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RUNNING TITLE: COGNITION BEHIND MODERN BOARD AND CARD GAMES

Title: The cognitive processes behind commercialized board games for intervening in mental health and education: a committee of experts

Running title: COGNITION BEHIND MODERN BOARD AND CARD GAMES

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Abstract

The use of modern board games has been growing last years in education, research, and mental health attendance. Often one professional selects games by his/her criteria depending on his/her objective with them. We evaluated the cognitive processes inherent to each modern board game to obtain a consensus of the cognitive profile of each. We explain how to choose the most suitable board games in future interventions. Fifteen education, mental health, and neuroscience research professionals with board games experience participated in an online assessment of 27 modern board games. Experts received a virtual neuroeducation formation and played the games selection for further analysis. Participants answered a Likert scale about 12 cognitive processes activated with each game. All modern board games obtained a high level of agreement ($ICC > .75$). Besides, most cognitive processes reached a high agreement, except for cognitive flexibility and problem-solving (moderate range; $.5 > ICC > .75$). Differentiated cognitive profiles have been obtained for each game, some of which could work on more than one cognitive domain at a time. Finally, initial evidence about which board game mechanisms activates with cognitive domain was found. To conclude, this expert consensus methodology became a useful tool for assessing the cognitive profile behind modern board and card games. The results obtained may facilitate the choice of games to be used in future studies depending on the objective cognitive domain to be trained under a criterion based on the observations of a group of experts and not just the researcher's individual criteria.

Introduction

Board and card games are characterized by presenting a fixed set of rules that limit the number of pieces on a board, the number of positions for such pieces, and the number of possible moves (1). Modern board games (created after 1950 by recognized authors) are more aesthetic and were designed with more innovative and varied mechanisms than traditional board games (2–4). Besides, some light modern board games (also known as “fillers” by gamers) rely on one specific cognitive process resembling assessment tools commonly used in neuropsychological assessment (5). In addition, it is supposed that board games benefit certain psychological processes (6) by enhancing brain activity (7).

Recent studies have showed that cognitive interventions based on modern board games are effective in maintaining cognitive health in older people (8–12). In general population but also in clinical cases, some other studies have shown that executive functioning may be improved using these games in children (5,13,14). Specifically, Vita-Barrull et al. (5) found that it is possible to transfer the effects of cognitive training to how executive functions are applied to the real world, decreasing executive dysfunctions and increasing the cognitive health of children. In addition, some studies have shown that modern board games may also be useful in decreasing psychopathological symptoms (14,15) and improving social functioning in psychiatric patients (16,17)

However, past interventions had an important limitation. All the studies mentioned above have used modern board games without being sure that the games selected properly activated the cognitive and emotional processes intended to work. How the authors selected those games but not others remain usually unknown. In

professional settings, the selection of games in mental health interventions is based on the researchers' individual criteria according to their knowledge of the processes that are supposed to be inherent in these games. It is often done by one unique professional, with his/her own bias. For all the above, it is considered that a multidisciplinary expert consensus with experience in the professional use of modern board games for educational and mental health purposes can lead to a systematic and consensual analysis of the games to guide future cognitive interventions. In the present study we also performed an exploratory analysis about the associations between board game mechanisms and the cognitive profile of the games to show one possible application of the methodology of experts consensus.

Materials and Methods

Overview

The present research used a methodology based on experts opinions. However, this methodology depends entirely on the professional experience and formation of each member(18). In the present study, professional experience was controlled by inviting reputed people in the field of board games, education and mental health in Spain. Regarding the formation on the cognitive processes, we designed a methodology to minimize the subjective bias.

Participants

Fourteen experts with experience in using modern board games as a tool of intervention participated in this expert consensus. Experts were recruited between December 2019 and January 2020 from community associations, public schools, private

mental health clinics, and a neuropsychology research group in Spain. The average age of all experts was 41 years ($SD=9.71$, 64.29% women) with an average of working experience of 14 years ($SD=10.03$) un education, mental health in/or research, and an average of working experience in playful methodologies of 7 years ($SD=8.38$). Three co-authors of this paper (NVB, NG, and JMH) participated as coordinators of the expert consensus without participating in the systematic evaluation of the games. The only compensation the experts received was the games analyzed themselves.

Procedure

Step 1: Selection modern board and card games and the experts for the consensus.

Coordinators of the expert consensus selected 27 modern board and card games (according to the definition by Sousa and Bernardo (2)) commercialized by a Spanish board game editorial. The selection was performed by convenience sampling, based on past studies about cognitive interventions with modern board games (5), but broaden the number of games to use them for future research. Two co-authors of this paper (NVB and JMH) selected three games per cognitive process according with their experience with those games. So, the selected games were (see Suppl Material for descriptions and theoretical allocation in the main cognitive domain): *Alles Tomate!* (19), Barnyard Buddies (20), Bee Alert (21), Blurble (22), Brain Connect (23), Catch the Match (24), Chakra (25), CLACK! (26), Connect the Thoughts (27), Dice Academy (28), Halli Galli (29), Kaleidos Junior(30) Layers (31) Le Roi Sommeil (32), Look around (33), Magic mandala (34) Magic fold(35), Monster Match (36), Ohanami (37), Pickomino (38), Piraten Kapern (39), Saboteur (40), Sherlock Express (41), Shrimp (42), Speed cups (43), Streams (44), Supertaki (45). The members of the committee were invited to participate as a convenience sample too.

Step 2: Expert's formation and play the game' selection

The experts were trained in executive functions and associated cognitive processes so that they all started from the same concepts before the game's assessment. Their training was evaluated through tests and video activities developed by the project coordination team (See Supplementary Material). Once the training phase was completed, the experts received the 27 selected games. They had to play at least three times each game for its correct evaluation.

