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Psychomotor performance in video games

Krzysztof Horoszkiewicz, ORCID 0000-0001-6719-256X,
e-mail: khoroszkiewicz@swps.edu.pl
SWPS University of Social Sciences and Humanities, Postgraduate Studies, Psychology, Poland, 40-326 Katowice, Techników 9

Bartosz Horoszkiewicz, ORCID 0000-0001-7321-514X,
e-mail: bhoroszkiewicz00@gmail.com
SWPS University of Social Sciences and Humanities, Psychology,
Poland, 61-719 Poznań, Kutrzeby 10

Grzegorz Załęski, ORCID 0000-0001-6240-2935,
e-mail: zaleski.pg@gmail.com
Academy of Applied Sciences, Poland, 33-100 Tarnów, Mickiewicza 8

Abstract

Introduction: Interactive electronic games allow to access virtual environments and interact using a computer or TV screen. Anyone who has played a video game, or seen others playing, is aware of the importance of reaction speed and eye-hand coordination skills.

Objective: To determine the differences in psychomotor performance between professional gamers and amateurs.

Material and Methods: A total of 62 gamers took part in the study, including 31 people - professional video game users who had participated in e-tournaments in the last month (age: M = 20.6, SD = 6.3) and 31 people who did not play video games or played very rarely (they declared that they did not participate in e-sports tournaments), who constituted the control

group (age: M = 17.9, SD = 5.4). Integrated computer SDP-System with an executive module for stimulus generation and reception was used to assess psychomotor performance.
Results: Professional gamers have higher psychomotor skills than amateurs. They reveal better results for fast thinking, motor reactions, perception, attention, and working memory.
Conclusion:
Playing video games has a positive impact on players' psychomotor performance and can promote improvements in elementary cognitive functions.
Key words: video-games; e-sport; psychomotor performance; cognitive functions

INTRODUCTION

Video games

Interactive electronic games, or video games, are designed to provide players with good entertainment. They allow them to access virtual environments, either 2D or 3D, and interact using a computer or TV screen [1]. Zajączkowski and Urbańska-Galanciak [2] distinguish 8 types of games: arcade, adventure, role-playing, strategy, simulation, sports, logic and educational. According to Gnyp [3], "video game" is a general term that includes computer, console, arcade and video games, and the nomenclature tends to be identified with the platform on which it is located.

Anyone who has played a video game, or seen others playing, is aware of the importance of reaction speed and eye-hand coordination skills [4]. Most games, especially so-called 'shooters', require players to react extremely quickly to 'obstacles' or 'hazards' that appear, and the appropriate usage of buttons on controllers, keyboards or mice – proper skills in terms of precision of movement and thinking. A pioneering study led by Griffith at al. [5] found that professional gamers significantly outperformed non-players of electronic games in this regard. It can be hypothesised that the number of hours spent training their skills in a particular game favour their performance. According to Franckiewicz at al. [6], most gamers devote an average of 21 hours per week to gaming, using a computer, and, to a lesser extent, a mobile phone, tablet or console. Most users of this form of entertainment are men under 30 years of age. Shooters are the most popular among Polish gamers, followed by role-playing games (RPG), in which participants identify themselves with the role of fictional characters (role-playing games), and action-adventure games [6].

An analysis of the scientific literature on video games reveals two emerging trends. One covers the issue of their impact on players' act and emotions, indicating positive [6]-[10] or negative consequences [11]-[13]. The second trend represents a disapproval of the expectation of dependency in the context of significant changes in player attitude [14], [15]. According to Witkowska [16], most of the available literature focuses on the negative consequences of playing video games emphasising the risk of increased aggressive behaviour or Internet addiction. There are fewer studies devoted to the beneficial cognitive aspects of e-gaming activity, including the assessment of their psychomotor performance. The present study seems to fill this gap, at least to some extent.

Psychomotor performance

Psychomotor fitness is an important factor influencing the specific performance of players in e-sports competition, whether in arcade or sports games. A study by Rosser at al. [17] showed that the psychomotor skills developed by players through playing interactive games are related to those to be developed in training for laparoscopic surgery. The study found that surgical residents and attending physicians who had played video games in the past made 37% fewer errors and completed their training 27% faster than those who had not played. It is worth noting that, in a follow-up study, surgeons who played video games for 6 minutes immediately before performing the laparoscopy also had significantly better suturing scores [17].

