Working memory: effects of its training based on multimedia routines

Memoria operativa: efectos de su entrenamiento basado en rutinas multimedia

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Ismael Esquivel Gámez*

ABSTRACT

The purpose of the present study was to evaluate the impact of a training program on the level of working memory in a sample of university students. For this, a quasi-experimental study with an active control group was implemented in 29 students of basic teaching and computer systems, applying complex span tasks before and after the intervention. For training, multimedia routines were used for the experimental group and an academic essay elaboration workshop for the control group. The pre-test confirmed intergroup statistical equality for all the measurements used and the post-test, in favor of the experimental group, detected significant difference and large effect size in visuospatial memory and non-significant with medium size, for verbal memory. Additionally, the *Raven's Matrices test* was applied to determine effects of training on intelligence, finding no significant difference. Therefore, it is concluded that training based on multimedia routines did not generate gains in intelligence or in working memory, in its verbal domain, although it did in its visual-spatial domain. However, the results must be taken with reservations, due to the limitation represented by the size of the sample, which, if corrected in future interventions, may enrich the findings on the means to improve working memory.

Keywords
Working memory; effects; training; multimedia routines

RESUMEN

El propósito del presente artículo fue evaluar el impacto de un programa de entrenamiento sobre el nivel de la memoria operativa en una muestra de universitarios. Para esto, se implementó un estudio cuasi-experimental con un grupo de control activo de 29 estudiantes de docencia básica y sistemas computacionales. Se aplicaron tareas de alcance complejo previo y posterior a la intervención. Para el entrenamiento se utilizaron rutinas multimedia para el grupo experimental y un taller de elaboración de ensayo académico para el grupo control. La preprueba confirmó igualdad estadística intergrupal para todas las mediciones usadas. La posprueba, a favor del grupo experimental, detectó una diferencia significativa y un tamaño del efecto mayor en la memoria visoespacial, y no significativa con tamaño mediano para la verbal. Adicionalmente, se aplicó la prueba matrices de Raven para determinar efectos del entrenamiento en la inteligencia, pero no se encontró una diferencia significativa. Se concluye que el entrenamiento basado en rutinas multimedia no generó ganancias en la inteligencia y tampoco en la memoria operativa, en su dominio verbal, aunque sí en su dominio visoespacial; sin embargo, los resultados deben ser considerados con reservas debido a la limitación que representó el tamaño de la muestra que, de subsanarse en intervenciones futuras, podrá enriquecer los hallazgos sobre los medios para mejorar la memoria operativa.

Palabras clave
Memoria operativa; efectos; entrenamiento; rutinas multimedia

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* Ph.D. in information technology and decision analysis by the Universidad Popular Autónoma del Estado de Puebla. Full time professor at the Universidad Veracruzana, Mexico. ORCID: https://orcid.org/0000-0001-7914-5170

INTRODUCTION

The operational memory (OM), or work memory, is defined as the set of processes or structures that enable that information be maintained and managed simultaneously (Baddeley, 2012). It is common that this is considered as a basic capacity affecting the manner in which other higher cognitive functions are done.

The updated model of multiple components (Baddeley, 2012), used for its analysis states that the OM is comprised by a central executive component, which is divided into two subsystems: the phonological buckle (verbal stimuli warehouse) and the visuospatial agenda (repository of visual and spatial information), and the episodic buffer. Its capacity to maintain and manage an amount of information during a specific period –both limited– is crucial for the daily function and academic and labor success (Miyake & Shah, 1999); therefore, the use of tasks has been generalized designed to index the function of OM. Over the last decades, a number of and a variety of tasks have proliferated for measurement and training (Morrison, Rosenbaum, Fair & Chin, 2016).

From the findings of Soveri *et al.* (2017), evidence is shown that studies on training have generated moderate gains in tasks similar to those already used, but small with regards to structurally different activities, and minimum gains in diverse actions. Because of the foregoing, it was decided to apply a multimedia software comprised by a mixture of tasks found in the most usual paradigms, configured to offer challenges which, mostly, may be faced in daily activities, which is different in this research in relation to other studies. Contributing to enrich the status of knowledge associated to training operational memory is expected.

