» [Intelligence, creativity and success in problem solving by middle school-age students in the "PLines" computer game]. *Ehksperimental'naya psikhologiya = Experimental Psychology (in Russia),* 2020. Vol 13, no. 1, pp. 122—137. DOI:10.17759/exppsy.2020130109

9. Polivanova N.I., Rivina I.V., Ulanovskaya I.M. Vyyavlenie umeniya uchashchikhsya nachal'noi shkoly deistvovat' sovmestno v usloviyakh sotsio-kognitivnogo konflikta [Identification of the ability of primary school students to act together in conditions of socio-cognitive conflict] [Elektronnyi resurs]. *Psikhologicheskaya nauka i obrazovanie = Psychological science and education* psyedu.ru, 2013. Vol 5, no. 4. URL: https://psyjournals.ru/psyedu_ru/2013/n4/65849.shtml (Accessed: 24.10.2022).

10. Raven Dzh.K., Kort Dzh.K., Raven Dzh. Rukovodstvo k progressivnym matritsam Ravena i slovarnym shkalam: Razdel 3: Standartnye progressivnye matritsy Ravena (Vklyuchaya parallelnye I plus versii) [Guide to the Progressive Raven Matrices and Vocabulary Scales: Section 3: Standard Progressive Matrices (including parallel and plus versions)]. Moscow: Kogito-Tsentr, 2002. 144 p.

11. Rubtsov V.V. Osnovy sotsial'no-geneticheskoi psikhologii [The socio-genetic psychology base]. Moscow, Voronezh, 1996. 384 p.

12. Stepanov S.YU., Orzhekovskii P.A., Ushakov D.V., Ryabova I.V., Gavrilova E.V., Morozova O.A., Sobolevskaya T.A., Shepeleva E.A., Valueva E.A., Ovsyannikova V.V., Mishina I.B., Titov N.A., Chernysheva L.A. Tsifrovizatsiya obrazovaniya: psikhologo-pedagogicheskie i valeologicheskie problemy [Digitalization of education: psychological, pedagogical and valeological problems.]. Moscow, 2021.

13. Tsukerman G.A. Igra i uchenie: vstrecha dvukh vedushchikh deyatel'nostei [Game and learning: the meeting of two leading activities]. *Kul'turno-istoricheskaya psikhologiya = Cultural-Historical Psychology*, 2016. Vol 12, no. 2, pp. 4—13. DOI:10.17759/chp.2016120201

14. Tsukerman G.A. Sovmestnoe uchebnoe deistvie: reshennye i nereshennye voprosy. *Psikhologicheskaya nauka i obrazovanie = Psychological science and education*, 2020. Vol 25, no. 4, pp. 51—59. DOI:10.17759/pse.2020250405

15. Shilina N.G., Gerashchenko S.M. Formirovanie universal'nykh uchebnykh deistvii v podgotovke studentov 1 kursa arkhitekturnykh spetsial'nostei [Collaborative learning action: resolved and unresolved issues]. *Sovremennye problemy nauki i obrazovaniya = Modern problems of science and education,* 2018, no. 3, p. 94.

16. Ehl'konin D.B. Vozrastnye vozmozhnosti usvoeniya znanii (mladshie klassy shkoly) [[Age-related learning opportunities (primary school)]. Moscow: Proseveshchenie, 1966. 442 p.

17. Brown A.L., Bransford J. Learning, Remembering, and Understanding (Technical report No. 244). Illinois University, Urbana Center for the Study of Reading by Bolt, Beranek, & Newman, Inc. Cambridge, MA, 1982. 261 p.

18. Foroughi C.K., Serraino C., Parasuraman R., Boehm-Davis D.A. Can we create a measure of fluid intelligence using Puzzle Creator within Portal 2? *Intelligence*, 2016. Vol. 56, pp. 58—64. DOI:10.1016/j.intell.2016.026.011
19. Gallagher D., Grimm L.R. Making an impact: The effects of game making on creativity and spatial processing. *Thinking Skills and Creativity*, 2018. Vol. 8, pp. 138—149. DOI:10.1016/j.tsc.2018.05.001
20. Stoet G. PsyToolkit — A software package for programming psychological experiments using Linux. *Behavior Research Methods*, 2010. Vol. 42(4), pp. 1096—1104.
21. Stoet G. PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology*, 2017. Vol. 44(1), pp. 24—31.

