Universitat de Lleida

Interventions based on board games to improve working memory, executive functions, and other cognitive processes related across lifespan

Verónica Estrada Plana

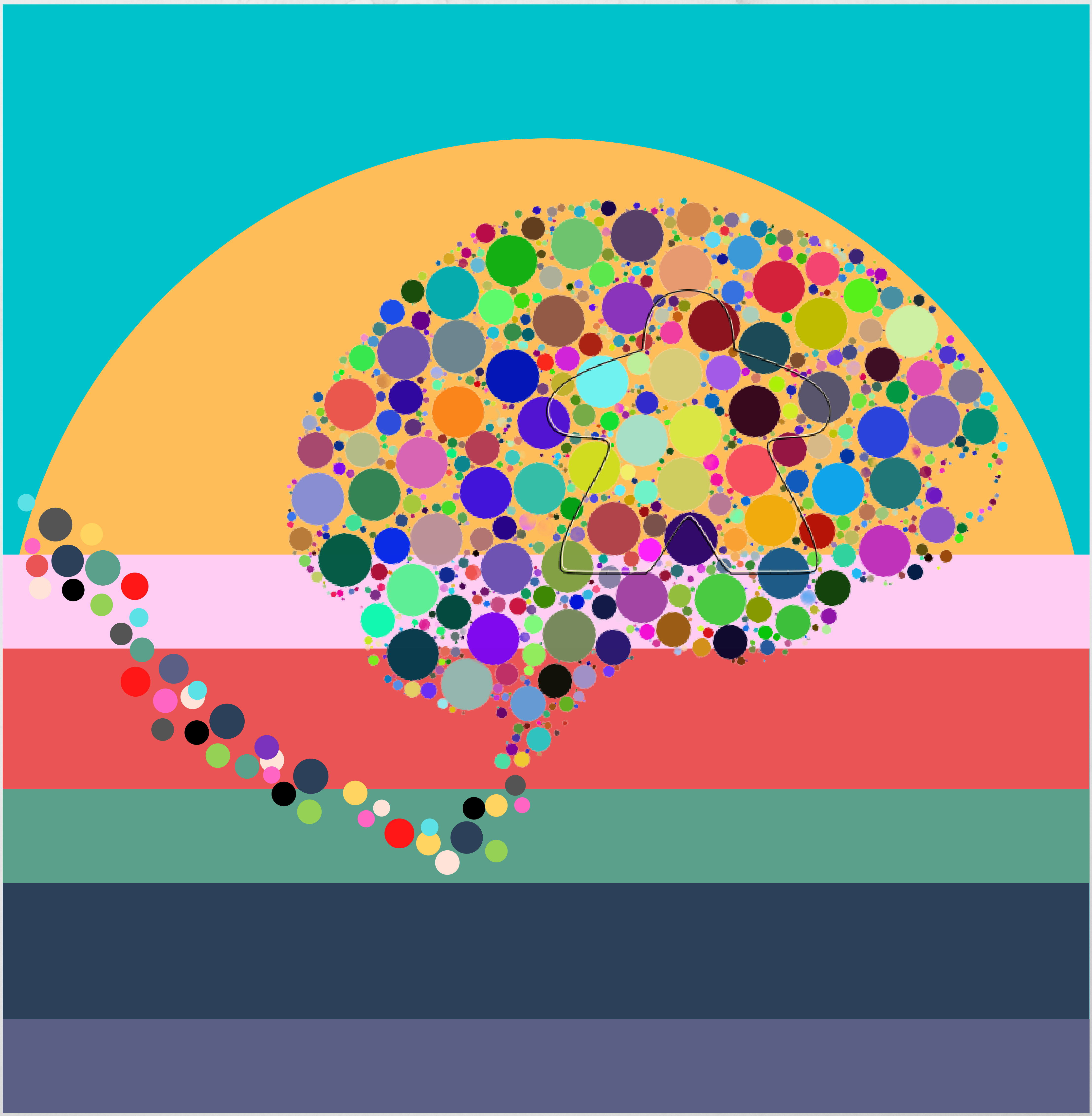
http://hdl.handle.net/10803/673011

INTERVENTIONS BASED ON BOARD GAMES TO IMPROVE WORKING MEMORY, EXECUTIVE FUNCTIONS, AND OTHER COGNITIVE PROCESSES RELATED ACROSS LIFESPAN

Verónica Estrada-Plana

Directed by Dr. Jorge Moya-Higueras and
Dr. Agnès Ros-Morente

UNIVERSITAT DE LLEIDA



Universitat de Lleida

TESI DOCTORAL

INTERVENTIONS BASED ON BOARD GAMES TO IMPROVE WORKING MEMORY, EXECUTIVE FUNCTIONS, AND OTHER COGNITIVE PROCESSES RELATED ACROSS LIFESPAN

Verónica Estrada Plana

Memòria presentada per optar al grau de Doctor per la Universitat de Lleida
Programa de Doctorat en Societat, Educació i Qualitat de Vida
2021

Director/a
Jorge Moya Higueras
Agnès Ros Morente

Tutor/a
Jorge Moya Higueras

“*Faculties thus developed certainly profit by this supplementary training which is free, intense, pleasurable, inventive, and secure. But it is never the function of play itself to develop these faculties. The purpose of play is play”*

Roger Caillois’s (1957) in Sala & Gobet (2017)

Acknowledgments

En un juego de mesa es importante conocer las diferentes piezas y reglas para comprender el objetivo del juego. Sin dichos elementos, no es posible entender cómo finaliza la partida. Como en un juego, cada una de las personas y las decisiones tomadas han marcado y dotan de sentido esta tesis.

En primer lugar gracias a ti, Jorge, por haberme acompañado desde mis inicios en esta carrera tan apasionante como es la investigación científica. Porque aún recuerdo ese mensaje en el Campus Virtual a todo el alumnado de Psicología que estuviera interesado en colaborar con el grupo. Porque ese mensaje y la rápida conexión que tuvimos –ha quedado patente en el *The Mind*®- hizo que los años hayan ido pasando sin darnos cuenta. Gracias por haber sido mi profesor, mi tutor, mi director, mi compañero y mi amigo.

Gràcies a tu també, Agnès, ja que el teu suport ha estat clau en diferents moments d'aquest camí científic tant meravellós com enrevessat (encara recordo una de les imatges que vas utilitzar en una presentació sobre el mapa de la recerca...).

I com no, a tu, Jaume, per aportar-me tots els teus coneixements i assessorar-me amb l'estadística. Com vas dir un dia, tant temps fent càlculs i gràfics i és la part que més ràpidament passa per sobre ... Però, com saps, sense aquesta part no hi haguera set possible.

Gràcies a la meva companya *predoc*, Nuria. Perquè des que ens vam conèixer, no van ser necessàries les paraules. Els dies al despatx han set massa curts al teu costat. Tant de bo que puguem continuar al despatx, encara que sapiguem que el camí no és fàcil…

També donar gràcies a totes les persones que han format part i formen part del grup de recerca *NeuroPGA*, en especial al Roger, l'Andrea, l'Ana, ... , ja que no només heu format part del grup, sinó que sense vosaltres no hagués estat possible aquesta tesi.

Donar també les gràcies a totes les persones que han col·laborat amb la tesi, ja sigui com a co-autors/es (Águeda, Maria, Núria, Rosa, Rocío, Montse...), com a assessors/es (Lu2, Eva...), o com a participants (tots els coles, persones i centres participants). Sense tots i totes vosaltres no hi haguera estat possible.

I gràcies a tots els professors i professores, mestres, amistats, que van fer que mai perdés l'interès per seguir aprenent. També agrair a totes les persones que m'han guiat i ajudat en el camí, segurament sense adonar-se'n.

A mis padres, mis abuelos, mi familia y mi familia faunística, por haberme enseñado el poder de la curiosidad, la observación y la paciencia. Sólo el tiempo me iba a explicar que el juego de mi infancia me enseñaría competencias fundamentales en la investigación. Y como no, a ti, *hermano*, por haber sido mi compañero de juegos.

Gracias a ti, Víctor, por tu visión crítica y constructiva. Por acompañarme, aconsejarme y ayudarme desde que decidimos ir por el mismo camino de la vida, sin soltarme de la mano, junto a mi lado. Porque sé que eres mi *muso*.

Y gracias a mis peques, Iván y Valeria, por recordarme a ver y entender el mundo desde la perspectiva de los ojos de un niñ@. Porque ellos son el motivo por el que mis ojos se iluminan.

Funding sources that made this dissertation possible:

Personal fellowship:

- Convocatòria d'ajuts de la Universitat de Lleida i Jade Plus per a personal predoctoral en formació per a l'any 2017

Project and group funding:

- To the Comissionat per a Universitats i Recerca del DIUE, Generalitat de Catalunya (2017SGR1577)
- To the Center for Biomedical Research Network on Mental Health (CIBERSAM)
- To the Spanish Ministry of Science, Innovation, and Universities (MICIU/FEDER; project RTI2018-099800-B-I00)

To everyone, I only can say you…

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Executive functions are a set of psychological processes key to our daily lives. Cognitive-focused interventions may improve them. The usage of ludic elements seems to increase the benefits of cognitive interventions. Thus, board games could be an interesting tool to be introduced in these interventions. The objective of the present dissertation was: i) Section 1: to review studies that assess the effectiveness of interventions based on board games; ii) Section 2: to test the effectiveness of interventions based on modern filler board games across the lifespan. Thus, we conducted a systematic review with meta-analysis and three experimental studies. 19 studies met inclusion criteria in the systematic review. Most of the studies included early and middle childhood and older people. Only 4 studies used modern board games. The majority of the studies reported some concerns, serious or high risk of bias. 12 studies were included in the meta-analysis. Only verbal STM in children showed significant results (g = 1.05, p <.001, 95% CI 0.47-1.63). Results from the experimental study conducted in children showed that specially math games improved Visuospatial STM and Updating-WM, Number Operation skills, and Number Ranking skills in third grade. In fourth grade, memory games improved their Problem-solving skills. In children with ADHD, modern filler board games improved verbal STM and conduct problems. In the pilot study conducted with older people, participants who played modern filler board games had a significant improvement in semantic verbal fluency compared to a passive control group. In the main study, both interventions –modern filer board games and paper-and-pencil tasks- showed significant improvements in phonemic verbal fluency, but only the game training group maintained the gains across time. In addition, whilst board games maintained impulsivity control, paper-and-pencil tasks improved speed in an inhibition task. To conclude, future studies should conduct well-designed randomized controlled trials.

RESUMEN

Las funciones ejecutivas son procesos psicológicos claves en nuestro día a día. Las intervenciones focalizadas en la cognición podrían mejorarlas. El uso de elementos lúdicos podría incrementar sus beneficios. Por tanto, incluir juegos de mesa en dichas intervenciones podría ser beneficioso. El objetivo de la presente tesis fue: i) Sección 1: revisar los estudios que evaluaban la efectividad de intervenciones basadas en juegos de mesa; ii) Sección 2: comprobar la efectividad de intervenciones basadas en juegos de mesa modernos a lo largo del ciclo vital. Por tanto, se llevaron a cabo una revisión sistemática con meta-análisis y tres estudios experimentales. 19 estudios cumplieron los criterios de inclusión en la revisión sistemática. La mayoría de los estudios incluyeron población infantil, escolar y personas mayores. Sólo 4 estudios incluyeron juegos de mesa modernos. La mayoría de los estudios mostraron un riesgo del sesgo moderado o alto. Sólo la memoria a corto plazo (MCP) verbal en población infantil/escolar mostró resultados significativos (g = 1.05, p <.001, 95% CI 0.47-1.63). Respecto al estudio experimental con población escolar, el alumnado de tercero mejoró la MCP y la memoria de trabajo visoespacial, así como el cálculo y ordenar números tras jugar a juegos matemáticos. A su vez, el alumnado de cuarto curso mejoró la resolución de problemas tras jugar a juegos de memoria. En el estudio que incluyó menores con TDAH se obtuvo que mejoraron la MCP verbal y los problemas de conducta tras jugar. En el estudio piloto con personas mayores, aquellos participantes que jugaron a juegos de mesa mejoraron la fluidez semántica. En el estudio principal, ambos grupos –juegos de mesa y fichas de papel y lápiz- mejoraron la fluidez verbal fonológica, aunque sólo se mantuvo en el grupo de juegos. A su vez, el grupo de juegos mantuvo el control de la impulsividad, mientras que el grupo de fichas mejoró la velocidad en una tarea de inhibición. Para concluir, se requieren futuros estudios con un diseño controlado aleatorizado.

RESUM

Les funcions executives són processos psicològics claus en el nostre dia a dia. Les intervencions focalitzades en la cognició podrien millorar-les. L'ús d'elements lúdics podria incrementar els seus beneficis. Per tant, la inclusió de jocs de taula en aquestes intervencions podria incrementar els seus beneficis. L'objectiu de la present tesi va estar: i) Secció 1: revisar els estudis que van avaluar l'efectivitat de les intervencions basades en jocs de taula; ii) Secció 2: comprovar l'efectivitat de les intervencions basades en jocs de taula moderns al llarg del cicle vital. D'aquesta manera es van dur a terme una revisió sistemàtica amb meta-anàlisi, així com tres estudis experimentals. 19 estudis van complir els criteris d'inclusió en la revisió sistemàtica. La majoria d'estudis inclosos es van dur a terme amb població infantil, escolar i persones grans. Només 4 estudis van incloure jocs de taula moderns. La majoria dels estudis van mostrar un risc de biaix moderat o alt. L'anàlisi meta-analític va mostrar resultats significatius en la memòria a curt termini (MCT) en la població infantil/escolar (g = 1.05, p <.001, 95% CI 0.47-1.63). Pel que fa a l'estudi experimental en població escolar, l'alumnat de tercer va millorar la MCT i la memòria de treball visuoespaial, així com el càlcul i l'ordenació de números. Tanmateix, l'alumnat de quart curs va millorar la resolució de problemes després de jugar a jocs de memòria. En l'estudi amb menors amb un diagnòstic de TDAH van millorar la MCT verbal i els problemes de conducta després de jugar. En l'estudi pilot amb persones grans, els participants que van jugar a jocs de taula van millorar la fluïdesa semàntica. En l'estudi principal, ambdós grups -jocs de taula i les fitxes de paper i llapis- van millorar la fluïdesa verbal fonològica, encara que només es va mantenir en el grup de jocs. A més a més, el grup de jocs va mantenir el control de la impulsivitat, mentre que el grup de fitxes va millorar la velocitat en una tasca d'inhibició. Per concloure, es requereixen estudis futurs amb un disseny controlat aleatoritzat.

1. INTRODUCTION

1.1. Executive Functions (EFs)

EFs have been largely studied in the last decades. It is widely accepted that there are fundamental psychological processes in daily activities and general life. However, what are EFs? How do they develop? For what are they important?

1.1.1. *Definition of EFs*

Luria (1973) was the first person that talked about EFs. Since then, EFs have been conceptualized and operationalized by different authors (Cristofori et al., 2019). Recently, EFs have been described as a set of cognitive processes that make it possible to follow a goal by controlling, directing, and coordinating other cognitive processes (Bull & Lee, 2014). EFs are not only important in cognitive tasks, but also socio-emotional and behavioral domains (Baggetta & Alexander, 2016a). Although, as Karr et al. (2018) stated, the EFs construct lacks a universal definition. However, Baggetta & Alexander (2016) tried to reach a consensus by reviewing different definitions of the construct in a systematic review. These authors investigated the conceptions of EFs in the literature. Among 106 studies, they classify definitions as explicit (59%) and implicit (41%). They analyzed in a wide extent explicit definitions with a word-level analysis. From this analysis, they extracted salient attributes and spheres of influence. Regarding salient attributes to describe the composition of EFs, the most included were: Cognitive processes (16), Higher-order cognitive processes (10), Processes (5), Cognitive abilities (4), Cognitive skills (3) or Higher-order processes (3). Regarding spheres of influence, EFs were related to some type of goal-oriented, goal-directed, or future-oriented action, behavior, or response, which involves the intentionality of doing something. In a lesser degree, EFs were related to: i) thought and action; ii) simple, complex and other related cognitive processes; or, iii) the self-regulation of emotions besides cognition and behaviors.

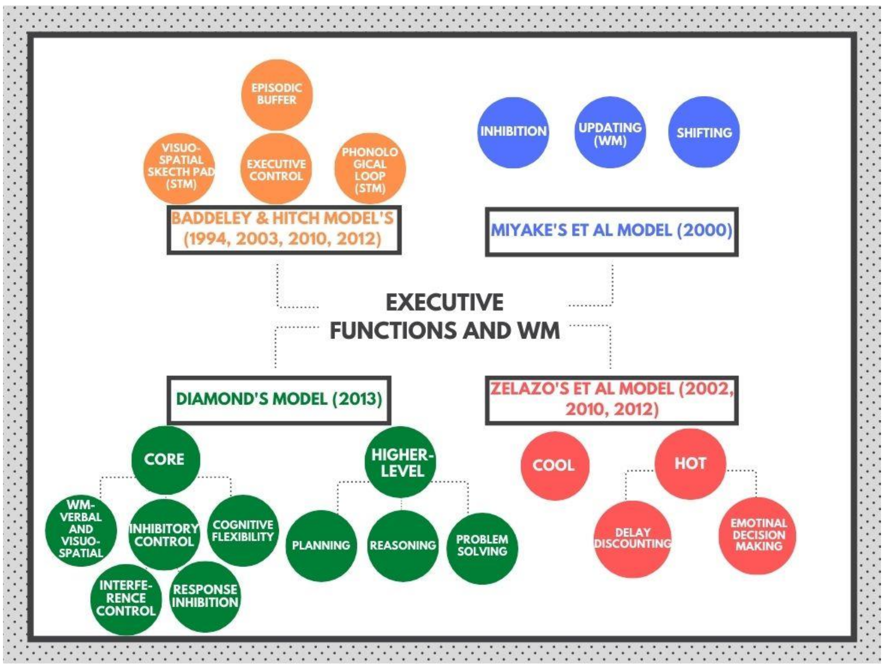
Taking into account all of these word-level analyses, EFs could be similar to an "*orchestra's director*" or an "*air traffic control*" that manage and control other cognitive processes to regulate our thought, behavior, and emotions to engage in purposeful and goal-directed behaviors (Cristofori et al., 2019; Miyake et al., 2000).

1.1.2. *Taxonomy and models of EFs*

Authors like Cristofori et al. (2019) consider that the EFs term is an umbrella to encompass the set of higher-order cognitive processes that are necessary to achieve a goal. Different authors have attempted to classify the psychological processes that are included in the construct of EFs. Different reviews (Baggetta & Alexander, 2016a; Cristofori et al., 2019) agreed that it is a complex and multi-dimensional construct that includes a range of psychological processes. Below, Figure 1 shows the most cited models of EFs (Baggetta & Alexander, 2016a). They appear in chronological order and with a conceptualization of their components.

Figure 1

Most cited models of EF and their components.



Model of Baddeley & Hitch (1974, 2003, 2010, 2012): Multi-component Working Memory model

The most widely accepted model of Working Memory (WM) is the multicomponent WM's model of Baddeley (2010). This is the model that fits better in school age-children (Alloway et al., 2006). The concept of WM evolved from the Short-Term Memory (STM) term (Baddeley, 2012), which is understood as the storage of information for brief periods (Baddeley, 2010). Thus, the first version of this model of WM included two temporary components: the phonological loop which is related to the storage of verbal information, and the visuospatial sketchpad which is related to the storage of visuospatial information (Baddeley, 2003, 2010). Afterward, the model also included the central executive which is related to the attentional control/supervisory system and the manipulation of information (Baddeley, 2003, 2010). Executive-loaded WM tasks can be divided into complex WM tasks and updating tasks (Henry, 2011). Previous studies in school-age children show that both tasks belong to the WM construct, but only updating tasks are related to EFs (St Clair-Thompson & Gathercole, 2006) (see Figure 2). In more recent studies (Baddeley, 2012), the final model added a third component: the episodic buffer. It allows linking with long-term memory. Hence, this model has been changing over time (Baddeley, 2012).

Model of Miyake et al. (2000): Unity and diversity EFs model

Differently, some systematic (Baggetta & Alexander, 2016a; Karr et al., 2018) and non-systematic (Cristofori et al., 2019; Diamond, 2013) reviews agree that the core EFs are the processes included in the model of Miyake et al. (2000). Miyake et al. (2000) included in their model three basic components: the updating's function of WM, shifting, and inhibition. Miyake & Friedman (2012) showed two different ways of organizing the components of the model: i) the three core EFs are distinguishable but interrelated into a common mechanism or, ii) a Common EF (unity), as well as two updating and shifting factors (diversity). For this organization, this model is called *the unity and diversity model* (Miyake et al., 2000; Snyder et al., 2015). This model also suggests that these EFs are necessary to perform more complex tasks which require higher-level EFs, such as planning.

Model of Diamond (2013): Core and high-level EFs model

Contrary to the models above, this model is based on theoretical issues. However, this model contributes to open research to some aspects that could improve the taxonomy of EFs. For instance, this model considers that there is not only one process of inhibition. As can be seen in figure 1 and table 1, Diamond (2013) suggested that there may be two different types of inhibitory control: interference control –divided into cognitive inhibition and attentional inhibition- and response inhibition (or 'self-control'). Diamond (2013) also suggested that there would be another type of inhibition related to self-regulation in terms of delay gratification. Other authors (Friedman & Miyake, 2004; Kane et al., 2017; Nigg, 2000; Stahl et al., 2014; Tiego et al., 2018) also suggested that the inhibition process could be hierarchic. In addition, this model includes a hierarchy of EFs. There would be different levels of EF based on their complexity. For instance, higher-level EFs would be those that require core EF, as in planning (Miyake & Friedman, 2012) or reasoning (Richland & Burchinal, 2013). Some examples of higher-order EFs would be planning, reasoning, or problem-solving (Cristofori et al., 2019; Diamond, 2013).

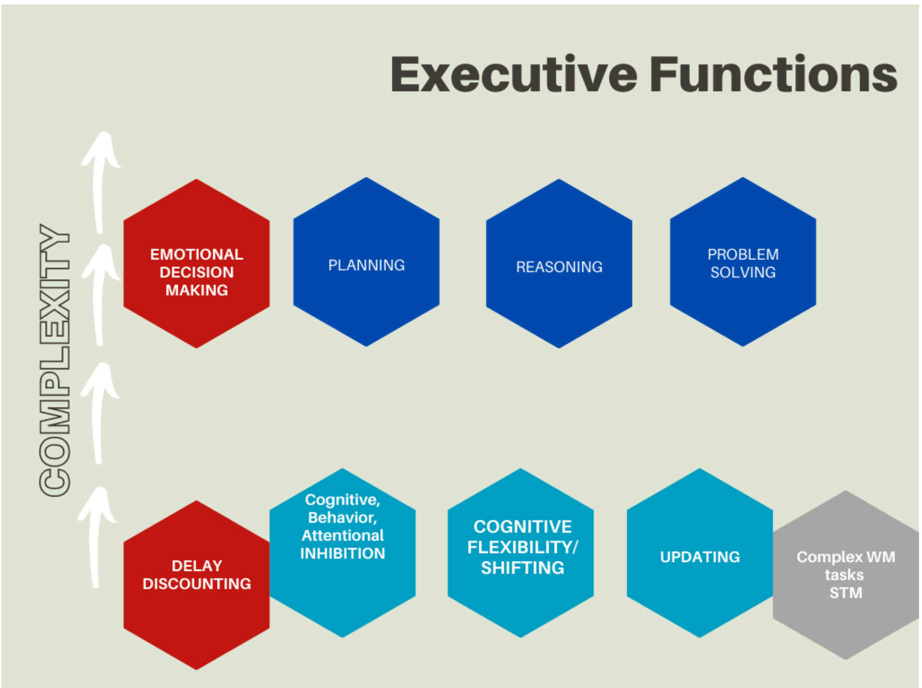
Model of Zelazo & Carlson (2002; 2010; 2012): Cool and Hot EFs model

Zelazo, Müller & Carlson (2002; 2010; 2012) proposed another classification: cool and hot EFs. These authors defined the construct considering their functionality depending on the task. Cool EFs would be those involved in analytic and logical situations without emotional aspects (Baggetta & Alexander, 2016b). In other words, hot EFs – such as emotional decision-making or delay discounting- would be involved in tasks with an emotional basis (Homer et al., 2019). Thus, hot EFs would be involved in contexts that generate emotion, motivation, and tension between immediate gratification and long-term rewards. Bunge & Zelazo (2006) suggested that both kinds of EFs can be used for different purposes in the same task.

To sum up, an integrative perspective of EFs is considering that there are two great clusters of EFs: hot and cool EFs. Cool EFs could be also divided into core and complex ones (see Figure 2).

Figure 2

Conceptualization of the relation between EFs and WM.



Note. Light blue: Core Cool EFs; Dark blue: Higher-level Cool EFs; Red: Hot EFs (adapted from Cristofori et al. (2019); Diamond (2013); Miyake et al. (2000); Zelazo & Müller (2002).

Table 1

Definition and examples of tasks that assess EFs and cognitive processes related.

			COOL-CORE EFs
Working Memory	Include cognitive processes involved in keeping the information accessible in mind and manipulate it while performing complex tasks, such as learning, reasoning, or comprehension (Baddeley, 2010).		
		Definition	**Example**
	Maintenance	Storage of information for short periods without external aid (Baddeley, 2003). The model includes two temporary components: the phonological loop which is related to the storage of verbal information and the visuospatial sketchpad which is related to the storage of visuospatial information (Baddeley, 2003, 2010).	Digit span forward Corsi block-tapping forward
	Manipulation	This function maintains the information in an active way ("holding on line") and manipulates information for short periods (Snyder et al., 2015).	Digit span backward Corsi block-tapping backward
	Updating	Updating function goes beyond the simple maintenance of task-relevant information and dynamically manipulation. This function allows monitoring and modifying incoming information considering its relevance and replacing the old information to accommodate newer, more relevant information (Miyake et al., 2000; Snyder et al., 2015). It is the only component of WM related to EF (St Clair-Thompson & Gathercole, 2006).	Keep Track Task N-back task

Table 1

Definition and examples of tasks that assess EF and cognitive processes related (continuation).

Inhibition	The capacity to suppress voluntarily goal-irrelevant stimulus from memory and control dominant or proponent (automatic) cognitive and behavioral responses (Diamond, 2013; Nigg, 2000; Tiego et al., 2018) to make a less automatic but task-relevant response (Snyder et al., 2015). It is suggested that it is a non-unitary factor (Friedman & Miyake, 2004; Howard et al., 2014).		
		Definition	**Example**
	Attentional inhibition	It refers to resisting interference control at the level of perception. Inhibit attention (or 'inhibitory control of attention' or 'attentional control') to particular stimuli and attend to others based on our goal or intention (Diamond, 2013).	Flanker task
	Response inhibition	It is the factor of inhibitory control that involves control over one's behavior (Diamond, 2013). It requires the effort of withholding a highly automatic response (Friedman et al., 2011) or to suppress an initiated response (as in stop-signal or Go/No-go tasks) (Tiego et al., 2018).	Stroop task Anti-saccade task 5 digits test
	Cognitive inhibition	It refers to resist interference control at suppressing mental representations (i.e. extraneous or unwanted thoughts or memories). It includes intentional forgetting; resisting proactive interference from information acquired earlier and resisting retroactive interference from items presented later (Diamond, 2013). Thus, it is necessary to execute a subdominant response in the face of a more dominant response (Friedman et al., 2011).	Hayling task

Table 1

Definition and examples of tasks that assess EF and cognitive processes related (continuation).

Shifting/ Cognitive Flexibility	The capacity of alternating between task sets, mental sets (Miyake et al., 2000), or response rules (Snyder et al., 2015) to adapt our behavior according to environmental change and to generate new ideas. It is unclear if it is a unitary construct or not (Bastian & Druey, 2017).		
		Definition	**Example**
	Set-shifting	It is a type of low-level cognitive flexibility that implies following one set of rules to complete a task and then shift using a different set of rules to complete the task (Dajani & Uddin, 2015).	Trail Making Test (TMT-B)
	Task-switching	A type of higher-level cognitive flexibility process that implies several trials in which the participant has to switch between tasks with different rules according to the feature of the stimulus or the cue showed (Dajani & Uddin, 2015). There exist different tasks with different complexity (Bastian & Druey, 2017; Bunge & Zelazo, 2006; Crone et al., 2006).	Dimensional Change Card Sort (DCCS) Wisconsin Card Sorting Test (WCST)
			COOL COMPLEX OR HIGHER-LEVEL EFs
	Definition		**Example**
Planning	Planning is a higher-level cognitive function that includes EF processes involved in the formulation, selection of actions required to attain a goal, and evaluation (Cristofori et al., 2019).		Tower of London (ToL) Tower of Hanoi
Reasoning	This process allows generalization and abstraction to enable concept formation (Cristofori et al., 2019).		Raven's Progressive Matrices
Problem S.	It is the process that allows working through details of a problem to reach a solution (Cristofori et al., 2019).		Self-reported tests

Table 1

Definition and examples of tasks that assess EF and cognitive processes related (continuation).

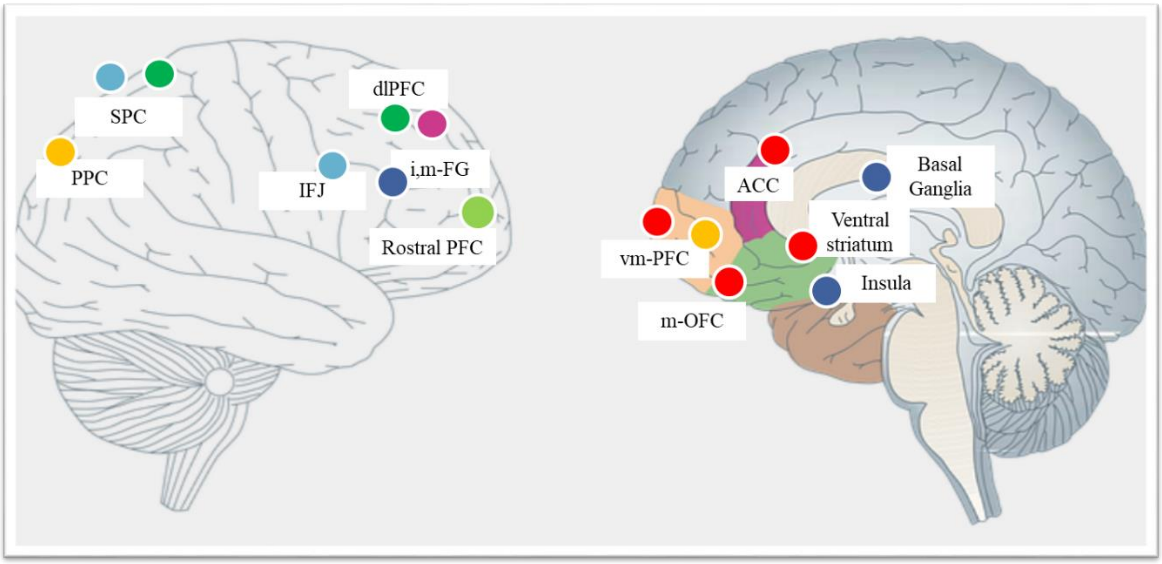
		HOT EFs
	Definition	**Example**
Delay-discounting	Tendency to choose a smaller, sooner reward over a larger, later rewards (Poon, 2018).	Gift wrap
Emotional decision-making	Selection process from more than one option with risk-taking using emotional and cognitive processes (Kouklari et al., 2018).	Hungry Donkey Task Iowa Gambling Task
		OTHER COGNITIVE PROCESSES RELATED TO EFs
	Definition	**Example**
Verbal fluency	Some authors suggested that this cognitive process is related to EF (Aita et al., 2019). Evoke verbal long-term memory information from phonemic and semantic cues and led to fluent speech (Aita et al., 2019).	Semantic and Phonemic (COWA) Verbal Fluency
Processing speed	It is defined as the amount of information that can be processed per unit of time, or velocity at which a variety of cognitive processes can be carried out (Rios-Lago & Periáñez, 2010).	Coding Trail Making Test-A

1.1.3. *Neuroanatomy of EFs*

Considering neural studies, cool EFs have been usually associated with lateral prefrontal cortex (PFC) and fontoparietal network (Lemire-Rodger et al., 2019; Niendam et al., 2012), whereas hot EFs are usually associated with ventral/medial PFC and orbitofrontal cortex (Guo et al., 2017) (see Figure 3 to have a summarized perspective of the brain regions linked to EFs). Furthermore, these regions interact in neural networks (Lemire-Rodger et al., 2019).

Figure 3

Neuroanatomy of cool and hot EFs in adult lifespan.



WM, **Inhibition**, **Cognitive Flexibility**, **Planning**, **Reasoning**, **Delay discounting**, **Decision making**

Note. Adapted from Cristofori et al. (2019); Dajani & Uddin (2015); Guo et al. (2017); Hajek et al. (2013); Kim et al. (2012); Loganathan et al. (2021); Newman et al. (2003).
ACC= anterior cingulate cortex; dlPFC=dorso lateral Prefrontal Cortex; ; IFJ= inferior frontal junction; i,m-FG= inferior-medial frontal gyrus; m-OFC=medial orbito frontal cortex; PPC=posterior parietal cortex; SPC = superior parietal cortex; vm-PFC=ventro-medial Prefrontal Cortex.

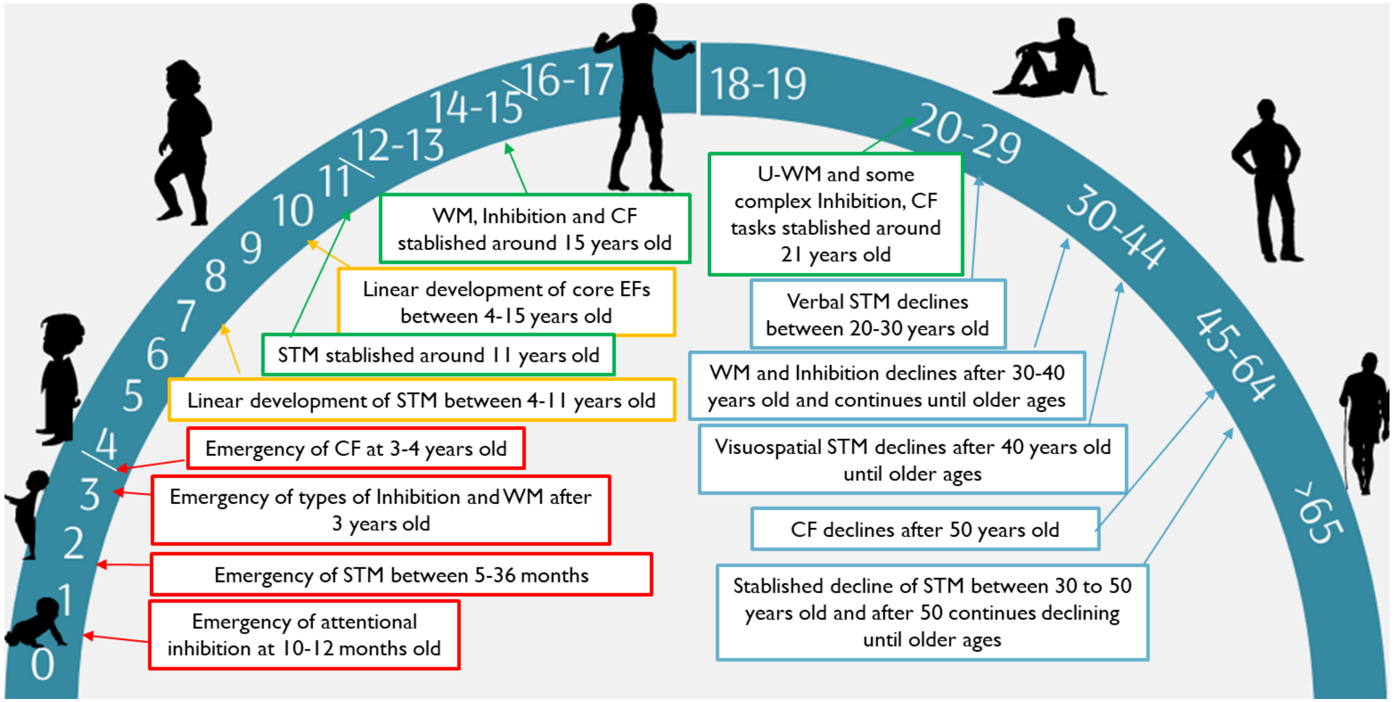
1.1.4. *Development of EFs and other related cognitive processes*

Development of STM and WM. The components of the WM model of Baddeley & Hitch (1974, 2003, 2010, 2012) show different developmental patterns. Different authors have attempted to describe its evolution. Alloway et al. (2006) found that all the components of STM and complex WM are in place at 4 years old. However, some authors suggested that STM may emerge before 2 years old (Garon et al., 2008; Wiebe et al., 2010), whereas complex WM may emerge at 3-4 years old (Garon et al., 2008). Following the study of Alloway et al. (2006), STM linearly develops between 4 and 11 years old. Regarding WM, it shows a linear increase between 4 to 15 years old (Alloway et al., 2006; Poon, 2018). It seems that STM is fully developed in late childhood (11 years old) (Linares et al., 2016) and WM between middle and late adolescence (Poon, 2018). Hartshorne & Germine (2016) found that verbal STM has a small decline in young adulthood (20-30 years old) and a higher decline after 50 years old which continues in older ages. Visuospatial STM declines after 40 years old and continues in older ages. WM starts its decline after 30 (Ferguson et al., 2021) or 40 years old (Hartshorne & Germine, 2016) until older ages.

Development of cool core EFs. It is widely accepted that cool core EFs are a multi-dimensional construct rather than unidimensional (Baggetta & Alexander, 2016a; Cristofori et al., 2019). However, subsequent Confirmatory Factor Analysis (CFA) of cool core EFs have shown inconsistent models across the lifespan (Karr et al., 2018). Developmental patterns could explain this contradiction (see Figure 4). Core EFs emerge and represent precursors for the future development of complex EFs in early ages (Cuevas et al., 2018). Karr et al. (2018) and Wiebe et al. (2011) found that the unidimensional model fits better in preschool ages. Some authors consider that an attentional inhibition component could be this factor (Anderson, 2002; Garon et al., 2008), but there is not yet known the exact nature of its component (Cuevas et al., 2018). During childhood, bidimensional or three-dimensional models fit better (Karr et al., 2018; Lee et al., 2013). The bidimensional model consisted of an Inhibitory factor and an Updating-WM factor, whereas the three-dimensional model also includes a differentiated Shifting factor. Nweze & Nwani (2020) found that WM and Inhibition are related to the development of Cognitive Flexibility. This has led to the so-called *unity-yet-diversity* model. This is what fundaments the model of Miyake et al. (2000) in earlier ages (Fiske & Holmboe, 2019). Cognitive Flexibility/Shifting is developed during school ages and stablished around middle-late adolescence, whereas Updating-WM continues its development until 21 years old (Huizinga et al., 2006). Regarding inhibition, Huizinga et al. (2006) conclude that inhibition does not have a unitary nature and depending on the task shows different developmental patterns (Howard et al., 2014; Huizinga et al., 2006). All these core cool EFs continue developing to a less extent in adolescence and young adulthood (Crone et al., 2006; Huizinga et al., 2006; Linares et al., 2016). Thus, in adolescence and adulthood, *the unity and diversity model* of Miyake et al. (2000) showed more evidence. In adulthood, these cognitive processes reach a peak. Moreover, at this age, a refinement of local connections with the prefrontal cortex and distal connection takes place. This includes areas such as fronto-parietal network and subcortical brain regions (Fair et al., 2009). Finally, in older ages, the unity and diversity model of Miyake et al. (2000) and the bidimensional model –WM and inhibition without a differentiated shifting factor-showed the most evidence of its organization. Ferguson et al. (2021) found that inhibition and WM decline in a similar way, while deterioration is different for cognitive flexibility. Some studies showed that, on average, children and older adults show poorer EF performance in comparison to young adults (Elgamal et al., 2011). Individual differences of older people in cognition

Figure 4

Developmental sequential stages of STM, WM, and cool core EFs.



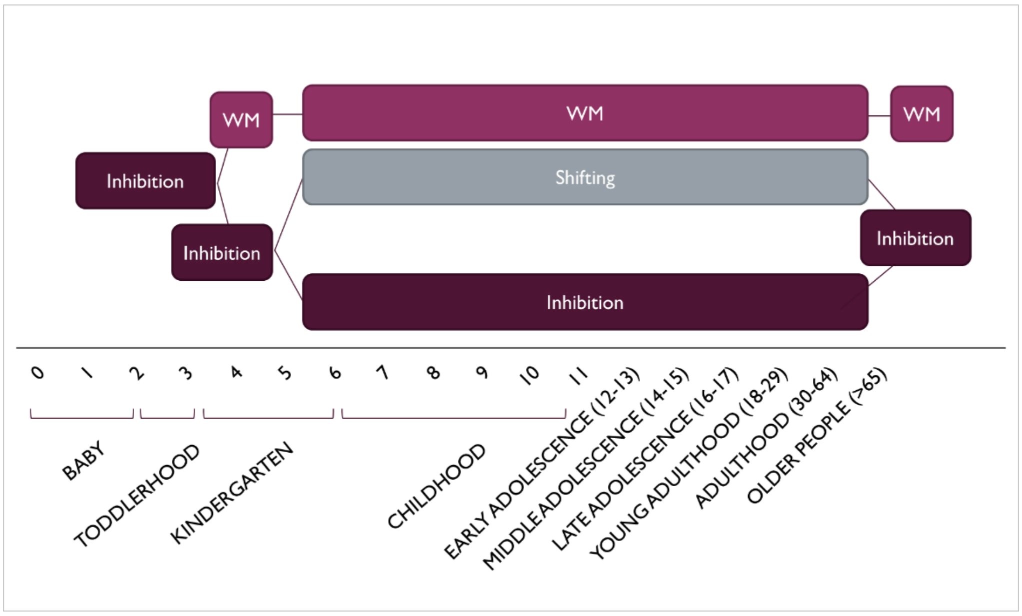
Note. Sequential stages: emerging (early stage of acquisition and not yet functional), developing (capacity is partially acquired but not fully functional), and established (ability fully mature) *(based on Anderson, 2002)*. Hypothetical development patterns adapted from Alloway et al. (2006); Anderson (2002); Cuevas et al. (2018); Ferguson et al. (2021); Garon et al. (2008); Hartshorne & Germine (2016); Howard et al. (2014); Huizinga et al. (2006); Linares et al. (2016); Poon, (2018).

CF: Cognitive Flexibility; STM: Short-term memory; U: Updating; WM: Working Memory.

may be explained by brain changes associated with aging (i.e. loss of grey matter (Minkova et al., 2017) and white matter (Bennett & Madden, 2014)).

Figure 5

Structural organization of EFs across the lifespan (Karr et al., 2018).



Hence, the structure and organization of cool core EF may exhibit a developmental change from a single latent factor during the firsts years of life to separate components when people are older (Karr et al., 2018; Lee et al., 2013) (see Figure 5). Interestingly, these developmental patterns of EFs aligned to neurophysiological development (Romine & Reynolds, 2005), activation (Crone et al., 2006), and connectivity (Fair et al., 2009) of the prefrontal cortex and other linked brain regions. For these reasons, some authors highlight a new model for EFs which captures the development of EFs across the lifespan (McKenna et al., 2017).

Development of complex EFs. Poon (2018b) suggested that it is necessary to develop core EFs to facilitate the development of other higher-order EFs. Planning may emerge at 4 years old (Anderson, 2002) and significantly develops between 7 to 11 years old (Kouklari et al., 2018). In adolescence (Poon, 2018) and adulthood (Huizinga et al., 2006), planning continues developing through the refinement of strategies. Based on the study of Ferguson et al. (2021), planning declines across adulthood (40-70 years old), with a small (positive) change in older ages.

Development of hot EFs. Apparently, cool and hot EFs have different patterns of development in preschoolers (O 'Toole et al., 2017), scholars (Lensing & Elsner, 2018; Kouklari, Tsermentseli, & Monks, 2018), and adolescents (Poon, 2018). Some studies suggested that hot EFs show a developmental regression in middle adolescence (Poon, 2018; Prencipe et al., 2011), whereas cool EFs specially develop in a linear tendency through childhood and adolescence. In addition, some studies suggested that in adulthood and older people can perform better in Hot EFs tasks (Samanez-Larkin & Knutson, 2015).

Development of other cognitive processes related to EFs. According to Anderson (2002), both Verbal Fluency and Processing Speed may emerge at 2-3 years old and may show development in preschool and school ages. Processing speed is relatively stablished between adolescence and young adulthood (Huizinga et al., 2006). Regarding Verbal Fluency, phonemic and semantic tasks show different developmental patterns (Becker et al., 2019) and brain regions associated (Henry & Crawford, 2004). Apparently, semantic verbal fluency develops earlier than phonemic conditions (Becker et al., 2019). In this sense, some studies found that after reach a peak in young adulthood, processing speed declines after 20 (Ferguson et al., 2021) or 30 years (Elgamal et al., 2011) old until older ages. Semantic verbal fluency shows a decline after 35 years old (Elgamal et al., 2011). Regarding phonemic verbal fluency some studies found that is more stable (Elgamal et al., 2011), whereas other suggest that also experiment a little decline in older ages (Gonzalez-Burgos et al., 2019).

1.1.5. *Importance of EFs in daily lives*

In an extensive review of Cristofori et al. (2019), it is widely accepted that: "*EFs allow individuals to alter their overlearned behavioral patterns when they become unsatisfactory, allow individuals to adapt to novel and complex everyday life situations. These functions are what enable us to understand complex or abstract concepts, solve problems we never encountered before or plan our lives, among others".* Therefore, according to the authors, we can assume that EFs are highly important for our daily lives. As can be seen in Table 2, different studies have found that EFs predict health, education, and job success, among other life domains. Hence, EFs are essential for people and are important in educative and social contexts.

Table 2

Impact of EFs in different life domains (adapted from (Cristofori et al., 2019; Diamond, 2013)*).*

Life Domain	How are EFs relevant to this domain in life?
Mental health	Some EFs are impaired in different disorders, such as: • Attention Deficit with/without Hyperactivity Disorder (ADHD) *(Willcutt et al., 2005)* • Depression *(Rock et al., 2014)* • Schizophrenia (Vöhringer et al., 2013) • Bipolar disorder (Vöhringer et al., 2013)
Physical health	EFs have been related to obesity *(Reinert et al., 2013)*, healthy behaviors - physical activity and dietary-*(Hall et al., 2008)*, or poor treatment adherence *(McNally et al., 2010)*, among others.
School success	EFs predict math *(Friso-van den Bos et al., 2013)*, reading skills *(Foy & Mann, 2013; Sesma et al., 2009)*, and academic achievement (Best et al., 2011; Cortés Pascual et al., 2019).

Job success	Poor EF decreases production, satisfaction and makes it more difficult to find and keep a job *(Bailey, 2007).*
Relationships	EFs are important in disruptive behavior *(Tsermentseli & Poland, 2016)* and to solve emotional problems (Poon, 2018). EFs are also important in love relationships *(Eakin et al., 2004).*
Quality of life	EFs are related to the quality of life *(Stern et al., 2017).*

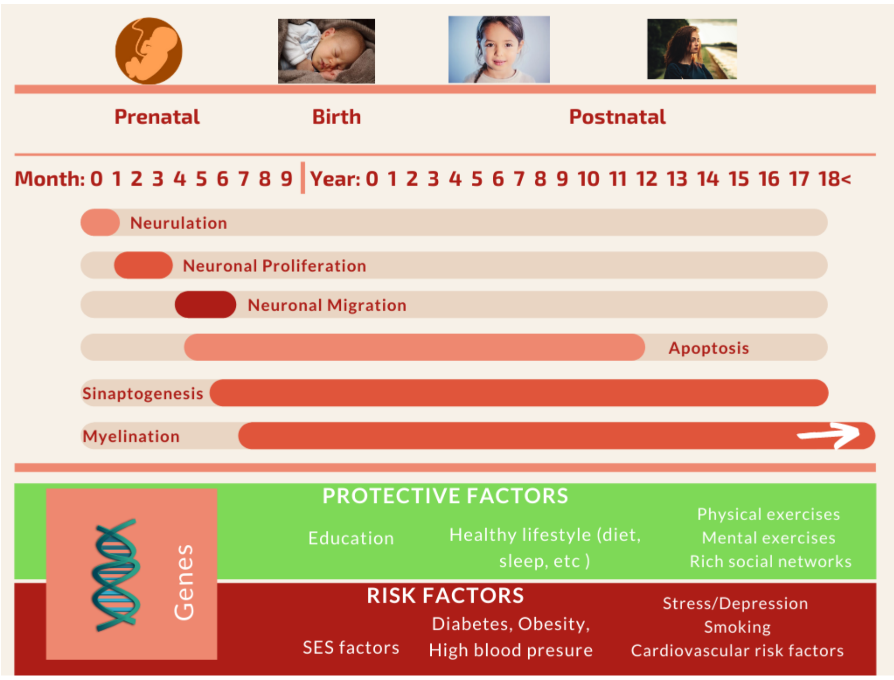
1.2.Cognitive-focused interventions and cognitive trainings

1.2.1. *First studies in animals and humans to train cognitive processes*

Cognitive processes, such as WM or EFs, are psychological processes located in brain structure. Taking into account their importance in daily life, an interesting question would be: Can our brain change, and can we improve our cognitive processes? Last century the answer would be negative. However, in the present century, the answer would be more positive. Maguire et al. (2000) published an article in which they conclude that changes in hippocampal grey matter were acquired after the environmental exposure in navigation training. Concretely, they scanned with structural MRI the brain of taxi drivers from London who receive navigational training for two years and a control group in a cross-sectional study. They found that the brains of the taxi drivers significantly increased grey matter volume in the bilateral posterior hippocampus compared with those of controls. However, control subjects showed greater volume in the anterior hippocampus compared to taxi drivers. Maguire et al. (2000) discussed these results considering a redistribution of grey matter in the hippocampus. Years later, the same researchers conducted a similar study in which they found improvements not only in brain structure but also in a memory neuropsychological task (Woollett & Maguire, 2011). Taxi drivers who achieved their license showed this pattern of results. These findings opened the possibility of local plasticity in the structure of the healthy adult human brain as a function of increasing exposure to an environmental stimulus and an impact on performance in cognitive tasks. These changes are possible thanks to neuroplasticity. Neuroplasticity is known as the brain's ability to create new pathways and rearrange existing ones for purposes of neural communication (Rapport et al., 2013). As it can be seen in Figure 6, our brain produces new synapsis –which is called synaptogenesis- until early adolescence. Those connections that are not needed can be deleted through apoptosis until late adolescence. However, connectivity through myelination can occur even in adulthood (Fair et al., 2009).

Figure 6

Brain development (adapted from Gibb & Kovalchuk (2018) and factors that can influence cognition across the lifespan (adapted from Kueider et al. (2014)).



Afterward, different studies have been conducted on animal models. For example, adult mice who were exposed to environmental enrichment –the analogous of environmental stimulation in human studies- showed better results in learning tasks and neurobiological parameters than mice who were not exposed (Leger et al., 2015). This animal model also opens the possibility of study in humans the stimulation of the brain and neural/behavioral plasticity. In addition, those mice that carried APOE*ε3 –a genetic precursor related to Alzheimer Disease (AD)- and were environmentally enriched were protected to a cognitive decline compared to those that did not receive the environmental enrichment (Levi et al., 2003; Nithianantharajah & Hannan, 2006). However, mice transgenic with alleles associated with a higher risk of AD -APOE*ε4- did not show this improvement in response to enrichment. Thus, unlike what was believed last century, it seems that our brain can change due to environmental factors, producing GenexEnvironment interactions in cognitive outcomes (Krell-Roesch et al., 2017).

However, which type of interventions has been described in the literature to directly improve cognitive processes?

1.2.2. *Definition and types of cognitive-focused interventions*

As Diamond & Lee (2011) consider, EFs can be improved through different activities, such as computerized and non-computerized trainings, aerobically exercise, martial arts, and mindfulness or classroom curricula. Bahar-fuchs et al. (2013) describe cognition-focused interventions as "*those interventions that directly or indirectly target cognitive functioning as opposed to interventions that focus primarily on behavioural (for example, wandering), emotional (for example, anxiety), or physical (for example, sedentary lifestyle) function*". Thus, computerized and non-computerized trainings whose main target is cognitive processes (such as WM or EFs) can be classified as cognition-focused interventions. These interventions can include different types of interventions (see Figure 7 for a comparison between these types of interventions). Cognition-focused interventions are specially described in studies that aim to prevent the decline in older people or to improve cognitive functions in psychological diseases (such as ADHD, mild cognitive impairment, or dementia). For instance, Bahar-fuchs et al. (2013), Kueider et al. (2014), and Vidovich & Almeida (2011) include in their classification of cognition-focused interventions the following: cognitive stimulation, cognitive training, and cognitive rehabilitation. Cognitive stimulation (or 'novelty interventions') typically involves engaging the person in a range of several new, challenging, and motivational activities –high task variability- and boost general cognition in social contexts, but are not focused on a specific process –low task-specificity- (Bahar-fuchs et al., 2013; Fissler et al., 2013; Kueider et al., 2014). Cognitive Training (or 'process-based cognitive training') are interventions designed to boost specific cognitive processes –high task-specificity- through combining standardized tasks –sometimes low task variability- which are repeated several times systematically (Fissler et al., 2013; Tajik-Parvinchi et al., 2014). These interventions aim to improve the process boosted in the trained task as well as tasks that are not specifically trained (Tajik-Parvinchi et al., 2014). Finally, cognitive rehabilitation was used in specific impairments arising from illness or injury to improve their functioning in the everyday context (Bahar-fuchs et al., 2013). Thus, cognitive rehabilitation is focused on individual needs and involves working on personal goals, usually implemented in real-world settings and often using external cognitive aids (Kueider et al., 2014).

Some authors consider that cognitive rehabilitation is mainly focused on a compensatory approach, whereas cognitive training is focused on a restorative approach. The compensatory approach (or 'strategic') teaches new ways to accomplish a cognitive task by working around cognitive weaknesses or deficits (Morrison & Chein, 2011; Rapport et al., 2013; Reichman et al., 2010). The compensatory approach not only uses external aids but also train strategies (Reichman et al., 2010). Thus, this approach is focused on changing the environment or the strategies of the person but not directly train the cognitive process. On the other hand, the restorative approach (or 'facilitative' or ‘core’) seeks to strengthen specific cognitive domains to improve functional performance more generally (Reichman et al., 2010). In addition, both kinds of interventions could use psycho-education and strategies component of compensatory approach although it is infrequent in cognitive training (Bahar-fuchs et al., 2013).

Figure 7

Differences between cognitive stimulation, cognitive training, and cognitive rehabilitation (adapted from Bahar-fuchs et al. (2013); Kueider et al. (2014); Vidovich & Almeida (2011)).

	COGNITIVE STIMULATION	COGNITIVE TRAINING	COGNITIVE REHABILITATION
CONTEXT	Social and general activities	Structured tasks and controlled environment	Real-world setting
CONTENT OF INTERVENTION	Group activities adapted on the target population and/or objectives	Standardized, repeatedly tasks designed to boost specific cognitive processes	Work on personal goals using external aids and/or teaching specific strategies
TASK SPECIFICITY	NO	YES	YES
GROUP SESSION	In group	Individual/In group	Individual
MAIN APPROACH	-	Restorative/Core/ Facilitative	Compensatory/ strategic
SECONDARY APPROACH	-	Psychoeducation/ Strategic	Psychoeducation/ Restorative/ Strategic
FOCUSED ON NDIVIDUAL	NO	NO	YES
GOALS	Engage mental processing through enjoyable activities	Maintain or enhance a particular set of cognitive processes	Improve everyday skills, functioning and minimize disability

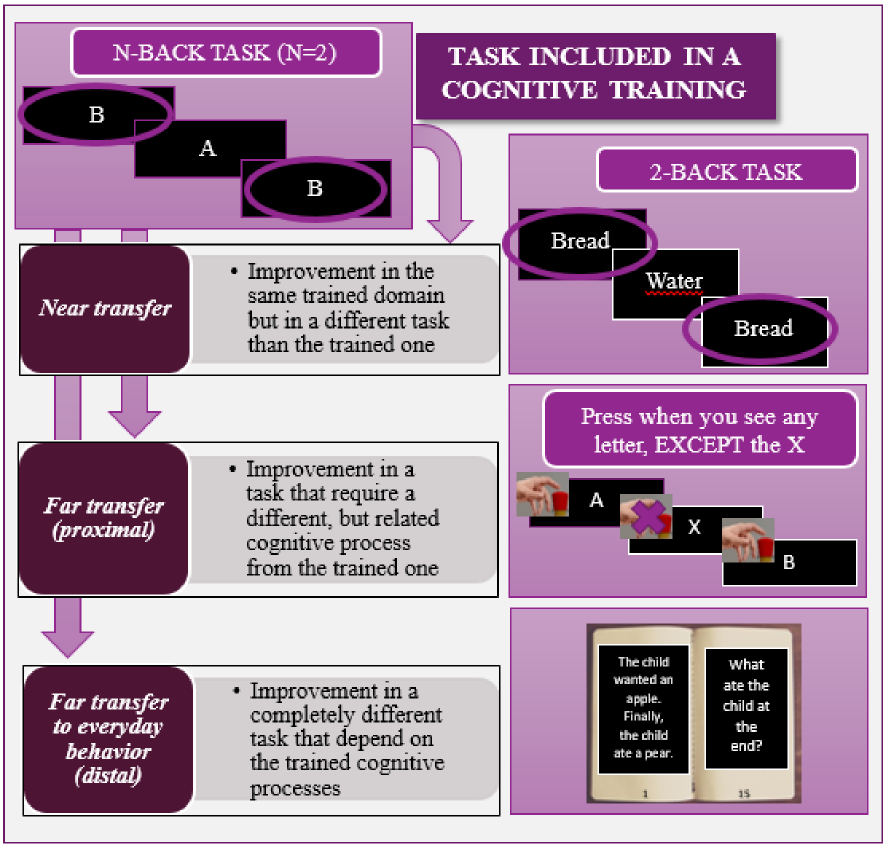
Recently, other authors described types into cognitive trainings specially in educative contexts. For instance, (Ramani et al., 2017) and (Johann & Karbach, 2021) differentiate general (or ‘broad’) and specific (or ‘narrow) domain trainings. General domain trainings consist of training cognitive processes that play a critical role in the specific domain, as it would be the case of WM or EFs trainings for mathematical development. On the other hand, specific domain trainings are those that trained specific skills, such as mathematical or reading tasks.

1.2.3. *Near and far transfer effects*

Bearing in mind the definition of cognitive training, these types of cognition-focused interventions can produce improvements in trained cognitive processes (*near* transfer), but also could produce improvements in untrained ones (what is called *far* transfer effect; Tajik-Parvinchi et al., 2014) (see Figure 8). On the one hand, *near* transfer refers to the improvement produced within the same trained domain, although it includes another task (Rapport et al., 2013). Thus, training on one task might enhance the cognitive process that is needed to perform similar tasks (e.g., when you train on a verbal Updating-WM task and the training improves a non-trained verbal Updating-WM task). On the other hand, the *far* transfer could happen when the gaining involves the improvement in another cognitive process different from the trained one (e.g., if you train on a verbal Updating-WM task and the training improves score in a task that requires sustained attention). Some authors suggested that this far transfer takes place in *proximal* outcomes (Tamm et al., 2013). Also, the far transfer occurs when there are improvements in the performance in activities of daily living (e.g., if someone trains a specific verbal-Updating WM task and the training improves reading comprehension into school context) or in everyday behavior (e.g., if you train on a verbal Updating-WM task and the training improves difficulty of remembering verbal messages). Hence, this type of far transfer would take place in *distal* outcomes (Tamm et al., 2013). The explanation of the improvement in non-trained tasks would be due to they share brain regions or, to a great extent, depend on the trained cognitive processes (Rapport et al., 2013). Other authors have suggested other relevant dimensions to explain results in near and far transfer effects (Barnett & Ceci, 2002).

Figure 8

Description of the types of transfer effects in cognitive trainings.



1.2.4. *Efficacy and effectiveness of cognitive-focused interventions to improve EF and WM*

As Vidovich & Almeida (2011) suggested, cognitive rehabilitation has been usually studied with case studies at considering individual needs. However, cognitive stimulation and cognitive trainings allow researching with bigger samples which can increase the generalizability of the results. Considering inherent characteristics of cognitive stimulation –low task-specificity, high task-variability, challenge tasks-, (Fissler et al., 2013) suggested that small transfer to general cognition is possible, but it is difficult to find near transfer to specific cognitive processes. For instance, Aguirre et al. (2013) found significant effects in general cognition in older people, but no effects were found in memory outcomes.

Differently, cognitive training is designed to train specific cognitive processes. Thus, considering inherent characteristics of cognitive training –high task-specificity, low task-variability, challenge tasks-, (Fissler et al., 2013) suggested that large near transfer to specific cognitive processes is possible (Bergman-Nutley & Klingberg, 2014). It seems that children and older people could benefit more from cognitive training than adults (Karbach et al., 2017). However, there is not an agreement about if the far transfer is possible (Au et al., 2015) or not (Sala et al., 2019). In addition, seems that when it is possible, there are small transfer effects (Au et al., 2015; Bergman-Nutley & Klingberg, 2014).

1.2.5. *Benefits of cognitive training with game elements*

In 2014, authors like Klingberg have concluded that it is necessary to find elements that could enhance transfer effects on cognitive training. Gamifying or using playful elements in cognitive training is increasing (Lumsden et al., 2016). Lumsden et al. (2016) found that introducing game elements did not assure an improvement in task performance (though it could), but it boosted participant motivation. Other studies point that gamifying cognitive training show better results than non-gamified interventions. For example, Ninaus et al. (2015) and Prins et al. (2011) conducted in their studies computerized cognitive training with and without game elements. Both cognitive trainings showed improvements in WM and EF's (Prins et al., 2011). Moreover, these studies found more improvements in WM game-based computerized cognitive training than without them. For these results, one possible explanation could be that people maybe are very engaged to it because it is a reinforcing activity (Prins et al., 2011). For instance, a recent study with adults found that prefrontal brain areas associated with attention and emotional/reward processes were more strongly activated in domain-specific training with game elements compared to a non-game-based version (Kober et al., 2020). Hence, the inclusion of game elements might enhance the effects on specific cognitive abilities in training studies.

1.3.The rationale behind cognitive training based on board games

1.3.1. *Definition and types of board games*

Board games are defined as analog games played on a board with pieces (and/or cards) on it, with predefined rules that fix the number of pieces/cards, the number of positions of the elements, and the number of their possible moves (Fernand Gobet et al., 2004; Sousa & Bernardo, 2019).

Board games can be classified into traditional/classic, mass-market, or modern board and card games (Sousa & Bernardo, 2019) (see a comparison in Figure 9).

On the one hand, traditional or classic board games are those that do not have a known author and do not have commercial rights. These kinds of games are usually known by word of mouth and are in public domains (Sousa & Bernardo, 2019). In addition, they usually have similar positional or abstract mechanics – like in Chess or Go Game-, not including a huge variety of innovative ones.