In the study presented here, a complex variable was adopted: "psychomotor performance" (including cognitive and motor aspects), which we understand as a level of functioning based on cognitive (perception, thinking) and executive (motor responses) processes. The cognitive and executive spheres condition each other, and, in the case of tests requiring motor responses, it is difficult to distinguish between them.

PURPOSE OF THE STUDY

The aim of the presented research was to determine the differences in psychomotor performance that exist between professional gamers (this group includes players from e-sports clubs) and amateurs.

Answers were sought to the following research questions:

1) Is there a statistically significant variation in the performance of video game players in terms of reaction speed and adequacy and eye-hand coordination?

2) Are there differences in thinking speed across the groups of gamers studied?

3) Do professional video game users differ in their level of precision of movement and quick thinking compared to so-called amateurs?

4) Are there differences between professional video game users and amateurs in terms of visual attention, perceptual speed, and working memory performance?

Playing video games involves developing psychomotor skills, which are important in terms of efficiency in receiving and processing information from the environment. We can venture the thesis that professional video game users, as people who play regularly for many hours a day, are more experienced and skilled at a given game than those who play less. One of the success factors is the efficiency of perception, attention and appropriate response to a stimulus. Like Witkowska [16], we can assume that they are characterised by highly developed executive functions, working memory, concentration of attention, ability to work under stress or speed of learning.

Based on theoretical findings and our own observations, the following hypotheses were formulated:

H1: Individuals who play video games more frequently (professional users) are characterised by higher (better) eye-hand coordination performance in terms of speed and reaction adequacy.

H2: Professional gamers display higher mental efficiency in psychomotor reactions than those who play video games less frequently (amateurs).

H3: People who play video games more frequently perform higher (better) than people who play games less frequently in terms of precision of movement and quick thinking.

H4: Professional video game users, compared to amateurs, have higher skills in elementary cognitive functions: perception, attention, and working memory.

MATERIAL AND METHODS

Study design and participants

The study was carried out in May-October 2021 on the premises of the Academy of Applied Sciences in Tarnow. Due to the COVID-19 virus epidemiological situation at the time, the number of participants was relatively small. A total of 62 gamers took part in the study, including 31 people - professional video game users who had participated in e-tournaments in the last month and 31 people who did not play video games or played very rarely (they declared that they did not participate in e-sports tournaments), who constituted the control group. There were 28 men and three women in the 'professional gamers' group and 29 men and two women in the control group. The minimum age in the 'professional gamers' group was 12 years and the maximum age was 33 years (M = 20.6; SD = 6.3), and just as in the 'amateur' group, in which the youngest gamer was 12 years and the oldest 32 years (M = 17.9; SD = 5.4). All subjects gave us consent to the study. Players were recruited by informing them about the study at meetings with e-sports coaches and an announcement on the university website. They did not receive any financial gratification.

Research tools

The SDP-System (Figure 1) is a device based on an integrated computer system with an executive module for stimulus generation and reception. The selection of appropriate test tasks allows psychomotor performance to be assessed. The device was certified by the Polish Patent Office (no. P.418621) on 16 April 2019. During the test tasks, heart rate was measured using a Polar OH1 wristband worn on the wrist using Bluetooth transmission.

Figure 1: SDP - Psychophysiological Diagnostic System
(Source: GPE Psychotronics archives)

The following test tasks were used in the study:

1. **The Numbers Test (TLB)** - consists of two arrays divided into square boxes with two-digit numbers inside. The task consists of memorizing successive numbers from the first board and then finding them among a set of numbers on the second board. To do this, the participant uses the keyboard buttons to move the frame to the box containing the memorized number. Attention, working memory and perceptiveness play an essential role in the task. For this reason, it is included in the battery of tests measuring these cognitive functions.

2. **The Test of Simple Co-ordination (TKP) in forced (TKP W) and imposed (TKP N) tempos.** This test is a method for testing eye-hand coordination and precision of movement. Numbers appear sequentially on the display module monitor, to which one must respond by pressing a keypad button labelled with the exposed digit. In the study, one-minute sequences

were used in the so-called forced and imposed modes. In the former, the next exposure occurs only after the subject has previously responded correctly, and in the latter, the next number appears after 500 milliseconds (in the absence of a response). The test was included among the variables assessing psychomotor performance in terms of speed and adequacy of response and eye-hand coordination.