Step 3: Modern board games assessment by experts

The experts evaluated the degree to which the games activated 12 cognitive processes using an online questionnaire created ad hoc. According to the scientific literature (46–49), the cognitive domains were: a) verbal working memory, visuospatial working memory, verbal short-term memory, visuospatial short-term memory, inhibition, cognitive flexibility, planning, reasoning, problem-solving, affective decision making, processing speed and verbal fluency (See definitions in Table 1 and in which mental health problems they are affected).

----- Insert Table 1 here -----

Each cognitive process was assessed using a 4-point Likert scale (0=None, 1=Low, 2=Moderate, 3=High), and each score had to be accompanied by a justification from the expert.

Step 4: Agreement analysis and elaboration of the cognitive profile of the games

Finally, we analyzed the degree of agreement between the experts in their evaluations of the games and cognitive processes. We obtained the cognitive profiles of each modern board and card game.

Statistical analysis

First, to take into account the subjective bias of each expert, we also analyzed rater agreement on cognitive functions and modern board and card games using the intraclass correlation (ICC). An expert consensus about the cognitive processes present in different play actions of a virtual game (50) used two criteria to assess experts' agreement. We used the most restrictive criterion that considers ICC's lower than 0.5 as low reliability, ICC's between 0.5 and 0.75 as moderate, ICC's between 0.75 and 0.9 as good, and ICC's above 0.9 as excellent reliability (51). Second, we analyzed the median scores of all the experts for each game in each cognitive process. This procedure helped us to find which game should be better to train each cognitive process. We also wanted to know whether the initial selection of games (with the criteria/intuition of two authors of the present study) agreed on the decision by the experts committee. So, we calculated the percentage of agreement between the theoretical main process active for selecting each game (see Suppl. Material) and the two most important cognitive processes as a result of the experts consensus. Finally, we performed the Mann-Whitney U test to analyze whether specific board game mechanisms differed or not in concrete cognitive domains. We calculated the Cohen's d effect size (52).

Results

Experts' agreement in modern board and card games

We obtained intraclass correlations indicative of excellent reliability in all modern board and card games (from *Look around* and *Streams* ICC=.91 to *Bee Alert* ICC=.97). We found two exceptions: *Kaleidos Junior* (ICC=.89) and *Pickomino* (ICC=.89). The intraclass correlations were interpreted as good reliability (See all the results in Table 2).

----- Insert Table 2 here -----

Experts agreement in cognitive domains

Intraclass correlations for each cognitive domain can be seen in Table 3. Intraclass correlations showed moderate reliability in Cognitive flexibility (ICC=.51) and Problem-solving (ICC=.74). We obtained intraclass correlations indicative of good reliability in all types of memory processes (from Verbal Short-Term Memory ICC=.76 to Visuospatial short-term memory ICC=.88) and Reasoning (ICC=.84). Excellent reliability was obtained in the remaining cognitive domains (from Inhibition ICC=.91 to Verbal Fluency ICC=.99).

Cognitive profiles of the selected games

Table 3 shows medians and interquartile ranges that selection of games obtained in each cognitive domain analyzed. To maximize higher activation and lower discrepancies between experts, we decided that the best games for each cognitive domain were those with the highest median and the lowest interquartile range.

According to this criterion, the best games for each cognitive domain analyzed were:

Alles Tomate! (M=2.5, IR =3) for verbal working memory; *Kaleidos Junior* (M=1.5, IR =3) for verbal short-term memory; *Bee alert* and *Le Roi Sommeil* (both M=3, IR =1) for visuospatial working and short-term memory; *Halli Galli* and *Shrimp* (both M=3, IR =1) for inhibition; *Magic fold*, *Shrimp* and *Super taki* (all of them M=3, IR =1) for cognitive

flexibility; Brain connect, Chakra and Saboteur (all of them $M=3$, $IR =0$) for planning; Brain connect ($M=2.5$, $IR =1$) for reasoning; Magic fold and Saboteur (both $M=2$, $IR =1$) for problem solving; Saboteur and Pickomino (both $M=3$, $IR =1$) for affective decision making; Connect the thoughts, CLACK!, Halli Galli, Kaleidos junior, Monster match, Catch the match, Barnyard buddies, Sherlock express, Shrimp and Speed cups (all of them $M=3$, $IR =0$) for processing speed; and Blurble, Dice academy and Look around (all of them $M=3$, $IR =0$) for verbal fluency. Some modern board and card games obtained high scores in all types of executive functions (see Figure 1).

----- Insert Table 3 and Figure 1 here -----

Percentage of agreement between expert's consensus and initial selection of the games per cognitive domain

When the games were analyzed for selecting them before the experts committee, we suspected that most of the games required processing speed because of their mechanisms. We suspected that several games activated processing speed but also another cognitive domain to win the game. So, only three games were previously selected as activating processing speed because it was suspected that processing speed was the only cognitive domain implied when playing (See Supplementary Material). Thus, we analyzed the data considering an agreement between pre-selection analysis and experts' consensus when the initial cognitive domain coincided with the first or the second cognitive domain according to expert consensus. The percentage of agreement was 74.1% ($N = 20$ games). We show the discrepancies at Table 3.

Board game mechanisms and differences in cognitive domains

As Sousa et al. (53) suggested, the study of game elements, such as game mechanisms, and their relation to the goals we have to use a game, is a key objective to better understand how games can be applied for specific purposes. Game mechanisms could be defined as those characteristics of the game that imply players interacting according to the game's rules to generate game (and cognitive) dynamics (53,54). The games analyzed by the experts committee accounted a total of 23 different game mechanisms. To test whether the game mechanisms differed in the cognitive domains activated according to expert's consensus, we focused only on mechanisms which were present in, at least, three games. We show the results at Table 4. To sum up, all the mechanisms except for pattern building were associated with at least one cognitive domain. All the results must be interpreted in the same way. Games with that mechanism activated more than one concrete cognitive domain, according with expert's consensus.