On the other hand, mass-market board games are those that have commercial rights and are commercialized and sold massively. These kinds of games do not have a known author or do not have innovative mechanics, like puzzles of Ravensburger®, Monopoly®, or Scrabble®. These kinds of board games also include subtypes: family games, pulp games, and party games (see Sousa & Bernardo (2019) for a further description).

Finally, in the lasts 40 years, new board games are being originally designed and published by a known author or company in a specific temporal moment. They are modern or hobby board games. According to Sousa & Bernardo (2019), these games are edited with an attractive visual appearance (more aesthetical), with different innovative mechanics (not only positional or abstract, like in traditional games), and can be commercialized in an extended way to a target market with relatively economical prices. One example is Settlers of Catan®, created in 1995. Modern board games can include different subtypes: wargames, collectible cards, role-play games, *Eurogames*, and *Ameritrash* (see Sousa & Bernardo (2019) for a further description).

Figure 9

Classification and characteristics of the main kinds of board games (adapted from Sousa & Bernardo (2019)).

Classification and Characteristics of different board games	Classical/ Traditional	Mass-market	Modern/ Hobby
Company/Organization ownership Created and produced for commercial reasons (property rights)	NO	YES	YES
Known author Originally designed and published by a known author/company	NO	NO	YES
Innovative Mechanics Have innovative mechanics (besides strategy or positional)and a original design	NO	NO	YES
Timeline Firsts copies of this kind of board game date from...	Dawn of civilization	Late XIX	1960’s

This classification is useful to classify and identify board games considering their timeline of creation. However, there exist other dimensions to classify board games. For instance, if we consider its simplicity and length, filler board games are not explicitly included in the classification of Sousa & Bernardo (2019). The main feature of filler board games is that they are set up quickly and last between 15 to 20 minutes, not filled to exceed 30 minutes. Thus, filler games could have several but simple mechanics and can be learned quickly because of simple rules (Bartolucci et al., 2019).

1.3.2. *Board games and cognition*

Cross-sectional and longitudinal studies show that board games could be related to cognitive processes included or related to the definition of EFs. It seems that those children who spent their time in tasks such as playing board games showed better EFs scores (Barker et al., 2014; Metaferia et al., 2020). Jirout & Newcombe (2015) found that playing block-play, puzzles, and board games were related to higher spatial reasoning abilities, more than other games as playing with trucks, riding a bike, or drawing in a sample of 1000 children between 4 to 7 years old. In school-age children, Nath & Szücs (2014) found that a mass-market construction game –Lego®- is related to numerical operations. This relation was mediated by visuospatial STM and WM. In adulthood, Fissler et al. (2018) found a relation between jigsaw puzzle experience across life and global visuospatial cognition. In older people, Dartigues et al. (2013) found in a longitudinal study of 20 years that those people who played board games reduced their risk of subsequent dementia compared to non-players. Recently, Altschul & Deary (2020) also found that playing games were associated with less cognitive decline. Despite this evidence, it is necessary to study causal mechanisms with experimental studies.

Three recent systematic reviews focused on the benefits of board games in different outcomes. Noda et al. (2019) and Nakao (2019) found different studies that use abstract and traditional board games –Chess, Go, and Ska-. They found that all of the studies included showed an improvement in some aspects of cognition. In addition, in the systematic review of Noda et al. (2019), the studies included focused on school-age children, children with a diagnose of ADHD, and older people. Regarding the review of Nakao (2019), results show that brain regions related to cognition are differently activated in people who usually play traditional board games and in novice players (Duan et al., 2012, 2014). In addition, they conclude that some brain regions improve their connectivity after training with the Go game, as in (Iizuka et al., 2020). Gauthier et al. (2019) review board games to improve health. They only found a book chapter that includes a study to improve EF in a sample with dementia through a cognitive intervention based on a mixture of self-developed board games and mass-market/modern board games (Fissler et al., 2013). They found that participants in the game group improved a composite score of EFs, while the passive control group did not improve it. Despite this evidence, neither of the systematic reviews used search words that specifically target executive functions and cognitive training.

Although it is scarce, in the scientific literature other experimental studies use board games created by researchers in children (Passolunghi & Costa, 2016) and older people (Kuo et al., 2018), or using a mix of self-developed board games and modern board games (Overman & Robbins, 2014) as in Fissler et al. (2013). All these studies found or nearly found near transfer effects. However, it is necessary to find more research to see if exist other studies with a similar aim.

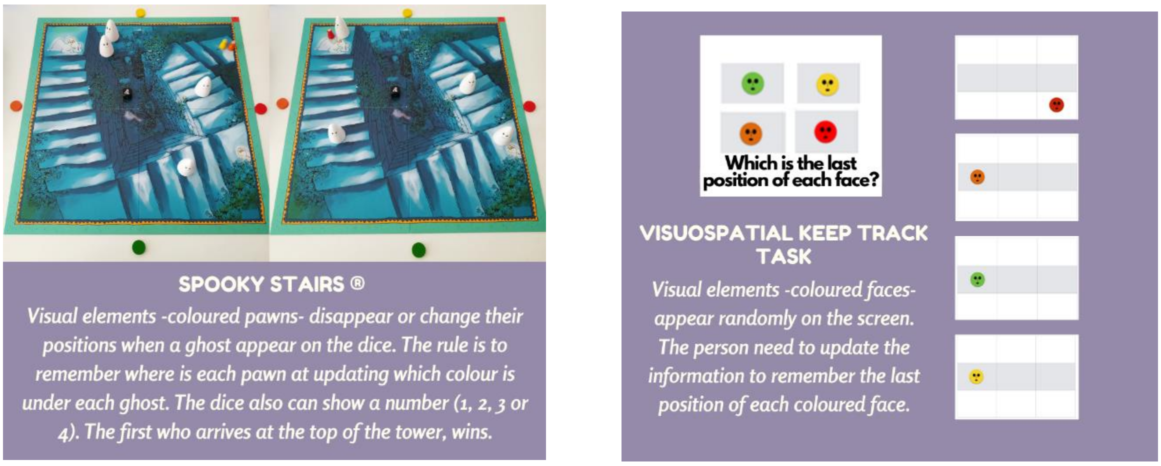
1.3.3. *Filler board games as cognitive tasks in cognitive training*

Cognitive training is usually conducted individually and does not include social interaction (Fissler et al., 2013). Previous studies found that playing alone a traditional board game shows less improvement in cognition than playing it with other people (Iizuka et al., 2019). Moreover, including game elements could enhance the benefits of cognitive training (see section 1.2.5). In fact, board games could increase learning, enhance interpersonal interactions among participants, and increase the motivation of participants (Noda et al., 2019). Hence, board games could be an interesting task to include in cognitive training. Research studies included in the systematic reviews mentioned above are focused on traditional board games. Only in some studies used filler and modern board games (Bartolucci et al., 2019; Ching-Teng, 2019; Fissler et al., 2013; Kuo et al., 2018;

Overman & Robbins, 2014). Besides the characteristics defined in section 1.3.1., some of these filler board games are very similar to neuropsychological tasks and rely on specific cognitive processes to play (see Figure 10). Bearing in mind the definition of cognitive training, these kinds of games could be used as tasks to be repeated into the schedule of cognitive training. Thus, filler board games could have the potential to be better than i) classic cognitive training which includes low variability of training tasks (Fissler et al., 2013) and difficulty show far transfer effects (Sala & Gobet, 2017); ii) computerized cognitive training based on game elements which are in individual contexts (Ninaus et al., 2015; Prins et al., 2011); iii) cognitive stimulation which includes unspecific processing demands (Fissler et al., 2013); iv) longer board games which are more difficult to explain and to include in cognitive training with high-variability tasks, and v) more motivational and engaging than board games created by researchers. To conclude, all these characteristics make that filler and modern board games could be high-variability tasks that boost a specific cognition domain in a social context, accessible, adaptive, and challenging for people (Fissler et al., 2013).

Figure 10

The similarity between a filler board game –Spooky stairs (Schannen, 2004) *–and a neuropsychological task –Visuospatial Keep Track Task (adapted from* Tamnes et al. (2010)*).*



2. OBJECTIVES AND HYPOTHESIS

2.1. Objectives of the research

In the introduction section, it is stated that it exists little research about the efficacy and the effectiveness of interventions based on board games to improve EFs and other related processes, such as short-term memory (STM), working memory (WM), Verbal Fluency, and Processing Speed.

Thus, the **main objective** of the dissertation was: i) Section 1: to review the literature about interventions based on board games to improve EFs and other related processes, and, ii) Section 2: to test if interventions based on mainly modern and filler board games are effective to improve/maintain EFs and other related processes or not in the most studied populations based on the results of the systematic review: primary school students, primary school students with diagnoses of ADHD and healthy older people.

The following **specific objectives** were stablished for each of the studies included in the pre-doctoral research:

Publication 1: The objective of this study was to review the scientific literature about interventions based on board games that pretend to improve or maintain EFs and other processes related. In addition, this study focused on finding if there exist experimental studies including cognitive training based on modern and filler board games.

Publication 2: The objective of this study is to test the effectiveness of both specific and general domain interventions based on filler board games to improve STM, Updating-WM and math skills in primary school children.

Publication 3: The objective of this study was to test the efficacy of cognitive training based on modern and filler board games to improve EFs in school-age children with a diagnosis of ADHD. Secondly, to test the effects of the intervention in ADHD symptomatology.

Publication 4: The objective of this study was to test the effectiveness of cognitive training based on modern and filler board games to maintain EFs and other related cognitive processes in healthy older people. Secondly, to test the effects of the intervention in depressive symptomatology and quality of life.

2.2. Hypotheses of the research

The hypothesis of the different publications included in the present dissertation were:

Publication 1: there would be a little amount of literature about the improvement of EFs and other psychological processes related, mainly with traditional board games. In addition, the majority of research studies included would consist of children and older people samples.

Publication 2: i) those children who were trained at playing board games would improve their STM and Updating-WM abilities after the intervention greater than the control group; ii) those children who were trained at playing games would improve their mathematical skills after the intervention greater than the control group.

Publication 3: the participants of the experimental group would get better scores on the EFs measures and would show far-transfer effects after the intervention in comparison to the control group.

Publication 4: both groups would maintain or improve cognitive processes after the cognitive training, but these benefits would be higher in the modern board games group than in the paper-and-pencil tasks group.

3. EXPERIMENTAL FRAMEWORK

3.1. Method

The method of the different publications included in the present dissertation were:

Publication 1: the method used in this study was a systematic review and a meta-analysis. Keywords included in the systematic review were related to EFs and other psychological processes related, interventions to improve/maintain cognition, and board games. Articles included in the meta-analysis were randomized controlled trials (RCT).

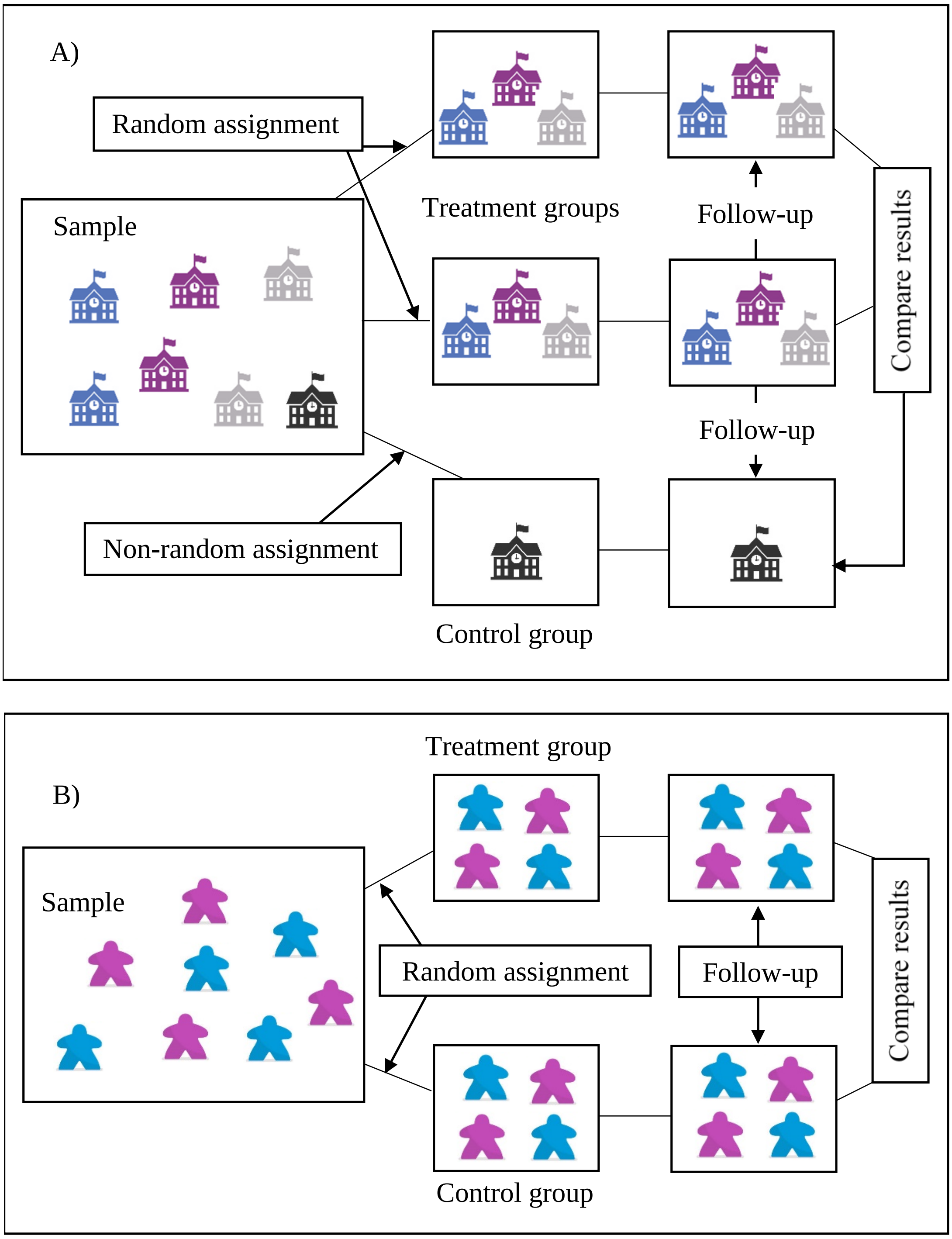
Publication 2: the method used in this study was a quasi-experimental design (see Figure 11.A). The three arms of the study were: i) a specific math domain intervention based on board games (Math GTG); ii) a general memory domain intervention based on board games that boosted STM and Updating-WM (Memory GTG); iii) a comparison control group (CG) which performed standard math lessons. Both game groups were compared to the CG which had better results in arithmetic and other memory and math outcomes. Participants were school-age students who were between 8 to 10 years old.

Publication 3: the method used in this study was a non-blind RCT (see Figure 11.B). The two arms of the pilot study were a treatment group that played modern and filler board games and a no-treatment control group (wait-list). Participants were children from 8 to 12 years old who had a diagnose of ADHD.

Publication 4: the method used in this study were two RCTs (see Figure 11.B). The first one was a non-blind pilot study with a small sample. The two arms of the pilot study were an experimental group that played modern and filler board games and a wait-list control group. The extended double-blind study had a bigger and a different sample (main study). The two arms of the pilot study were a treatment group that played modern and filler board games and an active-control group that performed cognitive paper-and-pencil tasks. Both studies followed consolidate standards of reporting trials guidelines (CONSORT guidelines). Participants were older people over 65 years old who assisted in a geriatric center (long-stay institution or adult day-care center).

Figure 11

Method design used in studies 2, 3, and 4.



Note. *A) Method design used in study 2; B) Method design used in studies 3 and 4.*

3.2.Publications

Director's report on impact factor

The present dissertation consists of four studies that have been published or have been submitted to international peer-reviewed journals. The impact factor of these journals shows the quality of the research conducted.

- Publication 1: **Can we improve executive functions and other cognitive processes related by playing board games? A systematic review and meta-analysis** submitted to *Neuropsychology Review*. This journal is devoted to reviewing articles on research relevant to neuropsychology in normal and clinical populations. This journal is indexed in the Journal Citation Reports (Social Science Edition) with an impact factor of 7.444 (2020, submitted in 2021). It is classified in the first quartile of the area of Clinical Psychology (ranking: 4/131; percentile: 97.328).

- Publication 2: **Benefits of Playing at School: Filler Board Games Improve Visuospatial Memory and Mathematical Skills**, submitted to *Contemporary Educational Psychology Journal*. This journal publishes original empirical articles on research based on theories to explicate and enhance the educational process. It is indexed in the Journal Citation Reports (Social Science Edition) with an impact factor of 4.277 (2020, submitted in 2021). It is classified in the first quartile of the area of Educational Psychology (ranking: 12/61; percentile: 81.148).

- Publication 3: **A pilot study of the Efficacy of a Cognitive Training based on Board Games in Children with ADHD: A Randomized Controlled Trial**, published in *Games for Health Journal: Research, Development and Clinical Applications*, *8*(4): 265-274, https://doi.org/10.1089/g4h.2018.0051. This journal is dedicated to advancing the impact of game research, technologies, and applications on human health and well-being. This journal is indexed in the Journal Citation Reports (Social Science Edition) with an impact factor of 1.859 (2019, published online on 2 August 2019). It is classified in the first quartile of the area of Rehabilitation (ranking: 13/71; percentile: 82.394).

- Publication 4: **Cognitive training with modern board and card games in healthy older adults: two randomized controlled trials**, published in *The International Journal of Geriatric Psychiatry, 36*(6): 839-850, https://doi.org/10.1002/gps.5484. This journal published results of original research in the causes, treatment, and care of all forms of mental disorder which affect older people and aging. This journal is indexed in the Journal Citation Reports (Social Science Edition) with an impact factor of 3.485 (2020, accepted on 29 November 2020 and first published on 4 December 2020). It is classified in the first quartile of the area of Gerontology (ranking: 9/36; percentile: 76.389).

As directors of the dissertation, we confirm the publication and submission of these studies.

Signed by Dr. Jorge Moya-Higueras and Dra. Agnès Ros-Morente

Lleida, June 2021

SECTION 1: REVIEW OF INTERVENTIONS BASED ON BOARD GAMES

3.2.1. Can we improve executive functions and other cognitive processes related by playing board games? A systematic review and meta-analysis

Verónica Estrada-Plana, MHS[1], Nuria Vita-Barrull, MHS[1], Agnès Ros-Morente PhD[1], Rosa Ayesa[2,3], Jaume March-Llanes, PhD[1], & Jorge Moya-Higueras, PhD[1,4]

[1]University of Lleida, Department of Psychology, Lleida, Spain; [2] Department of Psychiatry, School of Medicine, Marqués de Valdecilla University Hospital, University of Cantabria, Santander, Spain; [3] Center for Biomedical Research Network on Mental Health (CIBERSAM), Instituto de Salud Carlos III, Madrid, Spain; [4]Center for Biomedical Research Network on Mental Health (CIBERSAM), Instituto de Salud Carlos III, Barcelona, Spain.

Submitted to *Neuropsychology Review*

This is a pre-print version of the article submitted in Neuropsychology Review. If the article is accepted, the final authenticated version will be available online.

Abstract

Executive functions are a core of psychological processes key for our daily lives. Cognitive-focused interventions may improve them. Including ludic elements seems to increase the efficacy of cognitive interventions. Thus, board games could be an interesting tool to be introduced in cognitive interventions. This systematic review aimed to show or not whether cognitive interventions based on board games could improve executive functions across life. We found 2,293 studies through searching in 4 databases (Scopus, WOS, PsycINFO, Medline). 19 studies met inclusion criteria for the systematic review at assessing executive functions before and after interventions that used board games. 12 studies were included in the meta-analytical analysis. We found large effects in verbal short-term memory favoring cognitive interventions based on board games in comparison to control groups in children (g = 1.05, p < .001, 95% CI 0.47 - 1.63). We found a limited amount of studies that produced a high heterogeneity. We also conducted a sensitivity analysis to find possible implications of the risk of bias. Results are discussed based on intervention characteristics, cognitive development, and transfer effects. Future well-conduct randomized controlled trials are needed to conclude clinical implications.

Keywords: Board games, executive functions, cognitive focused interventions, Randomized Controlled Trials

Introduction

Executive functions (EFs) have been described as a set of cognitive processes that make it possible to follow a goal by controlling, directing, and coordinating other cognitive processes (Bull & Lee, 2014). EFs are not only important in cognitive tasks, but also socio-emotional and behavioral domains (Baggetta & Alexander, 2016). Therefore, EFs are basic to daily activities (Vaughan & Giovanello, 2010) and different aspects of life (Baggetta & Alexander, 2016; Cristofori et al., 2019; Diamond, 2013). Previously in the literature, different authors have considered it important to classify these cognitive processes to operationalize the construct of EFs (Baggetta & Alexander, 2016; Diamond, 2013; Jurado & Rosselli, 2007). The best model to explain the structure of core EFs in adulthood (Karr et al., 2018) is the model proposed by Miyake et al. (2000). Moreover, this model includes the most researched EFs (Baggetta & Alexander, 2016): shifting, updating, and inhibition. Shifting has been described as the capacity of alternating between tasks or mental sets (Miyake et al., 2000) or response rules to adapt our behavior according to environmental change and to generate new ideas (Diamond, 2013). On the other hand, inhibition is the capacity to suppress voluntarily dominant or proponent responses to make a less automatic but task-relevant response (Miyake et al., 2000). Finally, updating has been described as a function of working memory (WM) which enables to update and monitor information continuously in an online way (Cristofori et al., 2019). Moreover, Diamond & Ling (2016) argued that these core EF are the basis of the other higher-level EF, such as reasoning, problem-solving, or planning. In addition, other cognitive processes have been related to EFs, such as verbal fluency (Aita et al., 2019; Ghanavati et al., 2019), attention (Baggetta & Alexander, 2016), processing speed, and other components of WM, such as short-term memory (STM) (McCabe et al., 2010). Conversely, other authors (Zelazo & Carlson, 2012) have proposed another classification:

cool and hot EFs. All the EFs described above would be cool functions. These kinds of EFs would be usually involved in analytic situations without emotional aspects (Baggetta & Alexander, 2016). Otherwise, hot EFs –such as decision-making or delay discounting- would be involved in tasks with an emotional basis (Homer et al., 2019). Moreover, considering neural studies, cool EFs have been usually associated with lateral prefrontal cortex (PFC) and frontoparietal network (Lemire-Rodger et al., 2019), whereas affective aspects of EF are usually associated with ventral/medial PFC and orbitofrontal cortex (Guo et al., 2017). Furthermore, these regions interact in neural networks (Lemire-Rodger et al., 2019).

Past studies show that EFs could be improved or maintained through the life span with neuropsychological cognitive-focused interventions (Nguyen et al., 2019; Scionti et al., 2020). These interventions can include cognitive stimulation, cognitive or restorative training, and neuropsychological rehabilitation/remediation (Kueider et al., 2014; Reichman et al., 2010). Besides, they can include different elements like computerized tasks, videogames, and non-computerized activities, among others (Kueider et al., 2014).

Board games could be considered as non-computerized cognitive interventions. Board games are defined as analog games that are played over a board and/or a table with physical components (such as cards, pawns, or dices) (Sousa & Bernardo, 2019). Board games also include predefined rules that fix the number of pieces/cards, the number of positions of the elements, and the number of their possible moves (Sousa & Bernardo, 2019). Different classifications of board games have been proposed considering their characteristics (e.g. its length or its date of first copies published) (Bartolucci et al., 2019; Sousa & Bernardo, 2019). Fissler et al. (2013) consider those inherent characteristics of board games –motivating, social and challenging activities, some of them focused on specific cognitive processes- make them an interesting task to include in cognitive interventions.

Furthermore, cross-sectional and longitudinal studies have pointed to the relevance of playing board games. Different studies in childhood found that board games can benefit WM (Nath & Szücs, 2014) and higher spatial reasoning abilities (Jirout & Newcombe, 2015). In addition, those children who spent their time in tasks such as playing board games showed better EFs scores (Barker et al., 2014; Metaferia et al., 2020). In older people, Dartigues et al. (2013) found that the usage of board games reduced the risk of dementia, the decline in their cognition, and the incident depression compared to non-players. The protective factor of cognition when you play board games with other people across the lifespan has been found in other studies (Altschul & Deary, 2020; Singh-Manoux et al., 2003).

These studies have opened the door to conduct experimental designs. Moreover, the interest in the efficacy and effectiveness of board games like a cognitive intervention is recently increasing. For instance, three systematic reviews about board games as an element of intervention have been recently published (Gauthier et al., 2019; Nakao, 2019; Noda et al., 2019), showing significant effects. However, these systematic reviews were focused on general health or other outcomes, such as knowledge or education. Therefore, moving forward could be achieved by focusing on neuropsychological outcomes, and more specifically, in EFs considering their importance in our daily lives.

Thus, the present study aimed to systematically review all the available studies across the life span about cognitive interventions to improve EF using board games compared to both active and passive control group/s. We hypothesized finding significant results favoring cognitive interventions with board games. We also analyzed moderators accounting for systematic variations.

Method

The present study was performed following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Gates & March, 2016; Liberati et al., 2009).

Eligibility criteria

We included studies with participants from any sociodemographic background. We considered as inclusion criteria: a) the inclusion of analog board games in the intervention (including board games, card games, puzzles, dice games, word games, serious games, or specific traditional board games, such as chess or Go game); b) those studies that had cognitive functions as outcomes (including executive functions and other cognitive processes related, such as STM, verbal fluency, processing speed, and attention); c) those randomized and non-randomized studies that were focused on the validation of cognitive intervention. The exclusion criteria were: a) the topic of the paper was not concerned with the inclusion criteria; b) the cognitive intervention did not include only board games –excluding those interventions that included other elements, such as computer activities-, c) outcomes were not assessed at least at pre and post time; d) other kinds of publications (e.g., books or reviews); e) other designs of the studies; f) other languages that were not English, Spanish or French. We did not include in the meta-analysis those studies that did not report data about the validation of the intervention or those studies that did not have a comparison group. We contacted one author to access the data of his/her study. We excluded the study from the meta-analysis because the person did not respond.

Information sources and Search

We carried out a literature search using four bibliographic databases: PsycINFO, Medline, Scopus, and Web of Science. The search items were limited to the title, abstract,

and keywords. Search terms were generated from the synonyms found in the MeSH and Cochrane Library databases and by inspecting the common terminology used in board games or cognitive interventions literature. The keyword combination was: (stimulation OR training OR remediation OR intervention OR rehab* OR therap*) AND (table top game OR table-top game OR board game OR card game OR dice game OR serious game OR puzzle OR word game OR table game OR chess OR go game) AND (“processing speed" OR "attention" OR "concentrat*" OR "semantic fluency" OR "categoric* fluency" OR "phon* fluency" OR "verbal fluency" OR “executive function*" OR "memor*" OR "updating" OR "shifting" OR "*switching" OR "flexibility" OR "inhibition" OR "executive control" OR "inhibitory control" OR "planning" OR "plan*ification" OR "reasoning" OR "problem*solving" OR
"delay discounting" OR "decision*making" OR "self-regulation" OR "self-control").
The searches were performed on September 12, 2019, and we included studies available until this date. However, after this date, we kept updating with a search alert activated from Scopus. Besides, we also screened reference lists of available studies to include it following the “snowball sampling” method.

Study selection

The first and second authors reviewed all the studies recruited from the systematic search in a blind mode. After eliminating duplicate articles, we carried out two basic screenings using the Rayyan web and mobile app (Ouzzani et al., 2016). The first screening was focused on the title and the abstract. In this first phase, we used a conservative strategy. We excluded those studies that fitted the exclusion criteria and did not meet the inclusion criteria. In phase 2, after reading the full text, we resolved any ambiguity. Only the studies that both authors agreed that completely fitted inclusion criteria were considered for further analysis. If both authors found any exclusion criteria, then the report was excluded. For this reason, in phase 2 we followed a rigid strategy. In both screenings, discrepancies were solved by discussing with the last author.

Data collection process and data items

Two blinded authors –the first and the last authors- abstracted the data independently. Then, the first author checked the data to reduce possible errors (Buscemi et al., 2006). If data from both authors was not the same, they consulted it in original papers and discussed it until reach an agreement. We extracted different information from each included article: i) study design, ii) location, iii) sample size, iv) participants' characteristics, v) intervention's characteristics of the experimental and control groups vi) outcomes measured, vii) means and standard deviations of each outcome measured in every time point (pre-, post-, and follow-up) for each group. Finally, we coded only those outcomes that had been measured at least pre and post-intervention.

Problem of multiplicity

The meta-analysis contained more than once those studies which had more than one control group. Thus, the experimental group's data were included twice. Most of the studies contributed to more than one effect size because they assessed different EF domains. Finally, no study was reported in different scientific papers.

Risk of bias in individual studies

The first author of the study assessed the risk of bias in different domains. The last author reviewed each assessment. We assessed the risk of bias at the study and at the outcome level (Gates & March, 2016). Considering the design of the study, we used different quality assessment tools. We used the RoB 2.0 Cochrane's tool (Sterne et al., 2019) when the studies were individual-randomized controlled trials (RCTs). We used an adaptation of the RoB 2.0 tool to assess cluster-RCTs (Elridge et al., 2016). Otherwise, we used the ROBINS-I tool to assess the risk of bias of non-randomized studies (Sterne et al., 2016).

Statistical Analysis

We focused on all the studies in the qualitative analysis. However, in the meta-analysis, we only included studies with an RCT design to compare experimental and control groups. The Standardized Mean Differences (SMD) were used as the mean effect size (ES) measure (Hedge's *g*) for each cognitive outcome of board games relative to the control condition. We used the same formula as Mansor et al. (2020). 95% confidence intervals (CI) were also calculated. ES was interpreted as follows: small (ES=.20), medium (ES=.50), and large (ES=.80) (Mansor et al., 2020). We assumed a meta-analytic random-effects model due to variability in methods and samples' characteristics (Viechtbauer, 2010). We conducted a multivariate model analysis using Restricted maximum-likelihood estimator (REML) estimation to adjust for the correlation of effects with-in-studies in R (Metafor Package, R software; Viechtbauer, 2010). Not all the studies gave a correlation value. We used Monte Carlo method to simulate correlations, using r=0.1, r=0.3, r=0.5, r=0.9. The variance was scaled based on an assumed inter-correlation of r=0.3 due to it was the most conservative value. Cochran's Q statistic and I^2 tests were used to assess heterogeneity. Levels of heterogeneity reflected by I^2 were described as low (25%), moderate (50%), and high (75%) (Higgins et al., 2003). We performed a sensitivity analysis to determine the extent to which observed pooled effect sizes depend on the risk of bias of the studies. The sensitivity analysis was performed using the QM test statistic for the omnibus test of coefficients, Metafor Package, R software (Viechtbauer, 2010).

We displayed the forest plots key to understanding present results divided into children and older people population. For all results, except for flexibility, positive effect directions represented an effect size in favor of the board games group.

Results

Study selection

Initially, the search resulted in 2,293 articles (n=54 in PsycINFO; n=150 in Medline; n=1,231 in Scopus; n= 858 in Web of Science). After adjusting for duplicates, 1866 studies remained. We found 11 additional articles using "snowball search" from the references of the studies selected and the updating process. Figure 1 shows a flow diagram based on PRISMA guidelines (Liberati et al., 2009) which reports the number of studies included or excluded in each phase of the present study.

------*Insert Figure 1*-------

After preliminary screening of titles and abstracts, we discarded 1,733 studies (see Figure 1 for specific reasons of discard). The interrater reliability between the two raters was substantial (Landis & Koch, 1977), with κ=0.62, 95% CI [0.58, 0.67], and a 94.99% of agreement rate. In the second screening phase, interrater reliability was almost perfect (Landis & Koch, 1977), with κ=0.82, 95% CI [0.65, 0.98], and a 95.14% of agreement rate. There were more discrepancies in the first phase due to the unclear information and ambiguity of some titles and abstracts. After the full-text screening, 19 studies met the inclusion criteria and were included in the systematic review. 12 studies were included in the meta-analysis.

Study characteristics

Table 1 summarizes the study and participants' characteristics from those studies included. We included the design of the study (i.e. kind of RCT and/or blindness), the sample size of both experimental and control groups, and demographic characteristics of the participants (i.e. location, mean age, and sex).

Table 2 reports intervention and control group characteristics, and the tests used in each study.

------*Insert Table 1*------

------*Insert Table 2*-------

The included studies resulted in a total of 932 participants (M=23.32, SD=12.65, range = 17-118). The studies included in the systematic review showed a wide gap of age groups (M=42.42, SD=33.09, range = 3.3-96.0). Most of the studies were conducted in early and middle childhood (n=9; 47.4%) and older people (n=8; 42.1%). Regarding the other two studies (10.5%), one of them included participants above 30 years old and the second one included people from 50 years old. No studies were found in adolescence and young adulthood. Regarding sex, there was also a substantial variability (% female M=55.48, SD=25.67, range = 7.7-100.0). Studies included in the meta-analyses were conducted in 14 different countries. Additionally, 15 studies of 19 (78.9%) were conducted in the lasts 10 years, and 18 of 19 (94.7%) in the lasts 20 years. Regarding the design of the study, thirteen were individual RCT (68.4%); three were cluster-RCT (15.8%) and three were non-randomized studies (15.8%).

Concerning interventions in experimental groups, many of the studies (n=8; 42.1%) found in the systematic review included traditional board games: chess, Mahjong, Go, and Ska. One of them (5.3%) used puzzles classified as a mass-market board game. The other studies used modern board games (n=4; 21.0%) or games created *ad hoc* (n=6; 31.6%) in the neuropsychological interventions.

In addition, considering the social component of board games, there were more interventions delivered in pairs or groups (n=15; 78.9%) than with a researcher (n=3;

15.8%) or individually (n=1; 5.3%). Interventions usually took place in ecological settings (n=15; 78.9%); such as at school (n=6; 40.0%), in nursing/ community centers (n=7; 46.6%), in a psychotherapy room (n=1; 6.7%) or at home (n=1; 6.7%). In a less extent, interventions took place in laboratory settings (n=1; 5.3%). Three studies (n=3; 15.8%) did not include information about the location of the intervention. The duration of each session intervention usually took at least 1 hour (n=13; 68.4%), but they ranged from 15 to 180 minutes (M=67.14, SD=35.16). Interventions typically occurred 1-2 times per week (M=2.42, SD=1.60; range = 1-6) for an average of 10.45 weeks (SD=5.28; range = 2-16; a scholar year). Regarding the total time of the intervention, there was a wide range of duration from 1 to 160 hours, with a median of 33.88 hours of intervention (SD= 46.65 h). In addition, more than half of the interventions with board games were adapted to cognitive initial levels, difficulty, or speed (n=10; 52.6%), whereas only one was not adapted (5.3%). Eight studies (42.1 %) did not give information about adaptiveness.

We found that the largest number of studies used active control groups (n=11; 55.0%) compared to Treatment as usual (TAU) (n=7; 35.0%) or wait-list (n=2; 10.0%) as passive control groups. Active control groups consisted in health counselling (n=4; 20.0%), low load cognitive modern board games (n=1; 5.0%) or *ad hoc* board games (n=3; 15.0%), computer games (n=1; 5.0%), paper-and-pencil cognitive tasks (n=1; 5.0%) and physical training (n=1; 5.0%). Treatment as usual consisted in general or math lessons at the school (n=4; 57.1%), unspecific activities (n=2; 28.6%) or unspecific activities plus medical treatment as usual (n=1; 14.3%).

------*Insert Table 3*-------

10 of 18 studies (55.6%) were assessed 1-2 weeks after intervention and three studies (16.7%) were also probably assessed in this time of range. Five studies (27.8%) did not give information about when assessments were conducted. Regarding follow-up,

two studies assessed 4 weeks after post-intervention (Cheng et al., 2006; Estrada-Plana et al., 2019), another study at 8 (Scalise et al., 2020), and other at 12 (Estrada-Plana et al., 2020).

Risk of bias within studies

As can be seen in Figure 2.A., we assessed as low risk of bias only 2 RCT studies (10.5%). Most of the RCT studies were labeled as "some concerns" (n=8, 44.4%) or "high risk of bias" (n=6, 33.3%). The three non-RCT studies were assessed as "serious risk of bias".

------Insert Figure 2-------

Effects on executive functions and other related cognitive processes

Core Executive Functions: Visuospatial STM

Childhood. The combined effect size was not significant (g = -0.24, p = .560, 95% CI -1.03 – 0.56). Q statistic was significant (Q_4 = 15.81, p = .003) and I^2 (80.23%) indicated a high heterogeneity in effect sizes. The sensitivity analysis was not significant, indicating that results were not influenced by the quality of the studies (Q_1 = 0.38, p = .539). Regarding other studies not included in the meta-analysis, Kaufman & Kaufman (1975) found a reduction in errors in a visual task for the games group, but not in the control group.

Older people. The combined effect size was not significant (g = 0.81, p = .060, 95% CI -0.03 – 1.66). Q statistic was significant (Q_3 = 12.77, p = .005) and I^2 (78.65%) indicated a high heterogeneity in effect sizes. The sensitivity analysis was not calculated due to lack of variability.

Core Executive Functions: Visuospatial WM

Childhood. The combined effect size was not significant (g = 0.26, p = .630, 95% CI -0.81 - 1.33). Q statistic (Q_3 = 15.42, p < .001) was significant and I^2 (85.99%), indicated a high heterogeneity in effect sizes. The sensitivity analysis was also significant (Q_2 = 15.41 , p <.001), indicating that the results were influenced by the quality of the studies. Those studies that had a high RoB, the intervention favor more control groups (*g* = -1.77, *p* = .002, 95% CI -2.88 – -0.66) in comparison to those studies that had some concerns (*g* = 0.66, *p* = .101, 95% CI -0.13 – 1.46) or a low RoB (*g* = 0.36, *p* = .110, 95% CI -0.08 – 0.79) which did not favor to any specific group.

Adulthood. The other study (Fissler et al., 2018) in healthy adults found that playing puzzles at home for 30 days did not improve a composite score of visuospatial STM and WM.

Older people. Two studies focused on visuospatial WM (See Table 3). Iizuka et al. (2019) found an improvement in maintaining and manipulating visuospatial information after playing Go Game in person or on a tablet computer. However, those participants that received Go Game intervention in person reported higher benefits in comparison to playing on a tablet computer. Both groups showed higher post scores in visuospatial WM in comparison to assisting to health lessons. In Estrada-Plana et al. (2020), no improvements were found in people who played modern board games and did cognitive paper-and-pencil tasks.

Core Executive Functions: Verbal STM

Childhood. The combined effect size was largely significant (*g* = 1.05, *p* < .001, 95% CI 0.47 - 1.63), favoring games training group. *Q* statistic (Q_5 = 14.36, *p* = .013) was significant and I^2 (70.39%), indicated a moderate heterogeneity in effect sizes. The sensitivity analysis was also significant (Q_1 = 6.12, *p* = .013), indicating that both high risk of bias studies (*g* = 1.83, *p* = .013, 95% CI 0.38 – 3.27) and some concerns (*g* = 0.88, *p* < .001, 95% CI 0.46 – 1.29) favor game groups in different degree. Regarding other studies not included in the meta-analysis, all of them found improvements after playing board games (Kermani et al., 2016; Kim et al., 2014).

Older people. The combined effect size did not show significant results in this outcome (g = 0.43, p = .134, 95% CI -0.13 – 0.99). Q statistic (Q_7 = 23.94, p = .001) was significant and I^2 (74.57%) indicated a moderate heterogeneity in effect sizes. The sensitivity analysis was not significant (Q_7 = 0.21, p = .651), indicating that the results were not influenced by the quality of the studies. Regarding other studies not included in the meta-analysis, Cheng et al. (2006) found an improvement in this outcome, whereas Overman & Robbins (2014) did not find any improvement.

Core Executive Functions: Verbal WM

Childhood. In preschooler ages, Passolunghi & Costa (2016) found an improvement in verbal WM after playing verbal and visuospatial board games in class. Estrada-Plana et al. (2019) did not find an improvement in updating verbal elements in school-aged children with an ADHD diagnosis. Another study with ADHD children (Kermani et al., 2016) showed an improvement in maintaining and manipulating verbal information. However, the authors did not show the STM and WM results separately. Finally, Kim et al. (2014) found an improvement in total digit span in both ADHD and control groups.

Older people. The combined effect size was not significant (g = 0.30, p = .143, 95% CI -0.10 – 0.71). Q statistic (Q_4 = 5.18, p = .269) was not significant and I^2 (15.22%) indicated a low heterogeneity in effect sizes. The sensitivity analysis was not significant (Q_1 = 3.36, p = .069), indicating that the results were not influenced by the quality of the studies. Regarding other studies not included in the meta-analysis, Kuo et al. (2018) found an improvement in this outcome, whereas Overman & Robbins (2014) did not find any improvement.

Core Executive Functions: Inhibition

Childhood. Scalise et al. (2020) assessed inhibition with the head-feet task in 5-year-old children from low incomes. In this study, they found that not only playing a numerical memory card game (experimental group) improved inhibition but also playing a magnitude numerical card game. On the other hand, in school-aged children, both studies that measured inhibition did not find any improvement (Benzing et al., 2018; Estrada-Plana et al., 2019). However, Kaufman & Kaufman (1975) found an improvement in the Stroop task in children with learning disabilities after 16 weeks of individual intervention.

Adulthood. Demily et al. (2009) found that people with schizophrenia who played 10 hours of chess improved their number of reading items in the color and interference control task of the Stroop test, while no significant differences were found in the control group across time.

Older people. Estrada-Plana et al. (2020) found that people who played modern board games maintained impulsivity scores, whereas people who did cognitive paper-and-pencil tasks improved their speed in a cognitive inhibition task. Hence, it seems that interventions based on modern board games could benefit in accuracy terms, whereas interventions based on paper-and-pencil tasks could benefit in speed terms.

Core Executive Functions: Flexibility

Childhood. In school-aged children, Benzing et al. (2018) found a significant result in flexibility. In studies with school-age children with an ADHD diagnosis, we found opposite results. Kim et al. (2014) found a significant improvement in Children's Color Trail Test (CCTT)-2, whereas Estrada-Plana et al. (2019) did not find any changes in the Trail Making Test (TMT)-B between before and after the intervention.

Adulthood. Demily et al. (2009) found that people in the experimental group made more perseverative errors in the Wisconsin Card Sorting Test (WCST) than the control group. However, these differences disappeared after people with schizophrenia played 10 hours of chess. Nonetheless, in the same study, these authors did not find any change in Trail Making Test (TMT) in both groups. Furthermore, we found that the other study (Fissler et al., 2018) in adult people did not show any improvement in the TMT-B measure.

Older people. The combined effect size was not significant (g = -0.44, p = .139, 95% CI -1.02 – 0.14). Q statistic (Q_3 = 6.87, p = .076) was not significant and I^2 (57.27%), indicated a moderate heterogeneity in effect sizes. The sensitivity analysis was not calculated because of the lack of variability. Overman & Robbins (2014) did not find any improvement in the TMT-B measure, but Kuo et al. (2018) found an improvement in the color version of TMT.

------*Insert Figure 3*-------

------*Insert Figure 4*-------

Higher-level Executive Functions

Problem-Solving in childhood. Bartolucci et al. (2019) did not find an improvement in a scale that assessed problem-solving. Moreover, the statistic of this result was not reported. This was the main reason to consider this study with serious risk of bias.

Reasoning in childhood. Kaufman & Kaufman (1975) assessed reasoning with Raven's Matrices in school-aged children. They found an improvement in both experimental and control groups. Thus, playing board games did not involve any improvement. However, Bartolucci et al. (2019) found an improvement in two reasoning tests in a pre-post sample.

Reasoning in adulthood and older people. Kuo et al. (2018) assessed reasoning with Raven's Matrices in healthy older people. As in school-age children, they found an improvement in both experimental and control groups. Thus, playing board games did not involve any improvement. The other two studies were also conducted in already or nearly older adults. Fissler et al. (2018) found that playing puzzles at home for 30 days did not improve reasoning assessed with Block Design of WAIS-IV. Overman & Robbins, (2014) found that playing modern board games in small groups nearly improved reasoning assessed with Matrix Reasoning of Wechsler Adult Intelligence Scale, 4th edition, (WAIS-IV).

Planning in adulthood. Demily et al. (2009) assessed planning with the Tower of London (ToL) test. In this study, they found that patients with a chronic diagnose of schizophrenia decreased latency in producing the first movement in comparison to the wait-list control group after 10 sessions of playing chess. Moreover, they showed an increase in latency times while the task demanded more movements.

Hot Executive Functions

No study included in the systematic review used a measure of hot EFs.

Other related cognitive processes

Attention in childhood. Only one study assessed attention out of EFs (Scholz et al., 2008). Scholz et al. (2008) found an improvement in the outcome hits in a cross-out task after those children with learning disabilities played chess as an extra-curricular activity for one school year, but not in concentration (hits minus commissions' errors). Moreover, this result was only reported for the experimental group which was one of the reasons to consider this study with a high risk of bias.

Processing speed in childhood. Studies that assessed processing speed in school-aged children found contradictory results (Estrada-Plana et al., 2019; Kaufman &

Kaufman, 1975; Kermani et al., 2016; Kim et al., 2014). Estrada-Plana et al., (2019) did not find any improvement in TMT-A, but Kermani et al. (2016) found an improvement in a symbol search task. On the one hand, Kim et al. (2014) found that children with a diagnose of ADHD improved it, but no improvement was found in children without ADHD in color trails test. On the other hand, Kaufman & Kaufman (1975) found an improvement in the speed of reading words.

Processing speed in adulthood. Demily et al. (2009) and Fissler et al. (2018) did not find any change between experimental and control groups across phases in TMT and TMT-A, respectively.

Processing speed in older people. Overman & Robbins (2014) and Estrada-Plana et al. (2020) did not find any improvement in TMT-A and Coding, respectively. However, in other studies with healthy older people improvements in processing speed were found. For example, Iizuka et al. (2019) found a tendency towards significance, and Panphunpho et al. (2013) and Kuo et al. (2018) found significant improvements in TMT-A and a visual search measure, respectively.

Verbal fluency in older people. Only two studies assessed verbal fluency (Estrada-Plana et al., 2020; Iizuka et al., 2019). Two RCTs found contradictory results in phonemic verbal fluency (See Table 3). Both studies did not show any improvement in categorical verbal fluency (See Table 3). However, Estrada-Plana et al. (2020) also conducted a pilot study. In this pilot study, they found an improvement in categorical verbal fluency.

Discussion

This systematic review aimed to find all the scientific literature about the benefits in executive functions from neuropsychological interventions based on board games. In general, there is a scarcity of studies that trained executive functions with board games.

We found that children and older people were the most studied age ranges. As Anguera & Gazzaley (2015) explained, these ages are the most interesting taking into account development patterns. In general, it seems that these cognitive processes could be trained independently of age, as previous studies have stated (Schwaighofer et al., 2015). Afterward, we specify our findings according to each cognitive process.

Core Executive Functions

Visuospatial STM

We did not find an improvement neither in children nor in older people. Regarding preschool and school-age children, we found studies in favor to improve visuospatial STM (Kaufman & Kaufman, 1975) and against (Estrada-Plana et al., 2019; Passolunghi & Costa, 2016; Scalise et al., 2020). In healthy older people, we also found results in favor (Panphunpho et al., 2013) and against (Iizuka et al., 2019; Estrada-Plana et al., 2020). Schwaighofer et al. (2015) and Lampit et al. (2014) suggested that improvements in visuospatial STM could be modulated by the total amount of time that lasted the training (training dose). In children, the study that had the largest quantity of time was Kaufman & Kaufman (1975), where significant improvement effects were found. In older people, Panphunpho et al. (2013) carried out the longest intervention, too. Thus, it seems that more frequent and longer interventions yielded greater effects in visuospatial STM.

Visuospatial WM

We did not find a general improvement in this outcome. Only one study (Passolunghi & Costa, 2016) measured visuospatial WM in preschool children. In this study, the authors found an improvement in this measure. In school-aged children, both studies found contradictory results. One study (Benzing et al., 2018) found a trend in visuospatial WM, whereas the other study did not find any improvement (Estrada-Plana et al., 2019). The multimodality hypothesis (Schwaighofer et al., 2015) could explain these results. This hypothesis states that training in different modalities of WM tasks (i.e. verbal and visuospatial) could yield larger benefits. In the study conducted by Passolunghi & Costa (2016) these authors trained equally both verbal and visuospatial modality. Benzing et al. (2018) mostly used games that boosted visual WM and games that minority boosted verbal WM. However, Estrada-Plana et al. (2019) only included visual WM games. Conversely, in this last study, it seems that the control group showed a higher benefit than the experimental group. An explanation could be that adaptive studies in which researchers monitor and adapt the session showed higher benefits than non-adaptive, as other studies have suggested (Holmes et al., 2009; Schwaighofer et al., 2015). Future studies are needed to yield this conclusion.

In adulthood, only Fissler et al. (2018) assessed visuospatial WM after playing mass-market puzzles for 30 days. A previous meta-analytic study (Lampit et al., 2014) in healthy-older people suggested that doing cognitive training alone at home was less useful than doing it in a group. Future studies should consider these modifiers. Regarding older people, only Estrada-Plana et al. (2020) and Iizuka et al. (2019) measured visuospatial WM. Estrada-Plana et al. (2020) did not find transfer effects after cognitive training that boosted a few visuospatial WM. Iizuka et al. (2019) found that playing the game Go which requires the activation of regions linked to Visuospatial WM (Chen et al., 2003) improved this cognitive process. However, no study until now has measured updating in healthy older people. Future RCT studies should be conducted in older people assessing visuospatial updating of WM.

Verbal STM

We found that board games-based cognitive training can train verbal STM in childhood. We found improvements in all the studies conducted in school-age children with and without ADHD or learning disabilities (Estrada-Plana et al., 2019; Kaufman &

Kaufman, 1975; Kermani et al., 2016; Kim et al., 2014). In typically preschool-age children, Passolunghi & Costa (2016) did not find any improvement in verbal STM. The age range of the studies in school-age children was about 10 years old. As Peijnenborgh et al. (2016) suggested in their meta-analysis in children with learning disabilities, one possible explanation is that verbal STM and WM are easily trained in children with 10 years old, but more difficult at earlier ages.

Concerning transfer effects, Passolunghi & Costa (2016) directly trained verbal STM. In school-age children, Kaufman & Kaufman (1975) and Kermani et al. (2016) directly trained a few verbal STM. The other studies in school-age children did not train directly verbal STM. Thus, despite interventions that did not train directly verbal STM, maybe verbal STM was boosted at giving verbal self-instruction when older children and adults were doing visuospatial STM and WM tasks (Dunning & Holmes, 2014). Moreover, a previous meta-analysis (Rapport et al., 2013) in children with ADHD found improvements in verbal STM after receiving computerized cognitive training that boosted visuospatial WM.

In older people, we did not find significant results for board games-based cognitive training. Some studies found improvements in verbal STM (Cheng et al., 2006; Panphunpho et al., 2013), but the majority of the studies did not find any benefit of board games interventions (Estrada-Plana et al., 2020; Iizuka et al., 2018, 2019; Overman & Robbins, 2014; Vale et al., 2018). Those studies included at least bi-weekly sessions for 16 weeks and reported at least 40h. of total dose showed an effect for board game groups but not in control groups (Cheng et al., 2006; Panphunpho et al., 2013). A previous systematic review found that total dose moderated results in verbal STM in older people (Lampit et al., 2014). Furthermore, it is important to highlight that traditional board games like Chess or Go boost visuospatial STM, but not verbal STM. As in childhood, maybe verbal STM was boosted at giving verbal self-instruction at doing visuospatial STM and WM tasks (Dunning & Holmes, 2014).

Verbal WM

Passolunghi & Costa (2016) found improvements in verbal WM in preschool-age children after playing verbal and visual memory games. Kermani et al. (2016) also found that school-age children with ADHD improved verbal STM and WM after playing verbal and visual memory games. However, Estrada-Plana et al. (2019) and Kim et al. (2014) did not find any improvement in school-age children with ADHD after playing visual memory games. Those studies that included verbal and visuospatial games found significant results. These results are in line with those found in visuospatial WM and can be explained by the multimodality hypothesis (Schwaighofer et al., 2015). In adulthood, there were no improvements after paying visual puzzles at home.

In older people, the meta-analysis did not show significant effects in verbal WM. However, we found that the only study (Vale et al., 2018) that reported positive effects for the board game group included 100% of female participants. In a previous study (Rahe et al., 2015), participants with Mild Cognitive Impairment (MCI) have shown similar results in a manipulative verbal WM task. One possible explanation is that women engage more plasticity mechanisms from the cognitive reserve in verbal memory than men (Sundermann et al., 2016). Kuo et al. (2018) found improvements in cognitive board games and a trend in low cognitive board games in a composite score that included the Digit Backward task as a measure of verbal WM. We cannot conclude if the improvement in the composite score is due to verbal WM or other cognitive measures included. Nonetheless, the study of Kuo et al. (2018) was the only one that included in great extent games that boosted not only visuospatial WM but also verbal WM. This particularity yield the multimodality hypothesis (Schwaighofer et al., 2015).

Inhibition

The majority of the studies were conducted on children (Benzing et al., 2018; Estrada-Plana et al., 2019; Kaufman & Kaufman, 1975; Scalise et al., 2020). In Scalise et al. (2020), all the children, who have 5-year-old children, played card games to improve early numeracy and memory skills. All the children improved their scores in an inhibition task (Head-Feet task) after playing card games, specially memory, and numerical card games. Benzing et al. (2018) and Estrada-Plana et al. (2019) did not find improvements in computerized tasks that measure inhibition in children between 10-to-12 with a Flanker task and 8-to-12 years old with a go/no-go task, respectively. Kaufman & Kaufman, (1975) found an improvement in the Stroop test in children between 9 and 10 years old. Concretely, different studies suggested that there are different kinds of inhibition measured with different tasks (Diamond, 2013; Nigg, 2000, 2017). In addition, these kinds of inhibition could have different developmental patterns (Best & Miller, 2010; Huizinga et al., 2006; Nigg, 2017). Thus, the improvement in inhibition could be explained due to developmental patterns at these ages. However, an alternative explanation could be possible. Previously, Dahlin (2011) has suggested that WM training can improve reading abilities in children with special needs, as in the study of Kaufman & Kaufman, (1975). Moreover, different studies (Leon-Carrion et al., 2004; Martín et al., 2012) have suggested that the improvement in the speed of reading could explain the improvements in the Stroop task after 10 years old. Thus, the improvements in the Stroop task could be due to the improvement in reading words, like improved the Schonell Graded Word List in the same study. Nonetheless, other possible explanations for gains in inhibition could be the usage of paper-and-pencil assessment tasks instead of computerized tasks or received the intervention individually with a researcher. All these modifiers should be considered in future studies. Regarding adulthood, Demily et al.

(2009) also found an improvement in the Stroop task in adults with a diagnosis of chronic schizophrenia after playing chess. So, interference tasks could be trainable in people with cognitive deficits (Bora et al., 2017; Westerhausen et al., 2011). However, previous computerized cognitive training with attention and WM as target have not found improvements in the Stroop test after using computerized cognitive training with attention and WM as target (Mak et al., 2019). More studies should be conducted to elucidate if interference control can be trained in people with a diagnosis of schizophrenia. In older people, (Estrada-Plana et al., 2020) found that people who played board games improved control of impulsivity, whereas the cognitive paper-and-pencil tasks group improved cognitive inhibition. These authors explained these results considering the inherent characteristics of each intervention.

Flexibility

The meta-analysis did not show an improvement in older people. Flexibility or shifting is a construct composed of different factors, which can be measured with different neuropsychological tasks (Bastian & Druey, 2017). Our results can be explained by this assumption. In this systematic review, we found that responses to an adapted flanker task (Benzing et al., 2018), WCST (Demily et al., 2009; Panphunpho et al., 2013), and Color-TMT (Kim et al., 2014; Kuo et al., 2018) could be trained with board games in cognitive interventions. Estrada-Plana et al. (2020) did not find any improvement in the speed of doing the 5 digits test. Moreover, TMT-part B did not show any improvement independently of the characteristics of the intervention and the participants (Demily et al., 2009; Estrada-Plana et al., 2019; Iizuka et al., 2019; Fissler et al., 2018; Overman & Robbins, 2014). However, in Kim et al. (2014), only the participants from the ADHD group improved Color-TMT and in Kuo et al. (2018) this measure took part of a composite score of Executive control. Furthermore, previous studies show that both neuropsychological tests do not measure the same construct (Dugbartey et al., 2000). As in Demily et al. (2009), future studies should use different measures of flexibility to show if only improve specific measures or all the broad cognitive process.

Higher-Level Executive Functions

Planning

Regarding planning, we only found one study in people with a diagnosis of chronic schizophrenia (Demily et al., 2009). After playing chess for 10 weeks, they reduced their latency times in the 2 and 4 movements trials of the ToL task in comparison to the TAU group. Moreover, they showed an increase in latency times while the task demanded more movements. This could show an improvement in the planning, due to higher times in pre-planning movements denote better planning (Unterrainer et al., 2004). However, this study had a small sample size and a high risk of bias. Future studies are needed to prove if planning can be improved or maintained with game-based cognitive interventions.

Reasoning

On the other hand, reasoning has been assessed in a few more studies. None of the RCT studies found any improvement in reasoning neither in children (Kaufman & Kaufman, 1975) nor adults or older people (Fissler et al., 2018; Kuo et al., 2018). One possible explanation for these results is that none of the studies directly trained reasoning in a considerable amount of sessions, being one of the lowest EF trained in each intervention. Nonetheless, two studies with a pre-post design with and without a control group found significant results. In children, Bartolucci et al. (2019) found an improvement in two reasoning tasks after directly training to reason with modern board games. In older people, Overman & Robbins (2014) found a trend towards significance after playing one board and one card games that boosted directly reasoning in nearly all the sessions. Another explanation for the incongruent results above could be the duration of the intervention or the design of the study. On the one hand, a recent systematic review in healthy older people found that training less or equal to 10 hours in total could explain differences in transfer effects to reasoning after using WM training (Hou et al., 2020), as in Overman & Robbins (2014). On the other hand, Melby-Lervåg et al. (2016) found far transfer effects to reasoning in designs with passive control groups but not in active ones. Moreover, traditional board games -such as Chess, Go, or Ska- could activate reasoning. However, none of the studies (Cheng et al., 2006; Demily et al., 2009; Iizuka et al., 2018, 2019; Kim et al., 2014; Panphunpho et al., 2013; Scholz et al., 2008; Vale et al., 2018) that used traditional board games assessed reasoning. Future studies using traditional board games should include measures of reasoning.

Problem-Solving

Bartolucci et al. (2019) did not report an improvement in this outcome after playing modern board games. However, in the same study, they conducted a comparison study between non-players and players. They found higher scores in non-players. Future experimental studies should measure this outcome.

Other cognitive processes

Hot EF

We did not find any study that assessed hot EFs. Moreover, all of the board games played in groups in the cognitive interventions were competitive. Some neural studies have suggested that playing competitive games could activate regions more linked to cool EF, whereas cooperative games could activate regions more linked to hot EF (Decety et al., 2004). For instance, Staiano et al. (2012) found higher improvements in cool EF after playing an exergame in the competitive version than in the cooperative version. Moreover, Creighton & Szymkowiak (2014) found more improvements in social outcomes in the cooperative group than in the competitive one. Future studies should research all these issues in board games with different mechanics.

Verbal fluency

Only two studies (Estrada-Plana et al., 2020; Iizuka et al., 2019) assessed verbal fluency. In the study of Iizuka et al. (2019), participants played Go game which did not activate directly verbal fluency. We did not observe transfer effects. However, in the study of Estrada-Plana et al. (2020), participants improved verbal fluency after directly training it with modern board games and paper-and-pencil tasks. Kelly et al. (2014) suggested that cognitive stimulation could improve verbal fluency. Thus, future studies should elucidate if verbal fluency can be trained with board games that directly boost verbal fluency or if transfer effects are possible.

Processing speed

Regarding processing speed, we found contradictory results in school-age children. On the one hand, Estrada-Plana et al. (2019) did not find transfer effects in TMT-A with modern board games. On the other hand, Kermani et al. (2016) and Kaufman & Kaufman (1975) find transfer effects in the symbol search task of WISC-IV and Schonell Graded Word List, respectively. Kim et al. (2014) found mixed results in color trails test. In adults, Demily et al. (2009) and Fissler et al. (2018) did not find transfer effects in TMT-A. In older people, Overman & Robbins (2014) did not find transfer effects in TMT-A, but Kuo et al. (2018) and Panphunpho et al. (2013) find transfer effects in a visual search task and TMT-A, respectively. One explanation for these results in children and older people could be a total of sessions, in such a way that less than 10 sessions did not give gains in processing speed (Ball et al., 2013).

Attention

Finally, only one study with a high risk of bias assessed attention with task performance (Scholz et al., 2008). This study found benefits in hits but not in concentration after playing chess. Future studies should research types of attention and their improvement after playing chess.

Clinical implications

- Could we recommend the usage of board games as cognitive interventions?: Most of the studies included in the qualitative and the quantitative review found non-significant results. However, some studies found promising more improvements in children and better preservations in older adults. So, with the present evidence, we cannot recommend using board games as cognitive interventions without considering the following specifications.
- Near and Far transfer effects: our results suggest that near transfer could be possible in WM (Passolunghi & Costa, 2016), core EFs (Benzing et al., 2018) and higher-level EFs (i.e. planning (Demily et al., 2009), reasoning (Bartolucci et al., 2019; Overman & Robbins, 2014), or verbal fluency (Estrada-Plana et al., 2020)). However, this near transfer is not always explicitly, as in verbal STM or inhibition results. Future studies are needed to assess near and transfer effects based on the similarity of the trained and untrained tasks. Hence, it is important to analyze cognitively each game to predict possible cognitive benefits.
- Who benefits the most?: Some studies found improvements in children and older people. Thus, it seems that cognitive training based on board games can benefit independently to age. However, future studies are needed in adulthood. In addition, the initial cognitive level could predict gains in neuropsychological tasks (von Bastian & Oberauer, 2014). This lower baseline can be explained by developmental patterns,

as in inhibition results or verbal STM. Finally, older women may benefit from verbal WM.

- With whom and where?: Playing with other people benefited more cognitively than doing alone, as Iizuka et al. (2019) stated. In almost all of the studies, the participants played with other people (a researcher, in pairs, or small groups), except in one study (Fissler et al., 2018). This study did not find any improvement in none of the outcome measured. Previous studies have also found more improvements when the intervention is conducted in a group in comparison to when the intervention is conducted individually at home (Kelly et al., 2014; Lampit et al., 2014). Future studies should elucidate if conduct the intervention at home with other people or individually in laboratory settings could impact the benefits of the training.
- How many sessions? The longer-the better (Schwaighofer et al., 2015)?: Our results in visuospatial STM, verbal STM in older people, and processing speed show that more frequent, with more weeks of intervention and/or sessions yielded more cognitive benefits. However, maybe fewer sessions could benefit other cognitive processes, such as reasoning or verbal STM in childhood.
- Traditional or modern board games? Or better those created by researchers?: None of the studies included in the systematic review answer these questions. Related to traditional board games and those created by researchers, many of the studies showed some benefits in cognitive processes. We included four studies that used modern board games and also found improvements in some cognitive processes. However, only one study was an RCT (Estrada-Plana et al., 2020).
- Adaptive, gamified, strategies?: We found that adaptive cognitive training works better to improve visuospatial WM skills in children. In addition, Overman & Robbins (2014) include some gamification in the intervention at ranking positions in each

game. Finally, some studies give a role of learning strategies in cognitive training (Bartolucci et al., 2019; Kermani et al., 2016). Hence, future studies should elucidate the role of gamification and strategies in cognitive training based on board games.