3. **The test of complex coordination (TKZ) in forced (TKZ W) and imposed (TKZ N) tempo**. This test is a method of measuring psychomotor performance extended to include a thinking component. Stimuli were exposed for one minute, which were simple mathematical tasks based on adding or subtracting single numbers. The response consisted of typing the result of the presented action using a keyboard. The method illustrates the thinking time component of psychomotor responses. In this context, the described method was included in a battery of tests assessing psychomotor performance (cognitive and motor aspects).

4. **The PIM index**, which is the sum of good responses in both coordination tests with a forced programme, was used to assess the performance of precision of movements and quick thinking. The PIM index correlates strongly and positively ($r = 0.58$; $p < 0.001$) with the number of correct responses in the Raven's matrix test in the standardized version of the classic form, which is used to assess the level of fluid intelligence [18].

Statistical analyses

In order to answer the research questions posed, statistical analyses were performed using the IBM SPSS Statistics 27 package. With its help, an analysis of basic descriptive statistics was performed along with Shapiro-Wilk tests, Student's t-tests for independent samples and Mann-Whitney U tests. The classic threshold of $\alpha = 0.05$ was considered as the level of significance.

RESULTS

Level of cognitive and motor functioning of the study subjects

Basic descriptive statistics were calculated for the performance evaluation of individual cognitive and motor tasks in the so-called forced mode, together with the Shapiro-Wilk test to check the normality of the distribution of these variables. The variables analysed were the mean reaction times for the test of numbers (TLB), simple coordination (TKP) and complex coordination (TKZ), the level of heart rate while solving the aforementioned tests, the number of correct reactions in the test of simple and complex coordination, and the speed of precision of movements and thinking (PIM) index.

As can be seen in Table 1, this test showed that the distribution of all variables in terms of reaction times deviated significantly from a normal distribution. Non-parametric tests will be carried out for these variables and parametric analyses for the others.

Table 1
Descriptive statistics for cognitive and motor tasks applied in the forced mode (N=62)

	M	*Me*	*SD*	*Skew*	*Kurt*	*Min*	*Max*	*W*	*p*
TLB – time	5.84	5.57	1.42	1.30	2.85	3.36	10.60	0.91	<0.001
TLB – heart rate	88.98	90.00	12.56	-0.25	-0.49	61.00	115.00	0.98	0.574
TKP W – time	0.86	0.85	0.12	1.84	7.32	0.68	1.42	0.87	<0.001
TKP W – heart rate	90.92	90.00	13.63	0.14	0.22	65.00	132.00	0.98	0.276
TKP W – number of good responses	68.98	69.00	8.37	-0.31	1.35	41.00	87.00	0.97	0.08
TKZ W - time	4.25	1.57	20.41	7.81	60.95	0.93	161.00	0.12	<0.001
TKZ W – heart rate	92.21	92.00	12.90	0.01	-0.25	65.00	127.00	0.99	0.697
TKZ W – number of good responses	37.66	37.00	9.54	0.41	0.47	15.00	63.00	0.98	0.26
PIM	106.73	106.50	16.09	-0.01	0.97	56.00	146.00	0.98	0.446

M - mean; Me - median; SD - standard deviation; Skew. - skewness; Kurt. - kurtosis; Min and Max - lowest and highest value of the distribution; W - Shapiro-Wilk test score; p - significance; TLB - test of numbers; TKP W - test of simple forced-choice coordination; TKZ W - test of complex forced-choice coordination; PIM - speed index of precision of movement and thinking

An analogous analysis was carried out for tests of simple and complex coordination in the so-called imposed programme. The Shapiro-Wilk test was found to be statistically significant only for the number of omitted and erroneous responses in the TKP and TKZ. Non-parametric tests will be used in the evaluation of these variables and parametric analyses for the others.