The main objective of this study was to determine the effects on the capacity of the operational memory of a group of college students, in their verbal and visuospatial dominion, as well as in inductive and figurative reasoning, caused by cognitive training based on multimedia routines. An effectivity study is proposed, which, according to Green *et al.* (2019), assesses whether an intervention produces a desired positive impact and whether it involves less controlled ambiences that the ideal one. Secondary objectives were: a) to compare the effects achieved in the trained group against those of the active control group; b) to assess the difficulty level of the routines used in the training with a sample of college students, with the intention to propose improvements to the software applied; and c) to know what the memorization strategies implemented during training are.

The work is organized as follows: training transfer modes are documented, similar studies are described, the method and materials employed are explained, results are reported for study, and conclusions are exposed.

Cognitive training and transfer thereof

Cognitive training is the systematic instruction the purpose of which is preservation, improvement or development of cognitive capabilities. According to Green et al. (2019), there are circumstances where people could be potentially benefitted from improvements in these capabilities, such as in tasks that require high cognitive capacity (the military, police officers, athletes, surgeons, for example), and in the educational areas, such as sciences, technology, engineering and mathematics. Cognitive training interventions have gradually become more popular as a potential means to improve cognitive function throughout life (Guce, De Simoni & von Bastian, 2017); furthermore, OM has been the object of many training programs because of its central role in cognition and its relationship with high level skills (Maraver, Bajo & Gomez-Ariza, 2016).

OM benefits induced by training may be due to an increase in its capacity or efficiency, or both (von Bastian & Oberauer, 2014). An increase in capacity is reflected in structural changes that may generate a full transfer manifested as improvements to the performance of restricted tasks thereby; on the other hand, efficiency increase is manifested in a better exploitation of the available capacity by means of strategies or automated processes. Thus, while the use of specific paradigm strategies may predict transfer to similar tasks, a high automation level may transfer results to tasks based on mechanisms similar to OM (De Simoni & Bastian, 2018). A third possibility, according to Minear et al. (2016), is that during training, greater motivation or effort is found in the tasks after training in some of the participants, especially if they firmly believe in its efficacy.

According to Maraver, Bajo & Gomez-Ariza (2016), cerebral plasticity is the basis of the training effect over cognitive performance, which may be generalized and, therefore, be transferred. Transfer is the improvement of performance after an intervention in respect to that obtained as the base line before it (Karbach, Könen & Spengler, 2017). According to von Bastian & Oberauer (2014), near-transfer refers to the improvement of a task targeted to measure the same cognitive dominion that the trained dominion, whereas far-transfer is improved in a different domain. Linares et al. (2019) show they do exist, furthermore, very near-transfer, where improvements of in other versions of the same training task are presented. In its meta-analysis, Soveri et al. (2017) analyzed the effects of near-transfer with greater detail, and separate those tasks that were not trained using the same paradigm that the trained ones, however, with different stimuli (task specific) from those with a different structure to the trained ones (task general); to von Bastian & Eschen (2016), the latter may be called intermediate transfer.

The essential goal of training is the transfer of acquired skills; likewise, in recent studies, it has been found that OM training leads to the improvement of non-practiced tasks, fluid intelligence and long-term memory included (Au et al., 2015). Notwithstanding, there are meta-analysis shown that this training does not produce far-transfer (Melby-Levåg, Redick & Hulme, 2016), therefore, answers on the effectiveness of

OM interventions and transfers to intelligence measurements and cognitive control are still not clear (Minear et al., 2016).

Generally, two task paradigms have been used to train work memory, N back and the complex scope, which require to have irrelevant stimuli inhibited; in intra-attempts of N back and in inter-attempts scope tasks. The former involves updating information and the latter, commute between to non-associated tasks (Minear et al., 2016), which has shown to be more effective in terms of far-transfer (von Bastian & Oberauer, 2013). As stated by Fellman, Soveri, Waris & Laine (2017), it is greatly attractive to work on tasks of a different nature, above all because many of associated tasks usually are artificial activities, which employ sequences of digits, works or spatial positions.

Previous related studies

As studies were reviewed on training OM, those measuring the effects of specific near-transfer task, and general task –intermediate transfer– as well as far-transfer of young college students were briefly described.