***Литература***

1. *Выготский Л.С.* Умственное развитие детей в процессе обучения: Сборник статей. М.—Л.: Государственное учебно-педагогическое издательство, 1935. 136 с. URL: http://psychlib.ru/inc/absid.php?absid=9980.
2. *Гордеева Т.О., Сычев О.А., Лункина М.В.* Школьное благополучие младших школьников: мотивационные и образовательные предикторы // Психологическая наука и образование. 2019. Т. 24. № 3. С. 32—42. DOI:10.17759/pse.2019240303
3. *Гуружапов В.А.* Экспертиза учебного процесса в системе развивающего обучения Д.Б. Эльконина — В.В. Давыдова. М., 1999. 76 с.
4. *Давыдов В.В.* Теория развивающего обучения. М.: ИНТОР, 1996. 544 с.
5. *Леонтьев А.Н.* Проблемы развития психики. М., 1959.
6. *Марголис А.А., Гаврилова Е.В., Куравский Л.С., Шепелева Е.А., Войтов В.К., Ермаков С.С., Думин П.Н.* Оценка умственных действий с помощью компьютерной системы в условиях взаимодействия с партнером // Культурно-историческая психология. 2021. Том 17. № 2. С. 90—104. DOI:10.17759/chp.2021170209
7. *Марголис А.А., Куравский Л.С., Шепелева Е.А., Гаврилова Е.В., Петрова Г.А., Войтов В.К., Юркевич В.С., Ермаков С.С.* Возможности компьютерной игры «Plines» как инструмента диагностики комплексов когнитивных способностей школьников [Электронный ресурс] // Современная зарубежная психология. 2018. Том 7. № 3. С. 38—52. DOI:10.17759/jmfp.2018070304
8. *Марголис А.А., Куравский Л.С., Войтов В.К., Гаврилова Е.В., Ермаков С.С., Петрова Г.А., Шепелева Е.А., Юркевич В.С.* Интеллект, креативность и успешность решения задач учащимися среднего школьного возраста в компьютерной игре «PLines» // Экспериментальная психология. 2020. Том 13. № 1. С. 122—137. DOI:10.17759/exppsy.2020130109
9. *Поливанова Н.И., Ривина И.В., Улановская И.М.* Выявление умения учащихся начальной школы действовать совместно в условиях социо-когнитивного конфликта [Электронный ресурс] // Психологическая наука и образование psyedu.ru. 2013. Том 5. № 4. URL: https://psyjournals.ru/psyedu_ru/2013/n4/65849.shtml (дата обращения: 24.10.2022).
10. *Равен Дж.К., Корт Дж.К., Равен Дж.* Руководство к прогрессивным матрицам Равена и словарным шкалам: Раздел 3: Стандартные прогрессивные матрицы Равена (включая параллельные и плюс версии). М.: Когито-Центр, 2002. 144 с.
11. *Рубцов В.В.* Основы социально-генетической психологии. М.; Воронеж, 1996. 384 с.
12. *Степанов С.Ю., Оржековский П.А., Ушаков Д.В., Рябова И.В., Гаврилова Е.В., Морозова О.А., Соболевская Т.А., Шепелева Е.А., Валуева Е.А., Овсянникова В.В., Мишина И.Б., Титов Н.А., Чернышева Л.А.* Цифровизация образования: психолого-педагогические и валеологические проблемы. М., 2021.
13. *Цукерман Г.А.* Игра и учение: встреча двух ведущих деятельностей // Культурно-историческая психология. 2016. Том 12. № 2. С. 4—13. DOI:10.17759/chp.2016120201
14. *Цукерман Г.А.* Совместное учебное действие: решенные и нерешенные вопросы // Психологическая наука и образование. 2020. Том 25. № 4. С. 51—59. DOI:10.17759/pse.2020250405
15. *Шилина Н.Г., Геращенко С.М.* Формирование универсальных учебных действий в подготовке студентов 1 курса архитектурных специальностей // Современные проблемы науки и образования. 2018. № 3. С. 94.
16. *Эльконин Д.Б.* Возрастные возможности усвоения знаний (младшие классы школы). М.: Просвещение, 1966. 442 с.
17. *Brown A.L., Bransford J.* Learning, Remembering, and Understanding (Technical report No. 244). Illinois University, Urbana Center for the Study of Reading by Bolt, Beranek, & Newman, Inc. Cambridge, MA, 1982. 261 p.
18. *Foroughi C.K., Serraino C., Parasuraman R., Boehm-Davis D.A.* Can we create a measure of fluid intelligence using Puzzle Creator within Portal 2? // Intelligence. 2016. Vol. 56. P. 58—64. DOI:10.1016/j.intell.2016.026.011

19. *Gallagher D., Grimm L.R.* Making an impact: The effects of game making on creativity and spatial processing // Thinking Skills and Creativity. 2018. Vol. 28. P. 138—149. DOI:10.1016/j.tsc.2018.05.001
20. *Stoet G.* PsyToolkit — A software package for programming psychological experiments using Linux // Behavior Research Methods. 2010. Vol. 42(4). P. 1096—1104.
21. *Stoet G.* PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments // Teaching of Psychology. 2017. Vol. 44(1). P. 24—31.

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