- Similar control groups, similar gains? We found that when an active control group boosts cognitive skills, participants in this group could benefit from these tasks, as in Estrada-Plana et al. (2020). However, based on the intervention, the benefits could be different.

Research implications

First, more studies are needed. The present study shows promising results, though they are far to be so consistent to recommend the usage of board games as cognitive interventions out of the research field. Moreover, it is important to highlight the need of conducting more randomized control trials. In addition, it is important to consider some points to decrease the risk of bias. It is important to determine the method of randomization and the method to assure the allocation concealment. Regarding blindness, some of the studies included in the systematic review blinded the assessors. A scarcity of the studies blinded the participants and/or the people who conduct the intervention. Thus, future studies should consider being double or total blinded to minimize the risk of bias in the administration of the intervention or the assessment (Foroughi et al., 2016). In addition, it is important to select adequate active and/or passive control groups. Thus, we stressed the importance of the isolate active principle of board games to see if EF can be trained, as Au (2020) suggested in their meta-analysis. For example, Iizuka et al. (2019) consider an active control group doing the same activity but in computer and another group that only receives some healthy lessons. Considering our risk of bias assessments, we stress the importance of clinical trial registrations and protocols to minimize the lack of transparency. In addition, we consider that giving information about the timeline -as in Estrada-Plana et al. (2019) and Scalise et al. (2020)- can help other researchers to be conscious about time resources. Finally, task impurity should be taken considered.

Limitations of the review

We only included published articles. This can overestimate the effects found in the systematic review. However, we included some studies that did not find improvements in neuropsychological tasks due to the use of board games in cognitive training (Fissler et al., 2018; Overman & Robbins, 2014). Nonetheless, caution should be taken when interpreting the results. The main limitation was the variety in methodologies, neuropsychological tests, and the reduced number of studies included. All of these aspects difficult to select homogeneous studies to conduct a meta-analysis.

Conclusions/Recommendations

This systematic review notes that there is a scarcity of studies that trained executive functions by board games. It seems that some cognitive processes can be trained independently of age, specially verbal short-term memory in school-age children. Results could be explained by developmental patterns, moderators, and other cognitive training hypotheses. On the one hand, we cannot recommend the usage of board games as cognitive interventions with the found evidence. On the other hand, we encourage research in this field because we found some promising results. Future well-conduct RCTs are needed.

References

Aita, S. L., Beach, J. D., Taylor, S. E., Borgogna, N. C., Harrell, M. N., & Hill, B. D. (2019). Executive, language, or both? An examination of the construct validity of verbal fluency measures. *Applied Neuropsychology:Adult*, *26*(5), 441–451. https://doi.org/10.1080/23279095.2018.1439830

Altschul, D. M., & Deary, I. J. (2020). Playing Analog Games Is Associated with Reduced Declines in Cognitive Function: A 68-Year Longitudinal Cohort Study. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *75*(3), 474–482. https://doi.org/10.1093/geronb/gbz149

Anguera, J. A., & Gazzaley, A. (2015). Video games, cognitive exercises, and the enhancement of cognitive abilities. *Current Opinion in Behavioral Sciences*, *4*, 160–165. https://doi.org/10.1016/j.cobeha.2015.06.002

Au, J., Gibson, B. C., Bunarjo, K., Buschkuehl, M., & Jaeggi, S. M. (2020). Quantifying the Difference Between Active and Passive Control Groups in Cognitive Interventions Using Two Meta-analytical Approaches. *Journal of Cognitive Enhancement*, *4*, 192–210. https://doi.org/10.1007/s41465-020-00164-6

Baggetta, P., & Alexander, P. A. (2016). Conceptualization and Operationalization of Executive Function. *Mind, Brain, and Education*, *10*(1), 10–33. https://doi.org/10.1111/mbe.12100

Ball, K. K., Ross, L. A., Roth, D. L., & Edwards, J. D. (2013). *Speed of Processing Training in the ACTIVE Study : How Much Is Needed and Who Benefits ?* https://doi.org/10.1177/0898264312470167

Barker, J. E., Semenov, A. D., Michaelson, L., Provan, L. S., Snyder, H. R., & Munakata, Y. (2014). Less-structured time in children's daily lives predicts self-directed executive functioning. *Frontiers in Psychology*, *5*, 1–16. https://doi.org/10.3389/fpsyg.2014.00593

Bartolucci, M., Mattioli, F., & Batini, F. (2019). Do board games make people smarter? Two initial exploratory studies. *International Journal of Game-Based Learning*, *9*(4), 1–14. https://doi.org/10.4018/IJGBL.2019100101

Bastian, C. C. Von, & Druey, M. D. (2017). Shifting Between Mental Sets: An Individual Differences Approach to Commonalities and Differences of Task Switching Components. *Journal of Experimental Psychology: General*, *146*(9), 1266–1285. https://doi.org/10.1037/xge0000333.supp

Benzing, V., Schmidt, M., Jäger, K., Egger, F., Conzelmann, A., & Roebers, C. M. (2018). A classroom intervention to improve executive functions in late primary school children: Too 'old' for improvements? *British Journal of Educational Psychology*, 1–14. https://doi.org/10.1111/bjep.12232

Best, J. R., & Miller, P. H. (2010). A Developmental Perspective on Executive Function. *Child Development*, *81*(6), 1641–1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Bora, E., Binnur Akdede, B., & Alptekin, K. (2017). Neurocognitive impairment in deficit and non-deficit schizophrenia: A meta-analysis. *Psychological Medicine*, *47*(14), 2401–2413. https://doi.org/10.1017/S0033291717000952

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, *8*(1), 36–41. https://doi.org/10.1111/cdep.12059

Buscemi, N., Hartling, L., Vandermeer, B., Tjosvold, L., & Klassen, T. P. (2006). Single data extraction generated more errors than double data extraction in systematic reviews. *Journal of Clinical Epidemiology*, *59*(7), 697–703. https://doi.org/10.1016/j.jclinepi.2005.11.010

Chen, X., Zhang, D., Zhang, X., Li, Z., Meng, X., He, S., & Hu, X. (2003). A functional

MRI study of high-level cognition: II. The game of GO. *Cognitive Brain Research*, *16*(1), 32–37. https://doi.org/10.1016/S0926-6410(02)00206-9

Cheng, S. T., Chan, A. C. M., & Yu, E. C. S. (2006). An exploratory study of the effect of mahjong on the cognitive functioning of persons with dementia. *International Journal of Geriatric Psychiatry*, *21*(7), 611–617. https://doi.org/10.1002/gps.1531

Creighton, S., & Szymkowiak, A. (2014). The Effects of Cooperative and Competitive Games on Classroom Interaction Frequencies. *Procedia - Social and Behavioral Sciences*, *140*(01382), 155–163. https://doi.org/10.1016/j.sbspro.2014.04.402

Cristofori, I., Cohen-Zimerman, S., & Grafman, J. (2019). Executive functions. In M. D'Esposito & J. H. Grafman (Eds.), *Handbook of Clinical Neurology: The Frontal Lobes* (1st ed., Vol. 163, pp. 197–219). Elsevier B.V. https://doi.org/10.1016/B978-0-12-804281-6.00011-2

Dahlin, K. I. E. (2011). *Effects of working memory training on reading in children with special needs*. 479–491. https://doi.org/10.1007/s11145-010-9238-y

Dartigues, J. F., Foubert-Samier, A., Le Goff, M., Viltard, M., Amieva, H., Orgogozo, J. M., Barberger-Gateau, P., & Helmer, C. (2013). Playing board games, cognitive decline and dementia: A French population-based cohort study. *BMJ Open*, *3*(8), 1–7. https://doi.org/10.1136/bmjopen-2013-002998

Decety, J., Jackson, P. L., Sommerville, J. A., Chaminade, T., & Meltzoff, A. N. (2004). The neural bases of cooperation and competition: an fMRI investigation. *Neuroimage*, *23*(2), 744–751. https://doi.org/10.1016/j.neuroimage.2004.05.025.The

Demily, C., Cavézian, C., Desmurget, M., Berquand-Merle, M., Chambon, V., & Franck, N. (2009). The game of chess enhances cognitive abilities in schizophrenia. *Schizophrenia Research*, *107*(1), 112–113. https://doi.org/10.1016/j.schres.2008.09.024

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*, 136–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Ling, D. S. (2016). Conclusions about Interventions, Programs, and Approaches for Improving Executive Functions that appear Justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34–48. https://doi.org/10.1016/j.dcn.2015.11.005

Dugbartey, A. T., Townes, B. D., & Mahurin, R. K. (2000). Equivalence of the Color Trails Test and Trail Making Test in nonnative English-speakers. *Archives of Clinical Neuropsychology*, *15*(5), 425–431. https://doi.org/10.1016/S0887-6177(99)00034-7

Dunning, D. L., & Holmes, J. (2014). Does working memory training promote the use of strategies on untrained working memory tasks? *Memory and Cognition*, *42*(6), 854–862. https://doi.org/10.3758/s13421-014-0410-5

Elridge, S., Campbell, M., Campbell, M., Dahota, A., Giraudeau, B., Higgins, J., Reeves, B., & Siegfried, N. (2016). *Revised Cochrane risk of bias tool for randomized trials (RoB 2.0). Additional considerations for cluster-randomized trials*. https://sites.google.com/site/riskofbiastool/welcome/rob-2-0-tool/archive-rob-2-0-cluster-randomized-trials-2016

Estrada-Plana, V., Esquerda, M., Mangues, R., March-Llanes, J., & Moya-Higueras, J.

(2019). A Pilot Study of the Efficacy of a Cognitive Training Based on Board Games in Children with Attention-Deficit/Hyperactivity Disorder: A Randomized Controlled Trial. *Games for Health Journal*, *8*(4), 265–274. https://doi.org/10.1089/g4h.2018.0051

Estrada-Plana, V., Montanera, R., Ibarz-Estruga, A., March-Llanes, J., Vita-Barrull, N., Guzmán, N., Ros-Morente, A., Ayesa, R., & Moya-Higueras, J. (2020). Cognitive Training with Modern Board and Card Games in Healthy Older Adults: Two Randomized Controlled Trials. *International Journal of Geriatric Psychiatry*, gps.5484. https://doi.org/10.1002/gps.5484

Fissler, P., Küster, O. C., Laptinskaya, D., Loy, L. S., von Arnim, C. A. F., & Kolassa, I.-T. (2018). Jigsaw Puzzling Taps Multiple Cognitive Abilities and Is a Potential Protective Factor for Cognitive Aging. *Frontiers in Aging Neuroscience*, *10*, 1–11. https://doi.org/10.3389/fnagi.2018.00299

Fissler, P., Küster, O., Schlee, W., & Kolassa, I. T. (2013). Novelty interventions to enhance broad cognitive abilities and prevent dementia: Synergistic approaches for the facilitation of positive plastic change. In M. M. Merzenich, M. Nahum, & T. M. Van Vleet (Eds.), *Changing Brains Applying Brain Plasticity to Advance and Recover Human Ability* (Vol. 207). Elsevier B.V. https://doi.org/10.1016/B978-0-444-63327-9.00017-5

Foroughi, C. K., Monfort, S. S., Paczynski, M., Mcknight, P. E., & Greenwood, P. M. (2016). *Placebo effects in cognitive training*. *113*(27), 7470–7474. https://doi.org/10.1073/pnas.1601243113

Gates, N. J., & March, E. G. (2016). A Neuropsychologist's Guide To Undertaking a

Systematic Review for Publication: Making the most of PRISMA Guidelines. *Neuropsychology Review*, *26*(2), 109–120. https://doi.org/10.1007/s11065-016-9318-0

Gauthier, A., Kato, P. M., Bul, K. C. M., Dunwell, I., Walker-Clarke, A., & Lameras, P. (2019). Board Games for Health: A Systematic Literature Review and Meta-Analysis. *Games for Health Journal*, *8*(2), 85–100. https://doi.org/10.1089/g4h.2018.0017

Ghanavati, E., Salehinejad, M. A., Nejati, V., & Nitsche, M. A. (2019). Differential role of prefrontal, temporal and parietal cortices in verbal and figural fluency: Implications for the supramodal contribution of executive functions. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-40273-7

Guo, Q., Zhou, T., Li, W., Dong, L., Wang, S., & Zou, L. (2017). Single-trial EEG-informed fMRI analysis of emotional decision problems in hot executive function. *Brain and Behavior*, *7*(7), 1–9. https://doi.org/10.1002/brb3.728

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analysis. *BMJ*, *327*(2), 557–560. https://doi.org/10.1007/s10844-006-2974-4

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, *12*(4), 9–15. https://doi.org/10.1111/j.1467-7687.2009.00848.x

Homer, B. D., Plass, J. L., Rose, M. C., MacNamara, A. P., Pawar, S., & Ober, T. M. (2019). Activating adolescents' "hot" executive functions in a digital game to train cognitive skills: The effects of age and prior abilities. *Cognitive Development*, *49*, 20–32. https://doi.org/10.1016/j.cogdev.2018.11.005

Hou, J., Jiang, T., Fu, J., Su, B., Wu, H., Sun, R., & Zhang, T. (2020). The Long-Term Efficacy of Working Memory Training in Healthy Older Adults: A Systematic Review and Meta-Analysis of 22 Randomized Controlled Trials. *The Journals of Gerontology: Series B*, In press. https://doi.org/10.1093/geronb/gbaa077

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017–2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Iizuka, A., Suzuki, H., Ogawa, S., Kobayashi-Cuya, K. E., Kobayashi, M., Inagaki, H., Sugiyama, M., Awata, S., Takebayashi, T., & Fujiwara, Y. (2019). Does social interaction influence the effect of cognitive intervention program? A randomized controlled trial using Go game. *International Journal of Geriatric Psychiatry*, *34*(2), 324–332. https://doi.org/10.1002/gps.5024

Iizuka, A., Suzuki, H., Ogawa, S., Kobayashi-Cuya, K. E., Kobayashi, M., Takebayashi, T., & Fujiwara, Y. (2018). Pilot Randomized Controlled Trial of the GO Game Intervention on Cognitive Function. *American Journal of Alzheimer's Disease & Other Dementias®*, *33*(3), 192–198. https://doi.org/10.1177/1533317517753362

Jirout, J. J., & Newcombe, N. S. (2015). Building Blocks for Developing Spatial Skills: Evidence From a Large, Representative U.S. Sample. *Psychological Science*, *26*(3), 302–310. https://doi.org/10.1177/0956797614563338

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review*, *17*(3), 213–233.

https://doi.org/10.1007/s11065-007-9040-z

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological Bulletin*, *144*(11), 1147–1185. https://doi.org/10.1037/bul0000160

Kaufman, D., & Kaufman, P. (1975). Strategy Training and Remedial Techniques. *Journal of Learning Disabilities*, *12*(6), 416–419.

Kelly, M. E., Loughrey, D., Lawlor, B. A., Robertson, I. H., Walsh, C., & Brennan, S. (2014). The impact of cognitive training and mental stimulation on cognitive and everyday functioning of healthy older adults: A systematic review and meta-analysis. *Ageing Research Reviews*, *15*(1), 28–43. https://doi.org/10.1016/j.arr.2014.02.004

Kermani, F. K., Mohammadi, M. R., Yadegari, F., Haresabadi, F., & Sadeghi, S. M. (2016). Working memory training in the form of structured games in children with attention deficit hyperactivity disorder. *Iranian Journal of Psychiatry*, *11*(4), 224–233.

Kim, S. H., Han, D. H., Lee, Y. S., Kim, B. N., Cheong, J. H., & Han, S. H. (2014). Baduk (the game of go) improved cognitive function and brain activity in children with attention deficit hyperactivity disorder. *Psychiatry Investigation*, *11*(2), 143–151. https://doi.org/10.4306/pi.2014.11.2.143

Kueider, A., Krystal, B., & Rebok, G. (2014). Cognitive Training for Older Adults: What Is It and Does It Work. *Center on Aging at American Institutes for Research*, 1–8. http://www.air.org/sites/default/files/downloads/report/Cognitive Training for

Older Adults_Nov 14.pdf

Kuo, C. Y., Huang, Y. M., & Yeh, Y. Y. (2018). Let’s play cards: Multi-component cognitive training with social engagement enhances executive control in older adults. *Frontiers in Psychology*, *9*, 1–13. https://doi.org/10.3389/fpsyg.2018.02482

Lampit, A., Hallock, H., & Valenzuela, M. (2014). Computerized Cognitive Training in Cognitively Healthy Older Adults: A Systematic Review and Meta-Analysis of Effect Modifiers. *PLoS Medicine*, *11*(11). https://doi.org/10.1371/journal.pmed.1001756

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159. https://doi.org/10.2307/2529310

Lemire-Rodger, S., Lam, J., Viviano, J. D., Stevens, W. D., Spreng, R. N., & Turner, G. R. (2019). Inhibit, switch, and update: A within-subject fMRI investigation of executive control. *Neuropsychologia*, *132*, 107134. https://doi.org/10.1016/j.neuropsychologia.2019.107134

Leon-Carrion, J., García-Orza, J., & Pérez-Santamaría, F. J. (2004). Development of the inhibitory component of the executive functions in children and adolescents. *International Journal of Neuroscience*, *114*(10), 1291–1311. https://doi.org/10.1080/00207450490476066

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of Clinical Epidemiology*, *62*(10), e1-34. https://doi.org/10.1016/j.jclinepi.2009.06.006

Mak, M., Tyburski, E., Starkowska, A., Karabanowicz, E., Samochowiec, A., & Samochowiec, J. (2019). The efficacy of computer-based cognitive training for executive dysfunction in schizophrenia. *Psychiatry Research*, *279*, 62–70. https://doi.org/10.1016/j.psychres.2019.06.041

Mansor, N. S., Chow, C. M., & Halaki, M. (2020). Cognitive effects of video games in older adults and their moderators: a systematic review with meta-analysis and meta-regression. *Aging and Mental Health*, *24*(6), 841–856. https://doi.org/10.1080/13607863.2019.1574710

Martín, R., Hernández, S., Rodríguez, C., García, E., Díaz, A., & Jiménez, J. E. (2012). Datos normativos para el Test de Stroop: patrón de desarrollo de la inhibición y formas alternativas para su evaluación. *European Journal of Education and Psychology*, *5*(1), 39. https://doi.org/10.30552/ejep.v5i1.76

McCabe, D. P., Mcdaniel, M. A., Hambrick, D. Z., Roediger, H. L., Mcdaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The Relationship between working memory capacity and executive function. *Neuropsychology*, *24*(2), 222–243. https://doi.org/10.1037/a0017619.The

Melby-Lervåg, M., Redick, T. S., & Hulme, C. (2016). Working Memory Training Does Not Improve Performance on Measures of Intelligence or Other Measures of "Far Transfer": Evidence From a Meta-Analytic Review. *Perspectives on Psychological Science*, *11*(4), 512–534. https://doi.org/10.1177/1745691616635612

Metaferia, B. K., Takacs, Z. K., & Futo, J. (2020). The Relationship Between Parental Play Beliefs, Preschoolers' Home Experience, and Executive Functions: An Exploratory Study in Ethiopia. *Frontiers in Psychology*, *11*, 1–13.

https://doi.org/10.3389/fpsyg.2020.00624

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Nakao, M. (2019). Special series on "effects of board games on health education and promotion" board games as a promising tool for health promotion: a review of recent literature. *BioPsychoSocial Medicine*, *13*(1), 5. https://doi.org/10.1186/s13030-019-0146-3

Nath, S., & Szücs, D. (2014). Construction play and cognitive skills associated with the development of mathematical abilities in 7-year-old children. *Learning and Instruction*, *32*, 73–80. https://doi.org/10.1016/j.learninstruc.2014.01.006

Nguyen, L., Murphy, K., & Andrews, G. (2019). Cognitive and neural plasticity in old age: A systematic review of evidence from executive functions cognitive training. *Ageing Research Reviews*, *53*, 100912. https://doi.org/10.1016/j.arr.2019.100912

Nigg, J. T. (2000). On Inhibition/Disinhibition in Developmental Psychopathology: Views from Cognitive and Personality Psychology and a Working Inhibition Taxonomy. *Psychological Bulletin*, *126*(2), 220–246. https://doi.org/10.1037/0033-2909.126.2.220

Nigg, J. T. (2017). Annual Research Review: On the relations among self- regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *J Child Psychol Psychiatry.*, *58*(4), 361–383. https://doi.org/10.1111/jcpp.12675

Noda, S., Shirotsuki, K., & Nakao, M. (2019). The effectiveness of intervention with board games: A systematic review. *BioPsychoSocial Medicine*, *13*(1). https://doi.org/10.1186/s13030-019-0164-1

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan-a web and mobile app for systematic reviews. *Systematic Reviews*, *5*(1), 1–10. https://doi.org/10.1186/s13643-016-0384-4

Overman, A. A., & Robbins, R. E. (2014). Game-Based Community Cognitive Health Intervention for Minority and Lower Socioeconomic Status Older Adults: A Feasibility Pilot Study. *Games for Health Journal*, *3*(5), 303–310. https://doi.org/10.1089/g4h.2014.0052

Panphunpho, S., Thavichachart, N., & Kritpet, T. (2013). Positive Effects of Ska Game Practice on Cognitive Function among Older Adults. *Journal of Medical Association of Thailand*, *96*(3), 358–364.

Passolunghi, M. C., & Costa, H. M. (2016). Working memory and early numeracy training in preschool children. *Child Neuropsychology*, *22*(1), 81–98. https://doi.org/10.1080/09297049.2014.971726

Peijnenborgh, J. C. A. W., Hurks, P. M., Aldenkamp, A. P., Vles, J. S. H., & Hendriksen, J. G. M. (2016). Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. *Neuropsychological Rehabilitation*, *26*(5–6), 645–672. https://doi.org/10.1080/09602011.2015.1026356

Rahe, J., Liesk, J., Rosen, J. B., Petrelli, A., Kaesberg, S., Onur, O. A., Kessler, J., Fink, G. R., & Kalbe, E. (2015). Sex differences in cognitive training effects of patients with amnestic mild cognitive impairment. *Aging, Neuropsychology, and Cognition*, *22*(5), 620–638. https://doi.org/10.1080/13825585.2015.1028883

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8), 1237–1252. https://doi.org/10.1016/j.cpr.2013.08.005

Reichman, W. E., Fiocco, A. J., & Rose, N. S. (2010). Exercising the brain to avoid cognitive decline: examining the evidence. *Aging Health*, *6*(5), 565–584. https://doi.org/10.2217/ahe.10.54

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of Playing Numerical Card Games on Head Start Children's Mathematical Skills. *Journal of Experimental Education*, *88*(2), 200–220. https://doi.org/10.1080/00220973.2019.1581721

Scholz, M., Niesch, H., Steffen, O., Ernst, B., Loeffler, M., Witruk, E., & Schwarz, H. (2008). Impact of chess training on mathematics performance and concentration ability of children with learning disabilities. *International Journal of Special Education*, *23*(3), 139–149.

Schwaighofer, M., Fischer, F., Bühner, M., Schwaighofer, M., Fischer, F., & Markus, B. (2015). Does Working Memory Training Transfer ? A Meta- Analysis Including Training Conditions as Moderators Does Working Memory Training Transfer ? A Meta-Analysis Including Training Conditions as Moderators. *Educational Psychologist*, *50*(2), 138–166. https://doi.org/10.1080/00461520.2015.1036274

Scionti, N., Cavallero, M., Zogmaister, C., & Marzocchi, G. M. (2020). Is Cognitive Training Effective for Improving Executive Functions in Preschoolers? A

Systematic Review and Meta-Analysis. *Frontiers in Psychology, 10,* 1–23. https://doi.org/10.3389/fpsyg.2019.02812

Singh-Manoux, A., Richards, M., & Marmot, M. (2003). Leisure activities and cognitive function in middle age: Evidence from the Whitehall II study. *Journal of Epidemiology and Community Health*, *57*(11), 907–913. https://doi.org/10.1136/jech.57.11.907

Sousa, M., & Bernardo, E. (2019). Back in the Game. In N. Zagalo, A. I. Veloso, L. Costa, & Ó. Mealha (Eds.), *Proceeding from the 11th International Conference Videogame Sciences and Arts, held in Aveiro, Portugal, November 27 & 29, 2019* (pp. 72–85). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-37983-4_6

Staiano, A. E., Abraham, A. A., & Calvert, S. L. (2012). Competitive versus cooperative exergame play for African American adolescents' executive function skills: Short-term effects in a long-term training intervention. *Developmental Psychology, 48*(2), 337–342. https://doi.org/10.1037/a0026938

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ, 366*, l4898. https://doi.org/10.1136/bmj.l4898

Sterne, J. A., Hernán, M. A., Reeves, B. C., Savović, J., Berkman, N. D., Viswanathan, M., Henry, D., Altman, D. G., Ansari, M. T., Boutron, I., Carpenter, J. R., Chan, A. W., Churchill, R., Deeks, J. J., Hróbjartsson, A., Kirkham, J., Jüni, P., Loke, Y. K., Pigott, T. D., … Higgins, J. P. (2016). ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ (Online)*, *355*, 4–10. https://doi.org/10.1136/bmj.i4919

Sundermann, E. E., Maki, P. M., Rubin, L. H., & Lipton, R. B. (2016). *Evidence of sex-specific cognitive reserve*.

Unterrainer, J. M., Rahm, B., Kaller, C. P., Leonhart, R., Quiske, K., Hoppe-Seyler, K., Meier, C., Müller, C., & Halsband, U. (2004). Planning abilities and the Tower of London: Is this task measuring a discrete cognitive function? *Journal of Clinical and Experimental Neuropsychology*, *26*(6), 846–856. https://doi.org/10.1080/13803390490509574

Vale, R. G. D. S., DA GAMA, D. R. N., Oliveira, F. B. DE, Almeida, D. S. D. M., DE CASTRO, J. B. P., Meza, E. I. A., Mattos, R. D. S., & Nunes, R. D. A. M. (2018). Effects of resistance training and chess playing on the quality of life and cognitive performance of elderly women: A randomized controlled trial. *Journal of Physical Education and Sport*, *18*(3), 1469–1477. https://doi.org/10.7752/jpes.2018.03217

Vaughan, L., & Giovanello, K. (2010). Executive function in daily life: Age-related influences of executive processes on instrumental activities of daily living. *Psychology and Aging*, *25*(2), 343–355. https://doi.org/10.1037/a0017729

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor. *Journal of Statistical Software*, *36*(3), 1–48.

von Bastian, C. C., & Oberauer, K. (2014). Effects and mechanisms of working memory training: a review. *Psychological Research*, *78*(6), 803–820. https://doi.org/10.1007/s00426-013-0524-6

Westerhausen, R., Kompus, K., & Hugdahl, K. (2011). Impaired cognitive inhibition in schizophrenia: A meta-analysis of the Stroop interference effect. *Schizophrenia Research*, *133*(1–3), 172–181. https://doi.org/10.1016/j.schres.2011.08.025

Zelazo, P. D., & Carlson, S. M. (2012). Hot and Cool Executive Function in Childhood and Adolescence: Development and Plasticity. *Child Development Perspectives*, *6*(4), 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Table 1

Study and participant's characteristics (RCT Studies).

Author (year)	Location	Study Design	Experimental Group			Control Group			Sample characteristics
			n	Age (M/SD)	% F.	n	Age (M±SD)	% F.	
Bartolucci et al. (2019)	Italy	9	10	11.2 ± -	90.0	10	12.7 ± -	-	Primary school children
Benzing et al. (2018)	Switzerland	2	61	11.3 ± 0.6	48.3	57	11.5 ± 0.7	51.7	Primary school children
Cheng et al. (2006)[b]	China	8	33	83.9 ± 7.6	78.8	29	83.9 ± 7.6	82.8	Older people with dementia
Demily et al. (2009)	France	3	13	34.7 ± -	7.7	13	38.9 ± -	7.7	Patients with schizophrenia
Estrada-Plana et al. (2019)	Spain	3	13	9.5 ± 1.2	46.2	14	9.5 ± 1.1	28.6	Primary school children with ADHD
Estrada-Plana et al. (2020)	Spain	6	12	81.8 ± 8.9	66.7	15	82.9 ± 9.0	80.0	Healthy older people
Fissler et al. (2018)	Germany	5	51	62.7 ± 8.4	69.0	48	64.0 ± 7.8	58.0	Healthy adults
Iizuka et al. (2018)	Japan	3	9	89.1 ± 4.1	88.9	8	89.1 ± 6.6	87.5	Older people until moderate dementia
Iizuka et al. (2019)	Japan	4	25	76.8 ± 5.4	72.0	25/22[a]	76.5 ± 4.6/77.0 ± 3.5	80.0/72.7	Healthy older adults
Kaufman & Kaufman (1975)	Canada	4	34	9.4 ± 0.5	-	34	9.4 ± 0.5	-	4th-grade school children
Kermani et al. (2016)	Iran	3	30	9.9 ± -	40.0	30	9.8 ± -	43.3	3rd-to-5th grade school children
Kim et al. (2014)[c]	R. of Korea	7	17	10.1 ± 1.5	11.8	17	10.2 ± 1.6	17.6	Children with[E1] and without[E2] ADHD
Kuo et al. (2018)	Taiwan	5	23	73.9 ± 6.1	65.0	23/23[a]	73.5 ± 6.2/73.3 ± 5.4	70.0/48.0	Healthy older people
Overman & Robbins (2014)	USA	7	12	70.4 ± -	84.2	-	-	-	Healthy older people from low-SES
Panphunpho et al. (2013)	Thailand	4	20	64.2 ± 3.2	50.0	20	65.2 ± 3.2	50.0	Healthy older people
Passolunghi & Costa (2016)	Italy	4	15	5.5 ± 0.2	47.0	15/18[a]	5.4 ± 0.2/5.4 ± 2.7	40.0/50.0	5-year-old preschool children
Scalise et al. (2020)	USA	3	25	4.5 ± 0.6	46.0	27/24[a]	4.5 ± 0.6	46.0	Preschoolers from low-incomes
Scholz et al. (2008)	Germany	1	20	10.0 ± 0.6	25.0	10	10.0 ± 0.6	40.0	Children with learning disabilities
Vale et al. (2018)	Brazil	3	13	66.5 ± 4.3	100.0	14	66.1 ± 5.1	100.0	Healthy older women

Note. 1= Unblinded cluster-RCT; 2= Single-blinded cluster-RCT; 3= Unblinded individual-RCT; 4= Single-blinded individual-RCT; 5= Double-blinded individual-RCT; 6= Three-blinded individual-RCT; 7=Unblinded pre-post; 8= Single-blinded (assessors) pre-post; 9= Unblinded pre-post with control group. ADHD=Attention Deficit and Hyperactivity Disorder; F=Female; SES=Socio-Economical Level.

a. These studies have two control groups.

b. This study has two groups: the first one (n=33) the intervention was conducted biweekly [E1], while the other group (n=29) was conducted 4 times [E2] every week.

c. Participants in the experimental group had a diagnosis of ADHD, whereas, participants in the control group had typical development.

Table 2

Interventions' characteristics, outcomes measured, and near/ far transfer effects considering cognitive processes boosted in each intervention.

Author (year)	Weeks, total time	Session duration	Weekly Frequency	Intervention, Format (n per group), Adaptation, Place	Control group/s	Outcome's measures
Bartolucci et al. (2019)	2, 26h.	180'	5	Modern multi-domain BGs, Group (NI), NI, NI	TAU (school lessons)	Matrix reasoning (Raven's Matrices) and Remote Association Test (RAT); PSI
Benzing et al. (2018)	6, 6h.	30'	2	*Ad hoc* multi-domain BGs, Group (2 or 4), A, S	TAU (math lessons)	Visual 2 back-task, Simple Flanker task, Mixed Flanker Task
Cheng et al. (2006)	16, 40h./ 80h.	75'-90'	2[E1], 4 [E2]	Mahjong, Group (4), NI, C	-	DFT (span and sequence), Verbal Learning Test
Demily et al. (2009)	5, 10h.	60'	2	Chess, Group (2), NI, NI	TAU (unspecific)	Stroop Test; TMT A-B; ToL; WCST
Estrada-Plana et al. (2019)	5, 5h.	60'	1	Modern multi-domain BGs, Group (4), NA, L	Wait-list	CBFT; DFT; TMT-A; TMT-B; Go-no go task; Visual KTT; Verbal KTT
Estrada-Plana et al. (2020)	5, 10h.	60'	2	Modern multi-domain BGs, Group (4), NI, C	Cognitive paper-and-pencil tasks	CBFT; CBBT; DFT; DBT; 5 digits test; verbal fluency tasks; Coding; CARAS test
Fissler et al. (2018)	5, 30h.	≥60'	6	Puzzles, Individual, A, H	Health counseling	Block design, visual memory scale; TMT-A; TMT-B
Iizuka et al. (2018)	15, 15h.	60'	1	Go game, Group (2), A, C	TAU (unspecific)	DFT (span); DBT (span)
Iizuka et al. (2019)	12; 12h.	60'	1	Go game, Group (2), NI, C	Computerized Go Game [C1]/ Health lessons [C2]	CBFT and CBTB (span); DFT and DBT (span); LM I, verbal fluency tasks; TMT-A; TMT-B
Kaufman & Kaufman (1975)	16, 9.3h.	35'	1	*Ad hoc* multi-domain BGs, Individual with a researcher, A, S	TAU (unspecific)	DFT (span); Memory for designs; Raven's Matrices; Schonell Graded Word List; Stroop Test; Free and serial recall
Kermani et al. (2016)	12, 24h.	60'	2	*Ad hoc* mixed memory BGs, Individual with a researcher, A, PR	Wait-list	Digit span test (DFT+DBT); Symbol search

Table 2 (continued)

Author (year)	Weeks, total time	Session duration	Weekly Frequency	Intervention, Format (n per group), Adaptation, Place	Control group/s	Outcome's measures
Kim et al. (2014)	16, 160h.	120'	5	Baduk (Game of Go), Group (2), A, S	-	CCTT 1-2, DFT (span), DBT (span)
Kuo et al. (2018)	8, 16h.	60'	2	*Ad hoc* multi-domain BGs, Group (5-6), A, C	Low cognitive Modern BG [C1]/Health counseling [C2]	Composite score: CTMT; DBT (span) and Visual search task; Raven's Matrices
Overman & Robbins (2014)	10, 10h.	60'	1	Two modern reasoning BGs, one memory *ad hoc* BG, Group (2), A, C	-	DFT (span), DBT (span), TMTA, TMT B, Matrix Reasoning
Panphunpho et al. (2013)	16, 40h.	50'	3	Ska game, Group (2), NI, C	Health aging lessons	TMT-A; VPA I; VR I; WCST
Passolunghi & Costa (2016)	5, 10h.	60'	2	*Ad hoc* mixed memory BGs, Group (5), A, S	Early numeracy BG[C1]/TAU (school lessons)[C2]	CBFT; Word recall; Visual and word recall dual task
Scalise et al. (2020)	2, 1h.	15'	2	*Ad hoc* Numerical Memory BG, Individual with a researcher, A, S	Numerical magnitude BG [C1]/Shape-color matching BG [C2]	CBFT; Head-Feet Test
Scholz et al. (2008)	1 School year	60'	1	Chess, Group (2), NI, S	TAU (math lessons)	Cross-out test (hits and hits minus commission errors)
Vale et al. (2018)	16, 13.3h.	50'	1	Chess/Resistance training, Group (2), NI, NI	Resistance training	MMSE (registration/attention and calculation)

Note. A=Adaptive; BG=Board Game; C=Community center; CBTF=Corsi Block Test Forward; CBTB=Corsi Block Test Backward; CTMT= Color- Trail Making Test; CCTT= Children's Color Trial Test; DFT=Digit Forward Test; DBT=Digit Backward Test; FT=Far transfer; H= Home; HNT=Highly trained near transfer; KTT=Keep Track Task; L=Laboratory; LM=Logical Memory; LNT=Lowly trained near transfer; MMSE=mini-mental state examination; NA=no adaptive; NI=No information; PR= Psychotherapy Room; PRI= Problem Solving Inventory; S=School; STM=Short-term memory; TAU= Treatment as Usual; TMT= Trail Making Test; ToL= Tower of London; VPA=Verbal Paired Associates; VR=Visual Reproduction; WCST= Wisconsin Card Sorting Test; WM=Working Memory.

Table 3

Outcomes measured and main results in each study included in the systematic review considering age ranges.

	VS-STM	VS-WM	V-STM	V-WM	Inhibition	Flexibility	Planning	Reasoning	VF	PS
Preschool-age children										
Passolunghi & Costa (2016)[a]	→E,→C	↑E,→C^{1,2}	→E,→C	↑E,→C^{1,2}						
Scalise et al. (2020)[a]	→E,→C^{1,2}				↑E,↑^{t}C^{1}→C^{2}					
School-age children										
Bartolucci et al. (2019)								↑E,→C		
Benzing et al. (2018)		↑^{t}E,→C			→E,→C	↑E,→C				
Estrada-Plana et al. (2019)	→E,→C	→E,→C	↑E,→C	→E,→C	→E,→C	→E,→C				→E,→C
Kaufman & Kaufman (1975)	↑E,→C		↑E,→C		↑E,→C			→E,→C		↑E,→C
Kermani et al. (2016)			↑E,→C	↑E,→C						↑E,→C
Kim et al. (2014)[b]			↑E^{1,2}	↑^{t}E^{1,2}		↑E^{1},→E^{2}				↑E^{1},→E^{2}
Scholz et al. (2008)[c]										
Adulthood										
Demily et al. (2009)[d]					↑E,→C	↑, →E,→C	↑E,→C			→E,→C
Fissler et al. (2018)	→E,→C	→E,→C				→E,→C		→E,→C		→E,→C
Older people										
Cheng et al. (2006)[e]			↑E^{1,2}							
Iizuka et al. (2018)			→E,→C	↑E,→C						
Iizuka et al. (2019)[a]	→E,C^{1,2}	↑E,→C^{1,2}	→E, →C^{1,2}	→E, →C^{1,2}		→E, →C^{1,2}			→E,→C^{1,2}	↑^{t}E,→C^{1,2}
Estrada-Plana et al. (2020)[f]	→E,→C	→E,→C	→E,→C	→E,→C	↑E ↑C	→E,→C			↑^{P}→^{C}:E=C	→E,→C
Kuo et al. (2018)[a]				↑E,↑^{t}C^{1},→C^{2}		↑E,↑^{t}C^{1},→C^{2}		↑E, ↑C^{1,2}		↑E,↑^{t}C^{1}→C^{2}
Overman & Robbins (2014)			→E	→E		→E		→^{t}E		→E
Panphunpho et al. (2013)	↑E,→C		↑E,→C			↑E,→C				↑E,→C
Vale et al. (2018)			→E,→C	↑E,→C						

Note. E=Experimental Group (Cognitive games); C=Control Group; ^{C}=Categorical; ^{P}=Phonemic; PS= Processing Speed; STM=Short-term Memory; TMT= Trail Making Test; WCST= Wisconsin Card Sorting Test; V= Verbal; VF=Verbal Fluency; VS=Visuospatial; WM=Working Memory. ↑: improvement; →: no benefit of intervention or no change.

a. These studies have two control groups (See table 2).

b. Participants in the experimental group had a diagnosis of ADHD ^{E1}, whereas, participants in the control group had a typical development ^{E2}.

c. In this study, the only neuropsychological outcome was attention. Experimental group had higher hits but the same commission errors than control group after the intervention.

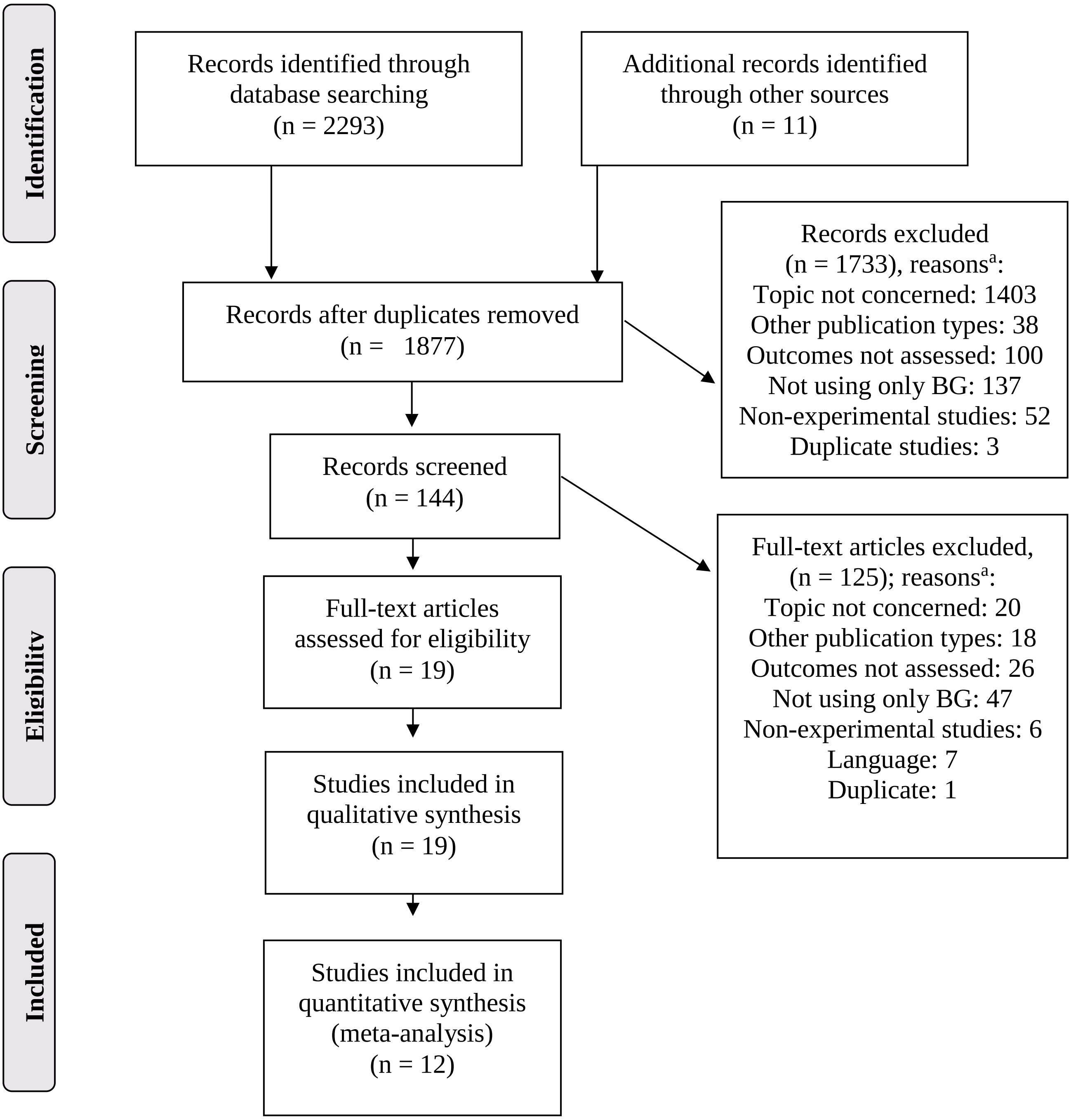
d. In this study, an Experimental group that played the chess game improved WCST tasks that measure flexibility but not TMT.

e. This study has two groups: the first one (n=33) the intervention was conducted biweekly ^{E1}, while the other group (n=29) was conducted 4 times ^{E2} every week.

f. In this study, the Experimental group improved control of impulsivity. The Control group that did paper-and-pencil tasks improved RT in an inhibition task.

Figure 1

Flow diagram through the different phases of the systematic review.



Note. BG=board games

a. Other publication types include review and meta-analysis papers, chapter books, books, book reviews, divulgation, opinion articles, conference, dissertation (dissertation, master' theses...), and protocol articles. Non-experimental studies include those studies that were not Randomized Controlled Trials.

Figure 2

Risk of Bias of each domain in the studies included in the systematic review. A) Randomized studies; B) Non-randomized studies.

A)

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Cluster-RCT[†]						
Benzing et al. (2018)	+	+	+	+	+	+
Cheng et al. (2006)	+	?	?	+	+	!
Scholz et al. (2008)	?	?	?	?	–	–
Individual-RCT						
Demily et al. (2009)	?	?	+	?	–	–
Estrada-Plana et al. (2019)	–	?	+	?	?	–
Estrada-Plana et al. (2020)	+	+	+	+	?	!
Fissler et al. (2018)	+	+	+	+	+	+
Iizuka et al. (2018)	?	?	?	?	?	!
Iizuka et al. (2019)	+	?	+	+	+	!
Kaufman & Kaufman (1975)	?	?	+	+	?	!
Kermani et al. (2016)	?	?	+	+	?	!
Kuo et al. (2018)	?	+	+	+	–	–
Passolunghi & Costa (2016)	?	+	+	+	?	!
Panphunpho et al. (2013)	?	?	+	+	?	!
Scalise et al. (2020)	?	–	+	?	?	–
Vale et al. (2018)	?	–	?	?	?	–

Note. Low risk of bias=green; Some concerns=yellow; High risk of bias=red.

[†]. Randomization process bias was divided into bias arising from the randomization bias and bias arising from the identification and recruitment of individual/cluster participants.

B)

Study	Confounding	Selection of participants	Classification of interventions	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Bartolucci et al. (2019)	L	NI	L	L	L	M	S	S
Kim et al. (2014)	L	S	L	L	L	M	S	S
Overman & Robbins (2014)	L	S	L	S	M	M	M	S

Note. L=low; M=moderate; S=serious; C=critical; NI= no information.

Figure 3

Forest plot in childhood: a) Visuospatial STM, b) Visuospatial WM, c) Verbal STM.

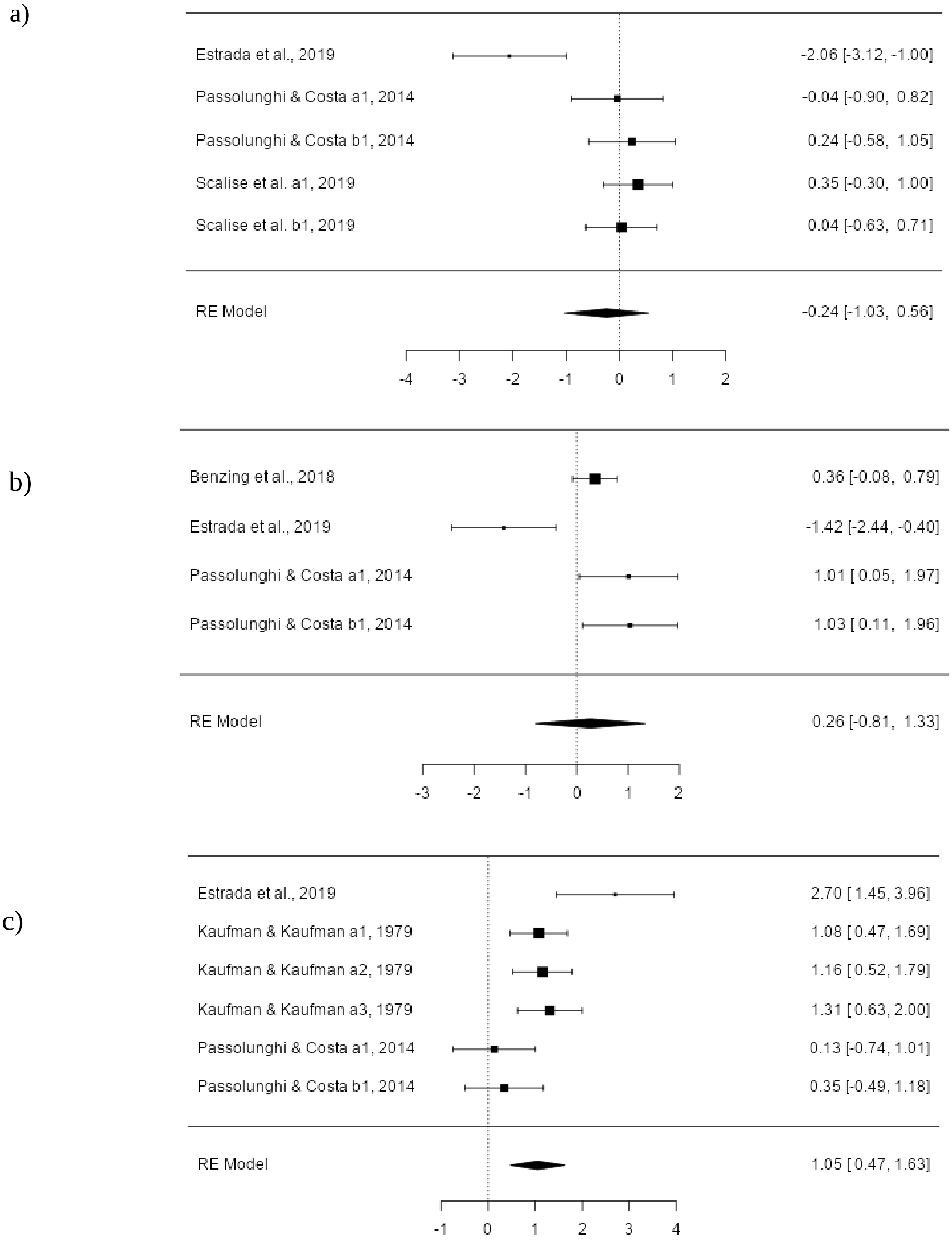
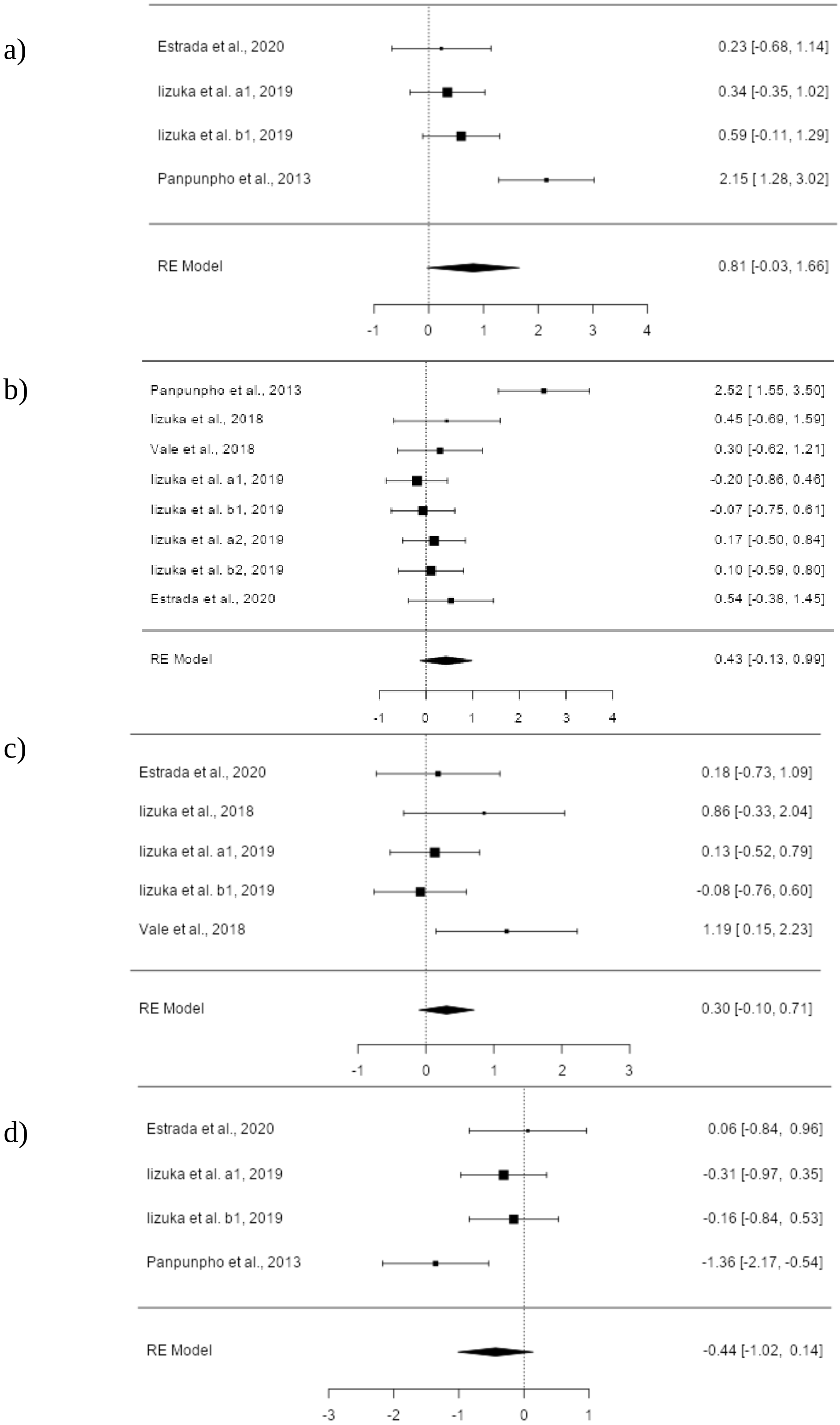


Figure 4

Forest plots in older people: a) Visuospatial STM, b) Verbal STM, c)Verbal WM, d) Flexibility.



SECTION 2: EFFICACY AND EFFECTIVENESS OF INTERVENTIONS BASED ON FILLER BOARD GAMES ACROSS THE LIFESPAN

3.2.2. Benefits of Playing at School: Filler Board Games Improve Visuospatial Memory and Mathematical Skills

Verónica Estrada-Plana*[a], Andrea Martínez-Escribano*[a], Agnès Ros-Morente[a], Maria Mayoral[b,c], Agueda Castro[d], Nuria Vita-Barrull[a], Jaume March-Llanes[a] & Jorge Moya Higueras[a,e] *Authors contributed equally to the manuscript

[a]University of Lleida, Department of Psychology, Lleida, Spain; [b]Instituto de Investigación Sanitaria Gregorio Marañón (IISGM), Madrid, Spain; [c]Centre for Biomedical Research Network on Mental Health (CIBERSAM), Instituto de Salud Carlos III, Madrid, Spain; [d]University of Barcelona, Faculty of Biology, Barcelona, Spain; [e]Centre for Biomedical Research Network on Mental Health (CIBERSAM), Instituto de Salud Carlos III, Barcelona, Spain

Submitted to *Contemporary Educational Psychology Journal*

This is a pre-print version of the article submitted in Contemporary Educational Psychology Journal. If the article is accepted, the final authenticated version will be available online.

Abstract

Short-term and working memory are two cognitive processes related to mathematical skills. The study aims to test the effectiveness of cognitive interventions based on board games in school settings. A parallel, quasi-experimental study was carried out with children (n=234) between 8 and 10 years old. The sample was divided into third and fourth grades. School centers were allocated into a general domain intervention whose participants played short-term and updating-working memory games or into a specific domain intervention whose participants engaged in mathematical games. These groups were compared to a control group, whose participants continue doing mathematical lessons without playing. Teachers carried out bi-weekly sessions during the last 30 minutes of mathematical lessons for 8 weeks (15 sessions in total). Before and after the intervention, we measured verbal and visuospatial short-term and updating-working memory as memory outcomes. Indeed, we measured four mathematical skills: Number Operations, Number Ranking, Number Production, and Problem Solving. All the outcomes were collected individually in the schools. The results showed significant transfer effects of both memory and math training. In third grade, we found that children who played math games showed medium-large effect sizes in the visuospatial short-term memory and updating working memory, Number Operations, and Number Ranking compared to the control group. In fourth grade, we found that children who played memory games showed significantly small effect sizes in Problem Solving compared to the control group. Playing board games could be a methodology that enhances cognitive and mathematical development in children.

Keywords: Board games, working memory, short-term memory, mathematical skills, school intervention

Introduction

Working memory (WM) is a fundamental cognitive process in scholastic skills and achievement (Titz & Karbach, 2014). WM is defined as the interaction of cognitive processes that are involved in keeping information accessible and manipulate it while performing complex tasks, such as learning, reasoning, or comprehension (Baddeley, 2010). The multicomponent WM's model (Baddeley, 2010) is the model that better fitted in school age-children (Alloway et al., 2006). This model has been changing over time (Baddeley, 2012). The concept of WM evolved from the Short-Term Memory (STM) term (Baddeley, 2012), which is understood as the storage of information for brief periods (Baddeley, 2010). Thus, the first model of WM included two temporary components: the phonological loop which is related to the storage of verbal information, and the visuospatial sketchpad which is related to the storage of visuospatial information (Baddeley, 2003; Baddeley, 2010). In addition, the model included the central executive which is related to the attentional control system and the manipulation of information (Baddeley, 2003; Baddeley, 2010). Parallel studies in executive functions (EF) included some tasks that require monitoring and update WM information (Miyake et al., 2000). This function allows WM to modify content considering its relevance and to replace the old information to accommodate new inputs. In fact, executive-loaded WM tasks can be divided into complex WM tasks and updating tasks (Henry, 2011). Previous studies in school-age children show that both tasks belong to the WM construct, but only updating tasks are related to EFs (St Clair-Thompson & Gathercole, 2006).

Previous studies show that STM and Updating-WM processes could be relevant outcomes for mathematics in preschool and school ages (Bull et al., 2008; Friso-Van Den Bos et al., 2013). Thus, improving STM and Updating-WM may be essential in the acquisition of mathematical concepts in school-age children.

The main strategies to increase STM and Updating-WM are called cognitive-focused interventions (Bahar-fuchs et al., 2013). One of these interventions is called Cognitive Training (CT), which "*entails repeated exercise of a specific cognitive process over a period to improve performance on the trained task as well as on tasks that were not specifically trained* " (Tajik-Parvinchi et al., 2014). Besides improvements in WM tasks (Sala & Gobet, 2017a), WM training has been related to increases in the activity of brain regions linked to WM, such as the frontoparietal and temporal regions (Astle et al., 2015). Following the definition of CT, improvements can take place on tasks that may not be specifically trained, which are called *transfer effects* (Rapport et al., 2013). Tamm et al. (2013) and Rapport et al. (2013) have suggested that there are different kinds of transfer effects. On the one hand, near transfer consists of an improvement in the same trained domain but in a different task than the trained one. On the other hand, far transfer consists of an improvement in a task that requires a different but related cognitive construct from the trained one or a completely different task that depends on the trained cognitive processes. Different meta-analyses concluded that near transfer effects in STM and WM tasks are possible after WM training in school-age children (Melby-Lervåg & Hulme, 2013; Sala & Gobet, 2017b; Schwaighofer et al., 2015). However, empirical and meta-analysis studies are not consistent in the conclusion about far transfer effects on mathematical skills. For instance, some studies found improvements in mathematical tasks after having been trained with WM cognitive training (Sánchez-Pérez et al., 2018), whereas other studies did not find significant results in mathematical skills (Sala & Gobet, 2017b). In addition, other authors (Ramani et al., 2017) differentiate general and specific domain training. General domain training consists of training cognitive processes that play a critical role in mathematical development, as would be the case of STM and WM training listed above. On the other hand, specific domain training is that trained specific skills, as mathematical tasks. Previous studies found that mathematical interventions can improve mathematical skills, but also WM measures (Kuhn & Holling, 2014; Ramani et al., 2017). This suggests a bidirectional relation between WM and mathematical skills (Clements et al., 2016).

All of the studies cited above included game elements in computerized cognitive training. Game-based computerized CTs have found significant results in WM tasks (Ninaus et al., 2015; Prins et al., 2011). Moreover, these studies have found more improvements in WM CTs' with game elements than in the same CTs without them. However, these interventions did not include social interaction, which could have a positive impact on cognition (Iizuka et al., 2019).

Recently, board games are receiving more attention in research (Gauthier et al., 2019). They are defined as games with a board with pieces (and/or cards) on it, with predefined rules that fix the number of pieces/cards, the number of positions of the elements, and the number of their possible moves (Gobet et al., 2004). Board games can be classified into traditional, mass-market, or modern board games (Sousa & Bernardo, 2019). On the one hand, traditional and classical games are those that do not have a known author and do not have commercial rights (i.e. chess). On the other hand, mass-market games are those that are commercialized massively but without a known author or innovative mechanics, like puzzles. Finally, modern board games are edited with an attractive and visual appearance, with different mechanics, and originally designed by a known author or company (Sousa & Bernardo, 2019). In addition, modern board games can be commercialized in an extended way with relatively economical prices.

This classification is useful to classify and identify board games considering their timeline of creation. However, they also can be classified considering their simplicity and length. Filler board games are not explicitly included in the classification of Sousa &

Bernardo (2019). The main feature of filler board games is that they are set up quickly and last between 15 to 20 minutes, not filled to exceed 30 minutes. Thus, filler games are brief, can have several but simple mechanics, and can be learned quickly because of their simple rules (Bartolucci et al., 2019).

As computerized CTs, interventions based on board games could have the potential to be beneficial to cognitive processes and mathematical skills. In school-aged children, Jirout & Newcombe (2015) found a relation between block-play, puzzles, and board games and higher spatial abilities. Newman et al. (2016) found a relation between the use of block-play and mental rotation. Furthermore, Nath & Szücs (2014) found that level in construction games is related to visuospatial WM, and this with mathematical performance.

As far as we know, there are only two studies that focused on testing possible improvements on Updating-WM using brief *ad hoc* board games or modern board games (Benzing et al., 2018; Estrada-Plana et al., 2019). In addition, some studies found improvements in STM after training this cognitive process with brief *ad hoc* board games (Kaufman & Kaufman, 1975; Kermani et al., 2016) or after playing the traditional Go game (Kim et al., 2014). All of the studies mentioned above showed improvements in STM or Updating-WM after playing board games. One of them found a significant transfer effect on a mathematical measure (Kermani et al., 2016). Also, some studies found that training mathematical skills with specific tasks produces near transfer effects in preschool ages (Ramani et al., 2012; Ramani & Siegler, 2011; Siegler & Ramani, 2008, 2009). Regarding preschool ages, two studies compared an STM and WM general domain intervention and a mathematical specific intervention with brief board games created *ad hoc* (Passolunghi & Costa, 2016; Scalise et al., 2020). Passolunghi & Costa (2016) found that an intervention focused on STM and WM improved complex WM tasks and early numeracy skills. However, Scalise et al. (2020) did not find an improvement in visuospatial STM after playing a memory card game. However, they found an improvement in early numeracy skills after playing a memory card game and specially after playing a mathematical card game. Most of the studies used brief board games, but no study was developed in school-age children training STM, Updating-WM and mathematical skills through specific and general domain interventions.

Aim and hypothesis

This study aimed to assess the effectiveness of a domain and specific training based on filler board games in a school setting in children between 8 and 10 years old, following CONSORT guidelines adapted to non-randomized trials (Reeves & Gaus, 2004). We hypothesized that: i) those children who were trained at playing filler board games would improve their STM and Updating-WM abilities after the intervention greater than the control group; ii) those children who were trained at playing filler board games would improve their mathematical skills after the intervention greater than the control group.