----- Insert Table 4 here -----

Discussion

Modern board and card games are increasingly accompanied by educational labels, even therapeutic in some cases (to improve mental health outcomes), on their cognitive, emotional, and social benefits. However, few studies have been performed to confirm these statements (13,55–58). Usually, the first issue when researching or applying board games is how to select them. How do we decide that a particular game activates a specific cognitive/emotional process? Professionals usually trust in their own knowledge, deciding only with one opinion, their own. We propose an initial solution in the present study. Multiple people deciding, minimize subjective bias and increase the likelihood of making better decisions. When making choices about mental health

questions (and also in other fields, such as in education), clinical/individual decisions are usually worse than actuarial/scientific judgements (59,60). So, for approximating to an actuarial perspective, we designed a methodology of experts consensus.

The first step was assessing the consistency of the experts rating each concept (cognitive process in our case) and game (61). Following the standard procedure (61,62), we found that most of the processes achieved a good level of reliability. In fact, Hallgren(62) proposed that, for maximizing inter-rater reliability: i) all the sample (of games in our case) should be rated by all the experts; ii) the system of ratings should be Likert-type scale; iii) the assessment should not have any restriction of range (what we achieved by selected very different games that were suspected to activate very different cognitive processes); iv) a considerable amount of training should be done to the experts to homogenize their criteria. We overcame these issues in the present study, so we can be confident that the cognitive processes were analyzed in a homogenous way, minimizing the subjective and initial background bias of the experts.

Visser & Swank(63) pointed that a committee of experts with only open discussions will facilitate that members of the group often feel a pressure to conform. This issue was not present in the present study, because experts rated the games independently and without sharing information among them. In addition, we propose a statistical procedure to finally select the games according to the cognitive profile by checking the median as central tendency statistic and the interquartile range for measuring the variability (64). An interquartile range of 0 means that there is no variability in the middle of the data (64). Thus, deciding which game we choose to intervene in a cognitive process should require the higher median (3 in our Likert scale) and the lower interquartile range possible (0). As show at Table 4 and summed up in the results section, several games could be chosen maximizing these criteria. For better

understanding how an expert consensus methodology could be useful, we analyzed the percentage of agreement between the hypothetical cognitive domain of each game before the analysis and the results of the expert consensus. The moderate coincidence between both highlights the limitation of single decisions favoring the expert committee methodology. The present results are in line with past studies that showed that the expert method is valuable in selecting playful methodologies to be used in prevention and intervention procedures (18,65,66).

As an exploratory procedure, we analyzed whether specific game mechanisms differed in the amount of activation of each cognitive domain according to the analysis by the experts committee. Some results could be considered as obvious. Games with the real-time mechanism (with all the players playing at the same time (54,67)) activated more the processing speed cognitive domain than games without it. However, other results are more surprising. According to the Board Game Geek (67), the pattern recognition mechanism should activate the reasoning cognitive domain, but our results showed no significant difference in reasoning. On the contrary, games with pattern recognition activated more basic executive functions, such as cognitive flexibility and inhibition. This result could be in line with Diamond(46) proposal of separating executive functions in basic and complex. Following Sousa et al.(53) suggestion, an expert consensus methodology could help us knowing better how game mechanisms are linked to psychological outcomes, such as cognitive domains. As far as we know, this is the first time that any study analyzes the associations between game mechanisms and cognitive domains. We encourage scientific studies in this line.

Limitations

The present research is not an experimental design, so it makes a low contribution to the level of evidence(68,69) in the association between game

mechanisms and cognitive processes. The present research gave us the first evidence about the relation between game mechanisms (and playing the game itself) with cognitive processes. But, it is necessary to support these results with quantitative data from correlational and experimental studies that allow us to know the relationship between these games' execution and the player's performance in neuropsychological tasks that evaluate these cognitive processes. These types of studies have been used in serious videogames with good results(70). However, the experts consensus is the much faster methodology to begin deciding how to select games without relying in the opinion of one only person, and it is the easiest methodology for professional settings.

The board games were selected according to past studies, but also broadening their number and variety to apply them to future interventions. However, the selection was intentional, non-random and with no other criteria than the subjective opinion of two authors of the present study. A better procedure should be the one proposed by Sousa et al.(53). However, the present study was developed before Sousa et al.'s proposal. Future studies should take into consideration their flowchart (53), focusing on Board Game Geek (67) stats.

Conclusion

To sum up, the present study proposed a methodology for selecting board games according to the cognitive process that are intended to activate. According to the present study, in professional and in research settings, several steps must be performed to select a game: 1) educate all the experts in the cognitive processes that they must analyze; 2) make experts play at least three times to have enough experience with the game; 3) use a well validated rating scale (Likert-type); 4) before analyzing medians, focus on the reliability of experts regarding the cognitive processes; 5) select the game with the higher median and lower interquartile range; 6) finally, consider other factors such as

number of players, enjoyment of the game and specific mechanism (using Board Game Geek ratings such as Sousa et al.(53) proposes), etc. The present methodology opens the doors to study the associations between game mechanisms and cognitive domains.

Considering that several mental health conditions show deficits in the cognitive processes investigated in the present study (See Table 1), selecting suitable games for each cognitive domain is one of the most important decisions when performing game-based interventions. Furthermore, future studies should include other elements to improve the playability of the games. For example, Sato and de Haan (71) experienced different ways of explaining the rules. This is a critical topic for populations with cognitive deficits, where players would have even more problems understanding how to play the game. How to adapt the game to populations with different characteristics is another topic derived from present and past research.