Table 2
Descriptive statistics for cognitive and motor tasks used in the imposed mode (N=62)

	M	*Me*	*SD*	*Skew*	*Kurt*	*Min*	*Maks*	*W*	*p*
TKP N – time	0.71	0.72	0.04	-0.25	0.58	0.58	0.81	0.98	0.411
TKP N – number of good responses	60.95	61.00	15.45	-0.17	-0.52	26.00	91.00	0.98	0.552
TKP N – number of omitted reactions	10.55	8.50	8.55	1.73	4.43	1.00	47.00	0.86	<0.001
TKP N – number of incorrect responses	12.32	11.00	8.10	0.88	1.03	0.00	39.00	0.95	0.012
TKP N – heart rate	93.06	93.00	14.02	0.25	0.53	62.00	137.00	0.99	0.694
TKZ N – time	1.24	1.24	0.15	0.16	0.31	0.87	1.66	0.99	0.925
TKZ N – number of good responses	36.92	37.00	11.77	0.09	-0.65	13.00	66.00	0.98	0.384
TKZ N – number of omitted reactions	5.39	4.50	4.03	1.03	0.69	1.00	17.00	0.89	<0.001
TKZ N – number of incorrect responses	6.52	6.00	4.24	0.85	0.92	0.00	19.00	0.94	0.006
TKZ N – heart rate	93.34	94.50	13.54	0.11	0.87	58.00	136.00	0.99	0.696

M - mean; Me - median; SD - standard deviation; Sk. - skewness; Kurt. - kurtosis; Min and Max - lowest and highest value of the distribution; W - Shapiro-Wilk test result; p - significance; TKP N - imposed simple coordination test; TKZ N - imposed complex coordination test

Comparison of study variables in professional video game users and amateurs

In order to test whether there was variation in performance on individual test tasks involving psychomotor performance in professional video game users and 'amateur' players, Student's t-tests (Table 3) and Mann-Whitney U tests (Table 4) were conducted respectively.

Analysis of the Student's t-test results revealed 7 statistically significant differences in the number of correct responses in the simple and complex coordination test in the forced and imposed modes, the total scores in both tests (PIM index) and the mean reaction times in the TKP and TKZ in the imposed mode. Higher scores in terms of the number of correctly perceived stimuli were found in those who played video games more frequently. Players in this group were also characterised by lower mean reaction times to the stimulus in tasks assessing levels of simple and complex coordination. The strength of the observed effects as measured by Cohen's d coefficient was large (Table 3).

Table 3

Student's t-test results for individual test tasks in amateur and professional video game players (N=62)

	Amateur video game players (n = 31)		Professional video game users (n = 31)				95% *CI*		
	M	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
TLB – heart rate	90.84	12.04	87.10	12.78	1.19	0.240	-2.57	10.05	0.30
TKP W – heart rate	92.65	14.28	89.19	12.72	1.01	0.319	-3.42	10.32	0.26
TKP W – number of good reactions	65.07	7.46	72.87	7.29	-4.17	**<0.001**	-11.55	-4.05	-1.06
TKZ W – heart rate	93.48	13.44	90.94	12.20	0.78	0.437	-3.97	9.07	0.20
TKZ W – number of good reactions	33.42	7.50	42.10	9.39	-4.02	**<0.001**	-12.99	-4.36	-1.02
PIM	98.48	13.44	114.99	14.36	-4.67	**<0.001**	-23.54	-9.42	-1.19
TKP N – time	0.72	0.04	0.70	0.05	2.27	**0.027**	0.00	0.05	0.58
TKP N – number of good reactions	55.07	15.45	66.84	13.23	-3.22	**0.002**	-19.08	-4.47	-0.82
TKP N – heart rate	95.87	14.11	90.26	13.58	1.60	0.116	-1.42	12.65	0.41
TKZ N – time	1.29	0.15	1.19	0.14	2.77	**0.007**	0.03	0.17	0.71
TKZ N – number of good reactions	33.65	11.92	40.19	10.82	-2.26	**0.027**	-12.34	-0.76	-0.58
TKZ N – heart rate	95.84	15.25	90.84	11.27	1.47	0.147	-1.81	11.81	0.37

M - mean; SD - standard deviation; t - Student's t-test result; p - statistical significance; CI - confidence interval; LL - lower limit; UL - upper limit; TLB - test of numbers; TKP W - forced-choice test of simple coordination; TKZ W - forced-choice test of complex coordination; PIM - speed of accuracy index of movements and thinking; TKP N - forced-choice test of simple coordination; TKZ W - forced-choice test of complex coordination

Table 4 shows the results of the Mann-Whitney U tests. Five statistically significant differences were noted. Those who played video games more frequently had lower reaction times in the tests of numbers and simple and complex forced-mode coordination, as well as a lower number of missed reactions in both coordination tests. The strength of the effects was large for reaction times in the simple coordination test and moderately large for the other variables.