To prove whether the practice with or without feedback on performance in each attempt would lead to persisting improvements of the visual capacity of the operational memory (COM), Adam & Vogel (2018) organized 101 youths in four training groups: with feedback, without feedback, with puzzle resolution and with no task. The authors worked with the participants in a pre-test session, six training one-hour sessions, and another post-test one. The training routing consisted of remembering the location and color of squares appearing on a screen to recover them afterwards. In order to measure intermediate transfer, a different task with the same stimulus was applied, and for the far one, a fluid intelligence test, among others.

With the intention of answering the question: who would be benefited more from training: people with low or with high COM? Foster *et al.* (2017) worked with 116 youths divided into low and high CPM for 23 sessions, three of which were assessed under one of three modes: retention tasks, updating tasks, and visual search task. During the assessment of eight cognitive skills, different tests were employed to measure near-transfer (OM: retention and updating), intermediate (attention control, primary and secondary memories) and far (fluid intelligence and multiprocessing skill).

The hypothesis posed by von Bastian & Eschen (2016), where training effectiveness is greater when tasks adaptive, was contrasted with measurements done to 130 youths, randomly assigned to one of four groups in essential training, based on the assigned level (adaptative, random, self-chosen, and active control). The approximate duration included five 20-minute sessions a week for one month, where they worked with complex scope tasks and, to assess near-transfer, they used similar tasks to those in training: three with verbal work memory for the intermediate one and five with reasoning for the far one.

In order to examine the effects of training OM in two ways (N back spatial and verbal complex scope), Minear *et al.* (2016) worked with four groups of 26 to 31 college students. Training regimens were N back spatial, adaptative and non –adaptative, complex tasks and videogames, with an approximate duration of five 20-minute sessions a week for one month. In order to assess near-transfer they employed N back verbal tests, three complex scope tests for the intermediate, and reasoning (verbal and visuospatial) for the far one, among others.

Zhao, Xu Fu & Maes (2017) worked with 45 youths divided into two groups (high and low motivation) for fourteen days to check the effect of motivation on gain transfer. They used N back visuospatial tasks in both cases, and to assess near-transfer, they used N back verbal tasks, whereas for the intermediate, one of a numerical update of a different structure, and for the far one, executive control and reasoning tasks.

In order to determine the transfer effects with three updating OM programs and the influence of the distribution of the practice, Linares *et al.* (2019) worked with 193 students associated to one of six groups (program and distributions) with backwards numerical tasks 2 and 3, arithmetical update and videogames. Very near-transfer was assessed with an equal task and another similar one, the near-transfer task with memory updating tests and the intermediate with the operations scope task, and the far one by means of the Cattel intelligence test.

In their work, Redick, Wiemers & Engle (2018) analyzed the role of oblivion caused by prior learning of 86 youths divided into two groups during ten sessions. During the experiment, they were trained with two operations tasks: one required that letters were memorized and, in other one, required that they memorized letters, digits and words alternatively arranged; in addition, the active control group was assigned several visual search tasks. To determine the effects, updating tests were applied on verbal and visuospatial OM for the intermediate, and verbal fluency and comprehensive reading for the far one.

Fellman *et al.* (2017) studied the effects of transfer ion 68 participants randomly assigned to a training and active control group. The authors used a novelty program that handled sentences as training stimuli, as well as a little complex scope reading tasks for the former, and an OM-unrelated online task for the second. Training took four 30-minute sessions per week during four weeks. To measure intermediate transfer, they employed four complex scope measurements in verbal OM, and for the far one, two measurements of episodic verbal memory and one on word fluency.

In order to determine the difference between the impact of the OM training and the inhibiting control (Maraver, Bajo & Gomez-Ariza, 2016) worked with hundred college students, randomly assigned to one of four groups (inhibiting control, operational memory, active control and passive control) for two weeks, in three sessions each. In the first one, they practiced Stroop-style tasks, go/stop style and conflict resolution; in the second, there were dual OM search and updating tasks N back; and in the third one, there were three processing speed tasks furthermore, they used

N back tasks to determine near-transfer, the operations scope for intermediate transfer, and for the fax one, cognitive proactive/reactive adjustment control tasks and Raven matrices.

In order to determine the training transfer degree of the executive control in three age groups, Karbach, Könen & Spengler (2017) implemented a four-session program which consists of commuting tasks for the experimental group and, and for the active control there were similar tasks, although they did not require executive control. Transfer was measured by means of two visuospatial tasks, verbal reasoning, perception speed and semantic knowledge.