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Authorship confirmation statements:

Nuria Vita-Barrull: She was the grant holder of the Industrial Doctorate. She designed the project and executed it. She also wrote the manuscript and was implied in all the tasks to develop the project. She also reviewed and approved the final version of the manuscript.

Jaume March-Llanes: He led the study design and the data analyses. He also reviewed and approved the final version of the manuscript.

Núria Guzmán: She coordinated the committee as an expert in the field. She also reviewed and approved the final version of the manuscript.

Maria Mayoral: She helped in writing and reviewing the manuscript.

Jorge Moya Higuera: He coordinated the committee and all the research. He helped in the writing of the final version of the manuscript.

Conectar Jugando Experts Committee: they assessed all the games and reviewed the final version of the manuscript.

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Table 1. Definitions of the executive functions (EF) assessed and deficiencies found in different mental health problems.

	<i>COGNITIVE DOMAIN</i>	<i>DEFINITION</i>	<i>DEFICIENCIES IN MENTAL HEALTH PROBLEMS</i>
<i>Basic Cool EF</i>	<i>Verbal working memory</i>	<i>Ability to maintain, manipulate and update linguistic information.</i>	<i>ADHD (1); Antisocial Disorder (2); Depression (3,4); Paediatric depression (5); Alzheimer disease (6); PTSD (7); Dyscalculia (8)</i>
	<i>Visuospatial working memory</i>	<i>Ability to maintain, manipulate and update information from visual and spatial stimuli.</i>	<i>ADHD (1,9); Antisocial Disorder (10); Depression (3); Mild cognitive impairment (MCI) (6)</i>
	<i>Verbal short-term memory</i>	<i>Ability to keep linguistic information in mind for a short time.</i>	<i>PTSD (7); Dyscalculia (8)</i>
	<i>Visuospatial short-term memory</i>	<i>Ability to keep visual and spatial information in mind for a short time.</i>	<i>ADHD (9)</i>
	<i>Inhibition</i>	<i>Ability to inhibit automatic responses when necessary.</i>	<i>ADHD (1), Parkinson's disease (11); Schizophrenia (12); Paediatric depression (5); Addiction (13)</i>
<i>Complex Cool</i>	<i>Cognitive flexibility</i>	<i>Ability to shift the focus of attention between multiple tasks, operations, or mental sets.</i>	<i>ADHD (1); Depression (3,4); Parkinson's disease (11); Autism (14); Schizophrenia (12); Paediatric depression (5); Alzheimer disease (6)</i>
	<i>Planning</i>	<i>Ability to formulate, evaluate and select the actions necessary to achieve a goal.</i>	<i>ADHD (1); Psychopathy (15); Parkinson's disease (11);</i>

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Hot EF
Other related cognitive domains

		<i>Autism (14); Schizophrenia (12); Depression (4)</i>
Reasoning	<i>Ability to make associations between elements so that generalizations can be reached. It allows making logical deductions based on the information available.</i>	<i>ADHD (1); Psychopathy (16); Alzheimer disease (6)</i>
Problem-solving	<i>The process of working through the details of a problem to find a solution.</i>	<i>Schizophrenia (12)</i>
Affective decision-making	<i>Selection process of one or more possible options under a particular risk in which rational and emotional processes are used.</i>	<i>Parkinson's disease (11), Schizophrenia (17)</i>
Processing speed	<i>Result of the time required to perceive and process the information and prepare and execute a response.</i>	<i>Mild cognitive impairment (MCI) (6)</i>
Verbal fluency	<i>Ability to retrieve linguistic information from long-term memory from phonological (sounds) and semantic (categories) elements.</i>	<i>Parkinson's disease (11); Paediatric depression (5); Alzheimer disease (6)</i>

Note. ADHD: Attention Deficit and Hyperactivity Disorder; PTSD: Posttraumatic Stress Disorder

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Table 2. Average Measure Intraclass correlation coefficients of each modern board or card game and for each cognitive domain

Modern board or card game	Intraclass correlation
Bee Alert	.97
Connect the Thoughts	.95
Blurple	.96
Brain Connect	.96
Chakra	.94
CLACK!	.96
Dice Academy	.95
Halli Galli	.95
Piraten kapern	.93
Kaleidos Junior	.89
Layers	.92
Look around	.91
Magic mandala	.93
Magic fold	.94
Monster Match	.92
Streams	.91
Ohanami	.93
Catch the Match	.93
Le Roi Sommeil	.94
Pickomino	.89
Barnyard Buddies	.92
Saboteur	.94
Sherlock Express	.92
Shrimp	.94
Speed cups	.94
Supertaki	.92
Alles Tomate!	.94
Cognitive Domain	Intraclass correlation
Verbal working memory	.87
Visuospatial working memory	.81
Verbal short-term memory	.76
Visuospatial short-term memory	.88
Inhibition	.91
Cognitive flexibility	.51
Planning	.96
Reasoning	.84
Problem-solving	.74
Affective decision making	.94
Processing speed	.98
Fluency	.99

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Table 3. Medians and interquartile ranges of the cognitive domains assessed in modern board and card games' selection