Table 4
Mann-Whitney U test results for individual test tasks in amateur and professional video game players (N=62)

	Amateur video game players (n = 31)		Professional video game users (n = 31)					
	M	*SD*	*M*	*SD*	*U*	*Z*	*p*	*r*
TLB – time	6.29	1.62	5.38	1.00	312.5	-2.37	**0.018**	0.35
TKP W – time	0.91	0.13	0.81	0.08	213.0	-3.78	**<0.001**	0.58
TKZ W – time	6.95	28.59	1.46	0.35	214.5	-3.62	**<0.001**	0.54
TKP N – number of omitted reactions	13.39	10.36	7.71	4.96	324.0	-2.21	**0,.028**	0.33
TKP N – number of incorrect reactions	13.87	9.17	10.77	6.66	378.0	-1.45	0.150	0.21
TKZ N – number of omitted reactions	6.48	4.21	4.29	3.59	326.5	-2.18	**0.030**	0.32
TKZ N – number of incorrect reactions	6.77	4.24	6.26	4.30	423.0	-0.81	0.420	0.12

M - mean; SD - standard deviation; U - Mann-Whitney U-test result; Z - standardized value; p - statistical significance; r - strength of effect; TLB - test of numbers; TKP W - test of simple forced coordination; TKZ W - test of complex forced coordination; TKP N - test of simple imposed coordination; TKZ W - test of complex imposed coordination

DISCUSSION

The study presented here aimed to capture the differences occurring between professional video game users and less frequent players (including non-gamers).

Hypothesis 1, that more frequent players have higher psychomotor skills, was confirmed. Analysis of the data for the simple coordination test in a forced and imposed programme showed that "professional users" of video games had a shorter average reaction time, as well as a higher number of correct reactions. The results obtained are quite consistent with those of other researchers [12], [19], [20]. The results of research work under the direction of H. Pardin-Torner [19] showed that video game players had shorter reaction times than non-video game players, although the groups studied did not differ significantly in the number of errors made. An earlier study by Griffin [5] had already shown that skill training or experience in playing games promotes better results in terms of reaction speed. We can assume the existence of a positive correlation between playing video games and psychomotor performance. The strength of these relationships, depending on a number of factors (e.g., related to age, education, temperament, level of game playing, etc.), can take on extremes ranging from high to low, or even, as in the case of the study by Gnambs and Appel [21], suggest even no relationship [21].

Hypothesis 2 regarding differences in speed of thought in psychomotor responses was successfully falsified. Analyses of the results of the forced and imposed complex coordination test showed that "professional gamers" needed less time to perform simple arithmetic operations on single numbers than less frequent video game players. At the same time, they had a higher number of good answers in both modes. It is noteworthy that completing a task in the imposed mode requires the player to focus their attention higher due to the limited exposure time of the stimulus. The complex coordination test is based on the so-called fast thinking described in Kahneman's work [22]. It presents two types of thinking processes that take place in our mind: fast thinking, so to speak, automatic and involuntary, associative thinking, and slow, or controlled, reflective thinking. In this context, the ECT measures the 'reflexive' mental operations that were 'trained' in early schooling in terms of addition and subtraction on single numbers. As noted by Bielecki [23], people who play so-called first-person shooters (FPS) are significantly more proficient at a range of cognitive tasks. Gamers also show a reduction in the time required to switch between different tasks, better memory functioning in terms of the speed of information 'exchange' and inhibition of distractors or simultaneous tracking of multiple moving objects. In addition, they are faster, perform better information selection, and ignore distractors more effectively [6].

Verification of the 3rd hypothesis involving differential performance in terms of movement precision and quick thinking was made possible by comparing players' performance on the PIM index. Those who played video games more frequently achieved significantly higher numerical (point) values than those who played less frequently. The results presented justify the acceptance of hypothesis 3. It was mentioned earlier that the PIM variable correlates strongly and positively with the Raven's matrices test. We can surmise that the professional video game users we studied were characterised not only by higher performance skills than non-players (or less frequent video game players), but also by higher intellectual potential. However, we cannot pinpoint the source of these skills. The obtained differences in cognitive functioning, as emphasised by Witkowska [16], cannot be related only to the positive effect of playing.