Method

Participants

The needed sample size was calculated considering the results obtained in verbal STM from Estrada-Plana et al. (2019). Sample size calculation was performed on a two-sided hypothesis test, 90% statistical power, and an alpha level of 5%. We also considered a 50% risk of possible losses. The analysis revealed that 11 subjects per group were enough for the present research. Initially, 343 children were contacted (see Figure 1). Inclusion criteria were: i) studying in second grade -3rd and 4th – of primary school, ii) studying in one of the 7 different schools of both rural and urban areas of Lleida

(Catalonia, Spain) selected by the Department of Education to participate in the present research, and iii) having signed the informed consent. Exclusion criteria were: i) having participated in previous similar research, ii) showing difficulties with the Spanish or Catalan languages, iii) having a lack of basic sociodemographic information, iv) missing data in some primary or secondary outcomes. After matching the inclusion criteria, 270 children were allocated into experimental or control groups. Concretely, we exclude some of them for the following reasons (see Figure 1): i) eight children had participated before in previous pilot research of our research group; ii) five children whose date of birth and one child whose school-grade level were not collected during the assessment period; iii) two children dropped out of their school after the intervention sessions started; iv) seven children didn't carry out the assessment individually in pre or post times for other reasons different from dropping out schools (i.e. being ill); v) one child did not carry out the assessment in a group session; vi) seven children did not carry out neither individual nor group assessment in some time across the study, and vii) five parents did not complete rating scales about their son or their daughters. Finally, taking the data above into account, the final sample consisted of 234 children. Participants who were allocated into intervention or control groups had higher socio-economical levels than those children who were not included in the analysis (U=1979.50, p=0.037, r=0.26). In addition, participants who were allocated into intervention or control groups had higher verbal STM than those children who were not included in the analysis ($U_{Verbal\ STM(hits)}$=2784.00, p=0.010, r=0.27). Finally, participants who were allocated into intervention or control groups had higher mathematical skills than those children who were not included in the analysis ($U_{\text{Number Operations}}$=2966.00, p<0.001, r =0.37; $U_{\text{Number Ranking}}$=3813.00, p=0.002, r =0.29; $U_{Number\ Production}$=3067.00, p<0.001, r =0.34; $U_{Problem\ Solving}$=3016.50, p<0.001, r =0.36).

The sample was divided considering elementary primary school grades (Alloway et al., 2006). Subsample 1 consist of children who were in third grade (n=121) and subsample 2 consist of children who were in fourth grade (n=113). Demographical and psychological data about children in the 3rd and 4th grades subsamples are summarized in Table 1. Participants who repeat a course (χ^2_{3rd} (1)=1.25, *p*=0.870, *V*=0.07; χ^2_{4th} (1)=1.45, *p*=0.484, *V*=0.11) and who had a psychological diagnose (χ^2_{3rd} (1)=1.25, *p*=0.535, *V*=0.10; χ^2_{4th} (1)=3.73, *p*=0.155, *V*=0.18) were equally distributed in the groups.

------*Insert Table 1*-------

------*Insert Figure 1*-------

Measures

Covariate measures

Previous studies showed that age (Alloway et al., 2006), socio-economic status (SES) (Hackman et al., 2015), fluid reasoning (Dehn, 2017; Green et al., 2017) and math's anxiety (Luttenberger et al., 2018) could be related with STM and WM or could modulate cognitive training. Therefore, the following covariates were assessed in the present study: age in years, SES index (formula's index was: ([education scale score] x 3) + ([occupation scale score] x 5)) (Hollingshead, 1975) and fluid reasoning assessed by Raven's Progressive Matrices Test (RPMT; (Raven et al., 2001). Finally, mathematical anxiety was assessed by the Abbreviated Math Anxiety Scale (AMAS) from Tejedor et al. (2009) was only considered in the analyses of mathematical competencies.

Memory outcome measures

Verbal STM. We used the forward Digit test from WISC-IV (Wechsler, 2003) to assess verbal STM. The participant must exactly repeat a digit's sequence that the researcher conveys. The difficulty of the task increased gradually (from two to nine digits). The task finished when participants make a mistake in two trials of the same difficulty. For every sequence remembered, one point was given. The measure included in the study was the sum of the trials repeated correctly. The task lasted 5 minutes.

Visuospatial STM. We used the forward Corsi block test to assess Visuospatial STM following the procedure of Andersson & Lyxell (2007). The child was instructed to observe the experimenter tap a sequence of blocks for a rate of one per second and then to attempt to repeat the sequence in the same order. Every span size had two different sequences of two to nine blocks. The task finished when participants made a mistake in two sequences of the same difficulty. For every sequence remembered, one point was given. The measure included in the study was the sum of the trials repeated correctly. The task lasted 5 minutes.

Verbal Updating-WM. The Keep Track Task was administered according to the guidelines presented in Tamnes et al. (2010). Participants saw different semantic categories (animals, clothing, colors, countries, fruits, and relatives) on the computer. Below each category, 3 words could appear related to its correspondent category (18 words in total). Each word appeared in a pseudorandomized order with a ratio of 2000 ms. The task itself consisted of two practice trials with 2 and 3 categories, four trials with three categories, four trials with four categories, and one with five categories. Subjects had to recall the last word presented in each one of the target categories. The outcome assessor registered each response. The task ended when all the trials are administered. The measure included in the study was the sum of the correct trials (maximum 33 words to be recalled). The duration of the task was 10 minutes.

Visuospatial Updating-WM. The Keep Track Task was created following the guidelines from Tamnes et al. (2010) to assess the visuospatial component of updating. A matrix 3 x 3 was shown on the computer screen on each trial. The targets consisted of

6 different faces from different colors (white, black, yellow, green, red, and blue). The faces appeared on the screen, in a changeable number of presentations (between one and five). Each face appeared in a pseudorandomized order with a ratio of 2000 ms. The task itself consisted of two practice trials with 2 and 3 colors, four trials with three different colors, four trials with four different colors, and one trial with five different colors. The task ended when all the trials were administered. The aim was to recall the last position of the faces. The outcome assessor registered each response. The measure included in the study was the sum of the correct trials. The duration of the task was 10 minutes.

Mathematical outcome measures

Alloway & Passolunghi (2011) considered different tasks to assess mathematical skills (the first three tasks below). Hence, we adopt the same methodology in the present study. In addition, we added a task to assess problem-solving skills. The scoring for all items were 0 (incorrect) and 1 (correct).

Number operations task. This task consisted of performing up to 40 mathematical written operations (20 addition operations and 20 subtraction operations) with increasing difficulty (single-digit operations, double-digit operations, and multi-digit operations) within 2 minutes. The measure included in the study was the sum of the correct operations (maximum score = 40). Based on our sample, this measure had good reliability (Cronbach's $\alpha = 0.86$).

Number Ranking task. Children were prompted to order numbers from the smaller to the higher (e.g. 1-9-3-5= 1-3-5-9). The students had a total of 16 items with increasing difficulty (from single-digit to three-digit numbers) and a maximum of 2 minutes to complete the task. The measure included in the study was the sum of the correct numbers (maximum score = 81). Based on our sample, this measure had good reliability (Cronbach's $\alpha = 0.85$).

Number Production task. In this task, the child translated numbers from the written representation to digit number representation in units (e.g. 3 dozens =36 units). There were 23 items and the time limit to perform the task was 2 minutes. The measure included in the study was the sum of the correct answers (maximum score = 23). Based on our sample, this measure had good reliability (Cronbach's α= 0.88).

Problem Solving task. The task consisted of 16 mathematical problems with increasing difficulty. The child needed to read each problem, decide which operation apply (addition or subtraction), and extract the information needed to conduct the operation. In 5 minutes, participants were prompted to solve the highest number of problems possible. As for the other tasks, the dependent variable used in the study was the sum of the correct problems solved (maximum score = 16). Based on our sample, this measure had good reliability (Cronbach's α= 0.82).

Intervention

The intervention used in the memory group included five different board games oriented and designed to boost STM and Updating-WM: *Alles Kanone!* (Knizia, 2007a), *Alles Tomate!* (Knizia, 2007b), *Spooky Stairs* (Schannen, 2004), *Out of Mine!* (Nedergaard-Andersen, 2014), *Chicken, Cha Cha Cha!* (Zoch, 1998). The intervention used in the mathematical group included five different board games oriented and designed to boost mathematical skills: *7ate9* (Hiron, 2009)*; Numenko in a bag* (Lennett, 2009), *Pig 10* (Pnueli, 2010), *Shut the box* (*Shut the Box*, n.d.), *Auf zack!* (Becker & Schliemann, 2009) (see a brief description of the games in Table 2).

------*Insert Table 2*-------

All the participants were exposed to 15 sessions (2 sessions per week, 30 minutes each) for eight weeks. Each participant played 3 sessions in each board game (90 minutes). The groups of play were invariant and composed of 4 children. The intervention sessions were applied from February to April in the year 2015, although each school adapted them to their specific calendar. The participants played the board games described above in the math lessons. Teachers conducted the intervention sessions. Each session was described in a handbook for the teachers to conduct systematically the intervention. In addition, every teacher had a document to register incidents during the playing time (i.e. the rules of each game were not properly followed) and the assistance of the participants. All the teachers from the Memory and the Math Game Training Groups (GTG) knew the aim of the study but did not know the specific hypothesis. Hence, children and teachers from both groups were masked. However, the CG was aware of its condition.

Procedure

Firstly, the Department of Education approved the project. Ethical requirements following the Declaration of Helsinki were approved by the University. The Department of Education selects five urban public schools and two rural public schools by convenience sampling method. For this reason, this study was multicentre. Headmasters from all the schools accepted to participate in the research. Afterward, six schools were assigned in both groups of the game (Math GTG and Memory GTG). Allocation was made by a code considering similar school characteristics (ratio 1:1). Both Math GTG and Memory GTG consisted of two urban public schools and one rural public school. The last author was the person who generated the allocation sequence, who enrolled participants, and who assigned participants into game groups. The Control Group (CG) was assigned by the Department of Education. This group was an urban school from higher socio-economic backgrounds. In addition, as can be seen in Table 1, performance in Number Operations, some memory, and mathematical outcomes were higher in CG than in the schools that played (de Souza-Salvador et al., 2019). Then, informed consent was given to the families of the children. The baseline assessment started after receiving parental authorization. Parents were asked about their social status and socio-demographical information about them and their children (e.g. age, sex, place of birth). STM, Updating-WM, and math anxiety tests were applied individually, while Mathematical Skill tasks and fluid reasoning tests were assessed in group. All the teachers were trained in one session to apply systematically each game and to register the incidences/attendance. The handbook with the description of the intervention was delivered to teachers. The material required for the intervention (i.e., board games and the document to register incidents) was also delivered to schools. After the intervention, memory and math outcomes were assessed again in the three groups. In all the assessments, the order of the neuropsychological tests on individual sessions was counterbalanced across participants to control assessment bias. The first, the second, and the last authors of the study, and other research assistants performed all the baseline and post-assessments. After the post-test assessment, the CG received the same intervention as Math GTG for ethical reasons. See Figure 2 for a detailed description of the timeline.

------*Insert Figure 2*-------

Statistical analysis

All the analyses were run with Jamovi 1.6.15 version (The jamovi project., 2021). Firstly, we calculated baseline differences in the main outcomes and demographical/psychological characteristics. Considering that the mean scores are generally not normally distributed, we used the Kruskal-Wallis test to compare quantitative outcomes. Dwass-Steel-Critchlow-Fligner posthoc pairwise comparisons were calculated to identify differences between groups. We used chi-square to compare nominal variables, such as sex or ethnicity. Epsilon squared (ε^2) and Cramer's V were calculated as effect size measures (Ellis, 2010), respectively. Secondly, changes before and after the intervention were tested between experimental and control conditions. A mixed-model analysis of covariance (ANCOVA) was used to calculate time by group interaction effects for each dependent variable. Group (Math GTG, Memory GTG, and CG) was a fixed factor and Time was a repeated measures factor (Pre and Post). We included subjects as random effects. The centered covariates included in the model were age, SES index, fluid intelligence (RPMT score), and math anxiety (AMAS score). Post-hoc pairwise comparisons adjusted with Bonferroni correction were calculated to identify differences between groups. We calculated simple main effects and compared the magnitude of the effects using Cohen's *d*. We followed the formula of Brysbaert & Stevens (2018) to calculate Cohen's *d*. We interpreted Cohen's *d* as follow (Ellis, 2010): $d<0.20$= trivial; $0.20\leq d<0.50$= small; $0.50\leq d<0.80$= medium; $d\geq 0.80$= large. We calculated Cohen's *d* between the Math GTG and the CG and between the Math GTG and the Memory GTG.

Results

Compliance with the intervention program

Grade 3

All the participants received between 13 to 15 sessions (98.84% of attendance in Math GTG; 100% of attendance in Memory GTG).

Grade 4

All the participants received between 11 to 15 sessions (98.82% of attendance in Math GTG; 99.09% of attendance in Memory GTG).

Descriptive and baseline comparisons

Grade 3

First of all, we found significant differences in math anxiety (χ^2 (2)=11.11, p=0.004, ε^2=0.09). Participants from the Math GTG had higher math anxiety than Memory GTG (W= -3.87, p=0.017) and CG (W= 3.57, p=0.031). Although we found a significant result in age (χ^2 (2)=7.13, p=0.028, ε^2=0.06), we did not find any significant difference in pairwise comparisons. In addition, we found significant differences in Number Operations skills (χ^2 (2)=17.77, p=<0.001, ε^2=0.15), Number Ranking skills (χ^2 (2)=30.17, p=<0.001, ε^2=0.25) and Problem Solving skills (χ^2 (2)=19.52, p=<0.001, ε^2=0.16). Participants from the Math GTG had lower scores than CG in these measures ($W_{Number\ Operations}$ = -5.80, p= <0.001; $W_{\text{Number Ranking}}$ = -7.60, p<0.001; $W_{Problem\ Solving}$=-5.98, p<0.001). Finally, participants from the Memory GTG had higher scores than Math GTG in Number Ranking (W= 3.75, p=0.022) and lower scores than CG in Number Operations (W= -3.32, p=0.049) and Problem Solving (W= -4.56, p=0.004).

Grade 4

First of all, we found significant differences in SES index (χ^2 (2)=8.92, p=0.012, ε^2=0.08). Participants from the Math GTG and from the Memory GTG had lower SES index than CG ($W_{Math\ GTG}$= -3.42, p=0.042; $W_{Memory\ GTG}$= -3.44, p=0.040). In addition, we found significant differences in verbal WM (χ^2 (2)=9.47, p=0.009, ε^2=0.09), in visuospatial STM (χ^2 (2)=7.47, p=0.024, ε^2=0.07) and visuospatial WM (χ^2 (2)=11.25, p=0.004, ε^2=0.10). Participants from the Memory GTG had lower scores than CG in visuospatial STM (W= -3.71, p=0.024). Participants from the Math GTG and from the Memory GTG had lower scores than CG in verbal WM ($W_{Math\ GTG}$= -3.70, p=0.024; $W_{Memory\ GTG}$= -3.74, p=0.022) and visuospatial WM ($W_{Math\ GTG}$= -3.40, p=0.043; $W_{Memory\ GTG}$= -4.47, p=0.004). Finally, we found significant differences in Number Operations skills (χ^2 (2)=11.44, p=0.003, ε^2=0.10). Participants from the Memory GTG had lower scores than CG in this measure (W= -4.75, p=0.002).

Intervention effects in Grade 3.

Memory Outcomes

We found significant differences between pre and post scores in all the memory outcomes, except for Verbal STM (from $F_{\text{Visuospatial STM(span)}}$ (1,116) = 4.66, p =0.033, d=.25 to $F_{\text{Visuospatial WM}}$ (1,117) =13.72, p=<0.001, d=.39; See all the results in Table 3). Significant main interactions were found between groups and times in Visuospatial STM (F_{Hits} (2,116)=3.32, p=0.040; F_{Span} (2,116)=5.19, p=0.007) and Visuospatial Updating-WM (F (2,116)=3.55, p=0.032) (see Table 3). For the Visuospatial STM and Updating-WM, simple main effects showed that scores in the Math GTG were significantly higher after the intervention ($F_{\text{Visuospatial STM (hits)}}$ (1,117)=17.36, p=<0.001; $F_{\text{Visuospatial STM (span)}}$ (1,117)=21.89, p=<0.001; $F_{\text{Visuospatial WM}}$ (1,117)=32.61, p=<0.001). The simple main effect showed that scores in the Memory GTG were nearly significant after the intervention in Updating-WM ($F_{\text{Visuospatial WM}}$ (1,116)=3.77, p=0.055), but were not significant in Visuospatial STM ($F_{\text{Visuospatial STM (hits)}}$ (1,117)=1.60, p=0.208; $F_{\text{Visuospatial STM (span)}}$ (1,115)=0.69, p=0.408). Regarding the CG, the simple main effect showed that scores in this group did not change after the intervention ($F_{\text{Visuospatial STM (hits)}}$ (1,116)=0.20, p=0.653; $F_{\text{Visuospatial STM (span)}}$ (1,115)=0.69, p=0.406; $F_{\text{Visuospatial WM}}$ (1,116)=0.16, p=0.690). The change of the Memory GTG in comparison to the CG showed small effect sizes in Visuospatial STM (hits: d=0.41; span: d=0.42) and Visuospatial Updating-WM (d=0.37). However, the change of the Math GTG in comparison to the CG showed significant medium-large effect sizes in Visuospatial STM (hits: d=0.61; span: d=0.85) and Visuospatial Updating-WM (d=0.58) (see Figures 3.A, 3.B and 3.C).

Math skills

We found significant differences between pre and post scores in all the mathematical outcomes (from $F_{\text{Problem Solving}}$ (1,121) = 8.08, p =0.005, d=.38 to F_{Number}

$_{\text{Operation}}$ (1,116) =61.68, *p*<0.001, *d*=.83; See all the results in Table 3). In addition, we found significant group differences in Number Ranking (*F* (2,117)=7.13, *p*=0.001) and Problem Solving (*F* (2,117)=7.36, *p*=<0.001). CG had higher global scores than Math GTG in Number Ranking skills (*t* (109)=3.67, *p*=0.001) and Problem Solving skills (*t* (110)=3.30, *p*=0.004). CG had higher global scores than Memory GTG in Problem Solving skills (*t* (127)=3.33, *p*=0.003), but not in Number Ranking skills (*t* (127)=1.03, *p*=0.914). Moreover, significant interactions were found between groups and times in Number Operation skills (*F* (2,113)=3.73, *p*=0.027) and Number Ranking skills (*F* (2,117)=6.22, *p*=0.003) (see Table 3). Simple main effects showed that scores in Number Operation were significantly higher after the intervention in the three groups ($F_{\text{Math GTG}}$ (1,108)=124.59 *p*=<0.001; $F_{\text{Memory GTG}}$ (1,122)=8.08, *p*=0.005; F_{CG} (1,107)=15.47, *p*=<0.001). Simple main effects showed that scores in Number Ranking skills were significantly higher after the intervention in the three groups ($F_{\text{Math GTG}}$ (1,108)=114.34, *p*=<0.001; $F_{\text{Memory GTG}}$ (1,132)=7.35, *p*=0.008; F_{CG} (1,106)=6.74, *p*=0.011). The change of the Memory GTG in comparison to the CG showed trivial and small effect sizes in Number Operations skills (*d*=0.07) and Number Ranking skills (*d*=0.32), respectively. However, the change of the Math GTG in comparison to the CG showed medium and large effect sizes in Number Operations skills (*d*=0.48) and Number Ranking skills (*d*=0.91), respectively (see Figures 3.D and 3.E).

Intervention effects in Grade 4.

Memory Outcomes

We found significant differences between pre and post scores in all the memory outcomes, except for Verbal STM (from $F_{\text{Visuospatial STM(span)}}$ (1,109) = 3.96, *p* =0.049, *d*=.26 to $F_{\text{Visuospatial WM}}$ (1,109) =33.65, *p*=<0.001, *d*=.68; See all the results in Table 3). In addition, we found significant group differences in Visuospatial STM (F_{Hits}

$(2,106)=4.90$, $p=0.009$; F_{Span} $(2, 106)=3.55$, $p=0.032$) and in Visuospatial Updating-WM (F $(2,106)=5.10$, $p=0.008$). CG had higher global scores than Memory GTG in Visuospatial STM (hits) (t $(106)=3.12$, $p=0.007$). CG had higher global scores than Math GTG (t $(106)=2.66$, $p=0.027$) and Memory GTG (t $(106)=2.89$, $p=0.014$) in Visuospatial Updating-WM. Although we found main group differences in Visuospatial STM span, we only found nearly significant post hoc comparisons (comparison between CG and Math GTG: t $(106)=2.34$, $p=0.063$; comparison between CG and Memory GTG: t $(106)=2.30$, $p=0.070$). Considering simple main effects, all the participants improved Visuospatial Updating-WM ($F_{Math\ GTG}$ $(1,109)=9.01$, $p=0.003$; $F_{Memory\ GTG}$ $(1,109)=31.84$, $p=<0.001$; F_{CG} $(1,109)=7.13$, $p=0.009$). Participants from the Math and Memory GTGs improved Verbal Updating-WM ($F_{Math\ GTG}$ $(1,108)=4.77$, $p=0.031$; $F_{Memory\ GTG}$ $(1,108)=9.20$, $p=0.003$; F_{CG} $(1,108)=0.08$, $p=0.605$) and only Memory GTG improved Visuospatial STM (hits) ($F_{Math\ GTG}$ $(1,109)=0.28$, $p=0.779$; $F_{Memory\ GTG}$ $(1,109)=8.05$, $p=0.005$; F_{CG} $(1,109)=1.78$, $p=0.185$). However, no significant interactions were found (see Table 3).

Math Skills

We found significant differences between pre and post scores in all the mathematical outcomes (from $F_{Problem\ Solving}$ $(1,97) = 27.40$, $p =<0.001$, $d=.49$ to $F_{Number\ Production}$ $(1,100) =60.92$, $p<0.001$, $d=.72$; See all the results in Table 3). In addition, we found significant group differences in Number Operations (F $(2,100)=9.33$, $p=<0.001$) and Number Production (F $(2,106)=3.48$, $p=0.034$). CG had higher global scores than Memory GTG in Number Operation skills (t $(105)=4.27$, $p=<0.001$) and nearly to significance in Number Production skills (t $(105)=2.43$, $p=0.050$). Significant interactions were found between groups and times in Number Production skills (F

(2,101)=8.00, p<0.001) and Problem-solving skills (F (2,98)=3.25, p=0.043) (see Table 3). Simple main effects showed that scores in Number Production were significantly higher after the intervention in the three groups ($F_{\text{Math GTG}}$ (1,99)=10.89, p=0.001; $F_{\text{Memory GTG}}$ (1,104)=10.95, p=0.001; F_{CG} (1,100)=53.73, p=<0.001). The change of the Math GTG (d=-0.46) and the Memory GTG (d=-0.76) in comparison to the CG showed a small and medium effect size in Number Production skills (see Figure 3.F), respectively. Simple main effects showed that scores in Problem Solving were significantly higher after the intervention in both Memory GTG (F (1,102)=47.53, p=<0.001) and CG (F (1,97)=5.57, p=0.020), but not in Math GTG (F (1,96)=2.50, p=0.117). The change of the Math GTG in comparison to the CG did not show any effect size in Problem Solving skills (d=-0.04). However, the change of the Memory GTG in comparison to the CG showed a small effect size in Problem Solving skills (d=0.41) (see Figure 3.G).

------*Insert Table 3*------

------*Insert Figure 3*------

Discussion

This study assesses the effects of a cognitive intervention based on filler board games to improve STM and Updating-WM processes and mathematical skills in children from 8 to 10 years old. This study could have relevant implications in terms of the early promotion of children's math learning and cognitive development through the implementation of similar training programs. Following the study of Ramani et al. (2017), a group of students played memory games (general domain) whereas another group of students played mathematical games (specific domain) compared to a control group.

Firstly, we found that SES status and mathematical skills were different between those children who were included in the analysis and those who were not included. Most of the participants were excluded because parents or children did not complete assessments. Ready (2010) found that SES status predicts absenteeism at school. As in previous studies (Garon-Carrier et al., 2018), we found that SES status correlated with mathematical skills ($r_{s\text{Number Operations}}$ =0.18, p=0.005; $r_{s\text{Number Ranking}}$ =0.18, p=0.003; $r_{s\text{Number Production}}$ =0.21, p=<0.001; $r_{s\text{Problem solving}}$ =0.23, p=<0.001) and verbal STM ($r_{s\text{Number Operations}}$ =0.25, p=<0.001).

Results showed that all the groups improved their levels in many outcomes – except for verbal STM- from baseline to post-assessments. Previous studies found similar results in children samples (Kuhn & Holling, 2014). We can explain this progress in STM, Updating-WM and/or mathematical skills because of development and school instruction (Hattie, 2009). Another explanation could be that we repeated the same tasks a second time.

Testing the hypotheses of the present study, we found significant transfer effects of playing board games. In third grade, those children who played memory board games nearly increased their visuospatial Updating-WM in comparison to CG. General memory training does not equally involve STM and Updating-WM processes. For example, all the games that played the Memory GTG involved visuospatial elements but none of them involved verbal stimulus. In addition, the most trained process was Visuospatial Updating-WM. This result could make sense considering the near transfer effects of general memory training (Melby-Lervåg & Hulme, 2013; Sala & Gobet, 2017a). Furthermore, in third grade, Math GTG (who played math games) revealed the greatest improvement in visuospatial STM and Updating-WM processes compared to CG. Not only STM and Updating-WM were directly trained when playing memory games, but also they were indirectly boosted when playing mathematical games. Previous studies showed that STM and Updating-WM are cognitive processes underlying mathematical skills (Friso-Van Den Bos et al., 2013). Moreover, WM and mathematical activities share common neurobiological substrates, such as frontoparietal regions (Ashkenazi et al., 2013; Klingberg et al., 2002). Thus, it is possible that playing mathematical board games may increase STM and Updating-WM because these processes were active while playing, producing a far transfer effect. However, *Auf zack!* (Becker & Schliemann, 2009) -a game played in the specific math intervention- has some STM mechanics that could even increase the activation of the STM. To clarify these explanations, future studies should compare specific math training with (Sánchez-Pérez et al., 2018) and without (Kuhn & Holling, 2014; Ramani et al., 2017) direct boosting of STM and Updating-WM. As Johann & Karbach (2020) stated, a combination of cognitive training with domain-specific training could be more effective than each training alone.

Regarding mathematical skills, all the participants increased their Number Operations and Number Ranking skills, but Math GTG had a higher increase in comparison to the CG. As can be seen in the description of the games, math training does not equally tap the mathematical skills. All of them involved calculation skills. Our results suggest that near transfer effects are possible after specific training with mathematical tasks. Previous studies which involved specific math training (Kuhn & Holling, 2014) and another study that involved mixed memory and math training (Sánchez-Pérez et al., 2018) found improvements in number operations. Related to far transfer, we found that children who played board games also improved Number Ranking skills. Previous studies found that order ascending is needed in number operations (Lyons & Beilock, 2011).

In fourth grade, we found an interaction in Problem Solving. Although both Memory GTG and CG increased their scores in Problem Solving, children who played STM/Updating-WM board games showed a small effect size in their increase in comparison to the CG. Previous studies suggested that problem-solving and number operations are the most related math skills to memory (Peng et al., 2016). For instance, Kuhn & Holling (2014) compared the effects of a WM computerized intervention with a number sense intervention. As in our study, the WM intervention improved Problem Solving, whereas the number sense intervention improved Number Operation skills. On the one hand, previous studies suggested executive functions are needed to correctly solve problems (Friso-Van Den Bos et al., 2013; Zheng et al., 2011). Maybe board games included in the Memory GTG are more executive demanding than games included in the Math GTG. On the other hand, maybe the improvement of mathematical skills depends on the trained tasks. The mathematical board games directly trained Number Operations and Number Ranking skills, but not Number Production or Problem Solving. However, Out of Mine! (Nedergaard-Andersen, 2014) included in the STM/Updating-WM board games has a scoring system similar to the Problem-Solving task. For example, players need to add or substrate points depending on their pieces and cards. Hence, adding some board games that directly trained mathematical problem solving may change the present results. Further studies are needed to elucidate this matter considering their interesting implications in-school interventions.

Finally, developmental patterns could explain the different results in third and fourth grades. Previous studies suggested that young and older children use different strategies to solve number operations. As Raghubar et al. (2010) stated in their review, although visuospatial STM and WM are general domains, these cognitive processes are more specific to early math skills than other executive processes which may be more generic in terms of supporting learning. For example, McKenzie et al. (2003) suggested that younger children use a combination of verbal and visual strategies to solve calculation problems whereas older children rely more on verbal strategies. These could explain why only third grade improves in visuospatial memory tasks. In addition, executive skills in the early primary grades may help mathematical learning and performance, but they are not necessarily associated with mathematical performance across age or all mathematical tasks or all domains of mathematics (Peng et al., 2016). As Raghubar et al. (2010) and de Souza-Salvador et al. (2019) suggested, growth in different components of working memory and executive processes differentially predict growth in different mathematical skills such as Number Operations compared to Problem Solving. These authors conclude that this information is needed to construct a developmental model which relates math and cognition.

Generalizability and limitations of the study

First of all, the procedure of the present study could be generalizable to school settings due to teachers administered both interventions. Nonetheless, teachers were aware of group conditions that could influence the results obtained. For example, teachers from the CG did not apply any intervention. Following the methodology of Ramani et al. (2012), future studies should be better using an active group that plays board games but without boosting STM, WM, and mathematical skills. The present study has other drawbacks that should be considered. It is important to note that it is a quasi-experimental study. We found some baseline differences in some outcomes. For theoretical reasons, some of these variables were introduced as covariates. Future studies should carry out randomized controlled trials what increases generalizability. This is in line with the results of (Sala & Gobet, 2017b), who found that randomization of participants and the inclusion of an active control group could reduce the significance of the results. In addition, no follow-up was performed in the current study. Future studies should include follow-ups to prove if effects persist after retiring the interventions.

Other limitations are related to interventions and outcomes. On the one hand, training did not equally tap basic mathematical skills. The most trained skill was Number Operations. However, any mathematical board games tapped Number Production or

Problem Solving. In addition, some games in the specific domain intervention include memory mechanics and some games in the general domain intervention boosted mathematical skills. Thus, future studies should include board games previously analyzed to apply “pure” specific and general interventions. Regarding the difficulty of the board games, Holmes et al. (2009) explained the importance of adapting interventions. Although it could be more difficult in board games than in computerized training, the skill levels of the other players might be considered. In the present study, the playing groups were formed randomly. Hence, it could be possible to find higher increases in the outcomes if children with the same initial level formed the playing groups. Future studies are needed to elucidate this question.

In addition, we focused only on STM-Updating-WM outcomes, but not on other manipulative complex WM tasks. In future studies, we should also assess executive functions to test the hypothesis that the children who improved problem-solving were because they activated other executive functions while were playing. As in previous studies (Kirk et al., 2017), future studies should not only include neuropsychological tasks, but also behavioral rating scales to assess transfer to everyday behaviors. Additionally, in future studies would be advisable to assess other variables associated with cognition (i.e., physical activity; (Diamond & Lee, 2011), to mathematical skills (i.e., time spent on homework; Cheema & Sheridan, 2015) or to training based on games (i.e., motivation versus board games or time spent playing; Prins et al., 2011).

Conclusions: implications for research and practices

According to our results, using board games in classroom settings could have some beneficial effects. In general, we found that mathematical and memory board games could help development in childhood in comparison to standard lessons. However, we need to take into account developmental patterns to understand the benefits of playing at school. On the one hand, we found that children between 8 and 9 years old who played in the classroom improved their visuospatial short-term and updating-working memory, Number Operations, and Number Ranking skills more than those who did these lessons without playing. On the other hand, those children between 9 and 10 years old who played memory games improved problem-solving skills, but with a small effect size. Thus, the usage of board games can be recommended as a complementary tool to usual educative practices specially in third grade. Moreover, the intervention has a great potential for being easy to incorporate in ecological settings cost-effectively. More studies are needed to elucidate the possible paper of board games as a tool for school interventions.

References

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and Visuospatial Short-Term and Working Memory in Children: Are They Separable? *Child Development*, *77*(6), 1698–1716. https://doi.org/10.1111/j.1467-8624.2006.00968.x

Alloway, T. P., & Passolunghi, M. C. (2011). The relationship between working memory, IQ, and mathematical skills in children. *Learning and Individual Differences*, *21*(1), 133–137. https://doi.org/10.1016/j.lindif.2010.09.013

Andersson, U., & Lyxell, B. (2007). Working memory deficit in children with mathematical difficulties: A general or specific deficit? *Journal of Experimental Child Psychology*, *96*(3), 197–228. https://doi.org/10.1016/j.jecp.2006.10.001

Ashkenazi, S., Black, J. M., Abrams, D. A., Hoeft, F., & Menon, V. (2013). Neurobiological underpinnings of math and reading learning disabilities. *Journal of Learning Disabilities*, *46*(6), 549–569. https://doi.org/10.1177/0022219413483174

Astle, D. E., Barnes, J. J., Baker, K., Colclough, G. L., & Woolrich, M. W. (2015). Cognitive Training Enhances Intrinsic Brain Connectivity in Childhood. *Journal of Neuroscience*, *35*(16), 6277–6283. https://doi.org/10.1523/JNEUROSCI.4517-

14.2015

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience*, *4*(10), 829–839. https://doi.org/10.1038/nrn1201

Baddeley, A. (2010). *Working memory*. *20*(4), 136–140.

Baddeley, A. (2012). Working Memory : Theories , Models , and Controversies. *Annual Review of Psychology*, *63*, 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Bahar-fuchs, A., Clare, L., & Woods, B. (2013). Cognitive training and cognitive rehabilitation for persons with mild to moderate dementia of the Alzheimer ' s or vascular type : a review. *Alzheimer's Research & Therapy*, *5*(35).

Bartolucci, M., Mattioli, F., & Batini, F. (2019). Do board games make people smarter? Two initial exploratory studies. *International Journal of Game-Based Learning*, *9*(4), 1–14. https://doi.org/10.4018/IJGBL.2019100101

Becker, K., & Schliemann, J.-P. (2009). *Auf Zack!* Drei Hasen in der Abendsonne.

Benzing, V., Schmidt, M., Jäger, K., Egger, F., Conzelmann, A., & Roebers, C. M. (2018). A classroom intervention to improve executive functions in late primary school children: Too 'old' for improvements? *British Journal of Educational Psychology*, 1–14. https://doi.org/10.1111/bjep.12232

Brysbaert, M., & Stevens, M. (2018). Power Analysis and Effect Size in Mixed Effects Models: A Tutorial. *Journal of Cognition*, *1*(1), 1–20. https://doi.org/10.5334/joc.10

Bull, R. . c, Espy, K. A. ., & Wiebe, S. A. . (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, *33*(3), 205–228. https://doi.org/10.1080/87565640801982312

Cheema, J. R., & Sheridan, K. (2015). Time spent on homework, mathematics anxiety and mathematics achievement: Evidence from a US sample. *Issues in Educational Research*, *25*(3), 246–259.

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly*, *36*, 79–90. https://doi.org/10.1016/j.ecresq.2015.12.009

de Souza-Salvador, L., Moura, R., Wood, G., & Haase, V. G. (2019). Cognitive heterogeneity of math difficulties: A bottom-up classification approach. *Journal of Numerical Cognition*, *5*(1), 55–85. https://doi.org/10.5964/jnc.v5i1.60

Dehn, M. J. (2017). How working memory enables fluid reasoning. *Applied Neuropsychology: Child*, *6*(3), 245–247. https://doi.org/10.1080/21622965.2017.1317490

Diamond, A., & Lee, K. (2011). Interventions Shown to Aid Executive Function Development in Children 4 to 12 Years Old. *Science*, *333*(6045), 959–964. https://doi.org/10.1126/science.1204529

Ellis, P. D. (2010). *The Essential Guide to Effect Sizes: Statistical Power, Meta-Analysis and the Interpretation of Research Results.* Cambridge University Press.

Estrada-Plana, V., Esquerda, M., Mangues, R., March-Llanes, J., & Moya-Higueras, J. (2019). A Pilot Study of the Efficacy of a Cognitive Training Based on Board Games in Children with Attention-Deficit/Hyperactivity Disorder: A Randomized Controlled Trial. *Games for Health Journal*, *8*(3), g4h.2018.0051. https://doi.org/10.1089/g4h.2018.0051

Friso-Van Den Bos, I., Van Der Ven, S. H. G., Kroesbergen, E. H., & Van Luit, J. E. H. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review*, *10*, 29–44. https://doi.org/10.1016/j.edurev.2013.05.003

Garon-Carrier, G., Boivin, M., Lemelin, J. P., Kovas, Y., Parent, S., Séguin, J., Vitaro, F., Tremblay, R. E., & Dionne, G. (2018). Early developmental trajectories of number knowledge and math achievement from 4 to 10 years: Low-persistent profile and early-life predictors. *Journal of School Psychology*, *68*(July 2016), 84–98. https://doi.org/10.1016/j.jsp.2018.02.004

Gauthier, A., Kato, P. M., Bul, K. C. M., Dunwell, I., Walker-Clarke, A., & Lameras, P. (2019). Board Games for Health: A Systematic Literature Review and Meta-Analysis. *Games for Health Journal*, *8*(2), 85–100. https://doi.org/10.1089/g4h.2018.0017

Gobet, F., Retschitzki, J., & de Voogt, A. (2004). Introduction. In F. Gobet, J. Retschitzki, & A. de Voogt (Eds.), *Moves in mind: The Psychology of Board Games* (pp. 1–10). Psychology Press.

Green, C. T., Bunge, S. A., Briones Chiongbian, V., Barrow, M., & Ferrer, E. (2017). Fluid reasoning predicts future mathematical performance among children and adolescents. *Journal of Experimental Child Psychology*, *157*, 125–143. https://doi.org/10.1016/j.jecp.2016.12.005

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: developmental trajectories and mediation. *Developmental Science*, *18*(5), 686–702. https://doi.org/10.1111/desc.12246

Hattie, J. A. C. (2009). The nature of the evidence: a synthesis of meta-analysis. In John Hattie (Ed.), *Visible Learning: A synthesis of over 800 meta-analysis relating to achievement*. Routledge.

Henry, L. (2011). The Working Memory Model. In L. Henry (Ed.), *The development of Working Memory in Children* (pp. 1–36). Sage pub.

Hiron, M. (2009). *7 ate 9*. 999 Games.

Hollingshead, A. B. (1975). *Four factor index of social status.* University, Yale.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, *12*(4), F9–F15. https://doi.org/10.1111/j.1467-7687.2009.00848.x

Iizuka, A., Suzuki, H., Ogawa, S., Kobayashi-Cuya, K. E., Kobayashi, M., Inagaki, H., Sugiyama, M., Awata, S., Takebayashi, T., & Fujiwara, Y. (2019). Does social interaction influence the effect of cognitive intervention program? A randomized controlled trial using Go game. *International Journal of Geriatric Psychiatry*, *34*(2), 324–332. https://doi.org/10.1002/gps.5024

Jirout, J. J., & Newcombe, N. S. (2015). Building Blocks for Developing Spatial Skills: Evidence From a Large, Representative U.S. Sample. *Psychological Science*, *26*(3), 302–310. https://doi.org/10.1177/0956797614563338

Johann, V. E., & Karbach, J. (2020). Education Application of Cognitive Training. In *Cognitive Training: An Overview of Features and Applications* (Second Edi, pp. 334–347).

Kaufman, D., & Kaufman, P. (1975). Strategy Training and Remedial Techniques. *Journal of Learning Disabilities*, *12*(6), 416–419.

Kermani, F. K., Mohammadi, M. R., Yadegari, F., Haresabadi, F., & Sadeghi, S. M. (2016). Working memory training in the form of structured games in children with attention deficit hyperactivity disorder. *Iranian Journal of Psychiatry*, *11*(4), 224–233.

Kim, S. H., Han, D. H., Lee, Y. S., Kim, B. N., Cheong, J. H., & Han, S. H. (2014). Baduk (the game of go) improved cognitive function and brain activity in children with attention deficit hyperactivity disorder. *Psychiatry Investigation*, *11*(2), 143–151. https://doi.org/10.4306/pi.2014.11.2.143

Kirk, H., Gray, K., Ellis, K., Taffe, J., & Cornish, K. (2017). Impact of Attention Training on Academic Achievement, Executive Functioning, and Behavior: A Randomized Controlled Trial. *American Journal on Intellectual and Developmental Disabilities*, *122*(2), 97–117. https://doi.org/10.1352/1944-7558-122.2.97

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Increased Brain Activity in Frontal and Parietal Cortex Underlies the Development of Visuospatial Working Memory Capacity during Childhood. *Journal of Cognitive Neuroscience*, *14*(1), 1–10. https://doi.org/10.1162/089892902317205276

Knizia, R. (2007a). *Alles kanone!* Zoch Zum Spielen.

Knizia, R. (2007b). *Alles tomate!* Zoch Zum Spielen.

Kuhn, J.-T., & Holling, H. (2014). Number sense or working memory? The effect of two computer-based trainings on mathematical skills in elementary school. *Advances in Cognitive Psychology*, *10*(2), 59–67. https://doi.org/10.5709/acp-0157-2

Lennett, T. (2009). *Numenko in a bag*. TSL Enterprises Ltd.

Luttenberger, S., Wimmer, S., & Paechter, M. (2018). Spotlight on math anxiety. *Psychology Research and Behavior Management*, *Volume 11*, 311–322. https://doi.org/10.2147/PRBM.S141421

Lyons, I. M., & Beilock, S. L. (2011). Numerical ordering ability mediates the relation between number-sense and arithmetic competence. *Cognition*, *121*(2), 256–261. https://doi.org/10.1016/j.cognition.2011.07.009

McKenzie, B., Bull, R., & Gray, C. (2003). The effects of phonological and visual-spatial interference on children’s arithmetical performance. *Educational and Child Psychology*, *20*(3), 93–108.

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270–291.

https://doi.org/10.1037/a0028228

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Nath, S., & Szücs, D. (2014). Construction play and cognitive skills associated with the development of mathematical abilities in 7-year-old children. *Learning and Instruction*, *32*, 73–80. https://doi.org/10.1016/j.learninstruc.2014.01.006

Nedergaard-Andersen, M. (2014). *Out of mine!* Huch! & Friends.

Newman, S. D., Hansen, M. T., & Gutierrez, A. (2016). An fMRI Study of the Impact of Block Building and Board Games on Spatial Ability. *Frontiers in Psychology*, *7*(AUG), 1–9. https://doi.org/10.3389/fpsyg.2016.01278

Ninaus, M., Pereira, G., Stefitz, R., Prada, R., Paiva, A., Neuper, C., & Wood, G. (2015). Game elements improve performance in a working memory training task. *International Journal of Serious Games*, *2*(1), 3–16. https://doi.org/10.17083/ijsg.v2i1.60

Passolunghi, M. C., & Costa, H. M. (2016). Working memory and early numeracy training in preschool children. *Child Neuropsychology*, *22*(1), 81–98. https://doi.org/10.1080/09297049.2014.971726

Peng, P., Namkung, J., Barnes, M., & Congying, S. (2016). A Meta-Analysis of Mathematics and Working Memory : Moderating Effects of Working Memory Domain , Type of Mathematics Skill , and Sample Characteristics. *Journal of Educational Psychology*, *108*(4), 455–473. https://doi.org/http://dx.doi.org/10.1037/edu0000079

Pnueli, A. (2010). *Pig 10*. Zoch Zum Spielen.

Prins, P. J. M., Dovis, S., Ponsioen, A., ten Brink, E., & van der Oord, S. (2011). Does Computerized Working Memory Training with Game Elements Enhance Motivation and Training Efficacy in Children with ADHD? *Cyberpsychology, Behavior, and Social Networking*, *14*(3), 115–122. https://doi.org/10.1089/cyber.2009.0206

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, *20*(2), 110–122. https://doi.org/10.1016/j.lindif.2009.10.005

Ramani, G. B., Jaeggi, S. M., Daubert, E. N., & Buschkuehl, M. (2017). Domain-Specific and Domain-General Training to Improve Kindergarten Children ' s Mathematics. *Journal of Numerical Cognition*, *3*(2), 468–495. https://doi.org/10.5964/jnc.v3i2.31

Ramani, G. B., & Siegler, R. S. (2011). Reducing the gap in numerical knowledge between low- and middle-income preschoolers. *Journal of Applied Developmental Psychology*, *32*(3), 146–159. https://doi.org/10.1016/j.appdev.2011.02.005

Ramani, G. B., Siegler, R. S., & Hitti, A. (2012). Taking it to the classroom: Number board games as a small group learning activity. *Journal of Educational Psychology*, *104*(3), 661–672. https://doi.org/10.1037/a0028995

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8), 1237–1252. https://doi.org/10.1016/j.cpr.2013.08.005

Raven, J. C., Court, J. H., & Raven, J. (2001). *Manual Matrices Progresivas de Raven* (3rd Ed.). TEA Ediciones.

Ready, D. D. (2010). Socioeconomic disadvantage, school attendance, and early cognitive development: The differential effects of school exposure. *Sociology of Education*, *83*(4), 271–286. https://doi.org/10.1177/0038040710383520

Reeves, B. C., & Gaus, W. (2004). Guidelines for Reporting Non-Randomised Studies. *Forsch Komplementärmed Klass Naturheilkd*, *11*(1), 46–52.

Sala, G., & Gobet, F. (2017a). Does Far Transfer Exist? Negative Evidence From Chess, Music, and Working Memory Training. *Current Directions in Psychological Science*, *26*(6), 515–520. https://doi.org/10.1177/0963721417712760

Sala, G., & Gobet, F. (2017b). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology*, *53*(4), 671–685. https://doi.org/10.1037/dev0000265

Sánchez-Pérez, N., Castillo, A., López-López, J. A., Pina, V., Puga, J. L., Campoy, G., González-Salinas, C., & Fuentes, L. J. (2018). Computer-Based Training in Math and Working Memory Improves Cognitive Skills and Academic Achievement in Primary School Children: Behavioral Results. *Frontiers in Psychology*, *8*, 1–12. https://doi.org/10.3389/fpsyg.2017.02327

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of Playing Numerical Card Games on Head Start Children's Mathematical Skills. *Journal of Experimental Education*, *88*(2), 200–220. https://doi.org/10.1080/00220973.2019.1581721

Schannen, M. (2004). *Spooky Stairs*. Iberia, Devir.

Schwaighofer, M., Fischer, F., Bühner, M., Schwaighofer, M., Fischer, F., & Markus, B. (2015). Does Working Memory Training Transfer ? A Meta- Analysis Including Training Conditions as Moderators Does Working Memory Training Transfer ? A Meta-Analysis Including Training Conditions as Moderators. *Educational Psychologist*, *50*(2), 138–166. https://doi.org/10.1080/00461520.2015.1036274

Shut the box. (n.d.). Gollnest & Kiesel.

Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development. *Developmental Science, 11*(5), 655–661. https://doi.org/10.1111/j.1467-7687.2008.00714.x

Siegler, R. S., & Ramani, G. B. (2009). Playing linear number board games—but not circular ones—improves low-income preschoolers' numerical understanding. *Journal of Educational Psychology*, *101*(3), 545–560. https://doi.org/10.1037/a0014239

Sousa, M., & Bernardo, E. (2019). Back in the Game. In N. Zagalo, A. I. Veloso, L. Costa, & Ó. Mealha (Eds.), *Proceeding from the 11th International Conference Videogame Sciences and Arts, held in Aveiro, Portugal, November 27 & 29, 2019* (pp. 72–85). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-37983-4_6

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

Tajik-Parvinchi, D., Wright, L., & Schachar, R. (2014). Cognitive Rehabilitation for Attention Deficit/Hyperactivity Disorder (ADHD): Promises and Problems. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *23*(3), 207–217.

Tamm, L., Epstein, J. N., Peugh, J. L., Nakonezny, P. A., & Hughes, C. W. (2013). Preliminary data suggesting the efficacy of attention training for school-aged children with ADHD. *Developmental Cognitive Neuroscience*, *4*, 16–28. https://doi.org/10.1016/j.dcn.2012.11.004

Tamnes, C. K., Østby, Y., Walhovd, K. B., Westlye, L. T., Due-Tønnessen, P., & Fjell, A. M. (2010). Neuroanatomical correlates of executive functions in children and adolescents: A magnetic resonance imaging (MRI) study of cortical thickness.

Neuropsychologia, *48*(9), 2496–2508. https://doi.org/10.1016/j.neuropsychologia.2010.04.024

Tejedor, B., Auxiliadora Santos, M., García-Orza, J., Carratalà, P., & Navas, M. (2009). Variables involved in math anxiety: A study in a sixth grade sample. *Anuario de Psicología*, *40*(3), 345–355. http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2010-13356-003&site=ehost-live jgorza@uma.es

The jamovi project. (2021). *jamovi (Version 1.6.15) [Computer program]*. https://www.jamovi.org

Titz, C., & Karbach, J. (2014). Working memory and executive functions: effects of training on academic achievement. *Psychological Research*, *78*(6), 852–868. https://doi.org/10.1007/s00426-013-0537-1

Wechsler, D. (2003). *Escala de Inteligencia de Wechsler para Niños-IV (WISC-IV).* TEA Ediciones.

Zheng, X., Swanson, H. L., & Marcoulides, G. A. (2011). Working memory components as predictors of children's mathematical word problem solving. *Journal of Experimental Child Psychology*, *110*(4), 481–498. https://doi.org/10.1016/j.jecp.2011.06.001

Zoch, K. (1998). *Chicken Cha Cha Cha*. Devir Iberia.

Table 1

Demographical/psychological characteristics and baseline outcomes divided in grades 3 and 4.

	Grade 3					**Grade 4**				
	Math GTG (n=75) [c]	**Memory GTG (n=18)**	**CG (n=28)**	χ^2 ***(p value)***	ε^2/V	**Math GTG (n=17)** [c]	**Memory GTG (n=66)**	**CG (n=30)**	χ^2 ***(p value)***	ε^2/V
	Demographical characteristics					Demographical characteristics				
Age (in years) M±SD	8.31±0.38	8.47±0.36	8.46±0.28	7.13* (.028)	0.06	9.42±0.26	9.39±0.40	9.39±0.32	0.79 (.673)	0.01
Sex [a]				4.66 (.097)	0.20				1.64 (.441)	0.12
Boys, *n (%)*	46 (62%)	14 (78%)	13 (46%)			6 (35%)	34 (52%)	13 (43%)		
Girls, *n (%)*	28 (38%)	4 (22%)	15 (54%)			11 (65%)	32 (48%)	17 (57%)		
SES Index, M±SD	32.80±11.14	33.89±9.74	35.46±12.16	1.26 (.532)	0.01	25.74±11.11	30.62±12.01	36.47±15.01	**8.92* (.012)**	**0.08**
Ethnicity [b]				0.64 (.728)	0.08				7.86 (.447)	0.20
Spanish	57 (92%)	15 (94%)	27 (96%)			10 (100%)	54 (87%)	29 (97%)		
European	5 (8%)	1 (6%)	1 (4%)			0 (0%)	5 (8%)	0 (0.0%)		
Others	0 (0%)	0 (0.0%)	0 (0.0%)			0 (0%)	3 (5%)	1 (3%)		
	Psychological characteristics					Psychological characteristics				
Fluid reasoning, M±SD	29.32±9.38	28.72 ±9.83	33.43±8.09	4.64 (.098)	0.04	31.88±9.82	32.56 ±8.92	31.70±9.86	0.01 (.993)	0.00
AMAS, M±SD	22.81±6.43	18.67±4.30	18.89±6.87	**11.11** (0.04)**	0.09	23.59±7.26	21.45±7.09	18.77±5.90	5.19 (.075)	0.05
	Baseline outcome levels					Baseline outcome levels				
Verbal STM (hits), *M±SD*	7.30 ±1.64	6.83 ±1.65	6.96 ±1.84	1.88 (.390)	0.02	7.00±1.90	7.41±1.75	8.20±2.04	5.06 (.080)	0.05
Verbal STM (span), *M±SD*	5.03±0.99	4.78±0.94	4.96±0.96	1.02 (.600)	0.01	4.81±1.11	5.18±1.04	5.50±1.11	4.49 (.106)	0.04
VS STM (hits), *M±SD*	6.49 ±1.56	6.89 ±1.53	6.93 ±1.76	0.80 (.669)	0.01	7.06 ±1.73	6.67 ±1.49	7.60 ±2.04	**7.47*(.024)**	**0.07**
VS STM (span), *M±SD*	4.78±0.91	5.00±0.77	5.11±1.10	1.42 (.492)	0.01	5.00±0.89	4.97±0.98	5.30±1.06	3.05 (.218)	0.03
Verbal WM, *M±SD*	21.70 ±4.54	21.89 ±3.32	21.75 ±4.28	0.15 (.929)	0.00	21.00 ±4.38	22.26 ±4.18	24.47 ±4.08	**9.47*(.009)**	**0.09**
VS WM *M±SD*	20.88 ±5.42	22.28 ±6.14	22.46 ±5.30	2.63 (.268)	0.02	20.31 ±6.76	21.59 ±4.88	24.97 ±4.47	**11.25**(.004)**	**0.10**
Number Operations, *M±SD*	12.52 ±4.00	13.67 ±3.11	16.21 ±3.44	**17.77***(<.001)**	**0.15**	16.18 ±4.64	14.80 ±4.47	18.30 ±4.32	**11.44**(.003)**	**0.10**
Number Ranking, *M±SD*	21.44 ±8.49	26.11 ±9.59	30.04 ±4.26	**30.17***(<.001)**	**0.25**	29.65 ±9.73	29.23 ±9.24	33.47 ±7.61	4.75 (.093)	0.04
Number Production, *M±SD*	4.96 ±3.95	5.22 ±5.38	6.29 ±4.66	1.53 (.465)	0.01	7.06 ±4.10	6.61 ±5.14	7.67 ±5.14	1.24 (.538)	0.01
Problem Solving, *M±SD*	4.35 ±2.24	4.11 ±2.30	7.00 ±2.82	**19.52***(<.001)**	**0.16**	6.47 ±2.83	5.77 ±3.04	7.37 ±3.85	3.69 (.158)	0.03

Note. AMAS=Anxiety Math Abbreviated Scale; CG=Control Group; GTG=Game Training Group; SES=Social Status; STM=Short Term Memory; VS=Visuospatial; WM=Working Memory.

[a.] Sex was only registered in a subset of children in Math GTG in grade 3 (n=74).

[b.] Ethnicity was only registered in a subset of children at pretest in grade 3 (n=106) and a subset of children at pretest in grade 4 (n=102).

[c.] Memory Tests were only administered to a subset of children in Math GTG in grade 3 (n=74) and a subset of children in Math GTG in grade 4 (n=16).

* $p<.05$. ** $p<.01$. *** $p<.001$.

$\varepsilon^2<0.02$= trivial; $0.02\leq \varepsilon^2<0.13$= small; $0.13\leq \varepsilon^2<0.26$= medium; $\varepsilon^2\geq0.26$= large. $V<0.10$= trivial; $0.10\leq V<0.30$= small; $0.30\leq V<0.50$= medium; $V\geq0.50$= large.

Table 2

Brief description of the games used in the Memory GTG and the Math GTG and the primary/secondary theoretically activated outcomes.

Memory filler board games used in Memory GTG		
BOARD GAMES	**PRIMARY MEMORY OUTCOMES**	**SECONDARY MATHEMATICAL OUTCOMES**
Alles Kanone! (Knizia, 2007a)	Visuospatial Updating-WM	-
Alles Tomate! (Knizia, 2007b)	Visuospatial Updating-WM	-
Chicken, Cha Cha Cha! (Zoch, 1998)	Visuospatial STM	-
Out of Mine! (Nedergaard-Andersen, 2014)	Visuospatial STM and WM	Number Operations, Problem Solving
Spooky Stairs (Schannen, 2004)	Visuospatial Updating-WM	-

Alles Kanone! (Knizia, 2007a): Seven themed cards are always face-up. One object card is positioned face-up, down the themed card with which it is related. Once all the players have seen the seven object cards, they are face-down. From the deck, one participant reveals a new object card. The first player to recall which element is on the face-down object card positioned down the themed card with the same color background is the person who will win the card. The topic of the game is pirates. The player who accumulates more cards becomes the winner.

Alles Tomate! (Knizia, 2007b): This game follows the same rules as Alles Kanone!, but with a topic about farming.

Chicken, Cha Cha Cha! (Zoch, 1998): four hen figures, with spaces at their back to place feathers, are positioned on one of the 24 egg-shaped (faced-up) tiles making a circle. In the middle of the circle, 12 octagons, each with a different chicken-related image, are positioned face-down. Each octagon image coincides with two egg-shaped tiles. To move his/her hen, the player has to find the correct combination of the octagon with one of the egg-shaped tiles. Once the octagon tile revealed its image, the tile is faced down another time. If one hen overtakes another, the one that overtakes steals the feather to the other one. The game ends when one player gets the four feathers. This person is the winner.

Out of Mine! (Nedergaard-Andersen, 2014): Every player has a tunnel board randomly assigned, which has to be completed with different bidimensional pieces of different forms (each one representing a different type of minerals). All the pieces fit together if they are properly combined. Moreover, each player has a card that indicates which pieces have to be used to win extra points. All players play at the same time. The topic of the game is dwarfs in a mine. The player who gathered the most points after one work week (7 game rounds) wins the game.

Spooky Stairs (Schannen, 2004): It is a race to arrive at the top of the stairs. Each participant has a pawn of a specific color. Rolling 6 sided dice, each participant keeps climbing unless he/she rolls a "ghost". Then, a ghost piece, connected by a magnetic field to the pawns head, covers completely the participant's pawn. When all the pawns are covered by the ghosts, all the players must remember which position of his/her ghost is. The game finishes when the first pawn reaches the top of the stairs. The player who belongs to this pawn is the winner.

Table 2 (*continuation*)

Mathematical filler board games used in the Math GTG		
BOARD GAMES	**PRIMARY MATHEMATICAL OUTCOMES**	**SECONDARY MEMORY OUTCOMES**
7ate9 (Hiron, 2009)	Number Operations	-
Auf zack! (Becker & Schliemann, 2009)	Number Operations	Visuospatial STM
Numenko in a bag (Lennett, 2009)	Number Operations	-
Pig 10 (Pnueli, 2010)	Number Operations	-
Shut the box (*Shut the Box*, n.d.)	Number Operations	-

7ate9 (Hiron, 2009): the 73 cards of the game are distributed for all the players. One card is faced up at the center of the table. Each card has a general number (from 1 to 10) and a smaller modifier in the corner (±1, ±2, or ±3). All the players play at the same time trying to add a card into the central pile (the one with the general number that applying the modifier score gets the number of the central card modified). The person who first runs out of cards is the winner.

Auf zack! (Becker & Schliemann, 2009): there are 44 cards from different families and a variable number of images, from 0 to 9. There are also 10 wooden pieces with a semi-circled form with a number written (it represents the solution). Play starts with a player turning two cards of a heap. If the cards are from the same family, all players must calculate the sum of the two objects drawn on the cards, and the first one to catch the wooden piece with the number of the sum wins the card. The player with the maximum quantity of cards wins.

Numenko in a bag (Lennett, 2009): some wooden pieces (with numbers from 0 to 9, operators or wildcards) are distributed through the participants and some others are placed in the middle of the table face-up. Players must combine the pieces to perform the maximum possible calculations, taking pieces from the middle if they need anyone. When all the players finished, all the calculations receive points according to some rules. If there is a mistake or someone has used a wildcard, gets a penalty of 10 points. A player who gets the lower final score wins.

Pig 10 (Pnueli, 2010)*:* players take 3 cards each from the 80 possible (all are numbered from 0 to 10). Every player in his turn has to put a card in the middle, taking into account the value of the card previously thrown, and steal another card from the heap. If the sum of the numbers from the stacked cards is equal to 10, round finishes and the person who has put the last card gets all the cards from the heap. If the sum is below 10, the turn is for the next player. If the sum is above 10, the person on the right from the player gets all the cards of the heap. Some modifiers could be applied with special cards. The player with the greatest quantity of cards wins.

Shut the box (*Shut the Box*, n.d.): game's material includes one board with a plate in the center, four groups of records numbered from 1 to 10, and two dices. In the beginning, all records are stand up. The player who starts throws the dices and sum the numbers of the results. The next step is to fall down the records, and the player can do it with the total sum or with a decomposition of it (i.e. if a player gets a 6, it can fall 6, 5+1, 4+2, 3+2+1). After three rounds, the player who has won most of the time wins.

Table 3

Before and after the intervention, memory scores (Mean±SE), math scores (Mean±SE), and mixed model results divided into grades 3 and 4.