Game	Verbal WM M (IR)	Visuospatial WM M (IR)	Verbal STM M (IR)	Visuospatial STM M (IR)	Inhibition M (IR)	Flexibility M (IR)	Planning M (IR)	Reasoning M (IR)	Problem- solving M (IR)	Affective decision- making M (IR)	Processing speed M (IR)	Fluency M (IR)	Matching (Y/N)
Alles Tomate!	2.5 (3)	2 (1)	1 (2)	2 (1)	2 (1)	1 (2)	0 (0)	0 (0)	0 (1)	0 (0)	3 (1)	2 (2)	Y
Barnyard Buddies	0 (1)	1 (3)	0 (0)	1 (2)	2 (0)	2 (1)	1 (1)	1.5 (2)	0 (1)	0 (0)	3 (0)	0 (0)	Y
Bee Alert	0 (0)	3 (1)	0 (1)	3 (1)	1 (1)	1.5 (1)	0 (0)	0 (1)	0 (0)	0 (1)	0 (0)	0 (0)	Y
Blurble	2 (3)	0 (0)	1 (2)	0 (0)	1.5 (1)	1 (1)	0 (0)	0 (1)	0 (0)	0 (0)	3 (1)	3 (0)	Y
Brain Connect	0 (0)	2 (2)	0 (0)	1 (1)	0 (1)	1.5 (2)	3 (0)	2.5 (1)	2 (2)	0 (0)	3 (1)	0 (0)	N
Catch the Match	0 (1)	1.5 (3)	0 (1)	1.5 (1)	2 (0)	2 (1)	.5 (1)	0 (1)	0 (1)	0 (0)	3 (0)	.5 (1)	Y
Chakra	0 (0)	1 (2)	0 (0)	1 (2)	1 (1)	2 (1)	3 (0)	2 (2)	1.5 (3)	1 (1)	0 (1)	0 (0)	Y
CLACK!	0 (0)	2 (1)	0 (1)	1.5 (1)	2 (1)	2 (1)	0 (0)	0 (1)	0 (0)	0 (0)	3 (0)	0 (0)	Y
Connect the Thoughts	0 (0)	1.5 (2)	0 (0)	1.5 (1)	1 (1)	1.5 (1)	.5 (1)	0 (1)	0 (0)	0 (0)	3 (0)	0 (0)	N
Dice Academy	2 (3)	0 (1)	1 (1)	0 (1)	2 (1)	2.5 (1)	0 (1)	.5 (1)	0 (0)	0 (0)	3 (1)	3 (0)	Y
Halli Galli	0 (0)	1.5 (3)	0 (0)	1 (2)	3 (1)	2 (2)	0 (0)	0 (1)	0 (2)	0 (0)	3 (0)	0 (0)	Y
Kaleidos Junior	2 (2)	2 (3)	1.5 (3)	1.5 (2)	1 (2)	2.5 (2)	1 (1)	1.5 (2)	0 (1)	0 (0)	3 (0)	3 (1)	Y
Layers	0 (0)	3 (2)	0 (0)	2 (2)	1 (1)	2 (2)	2 (2)	.5 (3)	2 (2)	0 (1)	3 (1)	0 (0)	N
Le Roi Sommeil	0 (1)	3 (1)	0 (0)	3 (1)	1 (1)	2 (2)	0 (1)	0 (0)	0 (0)	1 (2)	1 (1)	0 (0)	Y
Look around	2 (2)	.5 (2)	1 (2)	0 (1)	1 (1)	2 (2)	0 (1)	1 (2)	0 (1)	1 (1)	3 (1)	3 (0)	Y
Magic fold	0 (0)	3 (2)	0 (0)	3 (3)	1 (0)	3 (1)	2 (1)	2 (2)	2 (1)	1 (2)	3 (1)	0 (0)	N
Magic mandala	0 (0)	3 (2)	0 (0)	2 (2)	1 (1)	1 (1)	1.5 (2)	1 (2)	1.5 (2)	0 (0)	3 (1)	0 (0)	N
Monster Match	0 (1)	1 (2)	0 (1)	2 (1)	2.5 (1)	2 (1)	1 (1)	.5 (1)	0 (1)	.5 (2)	3 (0)	0 (0)	Y
Ohanami	0 (0)	1.5 (2)	0 (0)	0 (2)	0 (1)	2 (0)	3 (1)	2 (1)	.5 (2)	2 (1)	0 (1)	0 (0)	Y
Pickomino	0 (0)	.5 (1)	0 (0)	0 (1)	1 (2)	1.5 (1)	1 (2)	2 (2)	1.5 (3)	3 (1)	0 (1)	0 (0)	Y
Piraten kapern	0 (0)	0 (1)	0 (0)	0 (0)	1 (2)	2 (2)	2 (1)	2 (3)	2 (2)	2.5 (1)	0 (1)	0 (0)	Y
Saboteur	0 (0)	0 (2)	0 (0)	1 (1)	.5 (1)	2 (1)	3 (0)	2 (1)	2 (1)	3 (1)	0 (1)	0 (0)	Y
Sherlock Express	0 (1)	2 (2)	0 (1)	2 (2)	2 (1)	2 (1)	0 (1)	2 (1)	1 (2)	0 (0)	3 (0)	0 (0)	N
Shrimp	0 (1)	1.5 (2)	0 (1)	1 (2)	3 (1)	3 (1)	0 (1)	.5 (2)	0 (1)	.5 (1)	3 (0)	0 (1)	Y
Speed cups	0 (0)	2 (3)	0 (0)	2 (2)	1 (1)	2 (2)	2 (2)	0 (2)	0 (2)	0 (0)	3 (0)	0 (0)	Y
Streams	0 (0)	0 (1)	0 (1)	0 (0)	1 (1)	2 (2)	2.5 (1)	2 (1)	1.5 (2)	2 (2)	0 (1)	0 (0)	Y
Supertaki	0 (0)	1 (1)	0 (1)	0 (1)	0 (1)	3 (1)	2 (1)	1 (1)	1 (2)	2 (1)	1 (0)	0 (0)	Y

Note. WM: Working memory; STM: Short-Term Memory; M: Median; IR: Interquartile Range; Matching: match between the criteria for preselecting the games with the final median from the committee; Y: Yes; N: No

Table 4. Differences in cognitive domains between games with specific mechanisms.