With the purpose of disentangling the effects of training on the capacity and efficiency of OM, De Simoni & Bastian (2018) worked for five weeks with 197 youths randomly assigned to one of three groups (updating, context item link, and visual search tasks). To measure near-transfer they used similar tasks, for the intermediate, updating and cross-linking tasks and for the far one, reasoning, displacement, inhibiting and processing speed tasks. During training they practiced for ten minutes a different type stimulus for no more than 45 minutes per session.

With regards the main findings of the previous studies, Zhao *et al.* (2017) found that motivation has a modulating role on the training benefits, although far-transfer was not attained. Specifically, Fellman *et al.* (2017) say that specialty in the sentence-processing system could have caused the lack of training effects.

Maraver, Bako & Gomez-Ariza (2016), Karbach, Könen & Spengler (2017) and Adam & Vogel (2018) determined that training by means of executive control or visual discrimination efficiency tasks provide better transfer results than the most usual paradigms. Minear *et al.* (2016 and von Bastian & Eschen (2016) found that there were no differences in using adaptative and non-adaptative tasks, because having different difficulty levels was enough to obtain training improvements.

Foster *et al.* (2017), Linares *et al.* (2019), Redich, Wiemers & Engle (2018) and De Simoni & Bastian (2018) found that participants developed skills to implement specific strategies of task and content during training, more than a COM improvement, which is supported on the training results and on attained transfers.

In view that most of the studies reviewed have not found significant intermediate-and far-transfer effects, it is proposed that practices are used that provide challenges closer to those found in daily life. The intention is that training results in a broader generalization, that would effectively deter the use of specific task strategies, a condition which is amply found.

METHODOLOGY

From a quantitative approach, a quasi-experimental study was done with a longitudinal and prospective, experimental and active control group. Below are the features of the samples, instruments applied and followed procedure.

Participants

Sampling was of the non-probabilistic type as it was convenient due to the conditions existing in the participating institutions. We worked with 29 college students of the Bachelor studies of Basic Teaching and Administrative Computing Systems, of two institutions, a private one and a public one. The active control group was comprised by students in the second semester of Basic Teaching and there were fourteen participants with an average age of 18.6 years, all of them were women; the experimental group was comprised by students in the eighth semester of both bachelor studies, comprised by twelve women and three men, with an average age of 22.8 years. The invitation to participate was done in class.

INSTRUMENTS

Measuring intermediate transfer

Diverse measures of the COM were employed in this work. In accordance with Conway *et al.* (2005), a proper research strategy consists of applying multiple tasks because the shared variance of the measurements is a better representation of COM. The type of most usual tasks for this currently are of a complex scope, N back and detection of change.

According to Ellingsen & Engle (2019), in the scope type, the participant has to switch his/her attention between memorization and processing elements to then recover those that were memorized. In N back, the participant is given a set of items, and he/she has to specify whether the current one appeared N times before. In detecting change a group of elements is briefly presented, followed by a similar group, and the participant has to specify whether one of them is equal or different.

In this research there were complex tasks and behind 2 tasks with stimuli in both domains, from the NeuronsWorkOut software used in Esquivel-Gamez *et al.* (2018). The tasks used for the verbal domain were: reading, transactions, counting and behind 2 verbal tasks; and for the visuospatial, they were rotation, symmetry and behind 2 visual tasks.

Scope tasks handle four levels, each of them with three attempts and a number of stimuli to be recalled from two to five each, in accordance with the level. Between each stimulus, there is a distracting element, whose response is to be chosen between two options. When the memorized stimuli need to be recovered, they are to be entered in the order as they appeared to obtain a higher score.

So, in the reading test (Reading Span) there is a phrase, which is to be determined whether it is logical or not, and then a letter to be memorized. In operations (Operation Span) an arithmetic operation is shown which is to be verified whether it is correct and then to store one word. In the counting test (Counting Span), three-colored geometrical figures are deployed and the task is to verify whether the count of blue circles is an even or odd number, and then that count is to be memorized. For the rotation test (Rotation Span) there is a letter in a normal or turned over positions, and there must be an indication about whether it is rotated, and then an arrow is to be memorized in one of eight positions and two sizes. In the symmetry test (Symmetry Span), a matrix is shown with some black cells, it must be marked whether it is in symmetry with its vertical axis, and then show another matrix with a red cell, whose position is to be remembered. The 2 back (2 Back) tasks sequentially show a number (verbal) or a figure (visual) and the participant says whether this is of a stimulus which appeared two times before.