		Grade 3[a]						Grade 4[b]					
		Math GTG (n=75)	**Memory GTG (n=18)**	**CG (n=28)**	**Time** *(p)*	**Group** *(p)*	***Timex Group*** *(p)*	**Math GTG (n=17)**	**Memory GTG (n=66)**	**CG (n=30)**	**Time** *(p)*	**Group** *(p)*	***Timex Group*** *(p)*
Verbal STM	Pre	7.31±0.18	6.92±0.37	6.88±0.30	1.12	0.74	0.59	7.20±0.50	7.43±0.24	8.04±0.37	0.12	0.46	0.96
(hits)	Post	7.30±0.18	7.37±0.37	6.99±0.30	(.292)	(.480)	(.553)	7.58±0.50	7.68±0.24	7.67±0.37	(.730)	(.630)	(.386)
Verbal STM	Pre	5.03±0.11	4.84±0.22	4.91±0.17	1.34	0.71	0.62	4.92±0.25	5.20±0.12	5.41±0.19	0.89	0.79	0.59
(span)	Post	5.14±0.11	5.17±0.22	4.87±0.17	(.250)	(.493)	(.539)	5.17±0.25	5.35±0.12	5.35±0.19	(.349)	(.458)	(.554)
VS STM	Pre	6.53±0.18	6.94±0.37	6.80±0.30	**4.66***	0.66	**3.32***	7.06±0.38	6.66±0.19	7.61±0.28	**3.96***	**4.90****	0.53
(hits)	Post	7.35±0.18	7.44±0.37	6.66±0.30	**(.033)**	(.517)	**(.040)**	7.19±0.38	7.28±0.19	8.04±0.28	**(.049)**	**(.009)**	(.590)
VS STM	Pre	4.82±0.11	5.03±0.22	5.02±0.18	3.25[t]	0.74	**5.19****	4.99±0.24	4.97±0.12	5.30±0.17	3.07[t]	**3.55***	0.57
(span)	Post	5.44±0.11	5.25±0.22	4.84±0.18	(.074)	(.481)	**(.007)**	4.99±0.24	5.33±0.12	5.70±0.17	(.082)	**(.032)**	(.566)
Verbal WM	Pre	22.09±0.90	21.78±0.44	21.42±0.73	**13.30*****	0.21	0.24	21.32±1.01	22.30±0.50	24.21±0.74	**9.30***	1.97	1.27
	Post	23.93±0.90	23.23±0.44	23.56±0.73	**(<.001)**	(.808)	(.790)	23.82±1.01	24.03±0.50	24.64±0.74	**(.003)**	(.144)	(.284)
VS WM	Pre	21.23±0.57	22.30±1.15	21.66±0.93	**13.72*****	.80	**3.55***	20.81±1.09	21.67±0.53	24.53±0.80	**33.65*****	**5.10****	0.54
	Post	24.38±0.57	24.46±1.15	22.01±0.93	**(<.001)**	(.452)	**(.032)**	24.25±1.09	24.85±0.53	26.76±0.80	**(<.001)**	**(.008)**	(.583)
Number	Pre	12.76±0.44	13.63±0.89	15.56±0.72	**61.68*****	3.06	**3.73***	16.51±1.00	14.81±0.50	18.06±0.76	**42.20*****	**9.33*****	0.50
Operations	Post	16.96±0.44	16.29±1.04	17.96±0.72	**(<.001)**	(.050)	**(.027)**	18.63±1.00	17.36±0.53	21.23±0.77	**(<.001)**	**(<.001)**	(.606)
Number	Pre	21.69±0.77	26.39±1.58	29.22±1.28	**48.78*****	**7.13****	**6.22****	30.86±2.00	29.35±1.00	32.45±1.52	**37.26*****	2.44[t]	0.24
Ranking	Post	31.57±0.78	32.41±1.97	33.11±1.28	**(<.001)**	**(.001)**	**(.003)**	35.62±2.00	34.90±1.08	38.90±1.54	**(<.001)**	(.0.92)	(.789)
Number	Pre	5.28±0.53	5.25±1.09	5.39±0.88	**22.97*****	0.06	0.09	7.69±1.16	6.63±0.58	7.24±0.88	**60.92*****	**3.48***	**8.00*****
Production	Post	7.78±0.54	7.30±1.28	8.04±0.88	**(<.001)**	(.943)	(.914)	10.81±1.16	8.36±0.61	12.53±0.89	**(<.001)**	**(.034)**	**(<.001)**
Problem	Pre	4.53±0.26	4.19±0.54	6.48±0.43	**8.08****	**7.36*****	1.71	6.80±0.68	5.77±0.34	7.17±0.52	**27.40*****	1.13	**3.25***
Solving	Post	5.88±0.27	5.10±0.66	6.80±0.43	**(.005)**	**(<.001)**	(.185)	7.68±0.68	7.89±0.36	8.18±0.52	**(<.001)**	(.327)	**(.043)**

Note. CG=Control Group; GTG=Game Training Group; SE=Standard Error; SES=Social Status; STM=Short Term Memory; VS=Visuospatial; WM=Working Memory.

[a]. In third grade, memory tests were administered to a subset of children in Math GTG (n=74). Mathematical tasks were administered to a subset of children at post-test in Math GTG (n=73) and CG (n=11).

[b]. In fourth grade, memory tests were administered to a subset of children in Math GTG (n=16) and Memory GTG ($n_{\text{Verbal WM}}$=65). Mathematical tasks were administered to a subset of children at post-test in Memory GTG (n=54) and CG (n=29).

* *p*<.05. ***p*<.01. ****p*<.001.

Figure 1

Diagram flow.

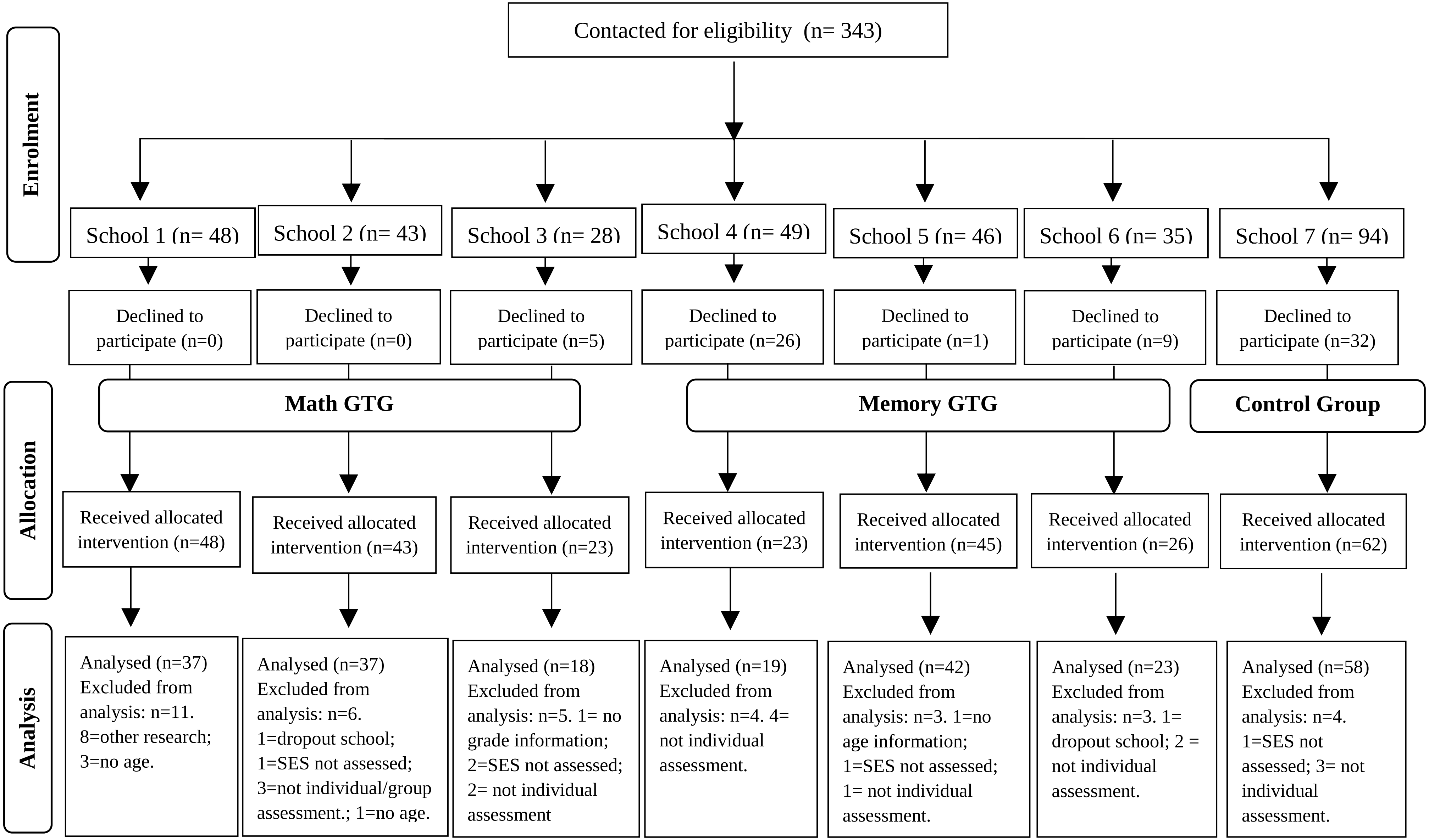
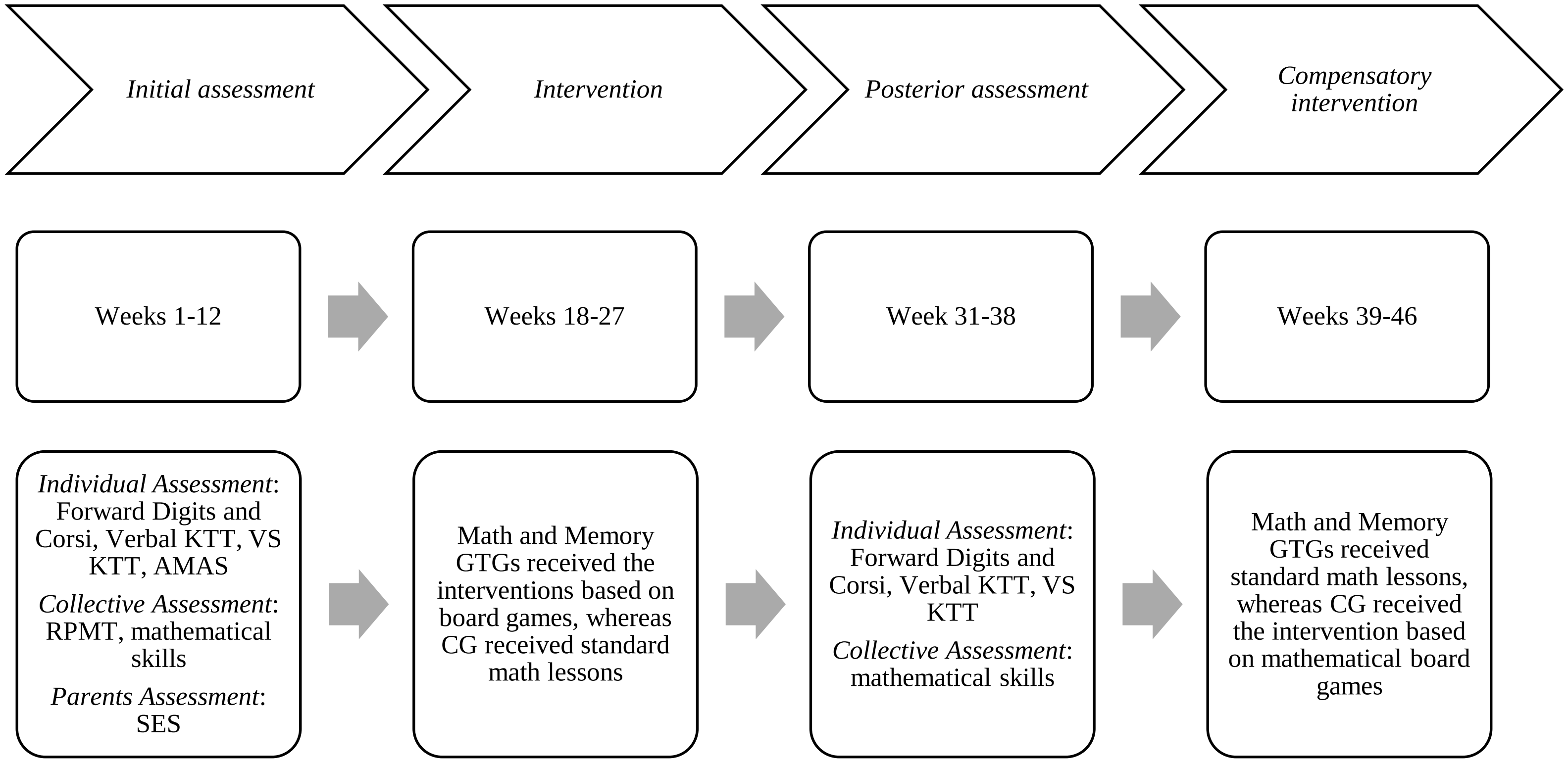


Figure 2

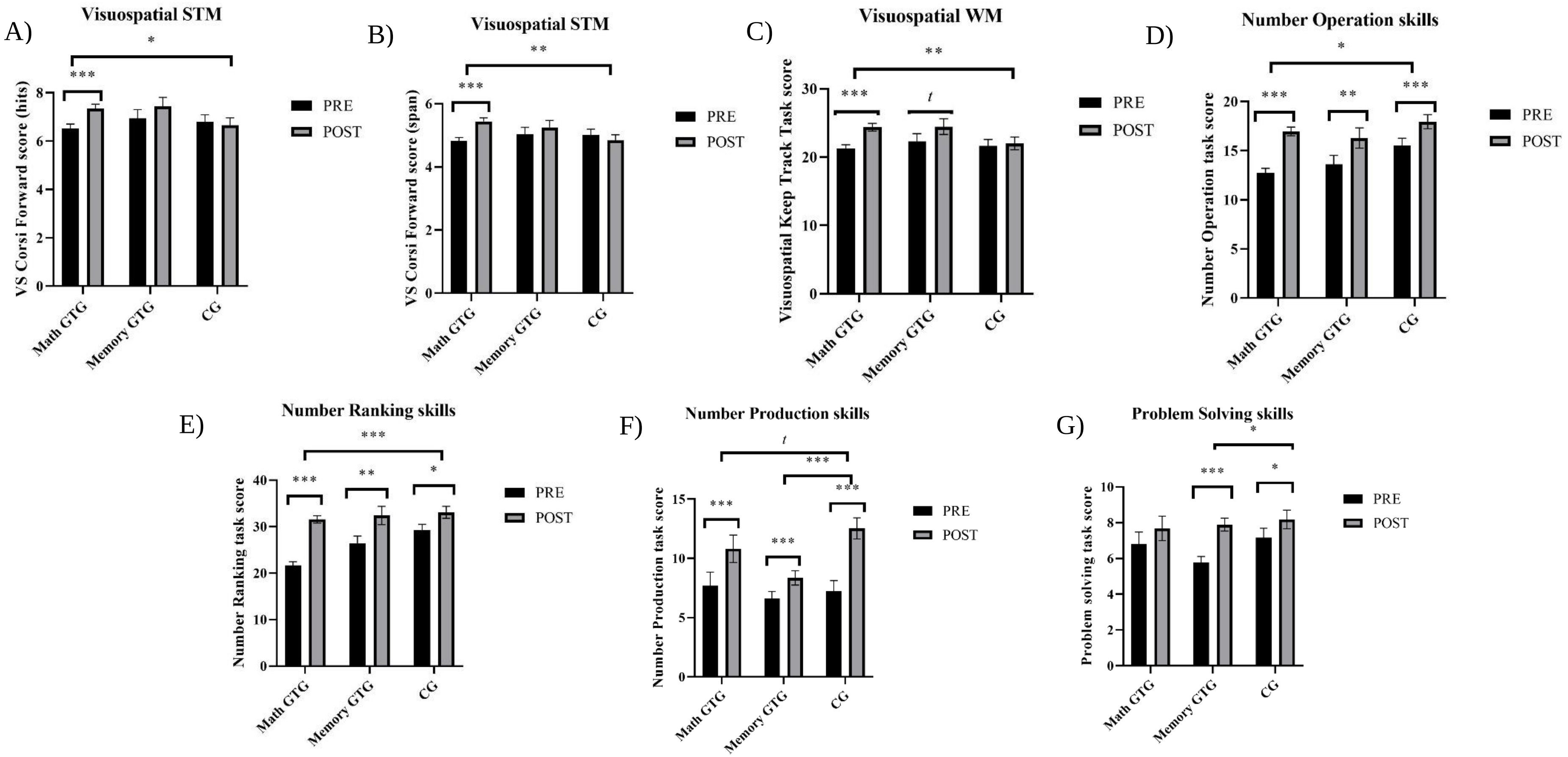
Timeline.



Note. AMAS=Anxiety Math Abbreviated Scale; CG=Control Group; KTT= Keep Track Task; RPMT =Raven Progressive Matrices Test; SES= Social Status; GTG=Game Training Group; VS= Visuospatial.

Figure 3

Plots from interaction results.



Note. A=visuospatial STM (hits) in third grade; B= visuospatial STM (span) in third grade; C= visuospatial WM in third grade; D=Number Operation skills in third grade; E= Number Ranking skills in third grade; F= Number Production skills in fourth grade; G=Problem Solving skills in fourth grade.

3.2.3. A pilot study of the Efficacy of a Cognitive Training based on Board Games in Children with ADHD: A Randomized Controlled Trial

Estrada-Plana V, Esquerda M, Mangues R, March-Llanes J, Moya Higueras J

Games for Health Journal 2019 8(3): g4h.2018.0051

DOI: 10.1089/g4h.2018.0051

Abstract

Objective: The main aim of this study was to prove the efficacy of an intervention based on board games on executive functions (EFs) and clinical symptoms in children with attention-deficit/hyperactivity disorder (ADHD).

Materials and Methods: A nonblinded randomized controlled trial was conducted with a sample of children with a diagnosis of ADHD (diagnosed by psychiatrists and clinical psychologists in a mental health center). Children were randomly allocated by matching age and sex, into two groups: experimental EF training group (n = 13; mean [M]age = 9.46, standard deviation [SD] = 1.20; boys = 53.8%) or a wait-list control group (n = 14; Mage = 9.50, SD = 1.09; boys = 71.4%). Measures assessed individually at pretest, posttest, and follow-up intervention included EFs and clinical symptoms.

Results: Analysis of covariance repeated measures analysis showed that linguistic short-term memory, $F(1,20) = 7.45$, $p = 0.02$, and conduct problems, $F(1,18) = 12.51$, $p = 0.00$, significantly improved with larger effects in the board games training group after intervention when compared to the wait-list group. Although nonsignificant effects were reported at the follow-up, large effect sizes were actually found.

Conclusion: Although future studies are needed, the results of this study highlight the importance of board games and its efficacy as a possible therapeutic and/or preventive intervention on ADHD.

Keywords: ADHD, Board games, Working memory, Executive functions, Conduct problems

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) constitutes the most prevalent neurodevelopmental disorder among children and adolescents, rising to a prevalence of 5.29% in individuals under the age of 18(1). Alterations in the frontal lobe have constituted one of the most important explicative hypothesis for ADHD, putting particular emphasis on the impairment of executive functions (EF) (see (2,3)). There is a broad consensus to accept that there are three relatively basic EFs (*shifting*, *updating (Working Memory (WM)* and *inhibition*) which can account for the other more complex ones(4). The impairment in these EFs in children with ADHD has consequences at different levels such as lowering academic achievement(5), increasing difficulties in socialization(6) or hindering of peer functioning (7,8). Dovis et al.(9) also found that, besides the WM functioning, ADHD children also showed impairments in the capacity of storage short-term information, also known as Short-Term Memory (STM).

Nowadays, psychopharmacological treatments are the primary interventions to treat ADHD, though there is not an agreement about its efficacy in improving EFs(10). Additionally, some children do not respond to this kind of treatment(11), and many others show secondary effects due to medication, such as insomnia or decreased appetite, which hampers treatment's acceptability by parents and children(12).

An alternative to pharmacological interventions, or even a complementary treatment to them, is the use of cognitive training procedures. Although the benefits of this kind of therapy have not been yet clarified concerning EFs(10), most studies have found significant effects of the trainability of WM and some of its components(13,14). Also, previous evidence shows that cognitive training of specific cognitive processes could improve the execution in other tasks for which the subject has not received specialized treatment (15). This is known as the *transfer effect*, which could be divided into *near*-

transfer (improvement when doing similar tasks or processes) and *far-transfer* (a broader improvement, such as the symptoms of ADHD attributed to the enhancement of the functioning of specific brain areas)(14). In relation with these effects, there are studies in favour(16) or opposing(14,17,18).

Recently, some authors suggested that computerized cognitive training procedures may improve the cognitive functioning(19), enhancing the dopaminergic tone(20) in neural structures related to the ADHD (21). Benefits of these cognitive training procedures could be higher with the inclusion of game elements because more cerebral areas could be activated(22). In different studies(23,24), it has been found that those children with ADHD who were trained with computerized training with game elements obtained better scores in WM and motivation than those who had not. In an analog way, Mohammad & El-Shamieh (25) found that playing chess improved concentration capacity in children with ADHD. Nowadays, sales(26) and research(27,28) of board games are arising. Modern board games are considered cognitive games that are mainly played on a board with pieces (and or cards) on it, with predefined rules that fix the number of pieces/cards on the board, the number of positions of the elements on the board, and the number of their possible moves (29). Some of these board games depend low on fate and are manufactured more attractive to children than chess and are easy to get. Board games are sometimes oriented and published by the editors to improve specific EFs(30). As far as we know, there is still no scientific study that assesses the efficacy of this kind of board games to improve the cognitive functioning and the recovery of symptoms in children with ADHD specifically.

To sum up, in the present study we aimed at studying the efficacy of board games as a cognitive training for EF (near-transfer effect) and for reducing general symptomatology (far-transfer effect) in children aged 8 to 12 years old with a diagnose of ADHD using a randomized control trial methodology. For this reason, we hypothesized that the participants of the experimental group would get better scores on the EF's measures and that they would show more far-transfer effects after the intervention in comparison to the control group. A follow up of a month was also conducted in the study.

Materials and Methods

Participants

The sample was initially composed of 29 children, aged 8 to 12 years old and recruited from one public mental health Center for children and adolescents in Lleida, Spain. All children were receiving treatment for ADHD at the moment of the study (see Table 1 for demographic characteristics). About ethnicity, the 97% of the sample was of Spanish origin.

Inclusion criteria for participation were i) being 8 to 12 years old, ii) studying in a primary school grade, and iii) having a diagnostic of ADHD disorder –including Inattentive or Combination subtype because no significant differences have been previously found in EF between children with hyperactivity alone or combined with inattention diagnose(31). ADHD's diagnosis was established after a clinical evaluation made by clinical psychologists –including second and third authors- and/or psychiatrists of the ADHD unit in the mental health center following the suggestions of the clinical practice guidelines for ADHD(32). Exclusion criteria included i) having other mental disorders, ii) having an estimated full-scale IQ measured by WISC-IV of less than 80 (clinical psychologists from the center gave this data), and iii) being in a sheltered center. The assessment necessary to apply the inclusion and exclusion criteria was performed by the team of psychiatrists and clinical psychologists of the mental health center which offered the data to the research team for this research.

Table 1.

Differences in Demographic Characteristics Between Children in the EF Game-Training (Experimental) and the Wait-List Condition (Control).

	Experimental (n=13)	**Control (n=14)**	t/χ^2	*d*/W
Age *M (SD)*	9.46 (1.20)	9.50 (1.09)	t=-0.09	.03
Gender			χ^2= 0.89	.37
Boys, *n (%)*	7 (53.8 %)	10 (71.4 %)		
Girls, *n (%)*	6 (46.2 %)	4 (28.6 %)		
Fluid reasoning, *M (SD)*	36.92 (20.34)	47.14 (26.18)	t = -1.13	.44
Socio-Economical Index, *M(SD)*	28.92 (9.58)	30.43 (12.73)	t = -0.35	.13
Diagnosis, *n (%)*			χ^2= 0.52	.25
ADHD-I	3 (23.1 %)	5 (35.7 %)		
ADHD-H/I	10 (76.9 %)	9 (64.3 %)		
Familiar history of ADHD, *n (%)*			χ^2= 0.30	.41
Yes	7 (53.8%)	9 (64.3%)		
No	6 (46.2%)	5 (35.7%)		
Pharmacology Type			χ^2= 1.72	.42
Stimulant	8 (61.5%)	10 (71.4%)		
Non-Stimulant	2 (15.4%)	1 (7.1%)		
Both	0 (0.0%)	1 (7.1%)		
No	3 (23.1%)	2 (14.3%)		
Pharmacological –dose/day *(M/SD)*	26.81 (23.14)	43.39 (32.79)	t= -1.51	.59

Note. Effect sizes were interpreted according to Cohen (1992) and Cárdenas (2014): d< .20= trivial; .20<d<.50= small; 50<d<.80= medium; d>.80= large; w< .10= trivial; .10<w<.30= small; .30<w<.50= medium; w>.50= large.

Measures

At the present study, as it can be seen in Table 2, the primary outcome measures consisted in the assessment of linguistic and visuospatial STM, the functioning of the updating process of the linguistic and visuospatial WM, and inhibition and shifting EF skills. We also analyzed the effects of the intervention in secondary outcomes: ADHD behaviors and general psychopathological symptoms. Finally, four confounding variables were assessed based in past research (3,10,33): dose per day of medication (in mg); socioeconomic index (formula's index was: [education scale score]x3 + [occupation scale score]x5) (34); fluid reasoning (RAVEN test(35)); and sustained attention skills (CARAS test(36)). As it can be seen in Table 3, reliability was high in most of the analyzed subscales. However, those SDQ subscales with reliability scores smaller than .50 were not considered in the analysis: hyperactivity/inattention, peer relationship problems, and prosocial behavior.

Table 2.

Description of instruments to assess outcome measures.

	Primary outcome measures
Working memory/updating	
Visuospatial STM	It was assessed by the Corsi block span task (Logie, 1995[55], adapted from Andersson & Lyxell, 2007) [56]. The measure included in the study was the total sum of the trials repeated correctly.
Linguistic STM	The direct digits from WISC-IV (Wechsler) [57] was used. For every trial remembered, one point was given. The final score was the sum of the previously obtained points.
Updating visuospatial WM	The Keep Track Task was adapted for school-aged children from Tamnes et al.[49] A table 3 · 3 was shown on the computer screen on each trial. The targets consisted of six different faces in different colors (black, blue, green, red, white, and yellow). Faces were presented on the computer screen, in a variable number of presentations (between one and five). The task was to recall the last position presented in each different color face. Trials with different memory load (three, four, and five different color faces) and presentation's time off, and between every item were the same as Tamnes et al.[49] The total of faces' positions to recall was 33. The total of faces' positions recalled was the measure of interest. The task ended when all the trials were administered.
Updating linguistic WM	The Keep Track Task was adapted administered according to the guidelines presented by Tamnes et al.[49] to assess linguistic WM in school-aged children and adolescents by a computerized task. The task consists of 18 words, 3 words from six possible categories (animals, clothing, colors, countries, fruit, and relatives). Words were presented on the computer screen, in a variable number of presentations (between one and five). The

	categories remained on the screen during the trial. The task was to recall the last word presented in each of these categories (four trials with three categories, four trials with four categories and one trial with five categories). The total words recalled was the measure considered in the study, scoring 1 point to every hit, with a maximum of 33 words to be remembered. The task ended when all the trials were administered.
Inhibition	A Go/NoGo task was used as outcome measure. It was a response inhibition task where a motor response has to be executed or inhibited (adapted from Bezdjian, Baker, Lozano& Raine) [58]. Four values were calculated for each condition: 1) correct responses to the target Go (hits), 2) misses of the target Go (omission errors), 3) incorrect responses to the NoGo letter (commission errors), and, 4) correct rejections to the NoGo letter. The average Reaction times (RT) were calculated by the mean of time used to press the letter in the condition to the target Go (hits).
Shifting	Trail Making Tests (TMT) A and B were administered according to the guidelines presented by Andersson & Lyxell [56]. In the present study, time to complete each part was recorded as dependent variable.
Secondary outcome measures	
ADHD behaviors	CPRS-48 (Conners)[59] was administered due to it is sensible to changes by treatment. For this study, the short parental version (48 items) was used. Subscales were: conduct problems, learning difficulties, psychosomatic, impulsive-hyperactive, anxiety, and a hyperactivity index.
General psychopathology	For the assessment of symptoms of psychopathology, the SDQ (Goodman)[60] was used. This instrument consists of a brief behavioral screening questionnaire with 25 items which are divided into 5 scales: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behavior. In the present investigation, the scale was reported by parents in a Likert scale 0 (not true) to 2 (completely true).

Treatment

The intervention consisted of a cognitive training based on board games. A total of 5 board games were used: Alles Tomate!(37) and Alles Kanone!(38) which are supposed to work the linguistic updating process of the WM; Spooky Stairs(39) which requires visuospatial information updating of WM; Out of Mine!(40) which is focused on visuospatial rotation; and Chicken Cha Cha Cha(41) which is specifically centered in visuospatial STM and WM (see Supplementary Material 1 for a detailed description adapting Baranowski's suggestions(42)).

Sessions were organized in closed groups (6-8 participants/group). The games consisted of 5 training sessions of about 60 minutes each one during 5 weeks. People who conducted the sessions were one researcher (the first author of the present paper) and two assistant researchers. The intervention team remained stable across the sessions. Each session was planned previously and described in a handbook for the research, and was always executed in the same way: i) during the first 15 minutes, different social activities were executed in order to facilitate the interactions between the participants (most of them did not know each other previously); ii) the first board game was administered during 30 minutes; iii) the second board game was administered during 30 minutes; iv) during the last 15 minutes, researchers thanked the participation and attended parents' questions about individual situations of their children. In the different sessions, the board games used were: session 1; Alles tomate! and Spooky Stairs; session 2; Out of mine! and Chicken Cha Cha Cha; session 3; Spooky Stairs and Alles tomate!; session 4; Chicken Cha Cha Cha and Out of mine!; session 5; Alles Kanone! and the game they liked most (this was decided democratically by all the participants in each wave). Every 4 participants formed a playing group. We had 2 playing groups in each wave. In each intervention session, 1 playing group played first with a board game and the other playing group to the another during the first 30 minutes. During the last 30 minutes, the games were interchanged between the playing groups. Researchers and assistant researchers only controlled that the rules of each game were properly followed but letting the participants managing different situations that naturally occurred during playing (i.e. chatting). At the end of the last session, a certificate of attendance was given to each participant. No adverse effects were found during the intervention.

Procedure

First, the Clinical Research Ethical Committee of the university accepted the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Sample size calculation was determined following the results obtained by Klingberg et al.(43), considering 2 points of variance. On the calculation, the fields introduced were: a bilateral 95% IC with a 90% statistical power and a 50% of possible drop-outs. Finally, 11 subjects of each group were determined, and 21 subjects in total were considered with possible drop-outs. For the recruitment, all children with an ADHD diagnose being treated at the Center were put on a list. After applying inclusion and exclusion criteria, 53 families were randomly contacted by telephone and informed by phone or in person about the research project by the first author of the article. Informed written consent was obtained from all individual participants included in the study. Those parents, who accepted the participation of their children in the investigation, answered the informant questionnaires. Also, at baseline, all the participant children were assessed in selection and outcome measures by researchers from the investigation group and research assistants trained before in a laboratory at the University. Then, participants were stratified by age and sex, randomly assigned by a code to a wait-list condition (n=14) or to the intervention group (n=13), with a 1:1 allocation ratio by the first author. During the present study, children continued with their regular treatment in their mental health center. Attendance at the sessions in the same laboratory at the University was collected to assess treatment adherence, due to all children, except one, assisted at least four sessions. After the intervention, a post-test and a follow-up (1 month) evaluation of the outcome measures were carried out by the same assessment team that performed the pre-intervention assessments. Between post-test and follow-up, no intervention was implemented. The first author was the person who generated the random allocation sequence, who enrolled participants and who assigned participants to interventions, and also made assessments and conducted the intervention. The other researchers weren't blinded, and even participants knew the group assigned. The order of the neuropsychological tests on individual sessions was counterbalanced across participants to control assessment bias. Due to technical circumstances, the assessments and the interventions were performed into two waves see the timeline in Supplementary Material 2). Figure 1 shows the diagram flow of participants through each stage of the study.

Statistical Analysis

First of all, sociodemographic (age, gender, birth's country, and socioeconomic index) and clinical (diagnose subtype, type, and dose of pharmacology, fluid reasoning level or family history of ADHD) differences between the experimental groups were analyzed using Chi-square tests for categorical variables and independent t-test for continuous variables. Baseline differences in the outcome measures were also reported.

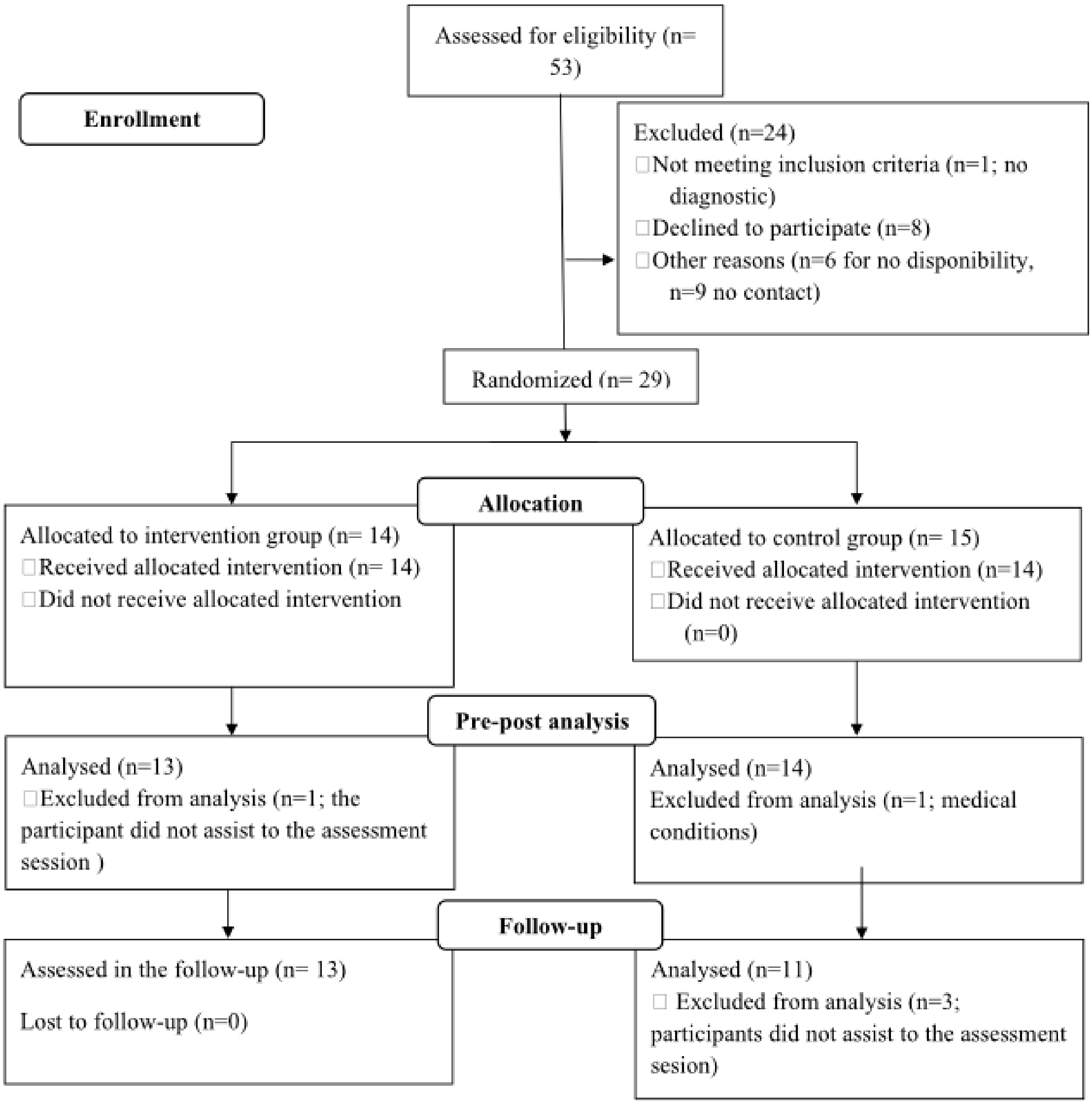


Figure 1. *Diagram flow.*

Effects sizes were calculated following Cohen(44) and Cárdenas(45). Regarding the SDQ and CPRS-48, a variable was created with the average of mother and father scores for each subscale. Then, differences between experimental and control conditions were tested with Analysis of Covariance (ANCOVA)s for repeated measures with the time of assessment as within factor (pre and post or pre and follow-up) and treatment condition as between factor (training or wait-list) to assess short and long-term effects. The effect of pharmacological-dose/day, attentional level, socio-economical level, and fluid reasoning was controlled in all the ANCOVAs. Multiples testing were corrected by Bonferroni correction. Following van der Oord et al.(46) methodology, missed items were replaced by the mean of the other items of the scale. If more than one item was missing, the subscale was not used in the analysis.

Results

Pre-test comparisons

No significant differences were found in any sociodemographic or clinical characteristics comparing the experimental and control groups (see Table 1).

Table 3 shows the mean, standard deviations and the comparison between the intervention and control groups in the outcome variables of the study (in addition to the reliability of the psychometric scales). We only found a trend towards significance for the Digits STM task, t (24) = -1.69, p= 0.10, and for Psychosomatic, t (21) = -2.03, p= 0.06, with medium effect sizes. The rest of the analyses were not significant.

Short-term effects of the intervention

EF. As can be seen in Table 4, we found one significant time effect at post-test assessment. Children of both conditions showed higher scores in linguistic WM, F (1,21) = 4.82, p = 0.04, at post-test than at pre-test, showing a large effect size (η_p^2= 0.19). This result was not significant after the Bonferroni correction. We also found one significant difference between both groups comparing pre- and post-test assessments.

Children in the EF Game-Training Condition showed significant increases at the linguistic STM scores, F (1,20) = 7.45, p =0.02, with larger effects (η_p^2= 0.27) than Wait-List Condition (see Figure 2a). Children in the EF Game-Training Condition improved their linguistic STM in 15.24%. This result remained significant after the Bonferroni correction.

Table 3.

Baseline Differences Between Children in the EF Game-Training (Experimental) and the Wait-List Condition (Control).

		EF Game-Training (n=13)		**Wait-List Condition (n=14)**			
		α	***M (SD)***	**α**	***M (SD)***	**t**	***d***
Performance tasks	CARAS	-	34.00 (7.54)	-	31.50 (12.45)	0.63	0.24
	TMT-A	-	65.00 (46.05)	-	48.64 (12.86)	1.28	0.48
	TMT-B	-	211.00 (108.39)	-	163.57 (98.51)	1.19	0.46
	Difference TMTB-TMTA	-	146.00 (87.90)	-	114.93 (93.09)	0.89	0.34
	Direct digits	-	6.15 (1.41)	-	7.31 (2.02)	-1.69	0.67
	Corsi-block tapping test	-	6.85 (1.46)	-	6.27 (1.83)	0.66	0.36
	Linguistic keep track task	-	17.69 (7.69)	-	21.64 (4.77)	-1.62	0.62
	Visuospatial keep track	-	21.38 (6.12)	-	20.71 (7.35)	0.26	0.11
	Go-nogo *hits*	-	237.00 (33.89)	-	229.08 (54.82)	0.44	0.17
	Go-nogo *omissions*	-	19.00 (33.89)	-	26.92 (54.82)	-0.44	0.17
	Go-nogo *commissions*	-	16.69 (13.85)	-	17.46 (13.62)	-0.14	0.06
	Go-nogo *correct foil*	-	47.31 (13.85)	-	46.54 (13.62)	0.14	0.06
	Go-nogo RT	-	515.38 (201.70)	-	482.39 (181.11)	0.44	0.17
Questionnaires	*CPRS-48 (M/SD)*						
	Conduct Problems	0.89	6.50 (5.11)	0.87	9.64 (5.04)	-1.51	0.62
	Learning difficulties	0.68	7.96 (2.25)	0.79	7.73 (2.46)	0.24	0.10
	Psychosomatic	0.80	1.62 (1.53)	0.58	3.14 (2.25)	-1.96	0.79
	Impulsive-Hyperactive	0.86	5.69 (2.41)	0.80	5.86 (3.13)	-0.15	0.06
	Anxiety	0.67	4.23 (2.29)	0.67	5.50 (1.90)	-1.46	0.60
	Hyperactivity Index	0.87	14.62 (5.90)	0.91	15.73 (6.13)	-0.45	0.18
	SDQ (M/SD)						
	Total	0.89	17.50 (7.24)	0.83	18.45 (6.56)	-0.33	0.14
	Emotional symptoms	0.81	4.04 (2.40)	0.83	4.36 (2.74)	-0.31	0.12
	Conduct problems	0.61	3.04 (2.05)	0.70	3.50 (1.78)	-0.59	0.24

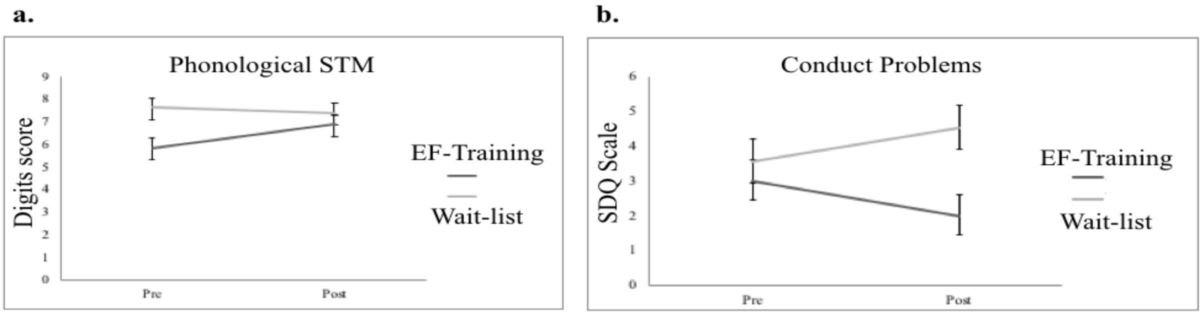
Note. SDQ=Strengths and Difficulties Questionnaire; CPRS=Conners Parent Rating Scale; TMT= Trail Making Test.

A Due to practical reasons, the SDQ and CPRS were only fully answered by a subset of parents at pretest and posttest (N=24/27).

B. Due to practical reasons, Digits and Go-Nogo task was only administered a subset of children at pretest (N=26/27).

All the analyses were non-significant. Effect sizes were interpreted according to Cohen (1992): d< 20= trivial effect size; 20<d<50= small effect size; 50<d<80= medium effect size; d>80= large effect size.

ADHD behaviors and general psychopathology. We found one significant effect at the Conduct Problems SDQ scale, *F* (1,18) = 12.51, *p* <0.001, with large effects (η_p^2 = 0.41) (See Table 4). Children in the EF Game-Training Condition showed lower conduct problems than children in the Wait-List Condition (see Figure 2b). Children in the EF Game-Training Condition reduced their conduct problems in 33.67%. This result remained significant after the Bonferroni correction.



Confounding variables values were: attention = 57.08; IQ = 43.173; SES = 28.88; dose/day = 34.0735

Confounding variables values were: attention = 53.96; IQ = 39.896; SES = 30.13; dose/day = 36.9129

Figure 2. a. *Average and 95% confidence intervals for the interaction within and between factor for Phonological Short-Term Memory assessed by Digits task.* **b.** *Average and 95% confidence intervals for the interaction within and between factor for Conduct Problems subscale assessed by SDQ questionnaire.*

Long-term effects of the intervention. When analyzing the effects of the intervention in the experimental group 1 month after the intervention (see Supplementary material 3 which shows all the long-term effects), only Linguistic Keep Track task showed a significant difference when carrying out an intra-group comparison, *F* (1,18) = 5.86, *p* =0.03, with a large effect size (η_p^2=0.25). Although the short-term interaction previously found at the Conduct Problems SDQ scale was not significantly replicated, $F_{SDQ's\ conduct\ problems}$ (1,13) = 2.25, *p* = 0.16), the effect size of the intervention could be considered as large (η_p^2=0.15).

Table 4.

Scores at Pretest, Postest for Children in the EF Game-Training (Experimental) and the Wait-List Condition (Control).

	Pretest		**Postest**					
	Experimental M (SD)	**Control** M (SD)	**Experimental** M (SD)	**Control** M (SD)	**Time**	η_p^2	**Time by group**	η_p^2
Executive functions								
TMT-A	63.88 (10.34)	49.70 (9.90)	65.18 (15.59)	40.69 (14.92)	F(1,21)= 1.72	0.08	F(1,21)= 1.01	0.05
TMT-B	215.42 (33.21)	159.47 (31.88)	213.72 (27.17)	140.34 (25.99)	F(1,21)= 0.01	0.00	F(1,21)= 0.19	0.01
Difference TMTB - TMTA	151.56 (29.76)	109.77 (28.47)	148.54 (19.48)	99.64 (18.64)	F(1,21)= 0.05	0.00	F(1,21)= 0.04	0.00
Direct digits	5.84 (0.44)	7.63 (0.44)	6.89 (0.53)	7.41 (0.53)	F(1,20)= 0.03	0.00	**F(1,20)= 7.45****	**0.27**
Corsi-block tapping test	6.88 (0.53)	6.40 (0.50)	6.48 (0.46)	7.12 (0.44)	F(1,21)= 0.12	0.01	F(1,21)= 2.28	0.10
Linguistic keep track task	17.61 (1.84)	21.72 (1.76)	19.65 (1.16)	23.75 (1.11)	**F(1,21)= 4.82***	0.19	F(1,21)= 0.00	0.00
Visuospatial keep track	22.10 (1.86)	20.052 (1.78)	21.93 (1.73)	22.57 (1.65)	F(1,21)= 2.31	0.10	F(1,21)= 1.02	0.05
Go-nogo *hits*	244.15 (13.01)	230.32 (12.41)	229.19 (11.06)	236.37(10.55)	F(1,19)= 0.04	0.00	F(1,19)= 0.73	0.04
Go-nogo *commissions*	15.69 (4.70)	17.52 (4.48)	15.19 (4.41)	24.67 (4.20)	F(1,19)=1.85	0.09	F(1,19)= 1.36	0.07
Go-nogo *omissions*	10.42 (11.96)	26.99 (11.46)	25.28 (10.19)	21.05 (9.76)	F(1,20)= 0.04	0.00	F(1,20)= 0.93	0.05
Go-nogo *correct foil*	48.31 (4.70)	46.48 (4.48)	48.81 (4.41)	39.32 (4.20)	F(1,19)= 1.85	0.09	F(1,19)= 1.36	0.07
Go-nogo *TR*	466.92 (50.34)	491.95 (48.03)	544.92 (54.92)	536.66 (52.47)	F(1,19)= 1.26	0.06	F(1,19)= 0.17	0.01
CPRS-48 (M/SD)								
Conduct Problems	6.61 (1.45)	9.51 (1.61)	6.42 (1.07)	7.50 (1.19)	F(1, 18)= 0.05	0.00	F(1, 18)= 0.69	0.04
Learning difficulties	7.97 (0.732)	7.72 (0.82)	6.57 (0.70)	7.51 (0.77)	F(1, 18)= 0.50	0.03	F(1, 18)= 1.95	0.10
Psychosomatic	1.63 (0.45)	3.12 (0.50)	1.62 (0.45)	2.55 (0.52)	F(1, 18)= 0.01	0.00	F(1, 18)= 0.33	0.02
Impulsive-Hyperactive	5.98 (0.92)	5.52 (1.02)	5.26 (0.78)	4.83 (0.87)	F(1, 18)= 0.39	0.02	F(1, 18)= 0.00	0.00
Anxiety	4.78 (0.60)	4.85 (0.66)	4.54 (0.65)	4.82 (0.72)	F(1, 18)= 0.02	0.00	F(1, 18)= 0.05	0.00
Hyperactivity Index	15.13 (1.70)	15.12 (1.86)	12.63 (1.59)	14.16(1.77)	F(1, 18)= 0.00	0.00	F(1, 18)= 0.41	0.02
SDQ (M/SD)								
Total	17.60 (2.18)	18.29 (2.42)	15.58 (1.53)	17.87 (1.70)	F(1, 18)=0.11	0.01	F(1, 18)=0.39	0.02
Emotional symptoms	4.04 (0.73)	4.40 (0.83)	3.50 (0.61)	3.65 (0.69)	F(1, 18)=0.01	0.00	F(1, 18)=1.26	0.09
Conduct problems	3.00 (0.59)	3.54 (0.66)	1.99 (0.55)	4.51 (0.61)	F(1, 18)=0.98	0.05	**F(1, 18)=12.51*****	0.41

Note. SDQ=Strengths and Difficulties Questionnaire; CPRS=Conners Parent Rating Scale; TMT= Trail Making Test.

A Due to technical reasons, SDQ and CPRS-48 (N=24/27) was only administered a subset of parents at pretest and postest

B. Due to technical reasons, Digits and Go-Nogo task was only administered a subset of children at pretest (N=26/27).

C. Due to technical reasons, Go-Nogo task was only administered a subset of children at postest (N=25/27).

p<0.05=*; p<0.01=**; p<0.001=***; η_p^2<.06= small effect size; 0.06<η_p^2<0.14= medium effect size; η_p^2 >0.14= large effect size (Cohen, 1988)

Discussion

Previous research showed that computerized training could be efficacious in ADHD to improve WM(14) and EF's (46). However, except for chess(25), no other board game has been studied in depth as a training tool for individuals with ADHD.

In general, we found few significant results. One possible explanation is about the limitations of the study (i.e., the number of subjects). Another argument is that it is difficult to find far transfer effects in cognitive training procedures(47). Furthermore, the board games used in the present research were focused in WM & STM processes and, in a weaker way, in the other EF's. It is possible that if we want to improve different cognitive processes, we must train them specifically. However, we found some significant results which are explained below.

Near-transfer effects

Results of the study showed that solely STM significantly improved after the intervention. It was estimated that those children who played board games could retain more linguistic information (up to 15.24% more information) than the control group. This fact is consistent with those studies which show that improvement can only be observed in the input capability (17,18). It is also in line with the studies which claim that, in many cases, this specific improvement is more noticeable in the linguistic STM(14).

Regarding linguistic WM, statistically significant improvements in time were found irrespective of whether the participants played the board games or not. This fact can be explained by the maturation effect produced in children of this age since it occurred in both groups (experimental and control). Previous literature has pointed at the relationship that may exist between this kind of WM and age or speed(48,49). This effect was replicated in the follow-up.

Far-transfer effects

The main short-term far-transfer effect found in this study is an important improvement regarding conduct problems. Since board games required the monitoring of standards and rules, as well as appropriate social interaction with other participants, an additive effect among the rules of the board games may have appeared. Taking into account the social impairment that many children with ADHD present(6) and that conduct problems and hyperactivity symptoms are highly associated(50), the reduction of conduct problems has clinical relevance. Specifically, before the intervention, both groups – experimental and control- were on a normal range on Conduct Problems. Following raw scores from the SDQ(51), children from the experimental group continued on the normal range, though with lower levels of conduct problems than before the intervention. On the contrary, the control group changed from normal range to subclinical range after the intervention. Hence, it seems that the board games intervention could prevent behavior deterioration. Moreover, group dynamics were taken into account in each one of the experimental sessions, which could have also helped in the control and maintenance of adequate behavior. Hence, future research is needed to clarify whether the improvement in conduct problems was due to playing to table-top games or to improving the STM capacity. The other results found, which were non-significant, were in line with past studies(17,18).

Assessments at the follow-up to explore the stability of the effects of the training (long-term far-transfer effect) did not show significant results. However, we did find a large effect size in conduct problems. Although the effect was not statistically significant, the large effect size found implies that the improvement in conduct problems could remain stable for one month after the cognitive intervention.

Limitations and future studies

The very first pitfall of the present study was the sample size. More participants are recommended in future studies. One explanation for this sample size was the strict inclusion and exclusion criteria, which included comorbidity.

The number of training sessions that participants took in the present investigation should also be considered. Klingberg(20) suggests that to ensure the efficacy of memory training, there should be 8 hours of session for each subject. Future investigations should take into account the training with more sessions and with board games which train another EFs. Also, future interventions should take into account a follow-up of a more extended period. Besides, another improvement to future studies is to assess the clinical outcomes with multiple reporters (i.e., teachers).

Concerning the design of the study, another limitation is that the trial wasn't blinded. As others authors consider(52), it is important to use this kind of methodology in future studies to guarantee the generalization and validity of the study. Also, it is essential to ensure an adequate control group, performing an in-group activity. In fact, probably, the best control group for the present intervention should be playing board games which would not train any EF. Another consideration is the percentage of children who did not accept to participate in the study (26.42 %), being interesting to assess ecological validity by playing at home or in school. Also, it would be interesting to perform an attrition analysis(53) to test if there would have differences between children who did accept to participate in the study and those who did not accept. As we could not assess any data from the non-participating children, we could not perform any attrition analysis in the present research.

Finally, future investigations should also measure other variables related to cognitive training (for example, previous experience with board games or motivation). Besides, the industry of board games have been adapted some of them to a video game environment. Future studies are intended to compare the efficacy of analog board games versus board video games. Finally, other diagnoses in childhood characterized by EF's impairments, such as autism spectrum disorder (ASD)(54), could profit from this intervention, suggesting future studies on this line.

Conclusions

To summarize, our study shows evidence regarding the improvement of linguistic STM trained with board games in children with ADHD. Additionally, children had the chance of interacting with other participants which in turn, improved their conduct problems. No other executive functions or behavioral outcomes were modified. Hence, although the benefits of this game based intervention are limited, it could be advisable to use it to help pharmacological interventions to improve the STM capacity and to reduce conduct problems in ADHD children.

Acknowledgments

Thanks to the Comissionat per a Universitats i Recerca del DIUE, Generalitat de Catalunya (2014SGR1636; 2017SGR1577) and to the Centro de investigación Biomédica en Red en Salud Mental (CIBERSAM). Thanks also to the Department of Pedagogy and Psychology of the University of Lleida which funded the purchase of the games and to the children and their families. We also need to express our gratitude to the experts of Lu2 Enterprises (Xavier Moratonas) for advising us in the selection of games and to the assistant researchers (Marina Adserias & Jordi Callizo). The present study was defended as a Thesis of the Master's Degree in Health General Psychology at the University of Lleida.

Author Disclosure Statement

No competing financial interest exists.

References

1. Polanczyk G. The Worldwide Prevalence of ADHD: A Systematic Review and Metaregression Analysis. American Journal of Psychiatry. 2007; 164:942.
2. Barkley RA. Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. Psychological Bulletin. 1997; 121:65–94.
3. Willcutt EG, Doyle AE, Nigg JT, Faraone S V., Pennington BF. Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. Biological Psychiatry. 2005; 57:1336–46.
4. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. Cognitive Psychology. 2000; 41:49–100.
5. Semrud-Clikeman M. The Role of Inattention on Academics, Fluid Reasoning, and Visual–Spatial Functioning in Two Subtypes of ADHD. Applied Neuropsychology: Child. 2012; 1:18–29.
6. Pardos A, Fernández-Jaén A, Fernández-Mayoralas DM. Social skills in attention deficit hyperactivity disorder Habilidades sociales en el trastorno por déficit de atención / hiperactividad. Revista de neurología. 2009; 48:1–5.
7. Hoza B. Peer Functioning in Children With ADHD. Journal of Pediatric Psychology. 2007; 32:655–63.
8. Stenseng F, Belsky J, Skalicka V, Wichstrøm L. Peer Rejection and Attention Deficit Hyperactivity Disorder Symptoms: Reciprocal Relations Through Ages 4, 6, and 8. Child Development. 2016; 87:365–73.
9. Dovis S, Van Der Oord S, Wiers RW, Prins PJM. What part of working memory is not working in ADHD? short-term memory, the central executive and effects of reinforcement. Journal of Abnormal Child Psychology. 2013; 41:901–17.
10. Bidwell LC, McClernon FJ, Kollins SH. Cognitive enhancers for the treatment of ADHD. Pharmacology Biochemistry and Behavior. 2011; 99:262–74.
11. Molina BSG, Hinshaw SP, Swanson JM, Eugene L, Ed M, Vitiello B, et al. The MTA at 8 years: Prospective Follow-Up of Children Treated for Combined Type ADHD in a Multisite Study. J Am Acad Child Adolesc Psychiatry. 2011; 48:484–500.
12. Tarver J, Daley D, Sayal K. Attention-deficit hyperactivity disorder (ADHD): An updated review of the essential facts. Child: Care, Health and Development. 2014; 40:762–74.
13. Holmes J, Gathercole SE, Dunning DL. Adaptive training leads to sustained enhancement of poor working memory in children. Developmental Science. 2009; 12:9–15.
14. Rapport MD, Orban SA, Kofler MJ, Friedman LM. Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. Clinical Psychology Review. 2013; 33:1237–52.
15. Karbach J, Kray J. How useful is executive control training? Age differences in

near and far transfer of task-switching training. Developmental Science. 2009; 12:978–90.
16. Spencer-Smith M, Klingberg T. Benefits of a Working Memory Training Program for Inattention in Daily Life: A Systematic Review and Meta-Analysis. Rypma B, editor. PLOS ONE. 2015; 10:1–18.
17. Chacko A, Bedard AC, Marks DJ, Feirsen N, Uderman JZ, Chimiklis A, et al. A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: a replication in a diverse sample using a control condition. Journal of Child Psychology and Psychiatry. 2014; 55:247–55.
18. Dentz A, Parent V, Gauthier B, Guay M-C, Romo L. L'entraînement de la mémoire de travail par le programme Cogmed et le TDAH. Psychologie Française. 2016; 61:139–51.
19. Houghton S, Milner N, West J, Douglas G, Lawrence V, Whiting K, et al. Motor control and sequencing of boys with Attention-Deficit/Hyperactivity Disorder (ADHD) during computer game play. British Journal of Educational Technology. 2004; 35:21–34.
20. Klingberg T. Training and plasticity of working memory. Trends in Cognitive Sciences. 2010; 14:317–24.
21. del Campo N, Chamberlain SR, Sahakian BJ, Robbins TW. The Roles of Dopamine and Noradrenaline in the Pathophysiology and Treatment of Attention-Deficit/Hyperactivity Disorder. Biological Psychiatry. 2011; 69:145–57.
22. Bateman C, Nacke LE. The neurobiology of play. In: Proceedings of the International Academic Conference on the Future of Game Design and Technology - Futureplay '10 [Internet]. New York, New York, USA: ACM Press; 2010.
23. Prins PJM, Dovis S, Ponsioen A, ten Brink E, van der Oord S. Does Computerized Working Memory Training with Game Elements Enhance Motivation and Training Efficacy in Children with ADHD? Cyberpsychology, Behavior, and Social Networking. 2011; 14:115–22.
24. Dovis S, Van Der Oord S, Wiers RW, Prins PJM. Improving executive functioning in children with ADHD: Training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial. PLoS ONE. 2015; 10:1–30.
25. Mohammad Nour ElDaou B, El-Shamieh SI. The Effect of Playing Chess on the Concentration of ADHD Students in the 2nd Cycle. Procedia - Social and Behavioral Sciences. 2015; 192:638–43.
26. Statista. Global board games market value in 2016 and a forecast for 2021 (in billion U.S. dollars). [Internet]. 2018. Available from: https://www.statista.com/statistics/829285/global-board-games-market-value/
27. Benzing V, Schmidt M, Jäger K, Egger F, Conzelmann A, Roebers CM. A classroom intervention to improve executive functions in late primary school children: Too 'old' for improvements? British Journal of Educational Psychology. 2018;1–14.
28. Gauthier A, Kato PM, Bul KCM, Dunwell I, Walker-Clarke A, Lameras P. Board Games for Health: A Systematic Literature Review and Meta-Analysis. Games for Health Journal. 2018; 8:1–16.
29. Gobet F, de Voogt A, Retschitzki J. *Moves in mind*. Hove: Psychology Press; 2004.
30. Devir. Aplicación de juegos en el aula. [Internet]. 2018. Available from: http://devir.es/juegos-en-el-aula/
31. Geurts H, Verte S, Oosterlaan J, Roeyers H, Sergeant J. ADHD subtypes: do they differ in their executive functioning profile? Archives of Clinical

Neuropsychology. 2005; 20:457–77.

32. Grupo de trabajo de la Guía de Práctica Clínica sobre el Trastorno por Déficit de Atención con Hiperactividad (TDAH) en Niños y Adolescentes. Guía de Práctica Clínica sobre las Intervenciones Terapéuticas en el Trastorno por Déficit de Atención con Hiperactividad (TDAH) [Clinical Guidline about the Therapeutic Interventions in the Attention Deficit and Hyperactivity Disorder (ADHD)] *Guía de Práctica Clínica sobre las Intervenciones Terapéuticas en el Trastorno por Déficit de Atención con Hiperactividad (TDAH) [Clinical Guidline about the Therapeutic Interventions in the Attention Deficit and Hyperactivity Disorder (ADHD)]*. Madrid: Ministerio de Sanidad, Servicios Sociales e Igualdad; 2017.
33. Hunt AD, Kronenberger WG, Dunn DW, Gibson BS, Gondoli DM. Predictors of change in short-term memory span following working memory training. Acta Neuropsychologica. 2014; 12:445–58.
34. Hollingshead AB. Four factor index of social status. *Four factor index of social status*. New Heaven: University, Yale; 1975.
35. Raven JC, Court JH, Raven J. Manual Matrices Progresivas de Raven. 3rd Ed. *Manual Matrices Progresivas de Raven*. Madrid: TEA Ediciones; 2001.
36. Thurstone LL., Yela M. CARAS Percepción de Diferencias. Manual. 10th Ed. *CARAS Percepción de Diferencias. Manual*. Madrid: TEA Ediciones; 2009.
37. Knizia R. Alles tomate! *Alles tomate!* Germany: Zoch Zum Spielen; 2007.
38. Knizia R. Alles kanone! *Alles kanone!* Germany: Zoch Zuch Spielen; 2007.
39. Schannen M. Spooky Stairs *Spooky Stairs*. Barcelona: Iberia, Devir; 2004.
40. Nedergaard-Andersen M. Out of Mine! *Out of Mine!* Germany: Huch! & Friends; 2014.
41. Zoch K. Chicken Cha Cha Cha *Chicken Cha Cha Cha*. Barcelona: Iberia, Devir; 1998.
42. Baranowski T. Descriptions for Articles Introducing a New Game for Health. Games for Health Journal. 2014; 3:55–6.
43. Klingberg T, Forssberg H, Westerberg H. Training of Working Memory in Children With ADHD. Journal of Clinical and Experimental Neuropsychology (Neuropsychology, Development and Cognition: Section A). 2002; 24:781–91.
44. Cohen J. A power primer. Psychological bulletin. 1992; 112:155–9.
45. Cárdenas Castro M, Arancibia Martini H, Serrano F, Sánchez P. Potencia Estadística Y Cálculo Del Tamaño Del Efecto En G * Power : Complementos a Las Pruebas De Significación Estadística Y Su Aplicación En Psicología. Salud & Sociedad. 2014; 5:210–24.
46. van der Oord S, Ponsioen AJGB, Geurts HM, Brink EL Ten, Prins PJM. A Pilot Study of the Efficacy of a Computerized Executive Functioning Remediation Training With Game Elements for Children With ADHD in an Outpatient Setting. Journal of Attention Disorders. 2014; 18:699–712.
47. Sala G, Gobet F. Does Far Transfer Exist? Negative Evidence From Chess, Music, and Working Memory Training. Current Directions in Psychological Science. 2017; 26:515–20.
48. Best JR, Miller PH. A Developmental Perspective on Executive Function. Child Development. 2010; 81:1641–60.
49. Tamnes CK, Østby Y, Walhovd KB, Westlye LT, Due-Tønnessen P, Fjell AM. Neuroanatomical correlates of executive functions in children and adolescents: A magnetic resonance imaging (MRI) study of cortical thickness. Neuropsychologia. 2010; 48:2496–508.
50. Fanti KA. Individual, social, and behavioral factors associated with co-occurring

conduct problems and callous-unemotional traits. Journal of Abnormal Child Psychology. 2013; 41:811–24.
51. Rodríguez-Hernández PJ, Betancort M, Ramírez-Santana GM, García R, Sanz-Alvarez EJ, De las Cuevas-Castresana C. Puntos de corte de la versión española del Cuestionario de Cualidades y Dificultades (SDQ). Revista de Psiquiatría Infanto-Juvenil. 2014;23–9.
52. Cortese S, Ferrin M, Brandeis D, Buitelaar J, Daley D, Dittmann RW, et al. Cognitive Training for Attention-Deficit/Hyperactivity Disorder: Meta-Analysis of Clinical and Neuropsychological Outcomes From Randomized Controlled Trials. Journal of the American Academy of Child & Adolescent Psychiatry. 2015; 54:164–74.
53. Dumville JC. Reporting attrition in randomised controlled trials. Bmj. 2006; 332:969–71.
54. Demetriou EA, Lampit A, Quintana DS, Naismith SL, Song YJC, Pye JE, et al. Autism spectrum disorders: A meta-analysis of executive function. Molecular Psychiatry. 2018; 23:1198–204.
55. Logie RH. Visuo-spatial Working Memory. Hove, UK: Lawrence Erlbaum; 1995.
56. Andersson U, Lyxell B. Working memory deficit in children with mathematical difficulties: a general or specific deficit? J Exp Child Psychol 2007; 96:197–228.
57. Wechsler D. Escala de Inteligencia de Wechsler para Niños-IV (WISC-IV). Escala de Inteligencia de Wechsler para Niños-IV (WISC-IV). Madrid: TEA Ediciones; 2003.
58. Bezdjian S, Baker LA, Lozano DI, Raine A. Assessing inattention and impulsivity in children during the Go/NoGo task. Br J Dev Psychol 2009; 27:365–83.
59. Conners CK. Conners' Rating Scales Conners' Rating Scales. Multi-Health Systems, editor. Toronto, Ontario; 1989.
60. Goodman R. Psychometric Properties of the Strengths and Difficulties Questionnaire. J Am Acad of Child & Adolesc Psychiatry 2001; 40:1337–45.