Cognitive Domain	Memory (N=3)		Pattern building (N=7)		Set collection (N=3)		Pattern recognition (N=11)		Real-time (N=12)		Lose a turn (N=5)	
	U	d	U	d	U	d	U	d	U	d	U	d
Verbal working memory	44.00	.18	65.50	.10	28.50	.22	86.50	.03	73.00	.32	58.00	.07
Visuospatial working memory	63.50**	.84	75.50	.12	20.50	.47	110.00	.43	128.50	.78	61.50	.16
Verbal short-term memory	41.50	.11	65.50	.10	28.50	.22	89.00	.02	73.00	.32	55.50	.01
Visuospatial short-term memory	67.50**	.93	66.50	.08	14.50	.67	113.00	.49	127.50	.75	72.50	.43
Inhibition	37.50	.00	47.00	.51	18.00	.55	142.00**	1.20	106.00	.30	106.00***	1.55
Cognitive flexibility	16.50	.62	41.50	.64	45.00	.27	129.50*	.86	81.00	.17	58.00	.07
Planning	10.50*	.82	94.50	.54	65.00*	.96	56.50	.63	87.00	.06	21.50*	.88
Reasoning	9.00*	.87	58.50	.25	61.50*	.82	78.50	.18	84.50	.10	40.50	.35
Problem-solving	18.00	.57	78.00	.17	55.50	.61	65.50	.44	91.00	.02	34.50	.51
Affective decision making	29.50	.23	58.00	.26	61.50*	.82	62.00	.51	49.50*	.82	42.00	.32
Processing speed	25.00	.36	72.50	.05	6.00*	1.00	137.50*	1.065	144.00**	1.18	77.50	.56
Fluency	39.00	.04	63.50	.14	27.00	.27	95.00	0.13	68.50	.41	52.00	.07

Note. N = number of games with that mechanism. U = U of Mann-Whitney test. d = Cohen's D statistic. $0 < d < .20$ = null effect; $.20 < d < .50$ = small effect; $.50 < d < .80$ = intermediate effect; $d > .80$ = large effect. Total number of games = 27. According to the Board Game Geek (67) and Engelstein & Shalev (53) the mechanisms are define as Memory ("Hidden, trackable information whose tracking gives players an advantage"), Pattern building ("Players must configure game components in sophisticated patterns in order to score or trigger actions"), Set collection ("The value of items is dependent on being part of a set"), Pattern recognition ("Players must recognize a known or emergent pattern created by the game components to gain objectives or win the game. This could for instance involve markers, typically with a color or symbol, placed to certain locations on a board, or relative to the other markers, forming an abstract or meaningful pattern, requiring deductive reasoning by players to determine its significance", Real-time ("There are no turns. Players play as quickly as possible, subject to certain constraints, until the game or phase is completed"), Lose a turn ("A player who "Loses a Turn" must skip their next opportunity for a turn, and will go to the next round, or the next time their turn arises").



Figure 1. Radial plots of the cognitive profiles from some multidomain board and card games.

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Note: 1=Basic Cool Executive Functions; 2=Complex Cool Executive Functions; 3=Hot Executive Functions; *=Other related cognitive domains. WM = Working Memory; STM = Short-term Memory; Affective D-M = Affective Decision Making

Supplementary Information

Previous training for experts: Introduction to executive functions

CONTENTS:

BLOCK 1 - What are executive functions?

- 1.1. Definition
- 1.2. Importance of EF in our daily lives
- 1.3. Classification

BLOCK 2 – Cool executive functions

2.1. Basic cool EF

2.1.1. Working memory: Baddeley multicomponent model, neural bases, examples of daily life, assessment instruments (verbal and visuospatial WM)

2.1.2. Inhibition and Flexibility: Definition, everyday example, evaluation instruments.

2.2. Complex cool EFs

2.2.1. Planning: Definition, daily example, evaluation tools.

2.2.2. Reasoning and problem solving: Definition, everyday example, evaluation tools.

BLOCK 3. Hot executive functions

Affective decision-making and delay discounting: Definition and assessment instruments.

BLOCK 4 - Related cognitive processes

4.1. Processing speed: Definition and assessment instruments.

4.2. Verbal fluency: Definition, types (phonological, semantics) and assessment instruments.

FINAL ACTIVITY

The experts were asked to record 3 videos of 2 minutes explaining some examples of daily life of the cognitive domains worked on in the training:

- Video 1: Basic cool executive functions (working memory, inhibition and flexibility)
- Video 2: Complex cool executive functions (planning, reasoning, and problem solving)
- Video 3: Hot executive functions (affective decision making and delay discounting)

In addition, we prepared the following 10 questions to test whether the expert's understood all the executive functions they were intended to analyze.

1. Select which of the following statements is false
 - A. When we replace old (and no longer relevant) information in reference to the spatial orientation of an element with relevant new information, we are working on visuospatial short-term memory.