For the scope tests, there are correct and orderly responses, the average reaction time, and the accuracy percentage for each participant, as well as a test and level. In order to obtain the memorization score, a proposal was employed similar to that by Conway *et al.* (2005), which divides the sum of quotients, of answers ordered and expected per each attempt of the relevant level divided by the total attempts. Thus, for example, if a participant managed to get 6, 9, 10 and 13 ordered answers, the score is obtained by dividing the total quotients 6/2, 9/3. 10/4, and 13/5 by twelve, which is the total. For the 2-back tests, the score was obtained by dividing the correct answers by the total expected times ten.

Measuring far transfer

Since in several of the works reviewed, it was determined to assess fluid intelligence with the progressive matrixes of Raven (Raven, Raven & Court, 1998), which includes 60 problems distributed in five series of twelve. The tasks are to complement sets of drawings where the last one was missing, by electing several figures presented. The difficulty increases in each set among itself, which results in direct points between 0 and 60.

Training

The MemoWorkOut software was used, piloted on Esquivel Gamez, Aguirre-Aguilar, Barrios-Martinez & Galvez-Buenfil (2020), which is comprised by multimedia routines with stimuli of both dominions, three difficulty levels with three attempts each, where 75% of correct answers is required to advance to the next level. Between each one, the difficulty is increased with the number of stimuli to be memorized, or rather, by increasing the deployment speed of stimuli. As described below, the routines handle numerical, verbal, visual and spatial stimuli, incorporated in a mixture of retention, processing, updating and linking activities.

Deactivated: for every minute, from an initial digit, you either add or subtract each of the five to seven digits shown gradually (digit update). Then, you are asked to record the result or the last one taking place (processing), as the case may be; if it is correct, there is an arrow either aiming left or right, so that they are both memorized (digit-symbol link).

Dancing: with each attempt, there are a couple of images of feet (left or right) and arrows (in one of eight orientations) to be memorized (image-symbol link) like dance steps. Then, there is a crab in an objective color and, when it disappears, there are several of different colors deployed randomly, to count those of the original color (digit update) and to choose the correct number among three options (processing), to finally repeat the steps.

League: for each attempt there are names/logos of football teams with their scores to be memorized (symbol-digit link). Then, for four times, game related images are shown for the goals scored and received in a day, and to determine whether the teams being reviewed lost, whether there was a draw or won (processing), in addition to renewing their scores (digit update). In the end, the team with the least points is chosen.

Mexican: in each attempt, initially there is a telephone number to be memorized. Then, there is a list of fruit amounts to be purchases, with a price assigned. As the fruit is put into a basket, you have to update the total purchase (digit update). When you are done, there is a payment bill and the change amount have to be entered (processing); if it is correct, you recover the telephone number.

Battle: for each attempt there is an empty military fort to which soldiers will enter and from which they will go out as well as military vehicles. The idea is to keep several pairs of type and number in mind (digit update). In the end, you are requested to enter the remaining amounts for each of them.

Crows: there is a Spanish alphabet and in every attempt a crow flies taking a letter along, which is dropped at the end of the flight (retention) and this is the basis to look for its antipode (processing). After repeating the previous sequence several times, you need to recover the original letters.

Lottery: there is a board with 16 figures in every attempt, then, one after the other, there are decks of cards with figures (1 of 54) and you have to check whether they are on the board. If so, you memorize and determine whether a specific pattern is formed with the last one (processing) to choose it from a series of buttons. Regardless of whether the pattern was chosen, it is necessary to retain the patterns that have already appeared, because choosing them again affects the score.

Bingo: this is similar to Lottery, although in this case there are 16 numbers on the board, in every attempt you hear one of these (1 of 54) and check whether it is there. With the last number you hear, you check whether one of the expected patterns has been formed (processing) to show it with one of the buttons on the board. You need to memorize the numbers shown and, therefore, the patterns already formed.