Address correspondence to:

Jorge Moya-Higueras, PhD

Department of Psychology, Faculty of Education, Psychology and Social Work,

University of Lleida, Avda. de l'Estudi General, 4, 25221, Lleida, Spain

E-mail: jmoya@pip.udl.cat

***Supplementary material 1*. Description of characteristics and instructions of board games**

Table 1.

Characteristics of a board game for health: Alles Kanone! (code BoardGameGeek (BGG): 149516)

General characteristics	
Health topic (s):	Phonological STM and WM, attention.
Short description of game idea:	It is supposed to specifically work the linguistic updating process of the WM when players have to keep in mind what is currently lying at the seven different objects of the cards, but this items are changing constantly.
Targeted age group:	6+
Target player (s) (check one):	Individual Dyad **Small group (2 to 8)** MMOG Other.
Other targeted group characteristics:	None.
Sensors used:	None.
Estimated play time:	15-20 minutes.
Type of game:	Active Action Adventure Role-playing Simulation Strategy Sports Casual Educational **Other: modern board games (cognitive skill training).**
Game platform(s) needed to play the game (check all that apply):	Smartphone Tablet Kinect Xbox Wii PlayStation Computer Handheld device **Other: table (Board games).**
Health outcome	
Guiding knowledge or behaviour change theory(ies), models or conceptual framework(s):	There are different cognitive-focused interventions that directly or indirectly target cognitive functioning[1]. One type of these interventions is cognitive training, which "*entails repeated exercise of a specific cognitive process over a period of time to improve performance on the trained task as well as on tasks that were not specifically trained (transfer effect)*"[2]. Some authors have considered that gaming could increase the improvement from computerised cognitive training in cognitive processes [3,4,5]. For all of the above mentioned, board games could be considered a tool included in cognitive training interventions with memory and other cognitive processes as the health's outcome.
Intended health behaviour changes:	To increase phonological STM and WM capacities and attention skills.
Knowledge element(s) to be learned:	None.
Behavior change procedure(s) (taken from Michie inventory) or therapeutic procedure(s) employed:	There is a game without chance. For this reason, in order to win the game, players have to put into operation cognitive processes.

Clinical or parental support needed? (please specify):	Clinicians help children to know the rules of the games and they ensured that game worked correctly.
Data shared with parent or clinician?:	Yes No **Others:** only clinicians, children play with clinicians in this randomised controlled trial, so clinicians have access to data, but no parents.
Story (if any)	
Synopsis (including story arc):	*"Johnny Jokey is a successful pirate. On his forays, he has amassed so many treasures that he sometimes gets quite confused. Is the parrot actually sitting on his shoulder or is it just depicted on his arm as a tattoo? Is the crown still hidden on the island or has he already looted it? Should he better go to the tavern now before driving himself crazy-or doesn't any of it matter anyway?! Helps him clear the decks!"*
How the story relates to targeted behaviour change:	There isn't a relation between targeted behaviour and the story, but children could be identified with the pirate due to they could have memory difficulties.
Game components	
Player's game goal/objective(s):	To achieve the bigger number of cards.
Rules:	1. Each player may always shout out only one term. 2. If several players simultaneously shout out the correct term and the other players cannot agree who was first, one of the fastest players receives the corresponding object card from the middle and the other players involved each receive one card from the card pile. One of the quickest players reveals the next object card. 3. If no player says the correct term, the respective object card is put back into the card pile. The card drawn from the pile is placed at the location now vacant.
Game mechanic(s);	This game uses two types of cards: the "themed or topic cards" and the "pirate's object cards". The themed cards are 7 cards which show the image of a pirate with a different background and color each. Each themed card is associated with different pirate's concepts. The other 49 cards of the deck are object cards, which show specific objects related semantically to each themed card. Visually, object and themed cards of the same semantic category are related because they have the same background color. Hence, there are 7 object cards per each themed card. The game initiates distributing the themed cards over a table. Next, one object card is positioned face-up down the themed card with the same background color. The rest object cards are positioned at the deck, face-

	down. All the players tell aloud which object is depicting each object card. Hence, all object cards are face-down. At this point, the game begins. One person takes the first object card from the deck and reveals the card's object. The first player to recall which element was on the face-down object card positioned down the themed card with the same color background wins the card. End of the game arrives as soon as all cards in the card pile have been used up.
Procedure to generalize or transfer what's learned in the game to outside the game:	Considering the kind of board games in order to improve cognitive skills, if phonological STM and WM and attention skills could be ameliorated, this could beneficiate all the daily activities which require them. Also playing board games implies abiding rules and playing in a social environment. For this reason, there could be an improvement in conduct problems involved in social relationships with peers and adults.
Setting or environment	Relaxed room, with adequate furniture elements (chairs, table) and favourable environmental conditions (adequate light, temperature, without noise).
Avatar	
Characteristics:	None.
Abilities:	None.

Note. Chosen option is in bold.

Table 2.

Characteristics of a board game for health: Alles Tomate! (code BGG: 32405)

General characteristics	
Health topic (s):	Phonological STM and WM, attention.
Short description of game idea:	It is supposed to specifically work the linguistic updating process of the WM when players have to update linguistic information from the objects of the cards.
Targeted age group:	6+
Target player (s) (check one):	Individual Dyad **Small group (2 to 8)** MMOG Other.
Other targeted group characteristics:	None.
Sensors used:	None.
Estimated play time:	15-20 minutes.
Type of game:	Active Action Adventure Role-playing Simulation Strategy Sports Casual Educational **Other: modern board games (cognitive skill training)**
Game platform(s) needed to play the game (check all that apply):	Smartphone Tablet Kinect Xbox Wii PlayStation Computer Handheld device **Other: table (Board games).**
Health outcome	
Guiding knowledge or behaviour change theory(ies), models or conceptual framework(s):	There are different cognitive-focused interventions that directly or indirectly target cognitive functioning[1]. One type of these interventions is cognitive training, which "*entails repeated exercise of a specific cognitive process over a period of time to improve performance on the trained task as well as on tasks that were not specifically trained (transfer effect)*"[2]. Some authors have considered that gaming could increase the improvement from computerised cognitive training in cognitive processes [3,4,5]. For all of the above mentioned, board games could be considered a tool included in cognitive training interventions with memory and other cognitive processes as the health's outcome.
Intended health behaviour changes:	To increase phonological STM and WM capacities and attention skills.
Knowledge element(s) to be learned:	None.
Behavior change procedure(s) (taken from Michie inventory) or therapeutic procedure(s) employed:	There is a game without chance. For this reason, in order to win the game, players have to put into operation cognitive processes.
Clinical or parental support needed? (please specify):	Clinicians help children to know the rules of the games and they ensured that game worked correctly.

Data shared with parent or clinician?:	Yes No **Others:** only clinicians, children play with clinicians in this randomised controlled trial, so clinicians have access to data, but no parents.
Story (if any)	
Synopsis (including story arc):	*Max and Emma, a farmer couple, have a huge barnyard. Therefore, they sometimes lose track of everything. Do the cherries belong in the henhouse, can the horse sleep in the bed, does the pitchfork stick in the butter or doesn't any of it matter anyway? Can you show Max and Emma where everything belongs?*
How the story relates to targeted behaviour change:	There isn't a relation between targeted behaviour and the story, but children could be identified with Max and Emma due to they could have memory difficulties.
Game components	
Player's game goal/objective(s):	To achieve the bigger number of cards
Rules:	1. Each player may always shout out only one term. 2. If several players simultaneously shout out the correct term and the other players cannot agree who was first, one of the fastest players receives the corresponding object card from the middle and the other players involved each receive one card from the card pile. One of the quickest players reveals the next object card. 3. If no player says the correct term, the respective object card is put back into the card pile. The card drawn from the pile is placed at the location now vacant.
Game mechanic(s);	This game uses two types of cards: the "themed cards" and the "object cards". The themed cards are 7 cards which show the image of a cow with a different background and color each. Each themed card is associated with different farming concepts (i.e., farming animals, farming tools). The other 49 cards of the deck are object cards, which show specific objects related semantically to each themed card. Visually, object and themed cards of the same semantic category are related because they have the same background color. Hence, there are 7 object cards per each themed card. The game initiates distributing the themed cards over a table. Next, one object card is positioned face-up down the themed card with the same background color. The rest object cards are positioned at the deck, face-down. All the players tell aloud which object is depicting each object card. Hence, all object cards are face-down. At this point, the game begins. One person takes the first object card from the deck and reveals the card's object. The first player to recall which element was on the face-

	down object card positioned down the themed card with the same color background wins the card. End of the game arrivea as soon as all cards in the card pile have been used up.
Procedure to generalize or transfer what's learned in the game to outside the game:	Considering the kind of board games in order to improve cognitive skills, if phonological STM and WM and attention skills could be ameliorated, this could beneficiate all the daily activities which require them. Also playing board games imply abiding rules and playing in a social environment. For this reason, there could be an improvement in conduct problems involved in social relationships with peers and adults.
Setting or environment	Relaxed room, with adequate furniture elements (chairs, table) and favourable environmental conditions (adequate light, temperature, without noise).
Avatar	
Characteristics:	None.
Abilities:	None.

Note. Chosen option is in bold.

Table 3.

Characteristics of a board game for health: Out of mine! (code BGG: 153509)

General characteristics	
Health topic (s):	It is also a memory game, focused on visuospatial rotation, which is related to visuospatial information short term memory (STM)[6].
Short description of game idea:	It is supposed to specifically work the visuospatial STM of the WM when players have to update linguistic information from the objects of the cards.
Targeted age group:	10+
Target player (s) (check one):	Individual Dyad **Small group (2 to 4)** MMOG Other.
Other targeted group characteristics:	None.
Sensors used:	None.
Estimated play time:	20 minutes.
Type of game:	Active Action Adventure Role-playing Simulation Strategy Sports Casual Educational **Other: modern board games (cognitive skill training)**
Game platform(s) needed to play the game (check all that apply):	Smartphone Tablet Kinect Xbox Wii PlayStation Computer Handheld device **Other: table (Board games)**
Health outcome	
Guiding knowledge or behaviour change theory(ies), models or conceptual framework(s):	There are different cognitive-focused interventions that directly or indirectly target cognitive functioning[1]. One type of these interventions is cognitive training, which "*entails repeated exercise of a specific cognitive process over a period of time to improve performance on the trained task as well as on tasks that were not specifically trained (transfer effect)*"[2]. Some authors have considered that gaming could increase the improvement from computerised cognitive training in cognitive processes [3,4,5]. For all of the above mentioned, board games could be considered a tool included in cognitive training interventions with memory and other cognitive processes as the health's outcome.
Intended health behaviour changes:	To increase visual rotation, which is related to STM capacities.
Knowledge element(s) to be learned:	None.
Behavior change procedure(s) (taken from Michie inventory) or therapeutic procedure(s) employed:	It is a game without chance. For this reason, in order to win the game, players have to put into operation cognitive processes.

Clinical or parental support needed? (please specify):	Clinicians help children to know the rules of the games and they ensured that game worked correctly.
Data shared with parent or clinician?:	Yes No **Others:** only clinicians, children play with clinicians in this randomised controlled trial, so clinicians have access to data, but no parents.
Story (if any)	
Synopsis (including story arc):	*"The mountain is calling! Equipped with pick axes and the secret knowledge of the mine elves, the dwarf's rush below ground in order to dig u precious crystals. Everybody gets his own mine gallery in which he tries to dig out the crystals that are said to lie there, according to the elves. If a dwarf manages to find the predicted crystals in all the sections of his gallery, he shouts aloud "Out of mine!". This is the signal for all dwarfs to drop their pick axes and return to daylight. Now a scoring takes place. But only at the end of the week, after the seventh round of digging, will it turn out which dwarf was the most successful one"*
How the story relates to targeted behaviour change:	None.
Game components	
Player's game goal/objective(s):	Players have to find the best combination of different crystals to complete his/her tunnel, in order to get better scores. The player who gathered the most points after one work week (7 game rounds) wins the game.
Rules:	1. If one player shouts aloud "Out of mine!", the rest of the players have to stop playing. 2. When points are counting up, a crystal is incorrectly placed if it protrudes over the edge of the gallery or has a color that is not listed on the treasure card, or if the number of the crystal you used dos not match the number on the treasure card. 3. Each player receives 10 plus points and for each empty space on his galley board, have to deduct one point. 4. The player who shout aloud Out of Mine!, additionally earns 2 points, if he has covered his gallery bard correctly. However, if he has not done everything right, he gets 2 minus points. 5. If a player has more than 10 empty gallery spaces, he gets zero points. 6. Players cannot repeat a gallery board. In this case, the player has to turn it to the other side.
Game mechanic(s);	Every player has a double-sided gallery or tunnel board randomly, which have to be completed with different precious crystals. Every player can decide on which side he wants to play. In order to

	complete the mind, every player also has a treasure card with some rules to do it. If one player finds the crystals to complete his/her tunnel, he/she has to say out loud “Out of Mine!”. Each crystal has a geometric form. After noting down points, new treasure card and gallery are randomly assigned to every player, unless the winner of the round before, who only changes his/her treasure card.
Procedure to generalize or transfer what’s learned in the game to outside the game:	Considering the kind of board games in order to improve cognitive skills, if visuospatial rotation related with STM could be ameliorated, this could beneficiate all the daily activities which require them. Also playing board games imply abiding rules and playing in a social environment. For this reason, there could be an improvement in conduct problems involved in social relationships with peers and adults.
Setting or environment	Relaxed room, with adequate furniture elements (chairs, table) and favourable environmental conditions (adequate light, temperature, without noise).
Avatar	
Characteristics:	Every player is a dwarf who works on a gallery.
Abilities:	None.

Note. Chosen option is in bold.

Table 4.
Characteristics of a board game for health: Spooky stairs (code BGG: 12346)

General characteristics	
Health topic (s):	Visuospatial information updating of WM, visuospatial STM, attention
Short description of game idea:	It is supposed to specifically work the linguistic updating process of the WM when players have to update linguistic information from the objects of the cards.
Targeted age group:	4+
Target player (s) (check one):	Individual Dyad **Small group (2 to 4)** MMOG Other.
Other targeted group characteristics:	None.
Sensors used:	None.
Estimated play time:	10-15 minutes.
Type of game:	Active Action Adventure Role-playing Simulation Strategy Sports Casual Educational **Other: modern board games (cognitive skill training).**
Game platform(s) needed to play the game (check all that apply):	Smartphone Tablet Kinect Xbox Wii PlayStation Computer Handheld device **Other: table (Board games).**
Health outcome	
Guiding knowledge or behaviour change theory(ies), models or conceptual framework(s):	There are different cognitive-focused interventions that directly or indirectly target cognitive functioning[1]. One type of these interventions is cognitive training, which "*entails repeated exercise of a specific cognitive process over a period of time to improve performance on the trained task as well as on tasks that were not specifically trained (transfer effect)*"[2]. Some authors have considered that gaming could increase the improvement from computerised cognitive training in cognitive processes [3,4,5]. For all of the above mentioned, board games could be considered a tool included in cognitive training interventions with memory and other cognitive processes as the health's outcome.
Intended health behaviour changes:	To increase visuospatial STM and updating-WM capacities and attention skills.
Knowledge element(s) to be learned:	None.
Behavior change procedure(s) (taken from Michie inventory) or therapeutic procedure(s) employed:	There is a game without chance. For this reason, in order to win the game, players have to put into operation cognitive processes.
Clinical or parental support needed? (please specify):	Clinicians help children to know the rules of the games and they ensured that game worked correctly.

Data shared with parent or clinician?:	Yes No **Others:** only clinicians, children play with clinicians in this randomised controlled trial, so clinicians have access to data, but no parents.
Story (if any)	
Synopsis (including story arc):	*"In an old castle ruin there is a spooky stair –Spirit Stairs-, where a ghost lives at the top of the stairs. Being completely quiet, a few brave children dart up the stairs- everyone wants to be first to scare the ghost with a "BOOOO! But the ghost knows this age-old game and tries to transform the players into ghosts - one after the other one! Which children will be the most courageous and will scare the old ghost?"*
How the story relates to targeted behaviour change:	None.
Game components	
Player's game goal/objective(s):	The objective is to arrive your pawn at first place to the top of the stairs. At that moment, the pawn that was inside the ghost piece is revealed. The player's pawn that arrives first, wins.
Rules:	1. The younger player starts the game. 2. If a dice shows a number, the player has to climb the number of stairs indicated by the dice. 3. There can be two or more pawns on a step. 4. If a dice shows a ghost, the player has to roll a "ghost"-his or to roll another player- and he/she should place a ghost piece over a player's pawn, which is connected by a magnetic field. 5. If all players become in ghosts and the dice shows a ghost, the player who throws the dice must change the position of two ghost pieces. 6. Players are not allowed to see the color of the pawn when is covered by the ghost piece.
Game mechanic(s);	This game consists of a race in an old castle ruin, where there is a ghost. Every player has to climb the stairs as fast as possible, as the number depicted in the dice indicates, moving a color pawn. If the dice shows a ghost (there is a ghost representation in two out of the 6 faces of the dice), the player has to roll a "ghost", and he/she should place a ghost piece over his or another player's pawn, which is connected by a magnetic field. The ghost piece positioned on player's pawn makes it impossible to see the pawn's color. Hence, at this point, players have to remember under which ghost their own and the other figures were, and many mistakes could be produced.

Procedure to generalize or transfer what's learned in the game to outside the game:	Considering the kind of board games in order to improve cognitive skills, if visuospatial updating from WM and STM capacities and attention skills could be ameliorated, this could beneficiate all the daily activities which require them. Also playing board games imply abiding rules and playing in a social environment. For this reason, there could be an improvement in conduct problems involved in social relationships with peers and adults.
Setting or environment	Relaxed room, with adequate furniture elements (chairs, table) and favourable environmental conditions (adequate light, temperature, without noise).
Avatar	
Characteristics:	Players are the children who want to scare the old ghost of the story's game. Children can become on ghosts, represented by a piece colored in white with face elements (two eyes and a mouth) which is positioned over the colored pawn.
Abilities:	None.

Note. Chosen option is in bold.

Table 5.

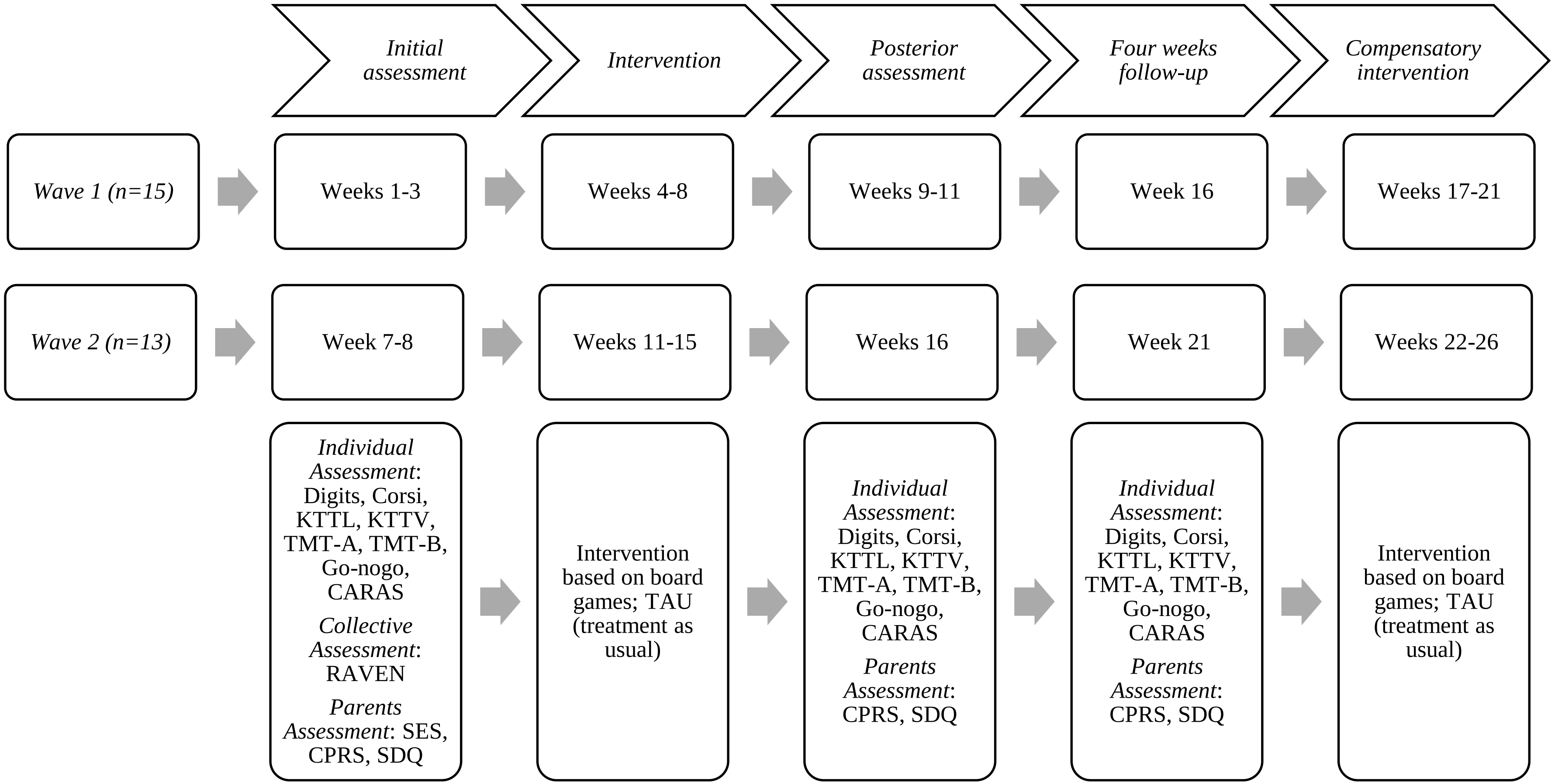
Characteristics of a board game for health: Chicken Cha Cha Cha (code BGG: 3570)

General characteristics	
Health topic (s):	Visuospatial STM, attention.
Short description of game idea:	It is supposed to specifically work the visuospatial updating process of the WM when players have to update linguistic information from the objects of the cards.
Targeted age group:	4+
Target player (s) (check one):	Individual Dyad **Small group (2 to 4)** MMOG Other.
Other targeted group characteristics:	None.
Sensors used:	None.
Estimated play time:	15-20 minutes.
Type of game:	Active Action Adventure Role-playing Simulation Strategy Sports Casual Educational **Other: modern board games (cognitive skill training).**
Game platform(s) needed to play the game (check all that apply):	Smartphone Tablet Kinect Xbox Wii PlayStation Computer Handheld device **Other: table (Board games).**
Health outcome	
Guiding knowledge or behaviour change theory(ies), models or conceptual framework(s):	There are different cognitive-focused interventions that directly or indirectly target cognitive functioning[1]. One type of these interventions is cognitive training, which "*entails repeated exercise of a specific cognitive process over a period of time to improve performance on the trained task as well as on tasks that were not specifically trained (transfer effect)*"[2]. Some authors have considered that gaming could increase the improvement from computerised cognitive training in cognitive processes [3,4,5]. For all of the above mentioned, board games could be considered a tool included in cognitive training interventions with memory and other cognitive processes as the health's outcome.
Intended health behaviour changes:	To increase visuospatial STM capacities and attention skills.
Knowledge element(s) to be learned:	None.
Behavior change procedure(s) (taken from Michie inventory) or therapeutic procedure(s) employed:	There is a game without chance. For this reason, in order to win the game, players have to put into operation cognitive processes.
Clinical or parental support needed? (please specify):	Clinicians help children to know the rules of the games and they ensured that game worked correctly.

Data shared with parent or clinician?:	Yes No **Others:** only clinicians, children play with clinicians in this randomised controlled trial, so clinicians have access to data, but no parents.
Story (if any)	
Synopsis (including story arc):	"*The hen house is scrambled! We are assisting to the Hen's Olympic Games. Today is the race where hens could be plucked. Each hen will try to overtake the others. When a hen overtakes the one in front of her, it will take the tail of the hen which has been passed. However, the hens are allowed to advance if they know the hen house very well. They must remember all the floor tiles accurately. The first hen which overtakes all the other hens will be the winner"*
How the story relates to targeted behaviour change:	There isn't a relation between targeted behavior and the story, but children could be identified with the hen due to they could have memory difficulties.
Game components	
Player's game goal/objective(s):	The game ends when one player has the four feathers. This one is the winner.
Rules:	1. At the beginning of the game, every player has a hen in one tile. 2. The younger player starts the game. 3. Hens can move on –in clockwise- if the player finds the same image of the next egg-shaped tile on the octagons positioned on the center of the table. 4. If one hen is just before other, in order to snatch the tile, the hen has to jump it. This can be done by finding the same octagon of the egg-shaped tile just before the other hen.
Game mechanic(s);	Twelve octagons are positioned face-down at the center of the table. Round the octagons, different egg-shaped tiles are positioned, where one hen figure by each participant is placed at an equidistant space among them. Each octagon has the same image of two of the egg-shaped tiles. There are five spaces at the back of each hen figure, where a feather could be placed. Each hen begins with one feather. To progress, each player, in his/her turn, has to successfully memorize the image on each of the twelve octagon tiles that the game has. Each player moves the number of times equivalent to the number of correct pairs he/she remembers. The circuit is a circle. Then, the hens are always moving, being like an endless race. When a hen overtakes another one, the first hen takes the nail of the second.

Procedure to generalize or transfer what's learned in the game to outside the game:	Considering the kind of board games in order to improve cognitive skills, if visuospatial STM capacities and attention skills could be ameliorated, this could beneficiate all the daily activities which require them. Also playing board games imply abiding rules and playing in a social environment. For this reason, there could be an improvement in conduct problems involved in social relationships with peers and adults.
Setting or environment	Relaxed room, with adequate furniture elements (chairs, table) and favourable environmental conditions (adequate light, temperature, without noise).
Avatar	
Characteristics:	Four hens, all of them colored differently (green, blue, yellow and beige) but have in common black eyes and red nose and tuft.
Abilities:	The hens can walk and jump over other hens, overtaking them. When a hen overtakes another one, the first hen takes the nail of the second.

Note. Chosen option is in bold.



Supplementary Material 2. Time-line.

Supplementary material 3.

Scores at Pretest, Follow-up for Children in the EF Game-Training (Experimental) and the Wait-List Condition (Control)

	Pretest		**Follow-up**					
	Experimental *M (SD)*	**Control** *M (SD)*	**Experimental** *M (SD)*	**Control** *M (SD)*	**Time**	η_p^2	**Time x group**	η_p^2
TMT-A	63.82 (10.51)	50.76 (11.56)	51.36 (7.93)	38.94 (8.72)	F(1,18)= 4.01 [t]	0.18	F(1,18)= 0.00	0.00
TMT-B	213.68 (32.98)	166.65 (36.28)	170.36 (16.30)	122.39 (17.93)	F(1,18)= 0.15	0.01	F1,18)= 0.00	0.00
Difference TMTB - TMTA	149.86 (29.58)	115.89 (35.54)	119.00 (13.24)	83.45 (14.57)	F(1,18)= 0.00	0.00	F(1,18)= 0.00	0.00
Direct digits	6.00 (0.44)	7.70 (0.51)	7.13 (0.62)	8.23 (0.72)	F(1,17)= 1,25	0.07	F(1,17)= 0.64	0.04
Corsi-block tapping test	6.74 (0.47)	6.04 (0.52)	6.67 (0.55)	6.66 (0.61)	F(1,18)= 2.33	0.11	F(1,18)= 1.03	0.05
Linguistic keep track task	17.75 (1.68)	21.29 (1.85)	20.61 (1.10)	21.65 (1.21)	**F(1,18)= 5.86***	**0.25**	F(1,18)= 0.83	0.04
Visuospatial keep track	21.94 (1.62)	19.08 (1.78)	24.10 (1.43)	22.24 (1.57)	F(1,18)= 2.81	0.14	F(1,18)= 0.20	0.01
Go-nogo *hits*	239.22 (8.13)	239.21 (9.41)	229.84 (13.51)	227.50 (15.64)	F(1,17)= 0.07	0.00	F(1,17)= 0.01	0.00
Go-nogo *commissions*	17.08 (4.39)	18.29 (5.08)	20.44 (4.23)	26.22 (4.90)	F(1,17)= 3.29 [t]	0.16	F(1,17)= 0.91	0.05
Go-nogo *omissions*	17.56 (7.71)	15.77 (8.86)	24.53 (12.87)	30.72 (14.78)	F(1,18)= 0.00	0.00	F(1,18)= 0.13	0.01
Go-nogo *correct foil*	46.92 (4.39)	45.71 (5.08)	43.58 (4.23)	37.78 (4.90)	F(1,17)= 3.29 [t]	0.16	F(1,17)= 0.92	0.05
Go-nogo *TR*	500.75 (54.57)	488.94 (63.18)	564.64 (47.38)	627.75 (54.85)	F(1,17)= 0.25	0.02	F(1,17)= 0.88	0.05
CPRS-48 (M/SD)								
Conduct Problems	6.87 (1.72)	10.19 (2.09)	6.80 (1.23)	8.65 (1.50)	F(1,13)= 2.37	0.15	F(1,13)= 0.94	0.07
Learning difficulties	7.78 (0.82)	8.25 (1.00)	7.31 (0.69)	7.52 (0.83)	F(1,13)= 0.48	0.04	F(1,13)= 0.06	0.00
Psychosomatic	1.75 (0.51)	3.72 (0.62)	1.44 (0.57)	3.01 (0.69)	F(1,13)= 0.04	0.00	F(1,13)= 0.14	0.01
Impulsive-Hyperactive	6.50 (0.98)	5.12 (1.19)	6.50 (0.98)	4.44 (1.20)	F(1,13)= 0.00	0.00	F(1,13)= 0.38	0.03
Anxiety	4.99 (0.67)	5.08 (0.82)	3.89 (0.57)	4.72 (0.67)	F(1,13)= 0.62	0.05	F(1,13)= 0.32	0.02
Hyperactivity Index	16.16 (1.94)	14.64 (2.36)	14.22 (1.65)	13.25(2.00)	F(1,13)= 0.02	0.00	F(1,13)= 0.06	0.00
SDQ (M/SD)								
Total	17.67 (2.47)	18.46 (3.01)	15.52 (1.62)	16.91 (1.97)	F(1,13)=0.02	0.00	F(1,13)=0.06	0.01
Emotional symptoms	4.52 (0.92)	4.16 (1.12)	3.27 (0.51)	3.45 (0.62)	F(1,13)=0.03	0.00	F(1,13)=0.24	0.02
Conduct problems	3.14 (0.71)	3.69 (0.87)	2.38 (0.65)	3.98 (0.80)	F(1,13)=0.06	0.01	F(1,13)=2.25	0.15

Note. SDQ=Strengths and Difficulties Questionnaire; CPRS=Conners Parent Rating Scale; TMT= Trail Making Test.

A Due to practical reasons, CPRS-48 (N=19/27) and SDQ (N= 19/27) was only administered a subset of parents at pretest and follow-up

B. Due to practical reasons, Digits task (N=23/27), TMT, Corsi-blocks tapping task, Lingüistic and Visuospatial keep track task (N=24/27) test was only administered a subset of children at pretest and follow-up.

C. Due to practical reasons, Go-Nogo task was only administered a subset of children at pretest and follow-up (N=23/27).

p<0.10= [t] ,p<0.05=*; p<0.01=**; η_p^2<.06= small effect size; 0.06<η_p^2<0.14= medium effect size; η_p^2 >0.14= large effect size

3.2.4. Cognitive training with modern board and card games in healthy older adults: two randomized controlled trials

Estrada-Plana V*, Montanera R*, Ibarz-Estruga A*, March-Llanes J, Vita-Barrull N, Guzmán N, Ros-Morente A, Ayesa R, Moya Higueras J *Shared first co-autohorship

International Journal of Geriatric Psychiatry 2020 36(6): 839-850

DOI: 10.1002/gps.5484

Abstract

Objectives. The aim of this study was to assess the effectiveness of a cognitive intervention based on modern board and card games. **Methods.** We conducted two two-arm parallel-group, randomized controlled trials. The first one (pilot study) was non-blind. The second one (main study) was a double-blind design. Participants (14 in a pilot study and 35 in the main study) were healthy older adults over 65 years old who were assisting to adult care institutions. In the pilot study, participants in the experimental group (n=6) played modern board and card games which activated cognitive processes; whereas the control group (n=6) was in the wait-list condition. In the main study, participants in the experimental group (n=12) also played modern board and card games; whereas the control group (n=15) performed standardized paper-and-pencil cognitive tasks. Psychologists specialized in older-people conducted all the interventions. In both studies, intervention sessions were bi-weekly for 5 weeks. The outcomes of both studies were cognitive status and executive functioning, depressive symptomatology, and quality of life measures. All assessment and intervention sessions took place in their habitual centers. **Results**. In the pilot study, participants in the games intervention showed a significant improvement in semantic verbal fluency. In the main study, both interventions showed significant improvements in phonemic verbal fluency. Whilst board and card games maintained motor impulsivity control, paper-and-pencil tasks improved speed in an inhibition task. **Conclusions.** Modern board and card games could be an effective cognitive intervention to maintain some cognitive functions.

Keywords: Modern board and card games, verbal fluency, impulsivity, cognitive training, randomized controlled trial

Key-points:

- Modern board and card game and paper-and-pencil trainings improved verbal fluency, but only game training group maintained this benefit three months later.
- Modern board and card game training maintained levels of motor impulsivity control, while paper-and-pencil training decreased.
- The modern board and card games may be useful as a cognitive training in healthy older institutionalized adults.

Introduction

Numerous countries are experiencing the challenge of an inversion of the pyramidal ages distribution [1]. Some cognitive processes, such as complex attentional processes, verbal fluency, processing speed and some executive functions (EFs) (for example, working memory (WM), inhibition or flexibility) decline with healthy aging [2]. Cognitive-based interventions [3], such as cognitive training (CT), attempt to improve trained (near transfer) and untrained processes (far transfer) [3,4]. These interventions are considered protective factors for cognitive decline in healthy older people [5], for the risk of developing mild cognitive impairment (MCI) [6], or for delaying onset of memory decline in people with dementia [7]. A common[8] and empirically effective[9] CT used with institutionalized older people is based on paper-and-pencil tasks. However, as Lampit, Hallock & Valenzuela[10] suggests, studies testing the efficacy of new cognitive-based interventions in aging are fundamental.

Computerized CTs [3,10,11] and video-games[12] have shown to be effective to improve some cognitive processes in cognitively-healthy-older adults, but they do not promote social interactions. Some authors [4,13] have noticed that engaging socialization could be beneficial for improving cognitive functions in older adults. Most of board and card games are played with other people face by face and engage social interactions[14,15]. So, they are gaining attention in relation to aging [16,17], and could be a good element to include in CT. In this line, traditional board games played during some sessions, like chess or Go, could improve or maintain cognition in older adults [17], both at the neural [18] and behavioural[13,19] levels.

Modern board and card games are produced for commercial reasons[20]. Authors emphasize game's design getting a great aesthetical sense, showing originality and challenging the players. In most cases, this is achieved by relying on cognitive activation of very specific cognitive domains to win [20]. Compared to traditional games, some modern ones are easier to learn and master, allow more than two players, and show innovative mechanics not used in traditional games[20]. For these reasons, among others, it seems that modern board and card games should be better than traditional games in cognitive interventions.

In children, modern board and card games have proved the efficacy to improve different cognitive processes [21,22]. However, research in older people with this kind of board and card games is scarce. Regardless this scarcity, a few studies have found improvements in some cognitive processes[4,23]. However, considering methodological issues, these studies were non-randomized controlled trials [23], without measuring all the main cognitive outcomes in aging [24] or only some of them[4, 25]. Besides, only a few studies (e.g. Overman & Robbins[23]) has considered non-cognitive outcomes, such as depressive symptoms [26] or quality of life [27].

Thus, this research aims to test the effectiveness of a CT based on modern board and card games in institutionalized, healthy older people over 65 years old as a tool to prevent cognitive decline. Secondly, we also tested the effects of the intervention in depressive symptomatology and quality of life. To achieve this objective, we performed two randomized controlled trials (RCTs): a pilot study with a small sample and an extended study with a different sample (main study). Both studies followed CONSORT guidelines [28]. We hypothesized that both groups would maintain or improve cognitive processes, but these benefits would be higher in the people who played board and card games.

Pilot study

Methods

Study design and Participants

We conducted a non-blind, two-arm parallel-group, RCT in accordance to the declaration of Helsinki. Inclusion criteria were: a) assisting on a public geriatric center (long-stay institution or adult day-care center); b) having at least 65 years old, and c) having at least a grade I of dependence. Exclusion criteria were: a) having a cognitive state lower or equal than 23 on the Mini-Mental State Examination (MMSE)[29]; b) having dementia or any major neurocognitive disorder; c) having major motor or perceptive deficiencies, and d) having medical conditions that could affect assessment or intervention. Participants were informed about the research and ethical considerations of the study in their centers. There, they signed the informant consent. 14 subjects were enrolled. 2 people were not allocated due to dropping out from the long-stay institution (See Supplementary Figure 1) before the randomization process. Hence, both geriatric centers were randomized and 12 people were included in the final analysis. After the centers were randomized, 6 participants were allocated into a Game Training Group (GTG; $mean_{age}$= 79.17±7.73; $\%_{women}$=100) and 6 into a Wait-list Control Group (WCG; $mean_{age}$= 81.33±6.80; $\%_{women}$=83.3), with a 1:1 allocation ratio. Each pre and post-intervention assessments lasted one hour and a half. All this procedure was performed by the third author, a professional with experience assessing and intervening older people.

Outcome Measures

Baseline characteristics. We obtained baseline characteristics from the participants, such as sex and age.

Cognitive primary outcome measures. Processing speed was assessed with the Trail-Making Test (TMT-A) [30] and Coding from Wechsler Adult Intelligence Scale-4th Edition (WAIS-IV) [31]. Phonemic verbal fluency was assessed with the FAS version of the Controlled Oral Word Association (COWA) test [32]. Semantic verbal fluency was assessed with animals, kitchen tools and countries categories for one minute [32,33]. In both verbal fluency tasks, participants were asked to avoid producing names of places or people and repetitions of words.

Non-cognitive secondary outcome measures. Depressive symptomatology was assessed with Geriatric Depression Scale-15 (GDS-15) [34]. Quality of life was assessed with the CECAVIR test [35].

Intervention

According to previous studies,[12,36] the intervention lasted 5 weeks, with sessions bi-weekly. The duration of every session was 90 minutes. The games used were: Look! What's different? [37], Alles Tomate! [38], Kaleidos Junior [39], Time's up! Kids[40], Halli Galli Junior[41] and Dobble[42] (See Supplementary Table 1 for a detailed description of the games used). The first two specially required from visual STM and WM. The next two stimulate verbal fluency. The two lasts boosted inhibition and processing speed, respectively. Each game was played 30 minutes every week. Players always played with the same people (groups of three).

Statistical analysis

All the analyses were performed using SPSS, version 24. Baseline characteristics and baseline levels in the outcomes of the study were calculated. We conducted an analysis of normality using Shapiro-Wilk test. Due to the criteria of normality was not met; we used non-parametric tests for statistical analyses. All tests were two-tailed and the significance level was set at 5%. In addition, we calculated effect sizes[43]. Additionally, missing imputation was applied in quality of life test, replacing missing data (maximum 1) by average scale value.

Results

Compliance with the program and baseline comparisons

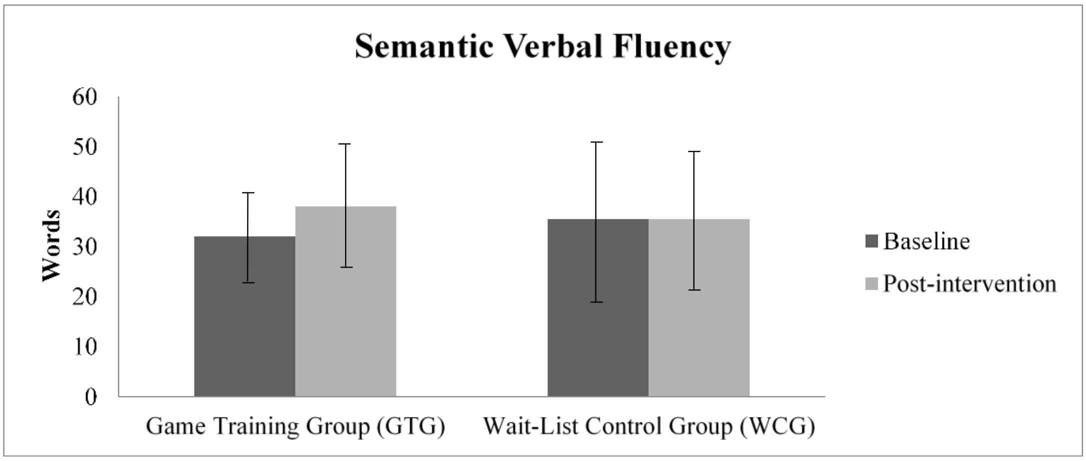
All the participants in the GTG received their assigned intervention. The rate attendance in the GTG was 90%. Therefore, the participants of both groups were included in the final analysis. No significant baseline differences were found between both groups (See Supplementary Table 3).

Intervention effects

We found a significant increase for the semantic verbal fluency in the GTG after the intervention with a large effect size (Z=-2.00, p=.046, d=2.83; +15.79%), but not in the WCG (Z=-0.11, p=.916, d=.09) (see Figure 1). Moreover, we conducted an exploratory analysis without those participants who did not have literacy. When we analyzed changes across phases in this sub-analysis, we found a nearly significant increase after the intervention in processing speed and semantic verbal fluency in the GTG with large effect sizes ($Z_{Processing\ speed\ (Coding)}$=-1.84, p=.066, d=2.28; $Z_{Semantic\ \mathrm{Verbal\ Fluency}}$=-1.83, p=.068, d=2.25), but not in the WCG ($Z_{Processing\ speed\ (Coding)}$=-0.54, p=.586, d=.54; $Z_{Semantic\ \mathrm{Verbal\ Fluency}}$=-0.11, p=.916, d=.09). Regarding non-cognitive outcomes, we found a tendency towards significance reduction in environmental quality of life in the WCG after the intervention (Z=-1.83; p=.068, d=2.25), but not in the GTG (Z=-1.36, p=.173, d=1.34). This result was the same when we removed those people who did not have literacy (Z_{GTG}=-0.37, p=.715, d=.31; Z_{WCG}=-1.83, p=.068, d=.2.25). We did not find other significant results (see Supplementary Table 4).

***F*igure 1**

Significant Improvement in Semantic Verbal Fluency in the Game Training Group But Not in the Wait-List Control Group. The dependant variable is the sum of the words said in 3 categories (Animals, Tools in the Kitchen and Countries).



Main Study

Methods

Sample size

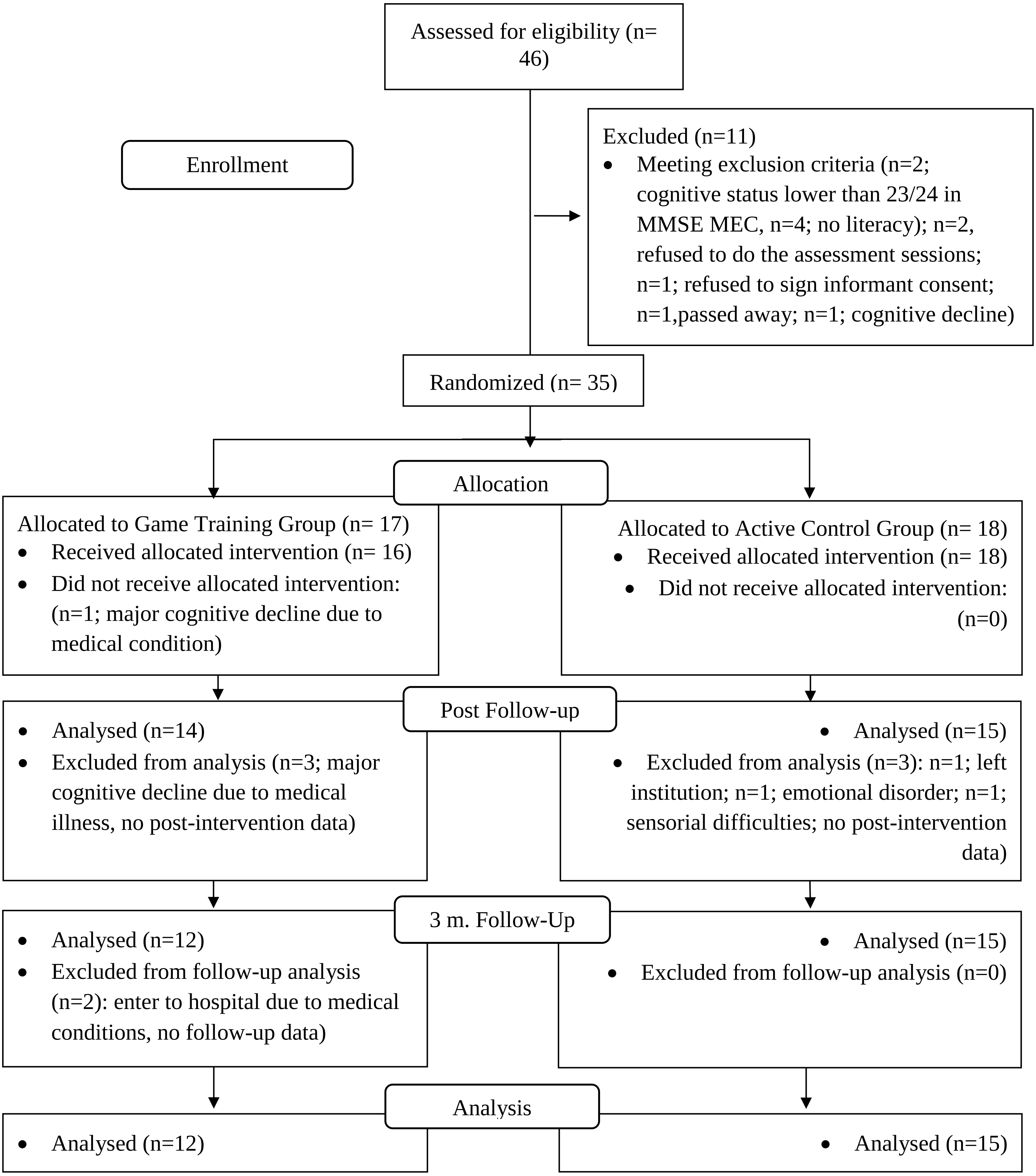
The sample size was calculated [44] considering the results of semantic verbal fluency from the pilot study. The analysis was performed on a two-sided hypothesis test, 95% power and an alpha level of 5%. The sample size obtained showed that 30 participants (15 in each group) would be needed, considering a 15% drop-out rate (n=35).

Study design and Participants

We conducted a double-blind, two-arm parallel-group, RCT. This study was accepted and registered in the local Ethical Committee (Arnau de Vilanova University Hospital) (CEIC-2000) and conducted in accordance to the declaration of Helsinki. The study started in February 2019 and finished in December 2019. Professional psychologists from the centers made a list with the people who fulfilled all the inclusion and exclusion criteria. Inclusion and exclusion criteria were the same as in the pilot study, except the inclusion of illiteracy as exclusion criteria. Then, 46 participants were informed about the research and ethical considerations of the study in a group session by the first and second authors of the study. 45 older adults signed their informant consents during this session. Then, they carried out pre-assessments (2 hours). As it can be seen in diagram flow (Figure 2), some participants were excluded during pre-test sessions due to exclusion criteria. After the first assessment, 35 older adults were randomly allocated into the Game Training Group who played board and card games (GTG; n=17; $mean_{age}$= 80.76±9.80; $\%_{women}$=70.6) and into the Active Control Group who did paper-and-pencil cognitive tasks (ACG; n=18; $mean_{age}$= 80.89±9.54; $\%_{women}$=83.3). The sample was simple randomized with an allocation ratio 1:1 using random excel formula by the last author, following previous studies[13]. Both intervention groups had the same number of people from each center (See Table 2).

Figure 2

Participants flow chart from the Main Study.



To reach allocation concealment, nobody -except the last author- knew the result of the allocation sequence until the first day of intervention. Participants were blinded because all of them knew that were going to receive a cognitive intervention, but in different moments. We conducted interventions' sessions one after another during the morning. After that, the second author implemented the intervention in the centers with another psychologist who worked in the institution and knew the participants. The intervention took place two times/60 minutes per week for 5 weeks (10 sessions). First and fifth authors, who were blinded to the participants groups, carried out post-assessments after the last session of intervention (90 minutes). Also, first and fifth authors performed a follow-up three months after the last session of post-assessment (see timeline in Supplementary Figure 2). The order of the assessment tasks was counterbalanced across participants in all the assessments. Finally, the active-control group played the modern board and card games and the experimental group performed paper-and-pencil tasks.

Outcome measures

Cognitive measures. Visuospatial short-term memory (STM) and WM were assessed with the Corsi block span forward and backward task from the Wechsler Memory Scale (WMS-III)[45], whereas verbal STM and WM were assessed with the digits span task from WAIS-IV[31]. We used Five-Digits Test (FDT)[46] to assess Inhibition and Flexibility. We also assessed verbal fluency[32,33] and control of impulsivity[47]. Differing from the pilot study, we only used one measure of processing speed[31] because of the protocol's length.

Non-Cognitive measures. Depressive symptoms were assessed with the Geriatric Depression Scale (GDS-15)[34]. In the main study, we assessed quality of life with the WHOQOL –Brief [48] because of the length of the protocol.

Subjective assessment of the intervention. An ad-hoc four-item questionnaire based on a previous study[49] with questions related to enjoyment, difficulty, future repetition and frequency. This questionnaire was the last answered to guarantee blinding of the assessors.

Baseline sociodemographics and covariates. Age in years, sex, level of education[50], cognition status (assessed with the MMSE[29]), visual acuity (hits in the test CARAS[47]), vocabulary[31], previous leisure activities related to cognition, and playing games were assessed at baseline.

Intervention

Game Training Group (GTG). The duration[12] and multi-domain option[51] of the intervention was scheduled following previous studies. According to an analysis performed by the authors of the study, the board and card games used tapped different EFs (see Table 1; for further explanation of the games used, see Supplementary Tables 1 and 2).

Active-Control Group (ACG). Participants from this group did paper-and-pencil standard tasks[52]. Following previous recommendations[8], we choose tasks that tap the same EFs and other cognitive processes than the board and card games (See Supplementary Table 5).

Table 1

Description of every session in the main study.

NUMBER OF SESSION	BOARD AND CARD GAMES	BOOSTED COGNITIVE PROCESSES
SESSION 1	Cocorico Cocorocó!	Visuospatial STM
	Pippo	Visuospatial STM, reasoning and processing speed
SESSION 2	Halli Galli Junior†	Inhibition and processing speed
	Ghost blitz	Visuospatial STM, reasoning and processing speed
SESSION 3	Halli Galli	Inhibition and processing speed
	Pippo	Visuospatial STM, reasoning and processing speed
SESSION 4	Pick-a-pig	Visuospatial STM, reasoning and processing speed
	Batti Burri	Visuospatial STM and processing speed
SESSION 5	Kaleidos junior	Verbal fluency and processing speed
	Fast words	Verbal fluency and processing speed
SESSION 6	Cocorico Cocorocó!	Visuospatial STM
	Spooky stairs	Visuospatial WM
SESSION 7	Halli Galli junior	Inhibition and processing speed
	Dobble	Processing speed and verbal fluency
SESSION 8	Halli Galli	Inhibition and processing speed
	Jungle speed safari	Flexibility and inhibition
SESSION 9	Pick-a-pig	Visuospatial STM, reasoning and processing speed
	Batti Burri	Visuospatial STM and processing speed
SESSION 10	Kaleidos Junior	Verbal fluency and processing speed
	Fast words	Verbal fluency and processing speed

†. In the center from wave 1, people in the Game Training Group (GTG) played Sooky stairs instead of Halli Galli Junior in session 2.

Statistical analysis

All the analyses were performed using SPSS, version 24. We conducted comparable statistical analyses like in the pilot study. Due to the criteria of normality was not met; we used non-parametric tests for statistical analyses. Thus, we conducted Friedman's F test- to analyze changes across phases. In addition, we performed Wilcoxon signed rank tests to test post hoc comparisons. All tests were two-tailed and the significance level was set at 5%. In addition, we calculated effect sizes[43]. Additionally, we applied missing imputation in quality of life test, replacing missing data (maximum 1) by average scale value.

Results

Compliance with the program and attrition analysis

Six people were dropped out from the pre-post analyses and three from the follow-up analyses (See Figure 2 for reasons). The rest were included. People excluded had significant lower levels of previous experience with crosswords (U (1, 33) =50.00, p =.022, d=0.84). No other differences between included and excluded participants were found. All the participants received their assigned intervention. The rate attendance in the GTG was 78.3% and in the ACG was 85.3%.

Descriptive and baseline comparisons

We did not find significant baseline differences between both groups in sociodemographic characteristics, previous experience in-game and other related activities (See Table 2) and in baseline cognitive and non-cognitive outcomes (See Supplementary Table 6).

Table 2

Differences in Basic, Demographic and Previous Experience Characteristics between the Game Training and the Active Control groups in the main study.

	Game Training Group (n=12)	**Active Control Group (n=15)**	***U/t/*** χ^2	***d***
Age *M*±*SD*	81.83±8.86	82.93±8.95	*t*=0.32	0.12
Sex			χ^2= 0.62	0.31
Male, *n (%)*	4 (33.3 %)	3 (20.0 %)		
Female, *n (%)*	8 (66.7 %)	12 (80.0 %)		
Level of education			χ^2=5.01	0.96
Primary Education/GCSE unfinished, *n (%)*	8 (66.7 %)	6 (40.0 %)		
Primary Education/GCSE finished, *n (%)*	3 (25.0 %)	6 (40.0 %)		
GCE / VET unfinished, *n (%)*	0 (0.0 %)	1 (6.7 %)		
GCE / VET Formative finished, *n (%)*	0 (0.0 %)	2 (13.3 %)		
University Degree unfinished, *n (%)*	1 (8.3 %)	0 (0.0 %)		
Cognitive Mental State (MMSE), *M*±*SD*	30.58 ±3.18	30.20±2.62	-0.34	0.13
Vocabulary scalar score, *M*±*SD*	12.25±3.44	11.2±2.08	*t*=-0.98	0.37
Visual acuity (CARAS test), *M*±*SD*	14.08±7.23	13.60±6.31	-0.19	0.07

Center type, *n (%)*				
Adult day-care center	3 (25.0%)	4 (26.7%)	χ^2= 0.01	0.04
Long-stay center	9 (75.0%)	11 (73.3%)		
Center location, *n (%)*			χ^2= 0.01	0.04
Center wave 1	5 (41.7 %)	6 (40.0 %)		
Center wave 2	7 (58.3 %)	9 (60.0 %)		
Previous experience with different kinds of board and card games *M*±*SD*				
Card games	3.50±2.07	3.60±1.99	*t*=0.13	0.05
Board games	3.17±2.48	3.07±2.05	*t*=-0.12	0.04
Puzzles	1.25±1.55	1.87±2.10	*U*=80.50	0.18
Word games	1.50±2.20	1.93±1.71	*U*=70.50	0.37
Crosswords	2.17±2.48	2.07±1.91	*U*=86.50	0.07
Knowledge games	1.58±2.02	2.27±1.83	*U*=68.00	0.42

Note. GCSE= General Certificate of Secondary Education; GCE= General Certificate of Education; VET= Vocational Education & Training; MMSE= Mini-Mental State Examination. $d< 0.20$= trivial effect size; $0.20<d<0.50$= small effect size; $0.50<d<0.80$= medium effect size; $d>0.80$= large effect size.

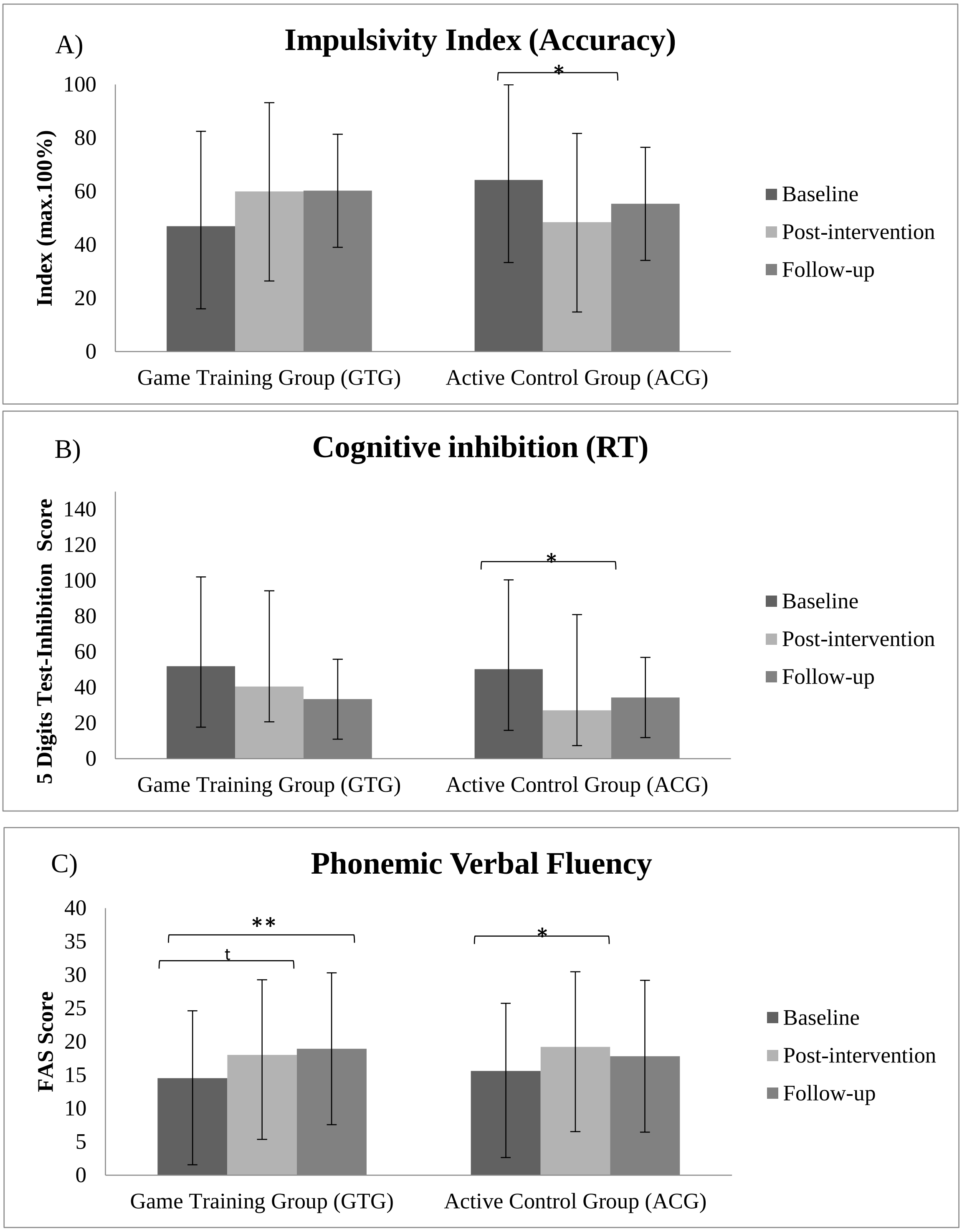
Intervention effects

The scores for each cognitive test and the details of the non-parametric results are shown in Supplementary Table 7.

Cognitive outcomes. In the ACG, we found a tendency towards significance in inhibition across phases ($\chi^2(2,15)=-5.41$, $p=.067$, $d=1.50$). Pre-post comparisons showed significant effects in this outcome between before and after intervention with a large effect size ($Z=-2.23$, $p=.026$, $d=1.41$), but not in the follow-up ($Z=-1.34$, $p=.182$, $d=0.62$). Participants in the ACG improved 45.96% their cognitive inhibition after the intervention. In addition, we found significant effects in impulsivity control index ($\chi^2(2,15)=-2.26$, $p=.024$, $d=0.84$) across phases. Pre-post comparisons showed a significant decrease of impulsivity control after intervention in the ACG with a large effect size ($Z=-2.26$, $p=.024$, $d=1.44$), but not in the GTG ($Z=-0.86$, $p=.388$, $d=0.46$). Participants in the ACG reduced 24.65% their control of impulsivity. Moreover, we found significant time effects in phonemic verbal fluency in the GTG across phases ($\chi^2(2,15)=-8.14$, $p=.017$, $d=2.90$). Pre-post comparisons showed a tendency towards significance in the GTG and a significant increase in the ACG of phonemic verbal fluency ($Z_{GTG}=-1.89$, p=.059, $d=1.30$; $Z_{ACG}=-2.55$, p=.011, $d=1.75$). Participants in the GTG improved 19.44% their phonemic verbal fluency, whereas participants in the ACG improved 18.75%. However, only GTG showed significant effects in the follow-up ($Z_{GTG}=-2.73$, p=.006, $d=2.56$; $Z_{ACG}=-1.55$, p=.122, $d=0.87$). We did not find other significant results. See Figure 3 for the main effects.

Figure 3

Significant Cognitive Outcomes in the Game Training Group and Active Control Group Control: A) Impulsivity Index; B) Cognitive Inhibition; C) Phonemic Verbal Fluency.



Note. Higher scores in Impulsivity Index mean greater inhibition of impulse (the score is the proportion of correct responses minus errors out of all attempted items).

Non-cognitive outcomes. Regarding non-cognitive outcomes, we found a tendency towards significance across phases in Physical Health (χ^2(2,15)=-5.48, *p*=.065, *d*=1.83) in the ACG. Pre-post comparisons showed significant effects in this outcome in the ACG (*Z*=-2.26, *p*=.025, *d*=1.44), but not in the GTG (*Z*=-0.89, *p*=.371, *d*=0.53). Thus, ACG improved 11.11% in physical health. We found other significant results in the ACG in general satisfaction with health (*Z*=-2.04, p=.041, *d*=1.24) and family and social relationships quality (*Z*=-2.24, *p*=.025, *d*=1.42) after the intervention, but not in the GTG ($Z_{\text{General Satisfaction with Health}}$=0.00, p=1.000, *d*=0; $Z_{\text{Family and Social Relationships Quality}}$=-1.53, p=.125, *d*=0.98).