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- B. the upgrade process is part of the working memory
 - C. The maintenance of linguistic information is what is known as verbal short-term memory .
 - D. Tasks such as memorizing a phone number , taking notes at a conference or orienting ourselves geographically involve activating working memory
2. Irene has a doctor's appointment at 11.30am. Before going to the doctor you need to run some errands. To optimize time and get to everything, he has designed a route with which you can pass through each of the sites without making your doctor wait. What process has Irene put in place in the design of this route?
- A. Planning
 - B. Update
 - C. Delay discounting
 - D. Inhibitory control
3. Jorge is thinking about investing his savings so that they can give him benefits and is weighing different options. The Rayyane company offers you small profits but a very low risk of loss. On the other hand, investing in the company SPSSando can get a lot of money in a short period of time, although they do not guarantee that you will keep your money if things get complicated. What process will Jorge activate in this situation?
- A. Affective working memory
 - B. Affective decision-making
 - C. Processing fluidity
 - D. Concurrent planning
4. Select the correct option
- A. When we control an automatic impulse to behave in an adapted way we are using our capacity for inhibition.
 - B. Shifting the focus of attention from one task to another involves activating cognitive flexibility.
 - C. All of the above are correct.
 - D. Cool executive functions are those that are activated in decontextualized situations (without emotional charge).
5. Carlos has his co-worker waiting for him in the portal to go to work together and has told him that if he does not go down in 5 minutes he will leave without him. Before going down you should find your laptop where the report you deliver today to your boss is stored. But his roommate was cleaning and has left him a note where he says he is in his room without specifying where. What cognitive process will Carlos start to find his laptop among all the junk in his room before his partner leaves?
- A. Affective decision-making
 - B. Inhibitory control
 - C. Processing speed
 - D. Cognitive flexibility
6. Zaka and Ariadne are in a school competition that aims to promote knowledge of the language. In the first test, the presenter will say a word to each team and they must spell it correctly to take a point. In the second test, a common category will be offered for both teams and participants will have to write on paper as many words as they can think of in relationship with that category. What processes will Zaka and Ariadne activate in each test?
- A. Verbal short-term memory in the first and planning in the second.
 - B. Verbal working memory in the first and processing speed in the second.
 - C. Verbal working memory in the former and semantic fluency in the latter.
 - D. Verbal short-term memory in the first and phonological fluency in the

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second.

7. Select the claim that is false
 - A. The Stroop task in which the color of the word must be said without reading it is known in the evaluation of inhibition and updating.
 - B. All of the above are true.
 - C. Planning and reasoning are complex cool executive functions and have been considered synonymous with fluid intelligence.
 - D. The tendency to prefer future major rewards over immediate minor rewards is what is known as delay discounting.

8. Jaume has always worked from 9 a.m. to 1 p.m. since he started in the company. For a month now, the new management has decided to change the working hours from 8 a.m. to 12 p.m. Even so, Jaume continues to arrive every day at 9 and leaves at 13h as he did before. What process should Jaume activate to adapt to the new situation?
 - A. Cognitive flexibility
 - B. Planning
 - C. Affective decision-making
 - D. Processing speed

9. Veronica has swapped her 5-speed car for a 6-speed car this past week. This morning he was going to take his car out of the parking lot in reverse and the car has been dropped because he has put the sixth gear instead of the mark back. What process has been affected in this situation?
 - A. Processing speed
 - B. Cognitive flexibility
 - C. Verbal short-term memory
 - D. Inhibitory control

10. Select the correct option
 - A. Affective decision-making assessment tasks involve the selection of risk-free options
 - B. Verbal working memory only allows us to maintain linguistic information, but not manipulate it.
 - C. Reaction time is a measure of processing speed
 - D. Hot executive functions are not affected by motivational and emotional processes

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MATERIALS

The resources were entirely designed by the research group for this training and were available on the university's virtual campus platform (only committee members had access). These were:

- Visual PDF presentations of each content block
- Explanation in text accompanying the presentations
- Evaluation test simulators to experiment and integrate concepts
- Summary table of all the concepts worked with basic definitions, everyday examples and the tests used to measure each cognitive domain
- Final evaluation: 10 test questions with 4 answer options on the concepts worked on to detect possible doubts about the theory. The coordinating team provided feedback on the results prior to the start of the evaluation of the games.

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Table S1. Description and characteristics of modern board and card games

Games (Author, date)	Description	Recommended age	Duration	Main cognitive domain
Alles Tomate! (1)	In this farm-based game, the goal is to be the quickest to say the item's name that appears on the flip card in each category. After each correct answer, the card is replaced by a new one, so they must update the information.	+6	15 min	Working memory
Barnyard Buddies (2)	The objective of this card game is to identify the card that meets the color and animal conditions indicated by the target card. We can find five different animals and five different colors in the cards. Four animals of four colors will appear on the target card, and the missing animal of the missing color must be found.	+4	15 min	Reasoning
Bee Alert (3)	A series of colored bees are hidden under their hives. Players must memorize their starting position. According to the card obtained in each turn, players will have to: a) bee card, find the hive in which the bee is the color of the card; b) hive card, take any hive from the center of the table or the space of another player; c) bear card, return a hive to the center of the table. The player who gathers four hives wins the game.	+4	15 min	Working memory
Blurble (4)	This game has numerous cards with different elements in each one with which the players will challenge themselves to vocabulary duels. When the player is the "Blurble," he/she challenges the rest of the players one by one showing one of the cards from the deck and trying to be the fastest by saying a word that begins with the same letter as the elements shown.	+8	15 min	Verbal fluency

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Brain Connect (5)	Each player has an individual panel with different moving parts. The game consists of turning over a card from the deck and connecting the two (or more) points of the board indicated by the card by moving the panel pieces as fast as possible.	+8	20 min	Problem solving
Catch the Match (6)	Attention game and recognition of shapes and colors with two game modes: In one, you draw two cards, and you have to look for a single identical object. On the other hand, the objects are larger, but you have to find two instead of one. The player with the most cards at the end of the game is the winner.	+5	15 min	Processing speed
Chakra (7)	The players have an individual board where the seven chakras are represented that must "harmonize" using small colored gems. To do this, they will need three crystals of the color corresponding to the chakra they wish to harmonize, considering that they have limited actions.	+8	30 min	Planning
CLACK! (8)	Each of the 36 discs with magnets combines three symbols with three different colors. The player must roll a dice and find the symbol and color indicated on the discs to catch the maximum number of discs with that combination.	+4	10 min	Processing speed
Connect the Thoughts (9)	All the cards are placed face down in the center of the table, and a buzzer is placed. The players must take a card from the center and link cards in which at least one of the elements matches as quickly as possible until they get seven linked cards.	+5	15 min	Inhibition
Dice Academy (10)	Vocabulary game in which category dice and letter dice are thrown. Players must find words from associations between categories and letters in sight, avoiding matching dice of the same color.	+8	15 min	Verbal fluency