Specifically, the Battle, Bingo, League and Lottery routines do not have memorization and processing tasks in separate, furthermore, both Dancing and Crows do not cancel the attempt if the answer is not correct in the stage they are found, this only reduces the numbers of right guesses. In addition, an online questionnaire was developed to know what the perception is on the difficulty and performance of routine resolution, as well as to have the strategies used during the exercise documented.

Procedure

Measuring COM: for both groups, the two measurements were made with an interval of six months. The first one was done in the computer room and the second one at the home of each participant by videoconference. In five hourly sessions, two daily tests were conducted approximately, where verbal and visuospatial domain were inserted. For this, the instructions and the relevant demonstration videos were shared previously. In addition, they were asked to put on earphones to reduce any caused distraction.

Everyone began level one of the tests at the same time and waited for the others to finish. After answering any questions, they were asked to finish the rest of the levels. The participants received support on technical difficulties or on the activity at all times. The 2-back tests could only be conducted on the experimental group in both instances and, after the participation, only to the active control group. It is important to highlight the fact that the experimental group was not offered any benefit for partaking, while the active control group was promised that the performance obtained in every test would be reflected in the grades of three subjects, with an expected better performance. Below, you will find the actions we applied.

Experimental group: 15 training sessions of 35 minutes were established for five weeks, prior to the second measurement; in general, almost an hour was used per routine (1.5 sessions). With the purpose of speeding up the practice, before each session they were shared instructions and a demonstration video of the routine by instant messaging. The execution was in an alphabetical order except for Bingo and Lottery, which were left at the end to reduce the frustration of participants, because of the degree of difficulty detected in Esquivel-Gamez *et al.* (2020).

In the same way as in the measuring section, it was requested that they put on earphones to reduce the effect of environmental noise. The session began by welcoming the group, and question they had was answered, and then, we went on with the practice until the session was completed. As they did an attempt, the software recorded the guesses per routing, the level and the participant, in addition to the date and time. In several routines, the number of guesses included the memorization and processing sum.

Control group: a writing workshop remained active for an argumentative essay with a topic elected by each participant, which included 29 work hourly sessions and two group and individual feedback sessions, distributed throughout five months. The workshop was comprised by activities and resources lodge in a Moodle platform, and organized by stages: framework, introduction to argumentation, basic essay handling, writing three drafts, assessment and co-assessment of a peer's work, and development of the final version of the academic essay.

RESULTS

Measuring: with the purpose of known whether there were any significant differences on measuring OM on accordance with the treatment they received, a Mann-Whitney U test was conducted by means of SPSS Statistics V22-0. Upon contrasting the means in the pre-test, no significant difference was found between the groups, which allowed us to continue with the initial formation thereof.

In order to enrich this contrast, averaged per dominion were obtained in the scope tests. After completing the interventions, statistics were calculated of the differences between the means and the paired groups and the magnitudes of the effect (see table 1). You can see that the greatest impact of the training became manifest in visuospatial dominion tasks, which obtained the lowest means during the pre-test.

Table 1. Descriptive of the measurements before and after the interventions

		Pretest		Post-test		Difference		
Test	**Group**	**Media**	**Typical deviation**	**Media**	**Typical deviation**	**Z value**	**P value**	**Effect size**
Verbal back	1	8.07	1.710	9.20	0.941	-1.86	0.063	-0.508g
	2	N/D	N/D	8.57	1.016	N/D	N/D	N/D
Visual back	1	7.73	1.981	9.80	0.414	-2.96	0.003	-0.965g
	2	N/D	N/D	8.64	1.906	N/D	N/D	N/D
Counting	1	0.92	0.108	0.93	0.124	-0.18	0.861	-0.041g
	2	0.90	0.060	0.91	0.137	-1.43	0.152	-0.079g
Reading	1	0.90	0.117	0.99	0.020	-2.58	0.010	-0.698g
	2	0.94	0.046	0.98	0.031	-2.67	0.008	-0.733g
mathematical operations	1	0.88	0.106	0.96	0.028	-1.85	0.064	-0.555g
	2	0.90	0.150	0.87	0.182	-1.60	0.109	0.221g

Rotation	1	0.73	0.178	0.92	0.051	-3.23	0.001	-1.143[g]
	2	0.67	0.182	0.81	0.108	-2.44	0.030	-0.653[d]
Symmetry	1	0.77	0.166	0.92	0.116	-3.10	0.002	-1.040[g]
	2	0.78	0.164	0.82	0.145	-0.72	0.487	-0.191[d]
Raven	1	46.13	7.328	48.13	6.578	-2.19	0.046	-0.564[d]
	2	43.50	7.643	44.79	6.204	-0.76	0.458	-0.204[d]

1 = Experimental; 2 = Active control; N/D = Not available; g = Hedges g; d = Cohen d.