Subjective assessment of the intervention. Both interventions reached good ratings related to their difficulty and enjoyment. More than 85% considered to repeat both interventions (See Table 3).

Table 3

Differences in the rating scale about de intervention sessions between the Game Training and the Active Control groups in the main study.

	Game Training Group (n=12)	**Active Control Group (n=15)**	U/χ^2	*d*
How much did you enjoy the intervention? *M*±*SD*	4.17±0.72	4.47±0.74	*U*=68.00	0.42
(1=very unjoyful;5=very enjoyable)				
How much difficult did you consider the intervention? *M*±*SD* †	3.00±1.10	2.87±0.74	*U*=75.00	0.29
(1=very easy; 5=very difficult)				
Would you repeat the intervention in the future?			χ^2= 0.17	0.16
Yes, *n (%)*	11 (91.7 %)	13 (86.7 %)		
No, *n (%)*	1 (8.3 %)	2 (13.3 %)		
How many times would you like the intervention take place in the future? *M*±*SD*	3.75±1.06	3.47±1.46	*U*=85.00	0.09
(1= once a week; 5=every day)				

d< 0.20= trivial effect size; 0.20<*d*<0.50= small effect size; 0.50<*d*<0.80= medium effect size; *d*>0.80= large effect size.

†.Due to one person did not clearly remember the intervention; we omitted the data of this person for this question.

Discussion

The aim of both RCT's studies was to test the effectiveness of a cognitive training based on modern board and card games in older people. Firstly, the pilot study revealed significant results in semantic verbal fluency, favoring people who participated in the board and card games intervention. To confirm these results and to explore other cognitive processes, we performed a double-blind RCT. Moreover, in contrast to the pilot study, we considered an active-control group doing paper-and-pencil tasks previously validated [9] which are usually used in long-stay institutions or adult day-care centers. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Focusing on the main study, both cognitive interventions could be effective to improve phonemic verbal fluency. However, these effects only remained stable for the follow-up in the game training group. It is unclear, however, whether the improvement is due to the interventions or because they were socializing. Kelly et al [53] found that one of the cognitive processes more benefited with social interactions is verbal fluency. Anyhow, this finding could have an important value for clinical reasons, as verbal fluency is one of the most impaired cognitive processes in older people and could predict the progression to Alzheimer Disease from MCI [54].

Besides, we found that speed in cognitive inhibitory skills was improved between baseline and post-intervention assessment in paper-and-pencil cognitive tasks' intervention. Uchida & Kawashima[55] also found that doing paper-and-pencil tasks – addition problem solving and reading comprehension stories- improved phonemic verbal fluency and interference of control. One possible explanation is that participants did different paper-and-pencil tasks during the same session. Thus, they had to change the instruction and inhibit the previous verbal command. On the other hand, we found that people who played modern board and card games maintained the impulsivity control compared to the paper-and-pencil intervention. Although the board and card games required different EFs, in the majority of them that we used, if one person did not find the correct visual element, they were penalized (for instance, Pippo, Halli Galli, Halli Galli Junior, Ghost Blitz, Batti Burri, Pick-a-Pig, Dobble, and Kaleidos Junior). Thus, all these games could have done that the participants received feedback about doing it correctly, as the impulsivity control measures. Thus, paper-and-pencil tasks maybe could improve speed of stopping an automatic cognitive impulse, but only board and card games' training allows maintenance in motor cognition in accuracy terms. Similar to our results, one study in older people found that accuracy and speed feedback could have a different role on performance[56]. Thus, more studies to elucidate the role of feedback on accuracy and RT in inhibition tasks are needed, considering that inhibition and impulsivity are important factors in aging [57].

Contrary to our expectations [4,12] , no other effects were found in cognitive outcomes. This could be explained in near and far transfer effects terms, as previous studies have done [4]. Those cognitive processes in which we found significant results were the most trained. However, some cognitive processes –such as flexibility or WM- maybe need more dosage of intervention to show effects. Maybe a more focused intervention on specific cognitive processes could show better results as other studies have found [4,13]. However, a meta-analysis [51] have considered better the usage of multi-domain interventions with computerized interventions. Future studies are needed to elucidate this question.

Regarding non-cognitive outcomes, the active-control group had an impact in the quality of the family and social relationships after the intervention, but not in the game training group. This result could have different explanations. Firstly, reliability in this scale in the game training group was weak. So, we cannot conclude that board and card games do not benefit social outcomes in older people. Moreover, although the active-control group did paper-and-pencil tasks, they did it in group. Furthermore, they helped between them. In contrast, participants in the game training games always played in a competitive way. Although board games are usually designed to promote social interactions (Rogerson & Gibs, 2018; Woods, 2009), Decety et al.[58] found in their study that playing cooperative games could activate more social behaviors and related neural regions than playing competitive games. Modern board and card games have created innovative mechanics not seen before in traditional board and card[20]. How these new designs and mechanics impact players differently according to their characteristics should be considered in future studies. An open question from the present study is whether modern board and card games can be used as serious games, going deep into the game designs and their effects on people.

An unexpected interaction effect between phase and group was found in health quality of life in the main study. We requested to the centers information about the health evolution of the participants external to the study (i.e., hospitalizations, falls). We found that 50% of people within the GTG experienced these kind of affections, while only 20% of ACG did (χ^2((1, 20) = 2.89, p =.09). Thus, our results could not be interpreted as deleterious effects of the board and card games intervention. In future studies, information about medication, mobility or functional aids should be considered because they could explain the amelioration of health quality of life. However, we did not find significant effects in depressive symptomatology, as other authors have found[11]. One possible explanation is that the participants did not get clinical cut-offs[34] in the baseline. Future studies are needed to elucidate if people with clinical depressive symptoms could be beneficiated from cognitive interventions based on modern board and card games.

Limitations of the study

First, a bigger sample would be needed to use parametric statistics. Some data scores did not adjust to normality parameters in at least one phase. Thus, we conducted non-parametric tests in all outcomes to give coherence in the results section. However, we noticed that some outcomes showed normality. For this reason we also conducted repeated measures analysis of covariance (ANCOVA) with some covariates (this analysis can be send under request). Age in years, level of education, vocabulary[59], enjoyment[60] , visual acuity (hits in the test CARAS[47]) and general cognition status (assessed with the MMSE[29])[61] were adjusted at analysis as covariate measures. We found comparable results between covariate-adjusted parametric analysis and non-parametric (Table can be seen under request).

Also, a passive control group would be helpful to achieve internal validity [4]. Although clinically significant, the present study was performed with healthy older people, so we do not know whether the same effects could be expected in patients with dementia or related issues, as other studies have found [25]. Regarding attrition analysis, we found that people in both groups were similar in previous gaming and paper-and-pencil tasks habits. However, there were differences in previous experience doing crosswords between those analyzed and those that dropped out the study for different reasons. The main reason for dropping-out was the cognitive deterioration of medical conditions. Previous studies have found that crosswords[62] and similar leisure activities, as Sudokus[63], could be protective leisure activities for older people's cognitive deterioration. Thus, maybe those who dropped out due to medical reasons and showed cognitive deterioration were less protected to this cognitive decline. In addition, other confounding variables [5] should be controlled in future studies. Finally, the present research has not allowed testing for different mechanics of games –such as compare cooperative vs. competitive or games based on paper-and-pencil mechanisms-, modalities[64], frequencies[65] or durations of the board and card games CT [66], as other studies have done. However, future studies should focused in these purposes.

Conclusion

Cognitive trainings should be used in older adults, not only to improve cognitive processes as verbal fluency, but also some factors of quality of life. Moreover, interventions with board and card games could be more effective to maintain impulsivity skills in comparison to paper-and-pencil tasks. Future studies overcoming the limitations mentioned are regarded to assess effectivity, effectiveness, and efficacy to this kind of intervention.

Acknowledgments

We would like to express our gratitude to the participants, the centers (Balàfia I and II, and Comtes Urgell) and all their workers. Thanks to the Comissionat per a Universitats i Recerca del DIUE, Generalitat de Catalunya (2017SGR1577), to the Center for Biomedical Research Network on Mental Health (CIBERSAM), and to Spanish Ministry of Science, Innovation and Universities (MICIU/FEDER; project RTI2018-099800-B-I00).

Conflict of interest

The authors report no conflicts with any product mentioned or concept discussed in this article.

References

1. World Health Organisation (WHO): Envejecimiento activo [Web site]. 2015. Available at: *http://apps.who.int/iris/bitstream/handle/10665/186466/9789240694873_spa.pdf*

;jsessionid=79A871520EB8970140F0CC3D2F5A3048?sequence=1. Accessed April 24, 2020

2. Harada CN, Love MCN, Triebel K: Normal Cognitive Aging. Clin Geriatr Med 2013; 29(4):737-752
3. Chiu H-L, Chu H, Tsai J-C et al.: The effect of cognitive-based training for the healthy older people: A meta-analysis of randomized controlled trials. PLoS One 2017; 12(5):e0176742
4. Kuo CY, Huang YM, Yeh YY: Let's play cards: Multi-component cognitive training with social engagement enhances executive control in older adults. Front Psychol 2018; 9:1-13
5. Baumgart M, Snyder HM, Carrillo MC et al.: Summary of the evidence on modifiable risk factors for cognitive decline and dementia: A population-based perspective. Alzheimer's Dement 2015; 11:718-726
6. Krell-Roesch J, Vemuri P, Pink A et al.: Association between mentally stimulating activities in late life and the outcome of incident mild cognitive impairment, with an analysis of the APOE ϵ4 genotype. JAMA Neurol 2017; 74(3):332-338
7. Hall CB, Lipton RB, Sliwinski M et al.: Cognitive activities delay onset of memory decline in persons who develop dementia. Neurology 2009; 73(5):356-361
8. León JMR De: Estimulación cognitiva en el envejecimiento sano, el deterioro cognitivo leve y las demencias: estrategias de intervención y consideraciones teóricas para la práctica clínica. Rev Logop Foniatría y Audiol 2012; 32(2):57-66
9. Calero García MD, Navarro Gonzalez E: Eficacia de un programa de entrenamiento en memoria en el mantenimiento de ancianos con y sin deterioro cognitivo. Clínica y salud 2006; 17(2):187-202
10. Lampit A, Hallock H, Valenzuela M: Computerized Cognitive Training in Cognitively Healthy Older Adults: A Systematic Review and Meta-Analysis of Effect Modifiers. PLoS Med 2014; 11(11)
11. Montoya-Murillo G, Ibarretxe-Bilbao N, Peña J et al.: Effects of Cognitive Rehabilitation on Cognition, Apathy, Quality of Life, and Subjective Complaints in the Elderly: A Randomized Controlled Trial. Am J Geriatr Psychiatry 2020; 28(5):518-529
12. Toril P, Reales JM, Ballesteros S: Video Game Training Enhances Cognition of Older Adults: A Meta-Analytic Study. Psychol Aging 2014; 29(3):706-716
13. Iizuka A, Suzuki H, Ogawa S et al.: Does social interaction influence the effect of

cognitive intervention program? A randomized controlled trial using Go game. Int J Geriatr Psychiatry 2019; 34(2):324-332

14. Rogerson MJ, Gibbs M, Smith W: “I love all the bits”: The materiality of boardgames. Edition Jofish K,Druin A,Lampe C et al., eds. Proceeding of the Conference Human Factors in Computing Systems, Held in San Jose, CA, USA, May 7 & 12, 2016. New York, New York, USA: Association for Computing Machinery, 2016:3956-3969
15. Xu Y, Barba E, Radu I et al.: Chores are fun: Understanding social play in board games for digital tabletop game design. Edition Copier M,Waern A,Kennedy HW, eds. Proceeding of DiGRA (Authors & Digital Games Research Association) ’11 International Conference: Think Design Play, Held in Hilversum, The Netherlands, September 14 & 17, 2011. DIGRA, Digital Library, 2011:1-16
16. Dartigues JF, Foubert-Samier A, Le Goff M et al.: Playing board games, cognitive decline and dementia: A French population-based cohort study. BMJ Open 2013; 3(8):1-7
17. Lillo-Crespo M, Forner-Ruiz M, Riquelme-Galindo J et al.: Chess Practice as a Protective Factor in Dementia. Int J Environ Res Public Health 2019; 16(12)
18. Iizuka A, Ishii K, Wagatsuma K et al.: Neural substrate of a cognitive intervention program using Go game: a positron emission tomography study. Aging Clin Exp Res 2020(0123456789)
19. Cheng ST, Chow PK, Song YQ et al.: Can leisure activities slow dementia progression in nursing home residents? A cluster-randomized controlled trial. Int Psychogeriatrics 2014; 26(4):637-643
20. Sousa M, Bernardo E: Back in the Game. Edition Zagalo N,Veloso AI,Costa L et al., eds. Proceeding of the 11th International Conference Videogame Sciences and Arts, Held in Aveiro, Portugal, November 27 & 29, 2019. Cham, Switzerland: Springer Nature Switzerland AG, 2019:72-85
21. Benzing V, Schmidt M, Jäger K et al.: A classroom intervention to improve executive functions in late primary school children: Too ‘old’ for improvements? Br J Educ Psychol 2018:1-14
22. Estrada-Plana V, Esquerda M, Mangues R et al.: A Pilot Study of the Efficacy of a Cognitive Training Based on Board Games in Children with Attention-Deficit/Hyperactivity Disorder: A Randomized Controlled Trial. Games Health J 2019; 8(4):265-274

23. Overman AA, Robbins RE: Game-Based Community Cognitive Health Intervention for Minority and Lower Socioeconomic Status Older Adults: A Feasibility Pilot Study. Games Health J 2014; 3(5):303-310
24. Ching-Teng Y: Effect of board game activities on cognitive function improvement among older adults in adult day care centers. Soc Work Health Care 2019; 58(9):825-838
25. Miltiades HB, Thatcher WG: Individuals with Alzheimer's learn to play a tile placement game: Results of a pilot study: Innovative practice. Dementia 2016; 18(2):802-807
26. Fiske A, Wetherell JL, Gatz M: Depression in Older Adults. Annu Rev Clin Psychol 2009; 5(1):363-389
27. Netuveli G, Blane D: Quality of life in older ages. Br Med Bull 2008; 85(1):113-126
28. Boutron I, Moher D, Altman DG et al.: Extending the CONSORT statement to randomized trials of nonpharmacologic treatment: Explanation and elaboration. Ann Intern Med 2008; 148(4):295-309
29. Lobo A, Al. E: Revalidacion y normalizacion del Mini-Examen Cognoscitivo. Interpsiquis 2001; 2(2):1-17
30. Llinàs-Reglà J, Vilalta-Franch J, López-Pousa S et al.: The Trail Making Test: Association With Other Neuropsychological Measures and Normative Values for Adults Aged 55 Years and Older From a Spanish-Speaking Population-Based Sample. Assessment 2017; 24(2):183-196
31. Wechsler D: WAIS-IV. Escala de Inteligencia de Wechsler Para Adultos-IV. Madrid, Spain: Departamento de I+D de Pearson Clinical & Talent Assessment, 2012
32. Tombaugh TN, Kozak J, Rees L: Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. Arch Clin Neuropsychol 1999; 14(2):167-177
33. Peña-Casanova J, Quiñones-Úbeda S, Gramunt-Fombuena N et al.: Spanish multicenter normative studies (NEURONORMA project): Norms for verbal fluency tests. Arch Clin Neuropsychol 2009; 24(4):395-411
34. Martínez de la Iglesia J, Onís Vilches MC, Dueñas Herrero R et al.: Versión española del cuestionario de Yesavage abreviado (GDS) para el despistaje de depresión en mayores de 65 años: adaptación y validación. Medifam 2002;

12(10):620-630

35. Molero M del M, Pérez-Fuentes C, Gázquez JJ et al.: Construction and Initial Validation of a Questionnaire to Assess Quality of Life in Older Institutionalized People. Eur J Investig Heal Psychol Educ 2012; 2(2):53-65
36. Klingberg T: Training and plasticity of working memory. Trends Cogn Sci 2010; 14(7):317-324
37. Shafir H (Designer), Craig K (Artist): Cucú Tras, ¿qué Hay Detrás? [Look! What's Different?]. Madrid, Spain: Mercurio Distribuciones, 2012
38. Knizia R (Designer), Silveira G (Artist): Alles Tomate! Germany: Zoch Zum Spielen, 2007
39. Albertarelli S (Designer), Mendicino V, Prette E (Artists): Kaleidos Junior. 1997
40. Sarrett P, (Designer & Artist): Time's up! Kids. Madrid, Spain: Asmodee, 2015
41. Shafir H (Designer), Freudenreich O, Vohwinkel F (Artists): Halli Galli Junior. Madrid, Spain: Mercurio Distribuciones, 1998
42. Blanchot, D; Gille-Naves, G., Cotterau, J. & Polouchine I (Designers), Blanchot D, Nyman IV et al.: Dobble [Spot It!]. Madrid, Spain: Asmodee, 2009
43. Lenhard W, Lenhard A: Calculation of Effect Sizes [Web Site]. 2016. Available at: *https://www.psychometrica.de/effect_size.html*. Accessed June 6, 2020
44. Georgiev GZ: Sample Size Calculator [Web site]. Available at: *https://www.gigacalculator.com/calculators/power-sample-size-calculator.php*. Accessed March 17, 2020
45. Wechsler D: Wechsler Memory Scale (WMS). Third. Madrid, Spain: Dpto I+D Pearson Clinical & Talent Assessment, 2008
46. Sedó M: FDT. Test de Los 5 Dígitos. Madrid, Spain: TEA Ediciones, 2004
47. Folch A, Torrente M, Heredia L et al.: Estudio preliminar de la efectividad de la terapia asistida con perros en personas de la tercera edad. Rev Esp Geriatr Gerontol 2016; 51(4):210-216
48. Lucas-Carrasco R, Laidlaw K, Power MJ: Suitability of the WHOQOL-BREF and WHOQOL-OLD for Spanish older adults. Aging Ment Heal 2011; 15(5):595-604
49. Prins PJM, Dovis S, Ponsioen A et al.: Does Computerized Working Memory Training with Game Elements Enhance Motivation and Training Efficacy in Children with ADHD? Cyberpsychology, Behav Soc Netw 2011; 14(3):115-122
50. Hollingshead AB: Four Factor Index of Social Status. In: Four Factor Index of Social Status. New Heaven, Connecticut: Yale University, 1975

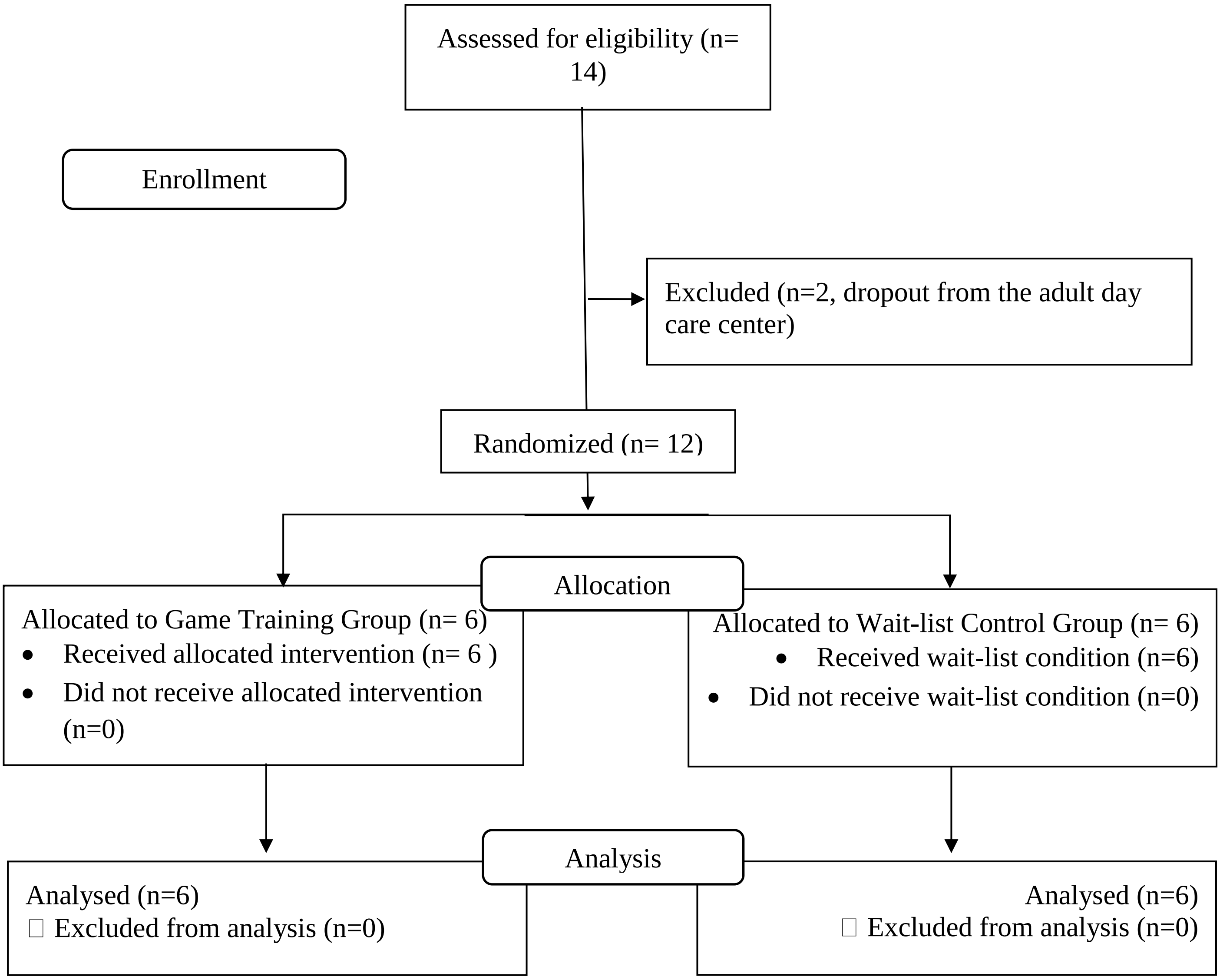
51. Cheng Y, Wu W, Feng W et al.: The effects of multi-domain versus single-domain cognitive training in non-demented older people: A randomized controlled trial. BMC Med 2012; 10
52. Esteve: Cuadernos de estimulación cognitiva [Web site]. Available at: *https://www.esteveagora.com/farmaceutico/cuadernos-de-estimulacion-cognitiva*. Accessed March 20, 2020
53. Kelly ME, Duff H, Kelly S et al.: The impact ofsocial activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. Syst Rev 2017; 6(1)
54. Vaughan RM, Coen RF, Kenny RA et al.: Semantic and Phonemic Verbal Fluency Discrepancy in Mild Cognitive Impairment: Potential Predictor of Progression to Alzheimer's Disease. J Am Geriatr Soc 2018; 66(4):755-759
55. Uchida S, Kawashima R: Reading and solving arithmetic problems improves cognitive functions of normal aged people : a randomized controlled study. Age (Omaha) 2008; 30:21-29
56. Touron DR, Hertzog C: Accuracy and speed feedback: Global and local effects on strategy use. Exp Aging Res 2014; 40(3):332-356
57. Morales-Vives F, Vigil-Colet A: Are old people so gentle? Functional and dysfunctional impulsivity in the elderly. Int Psychogeriatrics 2012; 24(3):465-471
58. Decety J, Jackson PL, Sommerville JA et al.: The neural bases of cooperation and competition: an fMRI investigation. Neuroimage 2004; 23(2):744-751
59. Borella E, Carbone E, Pastore M et al.: Working memory training for healthy older adults: The role of individual characteristics in explaining short- and long-term gains. Front Hum Neurosci 2017; 11(March)
60. Jaeggi SM, Buschkuehl M, Shah P et al.: The role of individual differences in cognitive training and transfer. Mem Cogn 2014; 42(3):464-480
61. Ball K, Berch DB, Helmers KF et al.: Effects of Cognitive Training Interventions With Older Adults. Jama 2002; 288(18):2271
62. Pillai JA, Hall CB, Dickson DW et al.: Association of Crossword Puzzle Participation with Memory Decline in Persons Who Develop Dementia. J Int Neuropsychol Soc 2011; 17(6):1-13
63. Ferreira N, Owen A, Mohan A et al.: Associations between cognitively stimulating leisure activities , cognitive function and age-related cognitive decline. Int J Geriatr Psychiatry 2014

64. Souders DJ, Boot WR, Charness N et al.: Older Adult Video Game Preferences in Practice: Investigating the Effects of Competing or Cooperating. Games Cult 2015; 11(1-2):170-200
65. Cheng ST, Chan ACM, Yu ECS: An exploratory study of the effect of mahjong on the cognitive functioning of persons with dementia. Int J Geriatr Psychiatry 2006; 21(7):611-617
66. Sanders LMJ, Hortobágyi T, Gemert S la B van et al.: Dose-response relationship between exercise and cognitive function in older adults with and without cognitive impairment: A systematic review and meta-analysis. PLoS One 2019; 14(1):1-24

Appendix

Supplementary Figure 1

Participants flow chart from the Pilot Study.



Supplementary Table 1

Games description from the pilot study.

Game	Description	
Look! What's different? [1]	In this STM, WM and processing speed game, there are different cards with the two sides drawn. The draws into the card are equal except by a detail (for example, on one side there is a tree with two apples and on the other side, with three apples). The set-up consists of five cards face-down in the middle of the table and the other cards dealt among all the players. In turns, every player turns over one of the cards in the center while the rest of the players have their eyes closed. The first player who detects the changed card, replace it by one of his or her deck. The player who undoes all their cards becomes the winner. BGG: 162191	***Time: 10'*** ***Players: 2-6*** ***Age: +4***
Kaleidos Junior [2]	Every player chooses one of four possible colors. Every color is represented in two draws where players must find the objects. Depending on the age of the players, they have low or more game' pieces. Roulette and a sandglass are positioned in the center of the table. You must choose one of the modalities of the game: to find objects by categories (for example, red things), to find objects by the first letter of the word (for example, things which the first letter is the A), to find objects by the first letter of the word with the difference that now players must write in a paper with a pencil and not to put the game pieces on the draw. When the round finishes, all the objects must be justified. The first player who finishes their game pieces or in five rounds -in the case of the paper-and-pencil modality- wins the game. For this reason, the cognitive processes theoretically activated in this game are verbal fluency, processing speed and selective attention. BGG: 24209	***Time: 15'*** ***Players: 2-12*** ***Age: +4***
Time's up! Kids [3]	The cognitive processes theoretically activated in this game are verbal fluency, STM and WM. The difference with the other games used in the experimental group is that this game is played in teams. In this version of the game Time's up there are three different rounds. 220 cards composed the game and for each time you play the game, you must choose 20 cards. Firstly, players must guess the object represented in a card by describing it with sentences, whereas in the second modality players must guess the object represented in the card by saying only one word. In the final round, one player must describe the object by mime. The time to guess the 20 cards in every round is 10 minutes which is counted by a sand glass. The team who guess more objects after three rounds wins the game. BGG: 174219	***Time: 20'*** ***Players: 2-12*** ***Age: +4***

Alles Tomate! [4]	The main cognitive process theoretically activated in this game is the updating component from WM, but also processing speed, verbal fluency and phonological STM. Seven themed cards are always face-up. One object card is positioned face-up down the themed card with which it is related. Once all the players have seen the seven object cards, they are face-down. From the deck, one participant reveals a new object card. The first player to recall which element is on the face-down object card positioned down the themed card with the same color background is the person who will win the card. The topic of the game is about farming. The player who accumulates more cards becomes the winner. BGG: 32405	***Time: 15-20'*** ***Players: 2-8*** ***Age: +6***
Halli Galli Junior[5]	The cognitive processes theoretically activated in this game are inhibition, visual perception and processing speed. 56 cards with different images of sad or happy clowns composed this game. All the cards must be dealt into all the players. The players hold their deck face down and, in turns, every player deals one face up in front of them. Players must ring a bell when there are on the table two clowns completely identical (the same color and facial expression). If the player who rings the bell is on the right, gets all the cards over the table. If the action of the player is on the wrong, he or she has to give one card to each player. The player, who accumulates all the cards, wins the game. BGG: 20832	***Time: 15'*** ***Players: 2-4*** ***Age: +4***
Dobble[6]	The cognitive processes theoretically activated in this game are visual perception, visual short-term memory, processing speed and verbal fluency. The game has 55 cards with different random symbols on it. It can be more than 50 different symbols with all the cards. However, in every card, there are 8 different symbols which can variate their size between the different cards. Players must find the same symbol between two cards. There are five different mini-games. After five rounds, the player who has won more rounds wins the game. BGG: 63268	***Time: 15'*** ***Players: 2-8*** ***Age: +7***

Supplementary Table 2

Games' description from the main study.

Game	***Description***	
Barnyard buddies [7]	In this card game, there are 5 different animals and 5 colors. Every animal and color is represented in a card. Additionally, there are cards which represent the 4 animals colored with a different color each one. Players must find the missing animal and color and take the corresponding card. This game could be related to Visuospatial STM, Processing speed and reasoning. BGG: 486	***Time: 15'*** ***Players: 2-8*** ***Age: +4***
Chicken cha cha cha [8]	Twenty four octagons (each pair has the same image) are positioned face-down at the center of the table. Round the octagons, different egg-shaped tiles are positioned, where one chicken figure by each participant is placed in an equidistant space among them. At the back of each chicken figure, there are four spaces, where a feather could be placed at the beginning. To progress, each player, in his/her turn, has to successfully memorize the image on each of the twelve octagon tiles that the game has. Each player moves the number of times equivalent to the number of correct pairs he/she remembers. When one chicken overtakes another, the one that overtakes steals the feather to the other one. The game ends when one player has the four feathers, who is the winner. BGG: 3570	***Time: 15-20'*** ***Players: 2-4*** ***Age: +4***
Ghost blitz [9]	Five wooden figures are in the middle of the table, waiting to be caught. Each card in the deck shows two objects in every picture, with one or both objects colored incorrectly. Someone has to reveal a card and then all players, at the same time, have to grab the "right" object. However, which object is right? If one object is colored correctly (for example, a green bottle and a red mouse) players need to grab the correctly colored object. On the other hand, if both objects are colored incorrectly players need to grab the object and color not represented among the four details shown. The first player to grab the correct object keeps the card in his or her deck of collected cards. If a player grabs the wrong object, she must discard one card previously collected. Once the card deck runs out, the game ends and whoever has collected the most cards, wins. This game could be related to Visuospatial STM, Processing speed and reasoning. BGG: 83195	***Time: 20'*** ***Players: 2-8*** ***Age: +8***
Halli Galli [10]	Each player has a deck of cards face down and must turn their cards one by one in turns. The cards represent different amounts of fruits. When 5 fruits of the same type can be counted among the exposed cards, players must press the bell as quickly as possible. The fastest player takes all the cards in his deck. The person who has all the cards wins the game. BGG: 2944	***Time: 10'*** ***Players: 2-6*** ***Age: +6***

Pick-a-pig [11]	There are 30 cards in a grid. Each player receives another card face-down. Each card represents a dog with different dual-attributes: light/dark, small/large, one/two arms, with/without sunglasses and with/without popcorn. All players start at the same time to get the biggest amount of cards. Each player can get cards only when the card grabbed from the grid is identical, or differ in only one attribute in comparison to the card in their hands. Once a player thinks that cannot grab more cards from the grid, all players check their cards. If one player makes a mistake, loses all their points. Each card represents a point. There is a bonus of one extra card for the person who said stop at grabbing more cards. The person who gets the most quantity of points wins the game. BGG: 63268	***Time: 15'*** ***Players: 1-5*** ***Age: +8***
Connect the thoughts [12]	Each card of the game is represented with many different objects or animals. The objective is to make a row of 7 cards connected by at least one element between each one as quickly as possible. BGG: 135851	***Time: 15'*** ***Players: 2-4*** ***Age: +5***
Spooky stairs [13]	The objective of the game is to climb the stairs of a ruined castle as fast as possible. The number depicted in the dice (from one to four) indicates how many stairs climb with a color pawn. If the dice shows a ghost, the player has to roll a "ghost" and he/she should place a ghost piece over another player's pawn, which is connected by a magnetic field. Hence, at this point, players have to remember under which ghost their own and the other figures were, and a lot of mistakes could be produced. The game continues till the first pawn arrives at the top of the stairs. At that moment, the pawn that was inside the ghost piece is revealed. The player whose pawn arrived first wins. BGG: 63268	***Time: 10-15'*** ***Players: 2-4*** ***Age: +4***
Jungle speed safari [14]	The setting-up of the game is 5 totems placed in the middle. In turn, each player reveals a card. Each card triggers an action. If a player does correctly the action, add this card to its amount. BGG: 144468	***Time: 15'*** ***Players: 2-6*** ***Age: +5***
Fast Words[15]	The setting-up of the game is a grid of 8 letters-cards and another card which represents a semantic category. Each player has to decide a word related to the theme, using as many letters as possible. The rest of the players can say another word until one player does not say any word. The player with most cards at the end is the winner. BGG: 63268	***Time: 15'*** ***Players: 2-4*** ***Age: +12***

References from Tables 1, 2

1. Shafir H (Designer), Craig K (Artist): Cucú Tras, ¿qué Hay Detrás? [Look! What's Different?]. Madrid, Spain: Mercurio Distribuciones, 2012

2. Albertarelli S (Designer), Mendicino V, Prette E (Artists): Kaleidos Junior. Madrid, Spain: Asmodee, 1997

3. Sarrett P, (Designer & Artist): Time's up! Kids. Madrid, Spain: Asmodee, 2015

4. Knizia R (Designer), Silveira G (Artist): Alles Tomate! Germany: Zoch Zum Spielen, 2007

5. Shafir H (Designer), Freudenreich O, Vohwinkel F (Artists): Halli Galli Junior. Madrid, Spain: Mercurio Distribuciones, 1998

6. Blanchot, D; Gille-Naves, G., Cotterau, J. & Polouchine I (Designers), Blanchot D, Nyman IV et al: Dobble [Spot It!]. Madrid, Spain: Asmodee, 2009

7. Staupe R (Designer), Francis G, Freudenreich O et al: Pippo [Barnyard Buddies]. Madrid, Spain: Mercurio Distribuciones, 1996

8. Zoch K (Designer), Matthäus D, Zoch K (Artists): Cocorico Cocorocó! [Chicken Cha Cha Cha]. Barcelona, Spain: Devir Iberia, 1997

9. Zeimet J (Designer), Silveira G (Artist): Fantasma Blitz [Ghost Blitz]. Barcelona, Spain: Devir Iberia, 2010

10. Shafir H (Designer), Freudenreich O, Spelger B (Artists): Halli Galli. Madrid, Spain: Mercurio Distribuciones, 1990

11. Landsvogt T (Designer), Wong A (Artist): Pick-a-Pig. Madrid, Spain: Mercurio Distribuciones, 2012

12. Shafir H (Designer), Shimoni Y (Artist): Batti Burri [Connect the Thoughts]. Madrid, Spain: Mercurio Distribuciones, 2013

13. Schanen M (Designer), Rüttinger J, Vogt R (Artists): La Escalera Encantada [Spooky Stairs]. Barcelona, Spain: Devir Iberia, 2003

14. Vuarchex T, Yakovenko P (Designers), Vuarchex T (Artist): Jungle Speed Safari. Madrid, Spain: Asmodee, 2013

15. Allué JM, Gómez D (Designers), Bellido S (Artist): Fast Words. Alicante, Spain: Cayro Games, 2014

Supplementary Table 3

Baseline differences in demographic and primary outcomes between the Game Training and the Wait-List Control groups.

	Game Training Group (n=6)	Wait-list Control Group (n=6)	$U/t/\chi^2$	*d*
Age, M±SD	79.17±7.73	81.33±6.80	-.52	.30
Gender				
Male, *n (%)*	0 (0.0%)	1 (16.7%)	1.09	.63
Female, *n (%)*	6 (100.0%)	5 (83.3%)		
Literacy				
Yes	4 (66.7%)	6 (100%)	.24	.29
No	2 (33.3%)	0 (0%)		
Cognitive measures, M±SD				
General cognition (MMSE)	29.00±2.53	30.67±2.07	-1.25	.72
Processing speed (TMT-A)	249.17±143.21	176.50±86.09	15.00	.28
Processing speed (CODING)	12.83±9.02	14.17±6.27	-.30	.17
Phonemic verbal fluency (FAS test)	8.17±5.85	20.17±11.46	-2.29^{t}	1.32
Semantic verbal fluency (COWAT)	32.00±9.03	35.50±16.62	16.00	.19
Quality of Life, M±SD				
Health	32.33±3.93	32.17±3.71	.08	.04
Family and social relationships	45.00±3.46	47.00±4.24	-0.78	.51
Activity and Leisure	35.67±3.27	34.67±3.08	.55	.31
Environmental quality	44.83±4.75	51.17±5.64	-2.11^{t}	1.21
Functionality	15.00±6.54	13.17±6.68	16.00	.19
Satisfaction with life	4.00±0.00	4.33±0.52	12.00	.60
Mental Health, M±SD				
Depressive symptoms (GDS-15)	2.50±1.76	3.00±1.27	.57	.33

Note. MMSE= Mini-Mental State Examination; TMT= Trail Making Test; COWAT= Controlled Oral Word Automatic Test; GDS=Geriatric Depression Scale.

$p<.10=^{t}$; $d<0.20$= trivial effect size; $0.20<d<0.50$= small effect size; $0.50<d<0.80$= medium effect size; $d>0.80$= large effect size.

Supplementary Table 4

Scores at Pretest, Posttest for the Game Training Group (GTG; n=6) and the Wait-list Control Group (WCG; n=6); and their analysis of normality.

		Normality Baseline	**Baseline** Mean±SD	**Normality Post**	**Post** Mean±SD	**Phase Pre-post‡**	***d***
Cognitive measures							
Processing speed (TMT-A)	GTG	0.98	249.17±143.21	0.97	256.17±128.17	*Z*=-0.42	0.35
	WCG	0.71**	176.50±86.09	0.90	179.83±73.19	*Z*=-0.31	0.26
Processing speed (CODING)	GTG	0.84	12.83±9.02	0.85	14.50±10.82	*Z*=-1.48	1.52
	WCG	0.96	14.17±6.27	0.92	14.67±7.47	*Z*=-0.54	0.45
Phonemic verbal fluency	GTG	0.98	8.17±5.85	0.93	10.50±10.29	*Z*=-0.95	0.84
	WCG	0.84	20.17±11.46	0.98	19.00±8.60	*Z*=-0.74	0.63
Semantic verbal fluency	GTG	0.63**	32.00±9.03	0.94	38.00±13.68	*Z*=2.00*	2.83
	WCG	0.96	35.50±16.62	0.75*	35.50±15.88	*Z*=-0.11	0.09
Quality of Life *(CECAVIR)*							
Health	GTG	0.86	32.33±3.93	0.83	32.67±4.89	*Z*=-0.31	0.26
	WCG	0.81	32.17±3.71	0.95	32.17±2.48	*Z*=-0.14	0.11
Family, social relationships†	GTG	0.84	45.00±3.46	0.98	47.40±3.85	*Z*=-1.63	5.57
	WCG	0.98	47.00±4.24	0.91	44.80±3.03	*Z*=-0.27	0.24
Activity and Leisure	GTG	0.86	35.67±3.27	0.96	36.17±2.56	*Z*=-0.42	0.35
	WCG	0.93	34.67±3.08	0.96	35.00±2.19	*Z*=-0.14	0.11
Environmental quality	GTG	0.94	44.83±4.75	0.82	49.67±4.84	*Z*=-1.36	1.34
	WCG	0.86	51.17±5.64	0.88	45.67±3.72	*Z*=-1.83ᵗ	2.25
Functionality	GTG	0.68**	15.00±6.54	0.95	11.67±4.37	*Z*=-0.94	0.83
	WCG	0.91	13.17±6.68	0.72*	14.17±6.56	*Z*=-0.67	0.57
Satisfaction with life	GTG	-	4.00±0.00	0.55***	4.33±0.52	*Z*=-1.41	1.41
	WCG	0.64**	4.33±0.52	-	4.00±0.00	*Z*=-1.41	1.41
Mental Health							
Depressive symptoms(GDS-15)	GTG	0.85	2.50±1.76	0.68**	1.67 ±1.03	*Z*=-1.41	1.41
	WCG	0.83	3.00±1.27	0.96	2.83 ±1.33	*Z*=-1.00	0.89

Note. GTG= Game Training Group; WCG= Wait-list Control Group; MMSE=Mini-Mental State Examination; TMT= Trail Making Test; GDS= Geriatric depression scale. p<0.10= ᵗ , p<0.05=*; p<0.01=**; p<0.001=***. *d*< 0.20= trivial effect size; 0.20<*d*<0.50= small effect size; 0.50<*d*<0.80= medium effect size; *d*>0.80= large effect size.
†. In this outcome, participant's measures were n=3 in GTG and n=5 in WCG due to it was needed to replace more than one item.
‡. We used non-parametric statistic –Wilcoxon signed rank test- to analyze those variables that did not follow a normal distribution using Shapiro-Wilk.

Supplementary Table 5

Description of paper-and-pencil tasks in active-control group in the main study.

Cognitive processes boosted	Description of the tasks
Verbal STM/WM	Read a story and remember it, Put in order the words of a sentence, Count elements, Copy a new, Create words mixing letters, Word search in different directions[§], Count forward/backward (i.e. add/subtract 2 from 18 until reach 130), Addition/Subtraction[§], Problem solving (gather different coins to pay a determinate product)[§]
Visuospatial STM	Remember the position of a visual element, Copy a picture, Remember elements from a photo
Cognitive flexibility	Worksheet as "TMT-B", but with months and numbers‡
Reasoning	Find which element should not remain, Find the correct arrow through clues
Planning	Put in order a sequence with visual or verbal elements
Processing speed	Worksheet as "TMT-A", Detect elements in a photo, Find the 5 differences, Maze task, Worksheet as "Coding"[a], Worksheet as "Symbol Search"[†]
Verbal fluency	Semantic and Phonemic verbal fluency task (written version)
Attention	Cross out only a letter, Cross out only a visual element, Encircle only the same element
Perception	Find an element into a picture (gnosis worksheet), Find the shape or the size of an element
Language	Connect words with their meaning, Find the opposite word, Find the missed letter, Find the orthographically correct words, Give a definition of words, Explain a recent story, Connect words with their colour
Praxis	Repeat a gesture in the same order
Semantic memory	Connect object-smell, name-profession, True or false sentences
Episodic memory	What did you like the most in yesterday?, Evoke from the smell

Note. TMT= Trail Making Test; WM=Working Memory.

[†]. These worksheets also boosted visuospatial STM.

‡. These worksheets also boosted processing speed.

[§]. These worksheets also boosted cognitive flexibility.

Supplementary Table 6

Baseline differences between the Game Training and the Active Control groups in the primary and secondary outcomes of the main study.

	Game Training Group (n=12)		Active Control Group (n=15)			
	α	***M±SD***	***α***	***M±SD***	***U/t***	***d***
Cognitive measures						
Verbal STM (Forward digits)	-	6.08±1.17	-	6.60±1.35	70.50	0.37
Verbal WM (Backward digits)	-	3.42±1.31	-	3.47±1.06	75.00	0.29
Visuospatial STM (Forward Corsi)	-	5.67±0.99	-	6.07±1.53	80.50	0.18
Visuospatial WM (Backward Corsi)	-	3.67±1.72	-	4.20±1.90	0.76	0.29
RT Inhibition (5 digits test)	-	51.92±50.20	-	50.20 ±53.70	88.00	0.04
RT Flexibility (5 digits test)	-	90.50±55.94	-	69.67±59.94	52.50	0.75
Impulsivity (CARAS)	-	46.92 ±35.57	-	64.33±33.19	55.50	0.69
Phonemic verbal fluency	-	14.50 ±10.12	-	15.60±11.26	0.26	0.10
Semantic verbal fluency	-	30.00±7.82	-	31.60±13.74	0.36	0.14
Processing speed (CODING)	-	16.17±6.89	-	18.73±14.22	0.57	0.23
Quality of Life (WHO-QOL Brief)						
General satisfaction with life	-	3.17±1.27	-	3.40±0.99	0.54	0.20
General satisfaction with health	-	3.25±1.14	-	3.13±0.99	77.00	0.25
Physical health	0.76	23.75±5.07	0.70	21.93±5.27	-0.91	0.35
Psychological health	0.67	21.92±3.85	0.72	21.60±4.45	82.00	0.15
Family and social relationships	0.65	9.92±3.34	0.02	11.20±2.40	1.16	0.44
Environmental quality	0.68	31.67±4.56	0.77	31.40±5.93	-0.13	0.05
Mental Health						
Depressive symptoms (GDS-15)	0.47	5.08±2.39	0.62	4.33±2.66	77.00	0.25

Note. MMSE=Mini-Mental State Examination; STM= short-term memory; WM= working memory; RT= reaction time; WHO-QOL=World Health Organization Quality of Life; GDS=Geriatric Depression Scale. $d<0.20$= trivial effect size; $0.20<d<0.50$= small effect size; $0.50<d<0.80$= medium effect size; $d>0.80$= large effect size.

Supplementary Table 7

Scores at Pretest, Posttest, Follow-up for the Game Training Group (GTG; n=12) and the Active Control Group (ACG; n=15); and their analysis of normality.

		Normality Baseline	**Baseline** Mean±SD	**Normality Post**	**Post** Mean±SD	**Normality Follow-up**	**Follow-up** Mean±SD	**Phase**†	***d***	**Pre-post**‡	**Pre-Follow-up** ‡
Cognitive measures											
Verbal STM	GTG	0.90	6.08±1.17	0.93	6.58±2.02	0.92	6.25±1.77	$\chi 2$(2,12)=0.59	0.45	*Z*=-1.20	*Z*=-0.58
(Forward digits)	ACG	0.85*	6.60±1.35	0.94	6.40±1.30	0.94	6.07±1.39	$\chi 2$(2,15)=3.74	0.58	*Z*=-0.59	*Z*=-1.63
Verbal WM	GTG	0.76**	3.42±1.31	0.81*	3.17±1.12	0.91	3.25±1.14	$\chi 2$(2,12)=0.77	0.52	*Z*=-1.13	*Z*=-0.43
(Backward digits)	ACG	0.90	3.47±1.06	0.84*	3.07±1.10	0.93	3.07±1.03	$\chi 2$(2,15)=1.54	0.68	*Z*=-1.28	*Z*=1.30
Visuospatial STM	GTG	0.88	5.67±0.99	0.92	6.00±1.28	0.87	5.50±0.80	$\chi 2$(2,12)=2.25	0.96	*Z*=-1.04	*Z*=-0.52
(Forward Corsi)	ACG	0.87*	6.07±1.53	0.93	6.20±1.52	0.86*	6.27±1.71	$\chi 2$(2,15)=0.15	0.20	*Z*=-0.28	*Z*=-0.54
Visuospatial WM	GTG	0.96	3.67±1.72	0.93	4.08±1.44	0.84*	3.67±0.78	$\chi 2$(2,12)=0.21	0.27	*Z*=-1.03	*Z*=-0.00
(Backward Corsi)	ACG	0.93	4.20±1.90	0.87*	4.47±2.70	0.85*	4.40±2.35	$\chi 2$(2,15)=0.28	0.28	*Z*=-0.60	*Z*=-0.42
RT Inhibition	GTG	0.83*	51.92±50.20	0.90	40.50±34.27	0.98	33.42±22.46	$\chi 2$(2,12)=1.50	0.76	*Z*=-0.94	*Z*=-1.61
(5 digits test)	ACG	0.65***	50.20±53.70	0.89	27.13±19.81	0.83*	34.33±30.52	$\chi 2$(2,15)=5.41^{t}	1.50	*Z*=-2.23*	*Z*=-1.34
RT Flexibility	GTG	0.78**	90.50±55.94	0.94	86.33±37.45	0.80*	95.58±66.01	$\chi 2$(2,12)=0.17	0.24	*Z*=-0.24	*Z*=-0.47
(5 digits test)	ACG	0.65***	69.67±59.94	0.96	61.47±30.55	0.87*	67.00±45.39	$\chi 2$(2,15)=0.31	0.29	*Z*=-0.14	*Z*=-0.66
Impulsivity	GTG	0.72**	46.92±35.57	0.93	60.00±30.93	0.91	60.25±21.19	$\chi 2$(2,12)=0.38	0.36	*Z*=-0.86	*Z*=-0.90
(CARAS)	ACG	0.87*	64.33±33.19	0.95	48.47±33.59	0.96	55.33±24.37	$\chi 2$(2,15)=6.52*	1.75	*Z*=-2.26*	*Z*=-0.97
Phonemic Fluency	GTG	0.90	14.50±10.12	0.94	18.00±12.97	0.97	18.92±11.38	$\chi 2$(2,12)=8.14*	2.90	*Z*=-1.89^{t}	*Z*=-2.73**
(COWA Test)	ACG	0.89	15.60±11.26	0.87*	19.20±12.67	0.77**	17.80±12.06	$\chi 2$(2,15)=3.38	1.08	*Z*=-2.55*	*Z*=-1.55
Semantic Fluency	GTG	0.97	30.00±7.82	0.94	31.67±8.98	0.96**	29.17±8.94	$\chi 2$(2,12)=1.17	0.66	*Z*=-0.67	*Z*=-0.62
(COWA Test)	ACG	0.93	31.60±13.74	0.82*	32.87±14.70	0.80	34.27±16.48	$\chi 2$(2,15)=0.56	0.39	*Z*=-0.76	*Z*=-1.38
Processing speed	GTG	0.89	16.67±6.89	0.93	16.67±8.66	0.93	17.67±10.21	$\chi 2$(2,12)=0.58	0.45	*Z*=0.00	*Z*=-0.04
(CODING)	ACG	0.89	18.73±14.22	0.84**	21.60±18.24	0.87*	18.93±14.76	$\chi 2$(2,15)=1.29	0.61	*Z*=-1.09	*Z*=-0.63

		Normality Baseline	Baseline Mean±SD	Normality Post	Post Mean±SD	Normality Follow-up	Follow-up Mean±SD	Phase†	*d*	Pre-post‡	Pre-Follow-up ‡
Quality of Life (WHO-QOL Brief)											
General satisfaction	GTG	0.94	3.17±1.27	0.87	3.50±0.91	0.86*	3.33±1.16	$\chi 2$(2,12)=0.59	0.45	*Z*=-1.61	*Z*=-052
with life	ACG	0.90	3.40±0.99	0.86*	3.87±0.99	0.89	3.67±0.98	$\chi 2$(2,15)=3.74	1.15	*Z*=-0.71	*Z*=-1.10
General satisfaction	GTG	0.91	3.25±1.14	0.78**	3.25±1.06	0.84*	3.17±1.47	$\chi 2$(2,12)=0.77	0.52	*Z*=0.00	*Z*=-0.28
with health	ACG	0.86*	3.13±0.99	0.85*	3.67±1.40	0.88*	3.33±0.82	$\chi 2$(2,15)=1.54	0.68	*Z*=-2.04*	*Z*=-1.34
Physical health	GTG	0.97	23.75±5.07	0.88	22.42±5.47	0.84*	22.33±4.12	$\chi 2$(2,12)=0.13	0.21	*Z*=-0.89	*Z*=-0.94
	ACG	0.97	21.93±5.27	0.92	24.67±5.46	0.92	23.40±4.15	$\chi 2$(2,15)=5.48^t	1.52	*Z*=-2.25*	*Z*=-1.13
Psychological health	GTG	0.85*	21.92±3.85	0.90	20.08±5.04	0.92	20.00±4.88	$\chi 2$(2,12)=0.40	0.37	*Z*=-1.28	*Z*=-0.06
	ACG	0.94	21.60±4.45	0.97	22.40±5.12	0.94	21.67±5.60	$\chi 2$(2,15)=2.54	0.90	*Z*=-0.97	*Z*=-1.47
Family and social	GTG	0.95	9.92±3.34	0.78**	11.75±2.90	0.92	10.91±3.50	$\chi 2$(2,12)=1.86	0.86	*Z*=-1.53	*Z*=-0.72
relationships	ACG	0.96	11.20±2.40	0.92	12.60±1.99	0.82**	12.00±2.45	$\chi 2$(2,15)=3.29	1.06	*Z*=-2.24*	*Z*=-0.88
Environmental quality	GTG	0.95	31.67±4.56	0.91	30.42±5.55	0.87	28.50±6.52	$\chi 2$(2,12)=0.89	0.57	*Z*=-0.59	*Z*=-1.30
	ACG	0.95	31.40±5.93	0.91	33.13±5.67	0.90	32.87±5.45	$\chi 2$(2,15)=2.61	0.92	*Z*=-1.93	*Z*=-0.65
Mental Health											
Depressive	GTG	0.86*	5.08±2.39	0.83*	4.42±3.20	0.90	5.25±4.03	$\chi 2$(2,12)=1.16	0.65	*Z*=-1.17	*Z*=-0.28
symptoms(GDS-15)	ACG	0.98	4.33±2.66	0.90	3.87±2.77	0.78**	3.87±2.90	$\chi 2$(2,15)=2.26	0.84	*Z*=-0.64	*Z*=0.73

Note. GTG= Game Training Group; ACG= Active Control Group; MMSE=Mini-Mental State Examination; STM= short-term memory; WM= working memory; RT=reaction time; COWA= Controlled Oral Word Association; WHO-QOL=World Health Organization Quality of Life; GDS= Geriatric depression scale.

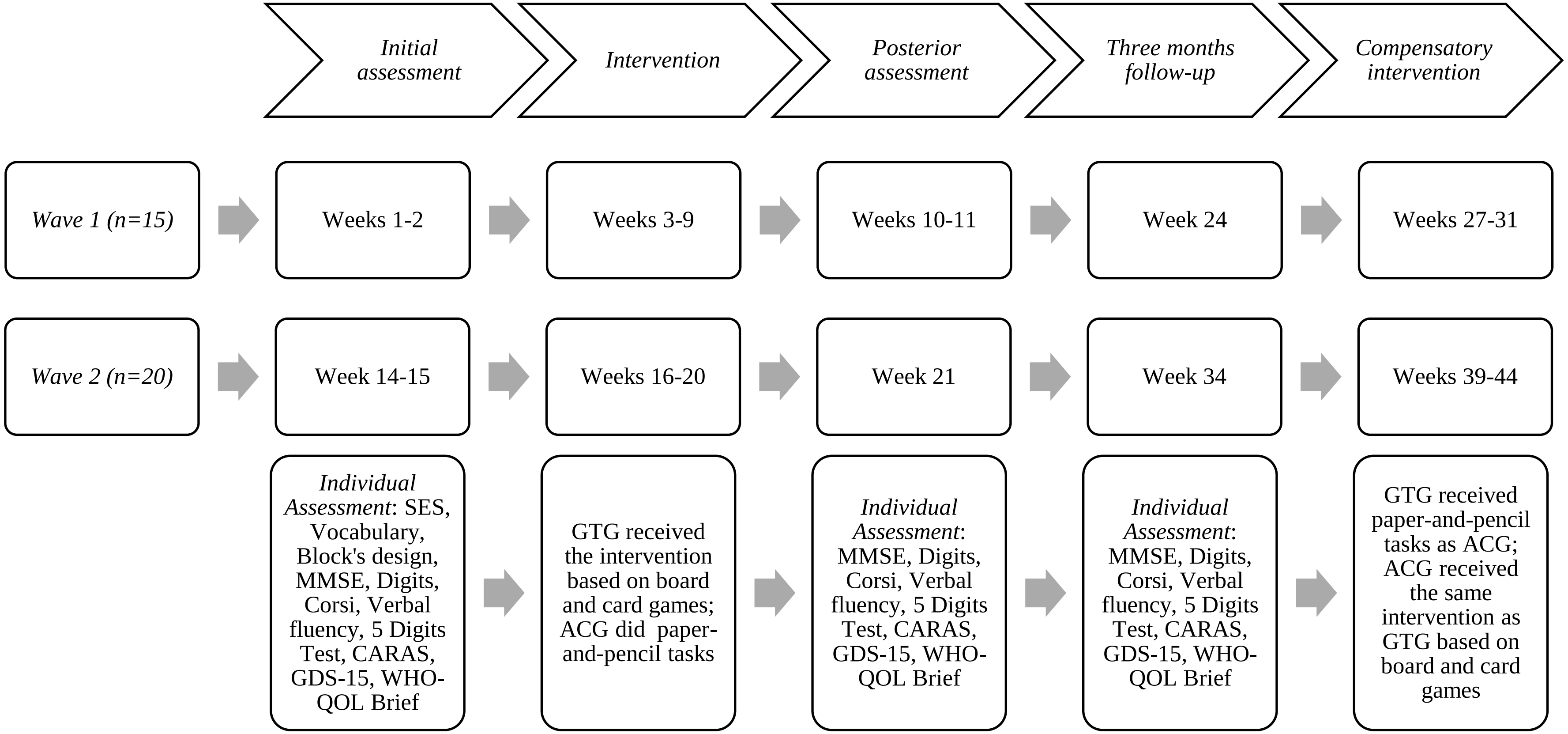
p<0.10= ^{t} , p<0.05=*; p<0.01=**; p<0.001=***. *d*< 0.20= trivial effect size; 0.20<*d*<0.50= small effect size; 0.50<*d*<0.80= medium effect size; *d*>0.80= large effect size.

†. We used non-parametric statistics - Friedman's F test- to analyze those variables that did not follow a normal distribution after being analyzed using Shapiro-Wilk.

‡. We used non-parametric statistics –Wilcoxon signed rank test - to analyze differences between phases.

Supplementary Figure 2

Time-line of the main study.



Note. MMSE= Mini-Mental State Examination; GDS=Geriatric Depression Scale; GTG=Game Training Group; ACG=Active Control Group

4. GLOBAL DISCUSSION OF THE RESULTS

4.1.General discussion

Firstly, the present dissertation aimed to review scientific literature to integrate the state-of-art of cognitive training based on board games. The second objective of the present dissertation was to increase scientific literature and to test if interventions based on filler and mainly modern board games were effective to improve WM, EFs, and other related processes in different age groups.

As we hypothesized, literature about cognitive training based on board games is scarce. Only 19 studies were found to study in the systematic review. Moreover, from these, only 12 studies were included in the meta-analysis. Many studies included preschool children, school children, and older people. A rational explanation is that these age groups could benefit more from cognitive training considering developmental patterns (Anguera & Gazzaley, 2015; Karbach et al., 2017). However, other age stages in which there would be quite development in the brain –such as adolescents (Poon, 2018)- lacks studies testing the potential of board games.

One of the main assumptions of this dissertation is that previous studies using cognitive training showed near transfer effects. In other words, it seems that it is possible improving or maintaining cognitive functions assessed with tasks that require the same cognitive domain but different from the used in cognitive training (Tajik-Parvinchi et al., 2014). Previous studies found near transfer both in children (Kassai, 2019; Melby-Lervåg et al., 2016) and older adults (Karbach & Verhaeghen, 2014). In the systematic review, we found that some of the studies showed near transfer effects after playing board games that theoretically boosted WM (i.e. Passolunghi & Costa, 2016), core EFs (i.e. (Benzing et al., 2019), and complex EFs (i.e. in planning (Demily et al., 2009) or reasoning (Bartolucci et al., 2019; Overman & Robbins, 2014)). These results were found beside the kind of board game used.

In addition, we partially confirmed the hypothesis of near transfer effects in the second section of the present dissertation. On the one hand, children with a diagnose of ADHD who received a visuospatial STM and Updating-WM training did not show any significant benefit in the untrained tasks within this domain (Study 3). On the other hand, school-age children who received the same visuospatial STM and Updating-WM training only showed a trend to significance in the non-trained visuospatial Updating-WM task (Study 2). Different given explanations could be behind these results. For example, Schwaighofer et al. (2015) concluded in their systematic review and meta-analysis that some moderators could influence the benefits of WM cognitive training. They concluded that near transfer is possible at different ages, but when WM is trained with tasks that require different modalities (e.g. verbal and visuospatial) larger effects could be yielded (multimodality principle). This conclusion has been supported in computerized WM training (Olesen et al., 2004). Furthermore, many of the studies included in the systematic review that found significant near transfer effects in WM used tasks that boosted both modalities (Kermani et al., 2016; Passolunghi & Costa, 2016). Thus, previous results seem to indicate that WM training including board games that boosted verbal and visuospatial domains yielded larger effects than single-domain training, as in Olesen et al. (2004). In addition, school-age children played in random small groups with other children who had the same age (Study 3). However, in the study that included children with ADHD (Study 2), small groups were formed with children of different ages (ranged from 8 to 12 years old). Overman & Robbins (2014) and Moro & Mezquita (2015) suggested that it is better to play with other players with similar levels to avoid being overwhelmed or bored. Hence, this also could explain mixed results.

When studying older people, we realized that we only found near transfer effects in verbal fluency. Some of the board games used in the cognitive training required verbal fluency. In addition, Elgamal et al. (2011) found that processing speed could explain improvements in verbal fluency. In the pilot study, we found an improvement in semantic verbal fluency and in processing speed when we analyzed only literate participants. In the main study, we found that people who did paper-and-pencil tasks reduce their reaction times in an inhibitory task and also increased phonemic verbal fluency after receiving the intervention. In the case of the cognitive training based on modern filler board games, could be possible that improvements in accuracy may explain longer improvements in verbal fluency tasks. Hence, maybe both improvements could be related.

Finally, dosage or frequency of sessions could explain near transfer improvements in children (Schwaighofer et al., 2015) and older people (Chiu et al., 2017). Bartolucci et al. (2019) suggested that a minimum of 26 hours are needed to show near transfer effects. Longer interventions could change these results.

Far transfer effects seem to be more difficult to achieve. A far transfer effect consists of an improvement beyond the trained domain. It is mainly generalization to other cognitive functions or even to everyday skills and academic performance. As Burch (2014) wrote: "*Doing something repeatedly can make you better at it, which is not the same as saying it makes you better*". Nonetheless, some studies reported small effects in some transfer effects at different ages (Bergman-Nutley & Klingberg, 2014; Karbach & Verhaeghen, 2014). How is it possible to reach these desired far transfer effects?

As Anguera & Gazzaley (2015) suggested, there are different factors related to the qualities of cognitive interventions that are worth considering. They suggested that understanding underlying game mechanics could explain results obtained in cognitive interventions. In addition, Vidovich & Almeida (2011) suggested that when gaining are translated into improvements in everyday life, the everyday activities are usually close and resemblance to the cognitive tasks used in the cognitive training. Unfortunately, not many of the systematic reviews focused on analyzing cognitive tasks and whose of them are used in cognitive trainings and those used to assess transfer effects. Although other factors can influence in the results obtained, it is important to stress that we follow this rational explanation in the three experimental studies. Our results yielded different benefits depending on the sample and other characteristics.

In this way, in Study 3 we found that children with a diagnose of ADHD who played board games improved behavioral problems (decreasing them) and verbal STM in comparison to a passive control group. One possible explanation is that all the modern filler board games required to follow established rules as well as to monitor and regulate appropriate social interaction with other participants. In addition, previous studies found an improvement in STM in children with ADHD (Rapport et al., 2013). Thus, an additive effect among the rules of the board games may have yielded significant results.