Hypothesis 4 concerning the differences found in players in terms of elementary cognitive functions: perception, attention and working memory was confirmed. The results of the test of numbers in terms of average reaction time show an advantage of these abilities in those who play video games more frequently. Our findings are consistent with numerous observations by other researchers [6]-[8], [16], [23]-[25]. They include, among others, a better ability to use information presented in the periphery of the visual field or the speed of its search and detection of changes in it. People who play action games, for example, allocate attention better, make better use of the resources of visual attention, and are thus more easily able to overlook irrelevant stimuli, and concentrate on the task at hand. Studies using functional magnetic resonance imaging (fMRI) conclude that playing video games is associated with more favourable brain functioning [26]. It is increasingly recognised that video games can stimulate the brain and various cognitive abilities - increasing attention and concentration, improving spatial visualisation, and memory [24].

We can assume that games affect psychomotor performance and elementary cognitive abilities in different ways. The type of game and the level of motivation of the player to achieve the best possible results is not without significance. As mentioned, the cognitive and motor aspects of psychomotor performance are difficult to precisely separate. The solution of a task and its realisation through action, e.g., the result of an addition written on a computer screen, on the one hand, depends on cognitive fitness (perception, thinking), and on the other hand, on motor fitness (reaction time, precision of movements). The contribution of each of these proficiencies to the overall picture of psychomotor performance varies. While in the case of the error rate, the contribution of cognitive fitness is crucial (especially when measuring reaction time, although an error due to low precision of target movements is also possible), in the case of response speed (reaction time), motor fitness comes to the fore.

In the analyses conducted, we also included the average heart rate level recorded during each test task. Assessment of heart rate levels has been used to evaluate various mental states such as stress, fatigue and sleepiness [27], [28]. Castellar at al. [29] showed that players' HR fluctuations become large when they behave aggressively in a role-playing game. The results of an experiment by Abe at al. [30] showed that heart rate (HR) levels during 'shooter' gameplay were related to failures and successes experienced at a given stage of the game. HR levels increased when the player defeated enemies on the road and decreased when he himself was hit by an enemy projectile, despite the fact that the game continued.

In our study, heart rate level did not differentiate between the study groups in terms of the methods used. However, it should be noted, unlike video games, especially popular 'shooters', the level of difficulty of the individual tasks we offered players was relatively low and their pattern was predictable. The HR assessment we undertook was exploratory only, and suggests that elements requiring higher cognitive function competencies and distractor resilience are worth introducing in the design of tasks requiring psychomotor competencies for players.

Limitations of the study, suggestions for future research and practical implications

A limitation is the focus on quantitative results only. Extending the research by analysing data related to education or current occupation (e.g., pupil, student, working person), the amount of time spent on a particular game, participation in e-tournaments, information on the type of game, etc., would allow a deeper interpretation of the results. In future research on groups of gamers, it would be worthwhile to use additional appropriately standardised research methods that can differentiate between these groups, such as the Colour Connection Test (CTT) or the Test of Attention and Perceptiveness (TUS). It would also be useful to include the role of 'distractors' in the design of test tasks. It would also be beneficial to indicate the implications of the results obtained. People who play video games more often have better psychomotor skills, which are crucial in many aspects of our lives (e.g., driving a car). It would be interesting to encourage older people to take up this type of activity. The presence of different types of games on the market encourages interactive challenges for any age group. Playing video games can help improve psychomotor skills. The higher the level of this skill, the better the performance in many situations that require quick and generally accurate decision-making.

CONCLUSIONS

1. People who play video games more often have higher psychomotor skills than those who play less and outperform them in terms of speed and appropriateness of response to stimuli.
2. Professional gamers are characterised by higher fast thinking skills than less frequent video game players.
3. People who play video games more frequently have higher manual dexterity skills in terms of accuracy of movement and quick thinking.
4. Professional video game users are characterised by higher skills in elementary cognitive functions: perception, attention, and working memory, compared to amateurs.
5. Playing video games has a positive impact on players' psychomotor performance and can promote improvements in elementary cognitive functions.

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