With regards the experimental group, there was no significant association of differences with the age or with the training time used (see table 2). When comparing the post-test means per independent groups, for the experimental group size effects were obtained (Cohen, 1988) of a lower proportion for counting (0.147) and reading (0.372), medium to 2-back verbal (0.625), operations (0.691) and symmetry (0.718), and greater to 2-back visual (0.830) and rotation (1.267). Significant values of differences were for 2-back visual (Z=2.206, p=.027) and rotation (Z=3.0017, p=.003).

Table 2. Levels of association between differences in test scores, training time and age for the experimental group

	Age	**Training time**	**Verbal back**	**Visual back**	**Counting**	**Reading**	**Mathematical operations**	**Rotation**	**Symmetry**	**Raven**
Age	1	0.491	-0.255	-0.424	-0.236	0.176	-0.120	0.057	-0.211	-0.174
Training time		1	-0.058	-0.166	-0.267	0.185	-0.024	-0.047	0.096	-0.332
Verbal back			1	.617(*)	0.071	-0.267	-0.382	-0.273	-0.287	-0.134
Visual back				1	0.379	0.210	0.179	0.146	0.048	-0.300
Counting					1	.554(*)	0.453	.539(*)	0.305	0.156
Reading						1	.785(**)	.898(**)	0.449	0.048
Mathematical operations							1	.821(**)	0.431	0.275
Rotation								1	0.401	0.122

Symmetry									1	0.122
Raven										1

* p < .05, ** p < .01.

Per dominion, inter-group comparison of the post-test detected a significant difference and a greater effect size in favor of the experimental group on visuospatial memory (Z=3.236, p=0.001, Hedges g=1.376), and not significant with respect to the medium size for the verbal test (Z=1.641, p=0.101, Hedges g=0.475). For the Raven test, in a similar comparison, the difference was not significant (t=1.407, p=.171).

Training: although in total there were 525 minutes programmed, per absence or tardiness, the average was 474 minutes, a term which, due to the lack of time or performance, was not sufficient, as some participants did not complete all the games. From the results, per participant, the following results were obtained: routine and level, the top number of guesses and attempts; and from them all, the indicators of score, efficiency and success rate. The score was obtained by dividing the top number of guesses obtained and the expected results per level, while efficiency corresponds to the quotient of guesses and attempts between the maximum number of guesses per level and the success rate, by dividing the times when they attained 75% of guesses among the three levels.

Per routine, the values of the three levels were averaged to know what the descriptors are of the mentioned indicators (see table 3) and, by contrasting the difference of successes among levels per each task, it was found that Battle had the greatest and Crows the lowest. From the online questionnaire, the perception regarding performance was 6.8, while the most difficult routines, at a range of 1 to 4 were: Bingo (3.1), Battle (3.0) and Lottery (2.6).

Table 3. Means of the indicators obtained from the routines

	Qualification	Efficiency	Success rate
Routine	**Media**	**Media**	**Media**
Dancing	.86	.43	.64
Battle	.63	.26	.44
Bingo	.74	.48	.36
Crows	.86	.71	.62
Deactivated	.71	.35	.44
League	.87	.38	.44
Lottery	.72	.46	.31
Mexican	.81	.48	.73
Global	.78	.45	.50

The mostly mentioned strategies were: for Dancing: "recreating with my feet what the sequence was"; for Battle: "repeating the color and number of each object, then subtract and add"; for Bingo: "keeping in my mind the box numbers I already heard"; for Crows: "assigning words to letters and to make a phrase"; to Deactivated: "using my fingers for arrows and repeating numbers"; for League: "ordering from largest to smallest and then updating scores, moving them from their position"; for Lottery: "memorizing figure boxes which have already appeared" and for Mexican: "continuously repeating the telephone number".