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Halli Galli (11)	Each player has a deck of cards face down and must turn their cards one by one in turns. The cards contain different amounts of fruits. Players must press the bell as quickly as possible when five fruits of the same type can be counted among the exposed cards. The fastest player takes all the cards to his deck.	+6	15 min	Inhibition
Kaleidos Junior (12)	The players have illustrations with many different elements and transparent pieces of different colors for each player. A roulette wheel is turned that indicates the objective of all the players, for example, something round, something that begins with the letter L, something liquid, and the players must mark with their pieces all those elements of the illustration that meet the roulette condition in a limited time.	+4	30 min	Processing speed
Layers (13)	In this game, players have different color and shape patterns with which they must copy the target pattern by superimposing layers. There are three levels of difficulty depending on the number of layers needed to represent the pattern. The fastest players to reproduce the design get the most points.	+8	30 min	Reasoning
Le Roi Sommeil (14)	In this game, a royal family will continuously change their position and clothes, and the players will have to remember all this information to obtain the most significant number of coins. Every time a royal family member appears, he stands on one of the beds, and this one moves to the right of the row of beds. If that member appears again, he covers the previous card with the new one and may have changed the color of his pajamas. When the ghost card appears, all beds are covered, and players will bet which member is on which bed and what color their pajamas are.	+5	10 min	Working memory

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Look around (15)	Card game in which different elements are shown on one card and one letter on another. Players must say a word that begins with the letter delivered and matches one of the elements shown or one of its characteristics.	+8	15 min	Verbal fluency
Magic mandala (16)	Pattern game in which players rotate and overlap different layers of mandalas to reproduce the pattern indicated on the target card.	+6	15 min	Reasoning
Magic fold (17)	The objective of this game is to be the first to reach the sky palace in a flying carpet race. Each player has a small cloth mat on which different pictures appear with different colors. To advance in the race, players must reproduce the patterns on the target cards with their mats. To do this, they will fold along the edges marked on the mat (by squares, never diagonally) until only the elements indicated on the card are visible and in the correct position.	+7	20 min	Problem solving
Monster Match (18)	Card game in which players must recover as many donuts as possible that have been stolen by monsters. Ten monster cards are placed in the center of the table in which you can see how many donuts you have and a die with body parts, and a die with numbers from 0 to 5 are rolled. The dice indicate which monster should be located. For example, if the dice show eyes and a 5, a monster with five eyes must be found, and players must place their finger on a card that shows a monster with five eyes. This process is repeated until the deck of cards is finished and the player with the most donuts wins.	+6	10 min	Inhibition
Ohanami (19)	Draft card game in which players build a garden that gives them the highest possible number of points in three rounds. Only cards of one color score in the first round. In the second round, two colors	+8	20 min	Flexibility

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score, and in the third, all are scored. In the construction of the garden, the numbers on the cards must be respected, only being able to place a card that shows a number lower than the lowest number already placed or higher than the highest number already placed.

Pickomino (20)	In this game, the player must roll the dice by selecting in each roll those that interest him most and throwing the remaining ones again. The resulting number of launches will be the piece of worms you must take. If there is no worm in the dice or the corresponding number is not available, the player loses his turn. The winner is the player with the highest number of worms at the end of the game.	+8	15 min	Affective decision making
Piraten Kapern (21)	Card and dice game in which players must get the maximum possible number of points to win the game. To earn points, players must consider the conditions of each turn's target card and manage their dice throws according to that condition.	+8	30 min	Affective decision making
Saboteur (22)	A hidden role-playing game in which players must reach a hidden treasure by digging in a mine while a saboteur tries to prevent them from getting the gold. The miners must discover which door the treasure is hidden behind and build the path in turns. But the saboteur will use his actions, either building in the wrong direction to waste their time, destroying their way, or blocking other players so that no one has managed to reach the treasure at the end of the game.	+8	30 min	Affective decision making
Sherlock Express (23)	Deduction game in which the players will be Sherlock's assistants to discover the culprit of 6 suspects. To find the culprit, they will turn over alibi cards, which will indicate who could not have been	+7	10 min	Problem solving

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the culprit. Alibi cards can show settings, characters, or accessories.

When only one possible culprit can be left after discarding the suspects with the alibis, players will place their finger on the culprit and take the card if they have hit the nail on the head. Whoever gets five cards first will be the winner.

Shrimp (24)	Card game in which players must meet five conditions: quantity, size, color, nationality, and the sum of 7 (prawn cocktail). The cards show shrimp that can vary under the specified conditions, and when all the cards in sight match at least one of the conditions, players will need to press a lemon as a buzzer and explain which condition matches.	+7	20 min	Flexibility
Speed cups (25)	Each player has five colored cups and must place them in the position indicated by the target card as quickly as possible.	+6	15 min	Planning
Streams (26)	Numerical ordering game in which the players must place in a row of 20 spaces, 20 numbers from 1 to 30 that will appear in random order, trying to follow as long ascending sequences as possible.	+7	10 min	Planning
Supertaki (27)	Card game in which players try to run out of cards as quickly as possible by connecting the cards by their color or number or by performing special actions that will affect the rest of the players.	+6	20 min	Flexibility

Note. The last column of the table specifies the cognitive domain that was considered to be the most significant in each preselected game before the experts' assessment. For the choice of games, the team that coordinated the committee tried to choose the same number of titles for each cognitive domain that in theory would work with them.

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