In school-aged children (Study 2), an analysis of the intervention could also explain the results obtained. In third grade, children who received the math-specific domain intervention showed greater improvements not only in arithmetic and order skills but also in both visuospatial STM and Updating-WM. In this training, children did arithmetic tasks in all the board games, and one of them directly trained visuospatial STM. Previous studies suggested that a combination of WM and math-specific domain interventions yield greater improvements than separated training programs (Sánchez-Pérez et al., 2018). Hence, in this intervention children were directly trained in STM and arithmetic skills, and indirectly trained in WM at doing arithmetic skills. In fourth grade, the participants who played memory board games improve in problem-solving with small effect sizes in comparison to doing standard mathematical lessons. As we concluded in this study, maybe one of the memory games used in the intervention was more similar than the math board games to the problem-solving task. In addition, maybe this memory intervention was more related to EFs needed to solve problem-solving (Sánchez-Pérez et al., 2018), but we did not assess other outcomes besides Updating-WM. Besides, Schwaighofer et al. (2015) suggest that maybe training narrow cognitive processes do not yield benefits in more complex activities (activity similarity hypothesis), such as mathematical tasks. However, cognitive functions could be substantially enhanced in more complex activity contexts. Thus, maybe complex and challenging contexts can enhance the benefits of transfer in STM and WM. In addition, mathematical and cognitive developmental patterns could modulate different results between third and fourth grades. Hence, it should be recommended to use mathematical board games, because they can improve both EFs and math skills. Finally, we cannot discard the fact that in both studies (Study 2 and 3), those groups that improved memory and math skills had a lower baseline. Hence, it is important to consider this moderator.

As we explained before about the study conducted in older people (Study 4), we found an improvement in the speed of performance in an inhibition task in the paper-and-pencil task intervention. We also found that accuracy in a control impulsivity task was maintained after playing modern and filler board games, but not in the control group (paper-and-pencil intervention). As we discussed in this study, in the paper-and-pencil task intervention, people had to change the instruction and inhibit the previous verbal command. In the cognitive training based on board games, finding the correct visual element to avoid penalization was required in many of them. All these games could have done that the participants received feedback about doing it correctly, as in the impulsivity control measures. In addition, Schwaighofer et al. (2015) concluded that training in which a person provides supervision and monitor (supervision principle) and a brief instruction of the task (ineffective instruction principle) could yield larger effects. These principles were achieved in both interventions. However, immediate and brief feedback (knowledge-results principle) was only achieved while people played the board games. These principles could explain the results of this study.

Therefore, it seems that achieving transfer depends on the degree of overlap between trained tasks and outcome tasks (Aksayli et al., 2019). From another perspective, Karbach & Kray (2021) hypothesized that finding far transfer in other EFs different from the trained ones could be based on the model of EFs. Hence, they suggested that the generalization of training gains in one EF does not necessarily result in benefits in another EF. However, the transfer could depend on the degree of domain-specific overlap, not only at a processing level but also at a neural level. As Karbach & Kray (2021) said: "*the more shared resources, the more likely the transfer should be*". As Taatgen (2020) concluded in his theory of transfer effects in cognitive training, the generalization in other tasks could be explained by the small or large overlap between tasks, but this overlap has to be critical in determining a difference in performance. For example, according to this theory, separate specific tasks with some commonalities could explain transfer effects. All of these are interesting points of view that could explain transfer results from the present dissertation: the improvements in verbal STM and the reduction in behavioral problems in children with ADHD (Study 3), the improvement in math and memory skills in school-age children and the improvement in verbal fluency (Study 2), inhibition and impulsivity control in older people (Study 4). All these trainings include a determining overlap of these outcomes in the different board games. Boosting –direct or indirectly- the same specific domain through different tasks could explain transfer effects ("*high-task variability*") (Fissler et al., 2013; Taatgen, 2021). To conclude, it seems that to increase the benefits of transfer effects, cognitive interventions should be: i) trained with other people (in pairs or in a group); ii) to plan multi-domain interventions and; iii) to include a variety of challenging, adaptive and motivational tasks within each domain (Fissler et al., 2013; Lampit et al., 2014).

Finally, regarding long-term effects, we conducted follow-up assessments in the study of children with ADHD (Study 3) and older people (Study 4) after 4 and 12 weeks, respectively. We did not find significant long-term effects in ADHD. However, in older people, we found that the game training group maintained their improvement in phonemic verbal fluency in comparison to the group who did paper-and-pencil tasks. This is according to the other studies included in the systematic review which conducted follow-up assessments (Cheng et al., 2006; Scalise et al., 2020).

4.2. Limitations of the studies

The present dissertation, which is structured in different studies, has limitations according to the singularities of each paper. For instance, the main limitation of the systematic review is the variety in methodologies, neuropsychological tests, and the reduced number of studies included. All of these aspects make it difficult to select homogeneous studies to conduct a meta-analysis. Hence, the results and conclusions from the systematic review should be taken with caution. As we concluded in the systematic review, future studies should follow well-conducted randomized control trials (RCTs) designs. In addition, we did not find any study with adolescents and only 2 in adults, but no one in young adults. Future studies should focus on these ages to see the impact of cognitive interventions based on board games. In addition, the studies included in the review with children samples focused on specific grades. Considering mixed results in the study in children from grades 3 and 4, future studies should focus on different grades to see if the impact of cognitive interventions based on board games is different considering developmental patterns. Moreover, most of the studies included traditional board games or board games created *ad hoc* by researchers. Hence, future studies should include mass market and modern board games.

The main limitations of the studies included in section 2 concerning methodological issues or sample sizes. We used a quasi-experimental design in Study 2. Although we found transfer effects to memory and mathematical outcomes, imitations in the internal validity of the study questioned our conclusions (Schmiedek, 2021). Both groups that received the interventions were comparable in baseline because they were randomly assigned and differences between these groups were more reliable. Hence, the control group was non-randomly assigned and had greater baseline scores in many of the outcomes assessed. It led us to see if filler board games can be a complementary tool in educative contexts and if these interventions allow students with lower number operation skills to achieve expected results for their age. Hence, future studies should conduct the best methodological design –the *gold standard* – in intervention studies: randomized controlled trials (RCTs) (Schmiedek, 2021). However, individual RCT –to assign each person to each condition- may be more difficult in educative settings, primarily to struggle blinding procedures due to practical reasons, among other considerations (Perman, 2017). Thus, it is interesting the usage of cluster RCTs in natural contexts: assigning a group of individuals that share some characteristics rather than individuals (Perman, 2017). In this study, we only measured STM and Updating-WM, but we did not measure other EFs (i.e. inhibition or planning). This fact limited to provide support to the explanation of the transfer in problem-solving.

In the other two studies included in the dissertation, we used RCTs designs and measured different EFs because we considered that it would be better not to threaten internal validity and to reach more reliable conclusions (Schmiedek, 2021). Despite this design, other limitations need to be into account. In the case of the study with children of

ADHD (Study 3), we compare the group who played modern filler board games to a wait-list passive group. Some meta-analytic studies found that comparing a cognitive training intervention to an active or passive control group could change the results (Melby-Lervåg et al., 2016; Rapport et al., 2013). Thus, we should include an active control group to see whether conduct problems are also reduced or not. Finally, in the study with older people (Study 4), we conducted an individual RCT with an active control group. However, we did not include a passive control group as other authors have done (Passolunghi & Costa, 2016). In addition, higher samples and preclinical registration of RCTs are needed in future studies (Schmiedek, 2021). Schmiedek (2020) also considers that the usage of single tasks as outcome measures are associated with certain deficits. Regarding EFs, it is largely accepted that tasks do not assess "*pure*" cognitive processes, but they can involve other processes. This is called "*task impurity*" (Friedman et al., 2011; Snyder et al., 2015). As a limitation, we measured each outcome with only one task.

Taking into account all the limitations above, we need to make more research in other samples as well as other contexts to achieve external generalizability. It is also necessary to do more research with well-conducted RCTs and bigger samples to reach internal generalizability. To conclude, more research is needed to overcome such limitations.

4.3. Future research studies

As Anguera & Gazzaley (2015) suggest, there are different external factors to the participants but related to the qualities of the cognitive intervention that are worth taking into account (i.e. motivation and game mechanics). These authors considered that the role of fun and motivation were fundamental to enhance benefits in cognition. In the study of a sample of older people (Study 4), we found that most of the participants scored the intervention as funny and would repeat it. Although we did not have a similar measure in studies with children, the attendance in the sessions was high in both interventions. Thus, future interventions should measure motivation and fun in the intervention to explain the results obtained. Interestingly, Anguera & Gazzaley (2015) also suggested that future studies should investigate the effects of fun and motivation in cognitive interventions. Thus, it would be interesting to compare groups playing board games with and without a cognitive boost, but applying a similar degree of fun in both interventions. As Schmiedek (2020) suggests, "*active*" control conditions need to be designed, which is a great challenge in cognitive training based on board games. In addition, some board games included in the systematic review were created by researchers. In the literature, "*broccoli covered of chocolate*" consisted of the creation of games focused on the improvement of some psychological characteristics, forgetting the importance of the aesthetic and engagement of the game (Gielis et al., *in press*). Hence, this effect implies that creating games to intervene could decrease the interest in the purpose of playing. In line with the study of motivation in cognitive training, future studies should also focus on these features of cognitive training at comparing board games created by researchers and those created by game designers to test which elements increase motivation and fun.

Regarding game mechanics, we understand mechanics of a game as those components, rules, or systems that facilitate and encourage the player to interact with the game -which is known as dynamics- and this evokes desirable emotional responses in the player –which is known as the aesthetic component of the board game- (Bartolucci et al., 2019; Hunicke et al., 2004). Traditional and mass-market board games usually do not innovate in their mechanics. In the case of the traditional ones, usually include abstract and strategic mechanics, whereas mass-market board games usually include a high rate of randomness (Bartolucci et al., 2019). Hence, innovative mechanics is one of the features that differ between modern board games and traditional or mass-market ones

(Sousa & Bernardo, 2019). In the systematic review, we included all the kinds of board games. However, we did not find any research that compared results between them. Thus, future studies should compare traditional and modern board games with similar mechanics to see if the aesthetic component of board games could influence the benefits of cognitive training. Board games can also be different taking into account the length and complexity (Bartolucci et al., 2019) Unlike the systematic review, in the experimental studies all the filler board games were modern (with one exception). Hence, although the majority of filler board games are modern, there also exist some traditional filler board games. In addition, Fissler et al. (2013) suggested that high task variability training could increase the improvements. However, other authors suggested that the complexity of activities could yield larger results (Schwaighofer et al., 2015). Both points of view are supported from the conclusions of the studies included in this dissertation: i) from the systematic review, cognitive training based on traditional board games that usually require higher-level EFs have shown some improvements despite the repetition of the same task, and ii) the training of the same cognitive domain through different tasks could explain the results obtained in the experimental studies. In this sense, different studies should be conducted considering both factors: i) compare longer traditional board games to longer modern board games (i.e. *Eurogames*) which require similar complex cognitive processes with a low-task variability; ii) compare traditional and filler board games to modern and filler board games which require similar core cognitive processes but with a high-task variability, iii) compare the four groups above mentioned to see the role of task-variability and aesthetical component and, iv) compare longer modern board games (i.e. *Eurogames*) –low-task variability- that boost higher-level EFs to filler modern board games –high-task variability- that boost core EFs to see the direction of vertical transfer. Furthermore, some studies suggest that train core and higher-level EFs could enhance the benefits on these outcomes (García-Madruga et al., 2016). Future studies similar to Bartolucci et al. (2019) should be conducted to clear this hypothesis.

In addition, all of the studies included in the present dissertation were competitive board games. Interestingly, Decety et al. (2004) suggested that cooperative video games could produce gains in hot EFs. Hence, there exist different types of mechanics that could influence the results of EFs in experimental studies. Future studies should compare other different dynamics to see their impact on cognitive benefits, as in video games (Özçetin et al., 2019).

Other authors explained the benefits of cognitive training focusing on internal characteristics of the players –baseline, age, diagnoses, among others- instead of focusing on external factors of the players (von Bastian & Oberauer, 2014). Karbach et al. (2017) found that children and older people benefit more than young adults with cognitive training. Considering the samples included in the present dissertation, future studies should include adolescent and adult samples. Furthermore, as Bartolucci et al. (2019) suggested, it would be interesting to use the same cognitive intervention based on modern board games to see how much these results can be achieved in different age groups, as in the study of Karbach et al. (2017). In addition, Karbach et al. (2017) also found that people with lower baseline scores yield greater benefits. Schwaighofer et al. (2015) speculated with the hypothesis that impaired cognitive functions could be improved at training specific cognitive functions, but for people with normal cognitive functioning, such training may not yield relevant benefits. There is a debate about if lower –Compensation effect- or higher –Matthew effect- baseline scores yield greater benefits (von Bastian & Oberauer, 2014). In the study of children with ADHD (Study 3) the only outcome that showed a tendency towards significance in baseline was verbal short-term memory. In the study of school-aged children, both groups that played board games started from lower scores in arithmetic skills. Hence, the studies conducted on children favored more the compensation effect hypothesis. However, future studies should explore if lower baseline scores and impaired cognitive functions could explain larger improvements in cognitive processes.

Related to transfer effects, it is important to highlight the need for a theoretical framework, as in (Taatgen, 2021). Schmiedek (2020) suggested that it is better to talk about narrow/specific or broad/general transfer rather than near or far transfer. However, it is important to differentiate this new nomenclature of transfer from specific and general domain interventions (Johann & Karbach, 2021). Also, it is important to consider which tasks are used to explain transfer effects in EFs and other cognitive processes related based on their similarity. Some questions arise from board games that can be commercialized: How can be sure that one board game boost cognition? Which board games are better to include in cognitive trainings to reach transfer effects? These perspective has been adopted from video games. For instance, Quiroga et al. (2015; 2019) found that high correlations between commercial video games from diverse genres and intelligence tasks using latent variable analysis. This conclusion led to open the door to not only use games to intervene, but also to assess cognitive functions. Mondéjar et al. (2016) also analyzed EFs required in broad mechanics of video games. Interestingly, these authors used electrophysiological measures. Some authors have adopted this design with traditional board games (Atherton et al., 2003; Chen et al., 2003) and other games developed to improve STEM skills (Newman et al., 2016). Other authors used longitudinal studies to see if commercial video games predict problem-solving in the future and this relation predicted future school achievement (Adachi & Willoughby, 2013) or correlate performance in a new gamified cognitive task to the performance in a non-gamified cognitive task. Related to modern board games, we only found one master thesis that aimed to study if these games were related to cognitive processes (Planelles Ferrer, 2015). This issue should be widely researched to solve contradictory results in transfer effects and maybe use board games as an element to include in the assessment of EFs.

Bearing in mind the comparison between analog and digital cognitive training, board games could have more social benefits than individual computerized cognitive training. Iizuka et al. (2019) found that playing the Go game in pairs enhances cognitive benefits more than playing individually through a tablet device. In addition, we found that children diagnosed with ADHD may clinically reduce problem behavior (Study 3). However, as Granic et al. (2014) concluded in their review, some video games –multi-player online, cooperative, etc.- could boost and improve prosocial behavior because they are played with other people. Therefore, future studies should compare cognitive training based on board games and video games/computerized tasks played alone or with other people to see if they differ in cognitive and social benefits. Bartolucci et al. (2019) describe that playing digital versions of board games "*drastic change in strategies caused by the absence of face-to-face playing*". The study of the transformation of analogic to digital board games is being developed by Rogerson et al. (2015). Looking at the future, it would be interesting to study if applying cognitive training based on board games streamed online have the same benefits as playing in vivo. Moreover, this could be interesting considering the lockdown measures adopted in the pandemic originated by the virus COVID-19 and to mitigate the possible psychological impairments and social isolation (Ingram et al., 2021).

Assessment and measurement of EFs constitute another aspect to take into account for future research. Regarding the measurement of EFs, future studies should include different tasks of each cognitive process to reduce the problem of *task impurity*

(Friedman et al., 2011; Snyder et al., 2015) and to capture common variance of the tasks (Schmiedek, 2021). Moreover, conclusions about the development of EFs could change considering changes in the tasks. For instance, Ling et al. (2021) found that 3-old children could succeed in DCCS tasks, contrary to what was believed. Thus, we need to highlight the importance of creating an EFs model including developmental changes and to consider the difficulty in tasks (Doebel & Zelazo, 2015). This development model should not only allow investigating the structure of core and complex EFs, but also the relation between EFs to other cognitive and non-cognitive outcomes (i.e. math skills) across the lifespan. Future studies should conduct longitudinal studies tracking within-subject changes in cognitive processes, strategies, brain structure, and brain function (Crone et al., 2006). For that reason, future studies should also measure neural changes, as in Iizuka et al. (2020). Regarding longitudinal studies, Burch (2014) and Schmiedek (2020), conclude that relatively little is known about the maintenance and long-term effects of cognitive training. This author suggests that the combination of training interventions and longitudinal studies would be desirable to assess the long-term effects of cognitive training. In addition, future studies should clear the minimal duration of each training session and the minimal training dose to yield transfer effects.

Strobach & Karbach (2020) said in the prologue of their book about the state-of-art of cognitive training that the first publication about cognitive training dates back 50 years. In addition, these authors agree on we are in the first era of cognitive training, characterized by heterogeneity and a lack of a theoretical model. As Vladisauskas & Goldin (2020) explained, we do not already know the impact of acute and chronic interventions, the frequency or length of sessions, the durability of the observed gains, the impact of motivation, or precise definitions of transfer. Many questions remain unclear about the generalizability to the untrained tasks and neural underpinnings. In addition, other studies focused on individual characteristics to check if baseline level, age, or vulnerability level could impact transfer effects. This makes it more complex to extract reliable conclusions. Future studies should focus not only on the study of efficacy and effectiveness of cognitive training based on board games but also in maximize transfer effects at understanding which features of training moderate the benefits (Karbach & Kray, 2021) as in Cella & Wikes (2017). This also will help to explain discrepancies between results of future studies.

If this is the situation of cognitive training, the state-of-art of cognitive training based on board games is still less developed. The present dissertation was made considering plausible theoretical explanations and prior hypotheses. Despite the mentioned limitations and the current context of cognitive training in research, this dissertation provides more evidence in the role of board games as tools to include in cognitive training. This is just a taste of what is to come.

5. FINAL CONCLUSIONS

The results of the studies provide new evidence about cognitive training based on filler board games. Overall, the main conclusions are:

1. The usage of cognitive training based on board games can be recommended in children, children with a diagnose of ADHD/learning disabilities, and older people. Some cognitive processes can be trained independently of age, specially verbal short-term memory in school-age children.
2. The most studied board games are traditional or designed *ad hoc*. There is little evidence about mass-market or modern board games. Filler board games are also studied to a lesser degree.
3. The more similar the assessment and intervention tasks, the greater transfer effects. In addition, sharing general components in different specific tasks (high-variability tasks) and complex contexts could improve transfer to specific and general domains.
4. A combination of math-specific and WM-general domain interventions can improve these processes. Concretely, the usage of board games that train math and WM can be recommended as a complementary tool to usual educative practices in math lessons, specially in third grade. Developmental patterns can explain differences between third and fourth grade.
5. Children with a diagnose of ADHD who received a short cognitive training intervention based on modern board games can improved behavioral problems. It seems that they also improved verbal STM.
6. Healthy older people can improve in the short-term their phonemic and semantic verbal fluency through cognitive interventions based on board games and paper-and-pencil tasks. Furthermore, healthy older people can maintain in the short and long term their phonemic verbal fluency.

7. Healthy older people can improve their speed in an inhibitory task after receiving an intervention based on paper-and-pencil tasks. One possible explanation is that this gain in inhibition is linked to the previous verbal commands. Healthy older people can maintain their control of impulsivity after receiving cognitive training based on modern board games may be due to inherent feedback in board games.
8. New hypotheses could explain the results above. Hence, future well-conduct randomized controlled trial designs are needed.

6. REFERENCES

Adachi, P. J. C., & Willoughby, T. (2013). More Than Just Fun and Games: The Longitudinal Relationships Between Strategic Video Games, Self-Reported Problem Solving Skills, and Academic Grades. *Journal of Youth and Adolescence*, *42*(7), 1041–1052. https://doi.org/10.1007/s10964-013-9913-9

Aguirre, E., Woods, R. T., Spector, A., & Orrell, M. (2013). Cognitive stimulation for dementia: A systematic review of the evidence of effectiveness from randomised controlled trials. *Ageing Research Reviews*, *12*(1), 253–262. https://doi.org/10.1016/j.arr.2012.07.001

Aita, S. L., Beach, J. D., Taylor, S. E., Borgogna, N. C., Harrell, M. N., & Hill, B. D. (2019). Executive, language, or both? An examination of the construct validity of verbal fluency measures. *Applied Neuropsychology:Adult*, *26*(5), 441–451. https://doi.org/10.1080/23279095.2018.1439830

Aksayli, N. D., Sala, G., & Gobet, F. (2019). The cognitive and academic benefits of Cogmed: A meta-analysis. *Educational Research Review*, *27*, 229–243. https://doi.org/10.1016/j.edurev.2019.04.003

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and Visuospatial Short-Term and Working Memory in Children: Are They Separable? *Child Development*, *77*(6), 1698–1716. https://doi.org/10.1111/j.1467-8624.2006.00968.x

Altschul, D. M., & Deary, I. J. (2020). Playing Analog Games Is Associated with Reduced Declines in Cognitive Function: A 68-Year Longitudinal Cohort Study. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *75*(3), 474–482. https://doi.org/10.1093/geronb/gbz149

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Anguera, J. A., & Gazzaley, A. (2015). Video games, cognitive exercises, and the enhancement of cognitive abilities. *Current Opinion in Behavioral Sciences*, *4*, 160–165. https://doi.org/10.1016/j.cobeha.2015.06.002

Atherton, M., Zhuang, J., Bart, W. M., Hu, X., & He, S. (2003). A functional MRI study of high-level cognition. I. The game of chess. *Cognitive Brain Research*, *16*(1), 26–31. https://doi.org/10.1016/S0926-6410(02)00207-0

Au, J., Sheehan, E., Tsai, N., Duncan, G. J., Buschkuehl, M., & Jaeggi, S. M. (2015). Improving fluid intelligence with training on working memory: a meta-analysis. *Psychonomic Bulletin and Review*, *22*(2), 366–377. https://doi.org/10.3758/s13423-014-0699-x

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience*, *4*(10), 829–839. https://doi.org/10.1038/nrn1201

Baddeley, A. (2010). *Working memory*. *20*(4), 136–140.

Baddeley, A. (2012). Working Memory : Theories , Models , and Controversies. *Annual Review of Psychology*, *63*, 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Baddeley, A., & Hitch, G. (1974). The social design of virtual worlds: constructing the user and community through code. *Medical Research Council*, 47–88.

Baggetta, P., & Alexander, P. A. (2016a). *Conceptualization and Operationalization of Executive Function*. *10*(1), 10–33.

Baggetta, P., & Alexander, P. A. (2016b). Conceptualization and Operationalization of Executive Function. *Mind, Brain, and Education*, *10*(1), 10–33. https://doi.org/10.1111/mbe.12100

Bahar-fuchs, A., Clare, L., & Woods, B. (2013). Cognitive training and cognitive rehabilitation for persons with mild to moderate dementia of the Alzheimer ' s or vascular type : a review. *Alzheimer's Research & Therapy*, *5*(35).

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences*, *1118*, 122–141. https://doi.org/10.1196/annals.1412.011

Barker, J. E., Semenov, A. D., Michaelson, L., Provan, L. S., Snyder, H. R., & Munakata, Y. (2014). Less-structured time in children's daily lives predicts self-directed executive functioning. *Frontiers in Psychology*, *5*, 1–16. https://doi.org/10.3389/fpsyg.2014.00593

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin*, *128*(4), 612–637. https://doi.org/10.1037/0033-2909.128.4.612

Bartolucci, M., Mattioli, F., & Batini, F. (2019). Do board games make people smarter? Two initial exploratory studies. *International Journal of Game-Based Learning*, *9*(4), 1–14. https://doi.org/10.4018/IJGBL.2019100101

Bastian, C. C. Von, & Druey, M. D. (2017). Shifting Between Mental Sets: An Individual Differences Approach to Commonalities and Differences of Task Switching Components. *Journal of Experimental Psychology: General*, *146*(9), 1266–1285. https://doi.org/10.1037/xge0000333.supp

Becker, N., Piccolo, L. R., & Salles, J. F. (2019). Verbal Fluency Development across Childhood: Normative Data from Brazilian-Portuguese Speakers and Underlying Cognitive Processes. *Archives of Clinical Neuropsychology*, *34*(7), 1217–1231. https://doi.org/10.1093/arclin/acz022

Bennett, I. J., & Madden, D. J. (2014). Disconnected aging: Cerebral white matter integrity and age-related differences in cognition. *Neuroscience*, *276*, 187–205. https://doi.org/10.1016/j.neuroscience.2013.11.026

Benzing, V., Schmidt, M., Jäger, K., Egger, F., Conzelmann, A., & Roebers, C. M. (2019). A classroom intervention to improve executive functions in late primary school children: Too ‘old’ for improvements? *British Journal of Educational Psychology*, *89*(2), 225–238. https://doi.org/10.1111/bjep.12232

Bergman-Nutley, S., & Klingberg, T. (2014). Effect of working memory training on working memory , arithmetic and following instructions. *Psychological Res*, *78*, 869–877. https://doi.org/10.1007/s00426-014-0614-0

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences*, *21*(4), 327–336. https://doi.org/10.1016/j.lindif.2011.01.007

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, *8*(1), 36–41. https://doi.org/10.1111/cdep.12059

Bunge, S. A., & Zelazo, P. D. (2006). A brain-based account of the development of rule use in childhood. *Current Directions in Psychological Science*, *15*(3), 118–121. https://doi.org/10.1111/j.0963-7214.2006.00419.x

Burch, D. (2014). What Could Computerized Brain Training Learn from Evidence-Based Medicine? *PLoS Medicine*, *11*(11), 1–2. https://doi.org/10.1371/journal.pmed.1001758

Cella, M., & Wykes, T. (2019). The nuts and bolts of Cognitive Remediation: Exploring how different training components relate to cognitive and functional gains. *Schizophrenia Research 203*, 12-15. https://doi.org/10.1016/j.schres.2017.09.012

Chen, X., Zhang, D., Zhang, X., Li, Z., Meng, X., He, S., & Hu, X. (2003). A functional MRI study of high-level cognition: II. The game of GO. *Cognitive Brain Research*, *16*(1), 32–37. https://doi.org/10.1016/S0926-6410(02)00206-9

Cheng, S. T., Chan, A. C. M., & Yu, E. C. S. (2006). An exploratory study of the effect of mahjong on the cognitive functioning of persons with dementia. *International Journal of Geriatric Psychiatry*, *21*(7), 611–617. https://doi.org/10.1002/gps.1531

Ching-Teng, Y. (2019). Effect of board game activities on cognitive function improvement among older adults in adult day care centers. *Social Work in Health Care*, *58*(9), 825–838. https://doi.org/10.1080/00981389.2019.1656143

Chiu, H.-L., Chu, H., Tsai, J.-C., Liu, D., Chen, Y.-R., Yang, H.-L., & Chou, K.-R. (2017). The effect of cognitive-based training for the healthy older people: A meta-analysis of randomized controlled trials. *Plos One*, *12*(5), e0176742. https://doi.org/10.1371/journal.pone.0176742

Cortés Pascual, A., Moyano Muñoz, N., & Quílez Robres, A. (2019). The Relationship Between Executive Functions and Academic Performance in Primary Education: Review and Meta-Analysis. *Frontiers in Psychology*, *10*, 1–18. https://doi.org/10.3389/fpsyg.2019.01582

Cristofori, I., Cohen-Zimerman, S., & Grafman, J. (2019). Executive functions. In M. D'Esposito & J. H. Grafman (Eds.), *Handbook of Clinical Neurology: The Frontal Lobes* (1st ed., Vol. 163, pp. 197–219). Elsevier B.V. https://doi.org/10.1016/B978-0-12-804281-6.00011-2

Crone, E. A., Donohue, S. E., Honomichl, R., Wendelken, C., & Bunge, S. A. (2006). Brain regions mediating flexible rule use during development. *Journal of Neuroscience*, *26*(43), 11239–11247. https://doi.org/10.1523/JNEUROSCI.2165-06.2006

Cuevas, K., Rajan, V., & Bryant, L. J. (2018). Emergence of Executive Function in Infancy. In S. A. Wiebe & J. Karbach (Eds.), *Executive Function: Development across the lifespan*. Routledge.

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences*, *38*(9), 571–578. https://doi.org/10.1016/j.tins.2015.07.003

Dartigues, J. F., Foubert-Samier, A., Le Goff, M., Viltard, M., Amieva, H., Orgogozo, J. M., Barberger-Gateau, P., & Helmer, C. (2013). Playing board games, cognitive decline and dementia: A French population-based cohort study. *BMJ Open*, *3*(8), 1–7. https://doi.org/10.1136/bmjopen-2013-002998

Decety, J., Jackson, P. L., Sommerville, J. A., Chaminade, T., & Meltzoff, A. N. (2004). The neural bases of cooperation and competition: An fMRI investigation. *NeuroImage*, *23*(2), 744–751. https://doi.org/10.1016/j.neuroimage.2004.05.025

Demily, C., Cavézian, C., Desmurget, M., Berquand-Merle, M., Chambon, V., & Franck, N. (2009). The game of chess enhances cognitive abilities in schizophrenia. *Schizophrenia Research*, *107*(1), 112–113. https://doi.org/10.1016/j.schres.2008.09.024

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions Shown to Aid Executive Function Development in Children 4 to 12 Years Old. *Science*, *333*(6045), 959–964. https://doi.org/10.1126/science.1204529.Interventions

Doebel, S., & Zelazo, P. D. (2015). A meta-analysis of the Dimensional Change Card Sort: Implications for developmental theories and the measurement of executive function in children. *Developmental Review*, *38*, 241–268. https://doi.org/10.1016/j.dr.2015.09.001

Duan, X., Liao, W., Liang, D., Qiu, L., Gao, Q., Liu, C., Gong, Q., & Chen, H. (2012). Large-scale brain networks in board game experts: Insights from a domain-related task and task-free resting state. *PLoS ONE*, *7*(3), 1–11. https://doi.org/10.1371/journal.pone.0032532

Duan, X., Long, Z., Chen, H., Liang, D., Qiu, L., Huang, X., Liu, T. C. Y., & Gong, Q. (2014). Functional organization of intrinsic connectivity networks in Chinese-chess experts. *Brain Research*, *1558*, 33–43. https://doi.org/10.1016/j.brainres.2014.02.033

Eakin, L., Minde, K., Hechtman, L., Ochs, E., Krane, E., Bouffard, R., Greenfield, B., & Looper, K. (2004). The marital and family functioning of adults with ADHD and their spouses. *Journal of Attention Disorders*, *8*(1), 1–10. https://doi.org/10.1177/108705470400800101

Elgamal, S. A., Roy, E. A., & Sharratt, M. T. (2011). Age and verbal fluency: The mediating effect of speed of processing. *Canadian Geriatrics Journal*, *14*(3), 66–72. https://doi.org/10.5770/cgj.v14i3.17

Fair, D. A., Cohen, A. L., Power, J. D., Dosenbach, N. U. F., Church, J. A., Miezin, F. M., Schlaggar, B. L., & Petersen, S. E. (2009). Functional brain networks develop from a “local to distributed” organization. *PLoS Computational Biology*, *5*(5), 14–23. https://doi.org/10.1371/journal.pcbi.1000381

Ferguson, H. J., Brunsdon, V. E. A., & Bradford, E. E. F. (2021). The developmental trajectories of executive function from adolescence to old age. *Scientific Reports*, *11*(1), 1–17. https://doi.org/10.1038/s41598-020-80866-1

Fiske, A., & Holmboe, K. (2019). Neural substrates of early executive function development. *Developmental Review*, *52*, 42–62. https://doi.org/10.1016/j.dr.2019.100866

Fissler, P., Küster, O. C., Laptinskaya, D., Loy, L. S., von Arnim, C. A. F., & Kolassa, I.-T. (2018). Jigsaw Puzzling Taps Multiple Cognitive Abilities and Is a Potential

Protective Factor for Cognitive Aging. *Frontiers in Aging Neuroscience*, *10*, 1–11. https://doi.org/10.3389/fnagi.2018.00299

Fissler, P., Küster, O., Schlee, W., & Kolassa, I. T. (2013). Novelty interventions to enhance broad cognitive abilities and prevent dementia: Synergistic approaches for the facilitation of positive plastic change. In M. M. Merzenich, M. Nahum, & T. M. Van Vleet (Eds.), *Changing Brains Applying Brain Plasticity to Advance and Recover Human Ability* (Vol. 207, pp. 403–434). Elsevier B.V. https://doi.org/10.1016/B978-0-444-63327-9.00017-5

Foy, J. G., & Mann, V. A. (2013). Executive function and early reading skills. *Reading and Writing*, *26*(3), 453–472. https://doi.org/10.1007/s11145-012-9376-5

Friedman, N. P., & Miyake, A. (2004). *The Relations Among Inhibition and Interference Control Functions : A Latent-Variable Analysis*. *133*(1), 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Friedman, N. P., Miyake, A., Robinson, J. L., & Hewitt, J. K. (2011). Developmental Trajectories in Toddlers' Self-restraint Predict Individual Differences in Executive Functions 14 Years Later: A Behavioral Genetic Analysis. *Developmental Psychology*, *47*(5), 1410–1430. https://doi.org/10.1037/a0023750.Developmental

Friso-van den Bos, I., van der Ven, S. H. G., Kroesbergen, E. H., & van Luit, J. E. H. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review*, *10*, 29–44. https://doi.org/10.1016/j.edurev.2013.05.003

García-Madruga, J. A., Gómez-Veiga, I., & Vila, J. Ó. (2016). Executive Functions and the Improvement of Thinking Abilities: The Intervention in Reading Comprehension. *Frontiers in Psychology*, *7*, 1–15. https://doi.org/10.3389/fpsyg.2016.00058

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive Function in Preschoolers: A Review Using an Integrative Framework. *Psychological Bulletin*, *134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gauthier, A., Kato, P. M., Bul, K. C. M., Dunwell, I., Walker-Clarke, A., & Lameras, P. (2019). Board Games for Health: A Systematic Literature Review and Meta-Analysis. *Games for Health Journal*, *8*(2), 85–100. https://doi.org/10.1089/g4h.2018.0017

Gibb, R., & Kovalchuk, A. (2018). Brain Development. In R. Gibb & B. Kolb (Eds.), *The Neurobiology of Brain and Behavioral Development* (pp. 3–27). Elsevier. https://doi.org/10.1016/B978-0-12-804036-2.00001-7

Gielis, K., De Croon, R., Dierick, P., Brito, F., Assche, V., Tournoy, J., & Vanden Abeele, V. (n.d.). An Expert Consensus Study on the Validity of Card Games to Assess Mild Cognitive Impairment. *Journal of Medical Internet Research*. https://doi.org/10.2196/preprints.18359

Gobet, Fernand, de Voogt, A., & Retschitzki, J. (2004). Introduction. In F. Gobet, J. Retschitzki, & A. de Voogt (Eds.), *Moves in mind: The Psychology of Board Games The psychology of board games.* Psychology Press.

Gonzalez-Burgos, L., Hernández-Cabrera, J. A., Westman, E., Barroso, J., & Ferreira, D. (2019). Cognitive compensatory mechanisms in normal aging: A study on verbal fluency and the contribution of other cognitive functions. *Aging*, *11*(12), 4090–4106. https://doi.org/10.18632/aging.102040

Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist*, *69*(1), 66–78. https://doi.org/10.1037/a0034857

Guo, Q., Zhou, T., Li, W., Dong, L., Wang, S., & Zou, L. (2017). Single-trial EEG-informed fMRI analysis of emotional decision problems in hot executive function.

Brain and Behavior, *7*(7), 1–9. https://doi.org/10.1002/brb3.728

Hajek, T., Alda, M., Hajek, E., & Ivanoff, J. (2013). Functional neuroanatomy of response inhibition in bipolar disorders - Combined voxel based and cognitive performance meta-analysis. *Journal of Psychiatric Research*, *47*(12), 1955–1966. https://doi.org/10.1016/j.jpsychires.2013.08.015

Hall, P. A., Fong, G. T., Epp, L. J., & Elias, L. J. (2008). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology and Health*, *23*(3), 309–326. https://doi.org/10.1080/14768320701212099

Hartshorne, J. K., & Germine, L. T. (2016). When does cognitive functioning peak? The asynchronous rise and fall of different cognitive abilities across the lifespan. *Psychological Science*, *26*(4), 433–443. https://doi.org/10.1177/0956797614567339.When

Henry, J. D., & Crawford, J. R. (2004). A Meta-Analytic Review of Verbal Fluency Performance Following Focal Cortical Lesions. *Neuropsychology*, *18*(2), 284–295. https://doi.org/10.1037/0894-4105.18.2.284

Henry, L. (2011). The Working Memory Model. In L. Henry (Ed.), *The development of Working Memory in Children* (pp. 1–36). Sage pub.

Homer, B. D., Plass, J. L., Rose, M. C., MacNamara, A. P., Pawar, S., & Ober, T. M. (2019). Activating adolescents' "hot" executive functions in a digital game to train cognitive skills: The effects of age and prior abilities. *Cognitive Development*, *49*(October 2018), 20–32. https://doi.org/10.1016/j.cogdev.2018.11.005

Howard, S. J., Johnson, J., & Pascual-Leone, J. (2014). Clarifying inhibitory control: Diversity and development of attentional inhibition. *Cognitive Development*, *31*(1), 1–21. https://doi.org/10.1016/j.cogdev.2014.03.001

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017–2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Hunicke, R., Leblanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. *Proceedings of the Challenges in Games AI Workshop, Nineteenth National Conference of Artificial Intelligence, Held in San José, California, July 25-29, 2004*, 1–5. https://users.cs.northwestern.edu/~hunicke/MDA.pdf#:~:text=MDA is a formal approach to understanding games,and development%2C game criticism%2C and technical game research.

Iizuka, A., Ishii, K., Wagatsuma, K., Ishibashi, K., Onishi, A., Tanaka, M., Suzuki, H., Awata, S., & Fujiwara, Y. (2020). Neural substrate of a cognitive intervention program using Go game: a positron emission tomography study. *Aging Clinical and Experimental Research*. https://doi.org/10.1007/s40520-019-01462-6

Iizuka, A., Suzuki, H., Ogawa, S., Kobayashi-Cuya, K. E., Kobayashi, M., Inagaki, H., Sugiyama, M., Awata, S., Takebayashi, T., & Fujiwara, Y. (2019). Does social interaction influence the effect of cognitive intervention program? A randomized controlled trial using Go game. *International Journal of Geriatric Psychiatry, 34*(2), 324–332. https://doi.org/10.1002/gps.5024

Ingram, J., Hand, C. J., & Maciejewski, G. (2021). Social isolation during COVID -19 lockdown impairs cognitive function. *Applied Cognitive Psychology*, 1–13. https://doi.org/10.1002/acp.3821

Jirout, J. J., & Newcombe, N. S. (2015). Building Blocks for Developing Spatial Skills: Evidence From a Large, Representative U.S. Sample. *Psychological Science, 26*(3), 302–310. https://doi.org/10.1177/0956797614563338

Johann, V. E., & Karbach, J. (2021). Education Application of Cognitive Training. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (Second Edi, pp. 334–347).

Kane, M. J., Meier, M. E., Smeekens, B. A., Gross, G. M., Silvia, P. J., & Kwapil, T. R. (2017). *Individual Differences In The Executive Control Of Attention, Memory, And Thought, And Their Associations With Schizotypy*. *145*(8), 1017–1048. https://doi.org/10.1037/xge0000184.Individual

Karbach, J., Könen, T., & Spengler, M. (2017). Who Benefits the Most? Individual Differences in the Transfer of Executive Control Training Across the Lifespan. *Journal of Cognitive Enhancement*, *1*(4), 394–405. https://doi.org/10.1007/s41465-017-0054-z

Karbach, J., & Kray, J. (2021). Executive Function Training. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 199–212). Springer International Publishing. https://doi.org/10.1007/978-3-030-39292-5_14

Karbach, J., & Verhaeghen, P. (2014). Making Working Memory Work: A Meta-Analysis of Executive-Control and Working Memory Training in Older Adults. *Psychological Science*, *25*(11), 2027–2037. https://doi.org/10.1177/0956797614548725

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological Bulletin*, *144*(11), 1147–1185. https://doi.org/10.1037/bul0000160

Kassai, R. (2019). A Meta-Analysis of the Experimental Evidence on the Near- and Far-Transfer Effects Among Children’s Executive Function Skills. *Psychological*

Bulletin, *145*(2), 165–188. https://doi.org/10.1037/bul0000180.supp

Kermani, F. K., Mohammadi, M. R., Yadegari, F., Haresabadi, F., & Sadeghi, S. M. (2016). Working memory training in the form of structured games in children with attention deficit hyperactivity disorder. *Iranian Journal of Psychiatry*, *11*(4), 224–233.

Kim, C., Cilles, S. E., Johnson, N. F., & Gold, B. T. (2012). Domain general and domain preferential brain regions associated with different types of task switching: A Meta-Analysis. *Human Brain Mapping*, *33*(1), 130–142. https://doi.org/10.1002/hbm.21199

Kober, S. E., Wood, G., Kiili, K., Moeller, K., & Ninaus, M. (2020). Game-based learning environments affect frontal brain activity. *PLOS ONE*, *15*(11), e0242573. https://doi.org/10.1371/journal.pone.0242573

Kouklari, E.-C., Tsermentseli, S., & Monks, C. P. (2018). Developmental trends of hot and cool executive function in school-aged children with and without autism spectrum disorder: Links with theory of mind. *Development and Psychopathology*, 1–16. https://doi.org/10.1017/S0954579418000081

Krell-Roesch, J., Vemuri, P., Pink, A., Roberts, R. O., Stokin, G. B., Mielke, M. M., Christianson, T. J. H., Knopman, D. S., Petersen, R. C., Kremers, W. K., & Geda, Y. E. (2017). Association between mentally stimulating activities in late life and the outcome of incident mild cognitive impairment, with an analysis of the APOE ϵ4 genotype. *JAMA Neurology*, *74*(3), 332–338. https://doi.org/10.1001/jamaneurol.2016.3822

Kueider, A., Krystal, B., & Rebok, G. (2014). Cognitive Training for Older Adults: What Is It and Does It Work. In *Center on Aging at American Institutes for Research* (pp. 1–8). http://www.air.org/sites/default/files/downloads/report/Cognitive Training for

Older Adults_Nov 14.pdf

Kuo, C. Y., Huang, Y. M., & Yeh, Y. Y. (2018). Let's play cards: Multi-component cognitive training with social engagement enhances executive control in older adults. *Frontiers in Psychology*, *9*, 1–13. https://doi.org/10.3389/fpsyg.2018.02482

Lampit, A., Hallock, H., & Valenzuela, M. (2014). Computerized Cognitive Training in Cognitively Healthy Older Adults: A Systematic Review and Meta-Analysis of Effect Modifiers. *PLoS Medicine*, *11*(11). https://doi.org/10.1371/journal.pmed.1001756

Lee, K., Bull, R., & Ho, R. M. H. (2013). Developmental changes in executive functioning. *Child Development*, *84*(6), 1933–1953. https://doi.org/10.1111/cdev.12096

Leger, M., Paizanis, E., Dzahini, K., Quiedeville, A., Bouet, V., Cassel, J. C., Freret, T., Schumann-Bard, P., & Boulouard, M. (2015). Environmental enrichment duration differentially affects behavior and neuroplasticity in adult mice. *Cerebral Cortex*, *25*(11), 4048–4061. https://doi.org/10.1093/cercor/bhu119

Lemire-Rodger, S., Lam, J., Viviano, J. D., Stevens, W. D., Spreng, R. N., & Turner, G. R. (2019). Inhibit, switch, and update: A within-subject fMRI investigation of executive control. *Neuropsychologia*, *132*(July), 107134. https://doi.org/10.1016/j.neuropsychologia.2019.107134

Levi, O., Jongen-Relo, A. L., Feldon, J., Roses, A. D., & Michaelson, D. M. (2003). ApoE4 impairs hippocampal plasticity isoform-specifically and blocks the environmental stimulation of synaptogenesis and memory. *Neurobiology of Disease*, *13*(3), 273–282. https://doi.org/10.1016/S0969-9961(03)00045-7

Linares, R., Bajo, M. T., & Pelegrina, S. (2016). Age-related differences in working memory updating components. *Journal of Experimental Child Psychology*, *147*, 39–

52. https://doi.org/10.1016/j.jecp.2016.02.009

Ling, D. S., Wong, C. D., & Diamond, A. (2021). Children Only 3 Years Old Can Succeed at Conditional "If, Then" Reasoning, Much Earlier Than Anyone Had Thought Possible. *Frontiers in Psychology*, *11*, 1–9. https://doi.org/10.3389/fpsyg.2020.571891

Loganathan, K., Lv, J., Cropley, V., Ho, E. T. W., & Zalesky, A. (2021). Associations Between Delay Discounting and Connectivity of the Valuation-control System in Healthy Young Adults. *Neuroscience*, *452*, 295–310. https://doi.org/10.1016/j.neuroscience.2020.11.026

Lumsden, J., Edwards, E. A., Lawrence, N. S., Coyle, D., & Munafò, M. R. (2016). Gamification of Cognitive Assessment and Cognitive Training: A Systematic Review of Applications and Efficacy. *JMIR Serious Games*, *4*(2), e11. https://doi.org/10.2196/games.5888

Luria, A. R. (1973). *The Working Brain: An Introduction to Neuropsychology*. Basic Books Inc.

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S. J., & Frith, C. D. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences of the United States of America*, *97*(8), 4398–4403. https://doi.org/10.1073/pnas.070039597

McKenna, R., Rushe, T., & Woodcock, K. A. (2017). Informing the Structure of Executive Function in Children: A Meta-Analysis of Functional Neuroimaging Data. *Frontiers in Human Neuroscience*, *11*. https://doi.org/10.3389/fnhum.2017.00154

McNally, K., Rohan, J., Pendley, J. S., Delamater, A., & Drotar, D. (2010). Executive functioning, treatment adherence, and glycemic control in children with type 1 diabetes. *Diabetes Care*, *33*(6), 1159–1162. https://doi.org/10.2337/dc09-2116

Melby-Lervåg, M., Redick, T. S., & Hulme, C. (2016). Working Memory Training Does Not Improve Performance on Measures of Intelligence or Other Measures of "Far Transfer": Evidence From a Meta-Analytic Review. *Perspectives on Psychological Science*, *11*(4), 512–534. https://doi.org/10.1177/1745691616635612

Metaferia, B. K., Takacs, Z. K., & Futo, J. (2020). The Relationship Between Parental Play Beliefs, Preschoolers' Home Experience, and Executive Functions: An Exploratory Study in Ethiopia. *Frontiers in Psychology*, *11*, 1–13. https://doi.org/10.3389/fpsyg.2020.00624

Minkova, L., Habich, A., Peter, J., Kaller, C. P., Eickhoff, S. B., & Klöppel, S. (2017). Gray matter asymmetries in aging and neurodegeneration: A review and meta-analysis. *Human Brain Mapping*, *38*(12), 5890–5904. https://doi.org/10.1002/hbm.23772

Miyake, A., & Friedman, N. P. (2012). The Nature and Organisation of Individual Differences in Executive Functions : Four General Conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458.The

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, a H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Miyake, Akira, & Friedman, N. P. (2012). The Nature and Organisation of Individual Differences in Executive Functions : Four General Conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14.

https://doi.org/10.1177/0963721411429458.The

Miyake, Akira, Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mondéjar, T., Hervás, R., Johnson, E., Gutierrez, C., & Latorre, J. M. (2016). Correlation between videogame mechanics and executive functions through EEG analysis. *Journal of Biomedical Informatics*, *63*, 131–140. https://doi.org/10.1016/j.jbi.2016.08.006

Moro, M. & Mezquita L. (2015). *Entrena't les neurones. Programa de rehabilitació neurocognitiva per a pacients amb trastorn mental greu* (1ª Ed). Universitat Jaume I.

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? the promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin and Review*, *18*(1), 46–60. https://doi.org/10.3758/s13423-010-0034-0

Nakao, M. (2019). Special series on “effects of board games on health education and promotion” board games as a promising tool for health promotion: a review of recent literature. *BioPsychoSocial Medicine*, *13*(1), 5. https://doi.org/10.1186/s13030-019-0146-3

Nath, S., & Szücs, D. (2014). Construction play and cognitive skills associated with the development of mathematical abilities in 7-year-old children. *Learning and Instruction*, *32*, 73–80. https://doi.org/10.1016/j.learninstruc.2014.01.006

Newman, S. D., Carpenter, P. A., Varma, S., & Just, M. A. (2003). Frontal and parietal participation in problem solving in the Tower of London: fMRI and computational modeling of planning and high-level perception. *Neuropsychologia*, *41*(12), 1668–1682. https://doi.org/10.1016/S0028-3932(03)00091-5

Newman, S. D., Hansen, M. T., & Gutierrez, A. (2016). An fMRI Study of the Impact of Block Building and Board Games on Spatial Ability. *Frontiers in Psychology*, *7*, 1–9. https://doi.org/10.3389/fpsyg.2016.01278

Niendam, T. A., Laird, A. R., Ray, K. L., Dean, Y. M., Glahn, D. C., & Carter, C. S. (2012). Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions. *Cognitive, Affective, & Behavioral Neuroscience*, *12*(2), 241–268. https://doi.org/10.3758/s13415-011-0083-5

Nigg, J. T. (2000). On Inhibition/Disinhibition in Developmental Psychopathology: Views from Cognitive and Personality Psychology and a Working Inhibition Taxonomy. *Psychological Bulletin*, *126*(2), 220–246. https://doi.org/10.1037/0033-2909.126.2.220

Ninaus, M., Pereira, G., Stefitz, R., Prada, R., Paiva, A., Neuper, C., & Wood, G. (2015). Game elements improve performance in a working memory training task. *International Journal of Serious Games*, *2*(1), 3–16. https://doi.org/10.17083/ijsg.v2i1.60

Nithianantharajah, J., & Hannan, A. J. (2006). Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience*, *7*(9), 697–709. https://doi.org/10.1038/nrn1970

Noda, S., Shirotsuki, K., & Nakao, M. (2019). The effectiveness of intervention with board games: A systematic review. *BioPsychoSocial Medicine*, *13*(1). https://doi.org/10.1186/s13030-019-0164-1

Nweze, T., & Nwani, W. (2020). Contributions of Working Memory and Inhibition to Cognitive Flexibility in Nigerian Adolescents. *Developmental Neuropsychology*, *45*(3), 118–128. https://doi.org/10.1080/87565641.2020.1765169

Olesen, P. J., Westerberg, H., & Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience*, *7*, 75–79. https://doi.org/10.1038/nn1165

Overman, A. A., & Robbins, R. E. (2014). Game-Based Community Cognitive Health Intervention for Minority and Lower Socioeconomic Status Older Adults: A Feasibility Pilot Study. *Games for Health Journal*, *3*(5), 303–310. https://doi.org/10.1089/g4h.2014.0052

Özçetin, M., Gümüstas, F., Çag, Y., Gökbay, I. Z., & Gökbay, A. (2019). The relationships between video game experience and cognitive abilities in adolescents. *Neuropsychiatric Disease and Treatment*, *15*, 1171–1180. https://doi.org/10.2147/NDT.S206271

Passolunghi, M. C., & Costa, H. M. (2016). Working memory and early numeracy training in preschool children. *Child Neuropsychology*, *22*(1), 81–98. https://doi.org/10.1080/09297049.2014.971726

Perman, G. (2017). Ensayos clínicos por conglomerados (clusters). *Evidencia, Actualizacion En La Práctica Ambulatoria*, *20*(1). https://doi.org/10.51987/evidencia.v20i1.6727

Planelles Ferrer, J. (2015). *Playing board games: capacidades cognitivas y juegos de mesa [Unpublished masther's thesis]*. Universitat Jaume I.

Poon, K. (2018). Hot and Cool Executive Functions in Adolescence: Development and Contributions to Important Developmental Outcomes. *Frontiers in Psychology*, *8*, 1–18. https://doi.org/10.3389/fpsyg.2017.02311

Prencipe, A., Kesek, A., Cohen, J., Lamm, C., Lewis, M. D., & Zelazo, P. D. (2011). Development of hot and cool executive function during the transition to adolescence.

Journal of Experimental Child Psychology, *108*(3), 621–637. https://doi.org/10.1016/j.jecp.2010.09.008

Prins, P. J. M., Dovis, S., Ponsioen, A., ten Brink, E., & van der Oord, S. (2011). Does Computerized Working Memory Training with Game Elements Enhance Motivation and Training Efficacy in Children with ADHD? *Cyberpsychology, Behavior, and Social Networking*, *14*(3), 115–122. https://doi.org/10.1089/cyber.2009.0206

Quiroga, M. A., Diaz, A., Román, F. J., Privado, J., & Colom, R. (2019). Intelligence and video games: Beyond "brain-games." *Intelligence*, *75*, 85–94. https://doi.org/10.1016/j.intell.2019.05.001

Quiroga, M. Á., Scorial, S., Román, F. J., Morillo, D., Jarabo, A., Privado, J., Hernández, M., Gallego, B., & Colom, R. (2015). Can we reliably measure the general factor of intelligence (g) through commercial video games? Yes, we can! *Intelligence*, *53*, 1–7. https://doi.org/10.1016/j.intell.2015.08.004

Ramani, G. B., Jaeggi, S. M., Daubert, E. N., & Buschkuehl, M. (2017). Domain-Specific and Domain-General Training to Improve Kindergarten Children ' s Mathematics. *Journal of Numerical Cognition*, *3*(2), 468–495. https://doi.org/10.5964/jnc.v3i2.31

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8), 1237–1252. https://doi.org/10.1016/j.cpr.2013.08.005

Reichman, W. E., Fiocco, A. J., & Rose, N. S. (2010). Exercising the brain to avoid cognitive decline: examining the evidence. *Aging Health*, *6*(5), 565–584. https://doi.org/10.2217/ahe.10.54

Reinert, K. R. S., Po'e, E. K., & Barkin, S. L. (2013). The relationship between executive function and obesity in children and adolescents: a systematic literature review. *Journal of Obesity*, *2013*(2), 820956. https://doi.org/10.1155/2013/820956

Richland, L. E., & Burchinal, M. R. (2013). Early Executive Function Predicts Reasoning Development. *Psychological Science*, *24*(1), 87–92. https://doi.org/10.1177/0956797612450883

Rios-Lago, M., & Periáñez, J. A. (2010). Attention and Speed of Information Processing. In G. Koob, R. F. Thompson, & M. Le Moal (Eds.), *Encyclopedia of Behavioral Neuroscience* (pp. 109–117). Elsevier. https://doi.org/10.1016/B978-0-08-045396-5.00208-6

Rock, P. L., Roiser, J. P., Riedel, W. J., & Blackwell, A. D. (2014). Cognitive impairment in depression: A systematic review and meta-analysis. *Psychological Medicine*, *44*(10), 2029–2040. https://doi.org/10.1017/S0033291713002535

Rogerson, M. J., Gibbs, M., & Smith, W. (2015). Digitising boardgames: Issues and Tensions [Conference]. In S. Björk, A. Waern, & M. Fuchs (Eds.), *DiGRA 2015 - Proceedings of the 2015 DiGRA International Conference: Diversity of Play, held in Lüneburg, Germany, 2015, May, 14-17* (pp. 1–16). http://www.digra.org/wp-content/uploads/digital-library/66_Rogerson-etal_Digitising-Boardgames.pdf

Romine, C. B., & Reynolds, C. R. (2005). A Model of the Development of Frontal Lobe Functioning: Findings From a Meta-Analysis. *Applied Neuropsychology*, *12*(4), 190–201. https://doi.org/10.1207/s15324826an1204_2

Sala, G., Deniz Aksayli, N., Semir Tatlidil, K., Tatsumi, T., Gondo, Y., & Gobet, F. (2019). Near and far transfer in cognitive training: A second-order meta-analysis. *Collabra: Psychology*, *5*(1), 1–22. https://doi.org/10.1525/collabra.203

Sala, G., & Gobet, F. (2017). Does chess instruction improve mathematical problem-solving ability? Two experimental studies with an active control group. *Learning* *and Behavior*, *45*(4), 414–421. https://doi.org/10.3758/s13420-017-0280-3

Samanez-Larkin, G. R., & Knutson, B. (2015). Decision making in the ageing brain: Changes in affective and motivational circuits. *Nature Reviews Neuroscience*, *16*(5), 278–289. https://doi.org/10.1038/nrn3917

Sánchez-Pérez, N., Castillo, A., López-López, J. A., Pina, V., Puga, J. L., Campoy, G., González-Salinas, C., & Fuentes, L. J. (2018). Computer-Based Training in Math and Working Memory Improves Cognitive Skills and Academic Achievement in Primary School Children: Behavioral Results. *Frontiers in Psychology*, *8*, 1–12. https://doi.org/10.3389/fpsyg.2017.02327

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of Playing Numerical Card Games on Head Start Children's Mathematical Skills. *Journal of Experimental Education*, *88*(2), 200–220. https://doi.org/10.1080/00220973.2019.1581721

Schannen, M. (2004). *Spooky Stairs*. Devir Iberia.

Schmiedek, F. (2021). Methods and Designs. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 9–18). Springer International Publishing. https://doi.org/10.1007/978-3-319-42662-4

Schwaighofer, M., Fischer, F., Bühner, M., Schwaighofer, M., Fischer, F., & Markus, B. (2015). Does Working Memory Training Transfer ? A Meta- Analysis Including Training Conditions as Moderators Does Working Memory Training Transfer ? A Meta-Analysis Including Training Conditions as Moderators. *Educational Psychologist*, *50*(2), 138–166. https://doi.org/10.1080/00461520.2015.1036274

Sesma, H. W., Mahone, E. M., Levine, T., Eason, S. H., & Cutting, L. E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology*, *15*(3), 232–246. https://doi.org/10.1080/09297040802220029

Snyder, H. R., Miyake, A., & Hankin, B. L. (2015). Advancing understanding of executive function impairments and psychopathology: bridging the gap between clinical and cognitive approaches. *Frontiers in Psychology*, *6*, 1–24. https://doi.org/10.3389/fpsyg.2015.00328

Sousa, M., & Bernardo, E. (2019). Back in the Game [Conference]. In N. Zagalo, A. I. Veloso, L. Costa, & Ó. Mealha (Eds.), *Proceeding from the 11th International Conference Videogame Sciences and Arts, held in Aveiro, Portugal, November 27 & 29, 2019* (pp. 72–85). https://doi.org/10.1007/978-3-030-37983-4_6

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

Stahl, C., Voss, A., Schmitz, F., Nuszbaum, M., Tiischer, O., Lieb, K., & Klauer, K. C. (2014). *Behavioral Components of Impulsivity*. *143*(2), 850–887.

Stern, A., Pollak, Y., Bonne, O., Malik, E., & Maeir, A. (2017). The relationship between executive functions and quality of life in adults with ADHD. *Journal of Attention Disorders, 21*(4), 323–330. https://doi.org/10.1177/1087054713504133

Strobach, T., & Karbach, J. (2021). Introduction. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 1–8). Springer International Publishing.

Taatgen, N. A. (2021). Cognitive training: An overview of features and applications. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 19–37). Springer International Publishing. https://doi.org/10.1007/978-3-319-42662-4

Tajik-Parvinchi, D., Wright, L., & Schachar, R. (2014). Cognitive Rehabilitation for Attention Deficit/Hyperactivity Disorder (ADHD): Promises and Problems. *Journal* *of the Canadian Academy of Child and Adolescent Psychiatry, 23*(3), 207–217.

Tamm, L., Epstein, J. N., Peugh, J. L., Nakonezny, P. A., & Hughes, C. W. (2013). Preliminary data suggesting the efficacy of attention training for school-aged children with ADHD. *Developmental Cognitive Neuroscience*, *4,* 16–28. https://doi.org/10.1016/j.dcn.2012.11.004

Tamnes, C. K., Østby, Y., Walhovd, K. B., Westlye, L. T., Due-Tønnessen, P., & Fjell, A. M. (2010). Neuroanatomical correlates of executive functions in children and adolescents: A magnetic resonance imaging (MRI) study of cortical thickness. *Neuropsychologia*, *48*(9), 2496–2508. https://doi.org/10.1016/j.neuropsychologia.2010.04.024

Tiego, J., Testa, R., Bellgrove, M. A., Pantelis, C., & Whittle, S. (2018). A hierarchical model of inhibitory control. *Frontiers in Psychology*, *9*, 1–25. https://doi.org/10.3389/fpsyg.2018.01339

Tsermentseli, S., & Poland, S. (2016). Cool versus hot executive function : A new approach to executive function. *Encephalos, 53*, 11–14.

Vidovich, M., & Almeida, O. P. (2011). Cognition-focused interventions for older adults: the state of play. *Australasian Psychiatry*, *19*(4), 313–316. https://doi.org/10.3109/10398562.2011.579973

Vladisauskas, M., & Goldin, A. P. (2020). 20 Años De Entrenamiento Cognitivo: Una Perspectiva Amplia. *Journal of Neuroeducation, 1*(1), 130–135. https://doi.org/10.1344/joned.v1i1.31628

Vöhringer, P. A., Barroilhet, S. A., Amerio, A., Reale, M. L., Alvear, K., Vergne, D., & Ghaemi, S. N. (2013). Cognitive Impairment in Bipolar Disorder and Schizophrenia: A Systematic Review. *Frontiers in Psychiatry*, *4*, 1–11. https://doi.org/10.3389/fpsyt.2013.00087 von Bastian, C. C., & Oberauer, K. (2014). Effects and mechanisms of working memory training: a review. *Psychological Research*, *78*(6), 803–820. https://doi.org/10.1007/s00426-013-0524-6

Wiebe, S. A., Lukowski, A. F., & Bauer, P. J. (2010). Sequence imitation and reaching measures of executive control: A longitudinal examination in the second year of life. *Developmental Neuropsychology*, *35*(5), 522–538. https://doi.org/10.1080/87565641.2010.494751

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A. C., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-old children. *J Exp Child Psychol.*, *108*(3), 436–452. https://doi.org/10.1016/j.jecp.2010.08.008

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Woollett, K., & Maguire, E. A. (2011). Acquiring "the knowledge" of London's layout drives structural brain changes. *Current Biology*, *21*(24), 2109–2114. https://doi.org/10.1016/j.cub.2011.11.018

Zelazo, P D, & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Blackwell Handbook of Childhood Cognitive Development* (pp. 445–469). Blackwell Publishers Ltd. https://doi.org/10.1002/9780470996652.ch20

Zelazo, Philip David, & Carlson, S. M. (2012). Hot and Cool Executive Function in Childhood and Adolescence: Development and Plasticity. *Child Development Perspectives*, *6*(4), 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Zelazo, Philip David, Qu, L., & Kesek, A. C. (2010). Hot executive function: Emotion and the development of cognitive control. *Child Development at the Intersection of Emotion and Cognition.*, 97–111. https://doi.org/10.1037/12059-006