DISCUSSION OF RESULTS

As a function of the main objective, an emphasis is made that for the trained group a significance was attained on the difference of results and the size of a greater effect for the back visual test, according to Minear *et al.* (2016); however, for the similar test with verbal stimuli this was not significant, different from the results of Redick, Wiemers & Engle (2018) for both trained groups in the 3-back verbal test.

In the counting scope test, there was no significant difference obtained, maybe because in the pre-test the highest results were obtained, close to maximum. For the reading task, there was a significant difference, as well as larges median of all the measurements, which may be due to the fact that stimuli used in the retention and processing correspond to elements associated to crystalized skills (FGellman *et al.,* 2017). In contrast, Minear *et al.* (2016 and Maraver, Bajo & Gomez-Ariza (2016) obtained a significant difference in their trained groups, as an operations scope task was measured, for this work, there were no positive results.

Regarding complex visuospatial dominion tasks, in line to Minear *et al.* (2016), for the trained group with N-back spatial tasks, highly significant differences and greater effect sizes in the symmetry and rotation tasks were obtained. In spite of the size of the sample, the results are not conclusive; in the figurative inductive reasoning test, a significant difference was obtained, like in the trained group with inhibiting control tasks, by Maraver, Bajo & Gomez-Ariza (2016).

Regarding the secondary objective of comparing the effects of both groups for the post-test, no significant difference was obtained in the 2-back verbal test, different from Zhao *et al.* (2017), who worked with a similar sample size, in favor of their high motivation group. In accordance with Maraver. Bajo & Gomez-Ariza (2016), a significant difference was obtained in the measures of the N-back visuospatial task, although the authors measured several levels.

Similarly, in accordance with Minear *et al.* (2016), no significant difference was obtained in the reading and symmetry scope measurements. In the former, maybe because the control group continuously managed reading-writing activities, which could have had an influence on their performance. In the latter, the difference was close to the significance level; with a sample of greater size, a future intervention may be obtained.

Furthermore, in comparison to Maraver, Bajo & Gomez-Ariza (2016), who reached a greater effect size in the operations task, between a trained group and a passive one, as well as Minear *et al.* (2016; Linares *et al.* (2019 and Fellman *et al.* (2017), no significance was obtained in the results difference in a similar task. In this case, this may be due to the fact that processing has a great cognitive load for the sample under study, similar to the one used by Esquivel-Gamez, Barrios-Martinez & Galvez-Buenfil (2020).

According to Karbach, Könen & Spengler (2017), training had improvements on the symmetry scope task and, when comparing means grouped per dominion, the improvement was evident in the visuospatial domain. In its case, the authors found compensation effects, that is, the initial levels were more correlated with the gains of the trained group, which may imply effects associated to training and, although similar associations were attained in this study, they are not representative because of the size of the sample.

Different from Maraver, Bajo & Gomez-Ariza (2016), who used inhibiting control tasks, and in accordance with Adam & Vogel (2018), Foster *et al.* (2017, Minear *et al.* (2016, Zhao *et al.* (2017 and von Bastian & Eschen (2016), no significant difference was obtained in the figurative inductive reasoning.

Regarding the objective intended to estimate the difficulty level in each routing, it was found that Mexican, Dancing and Crows had a lower challenge; possibly due to the fact that in Mexicana, it is required to memorize the telephone number going from five to seven digits, according to advancing a level; whereas in Dancing, repeating a step sequence was reduced as they advance a level, therefore, there were several opportunities to memorize stimuli, and in Crows, this is very simple, because this is about memorizing a group of letters in the alphabet and look for the antipode letter as a distracting activity.

Greater complication routines were Battle, Lottery and Bingo. In the first one, because stimuli go in and out very close together, and in Lottery and Bingo, because of the need to update visuospatial stimuli, in addition to deciding in a short time whether an eligible pattern has been formed.

The largest number of attempts included routines where it takes less time for the participant to fail (Dancing, Battle and Deactivated), hence there was greater efficiency in Crows and lower for Battle, because of the score obtained and the number of attempts. The previous results were in line with the answers of the questionnaire, as they indicated that Bingo and Lottery were the most difficult, and Mexican and Crows the easiest.

In order to answer to the objective associated to know what the memorization strategies used were, like in Minear *et al.* (2016); in the Crows routine, they said they have assigned words to letters to make phrases. On the other hand, as in the study of Morrison *et al.* (2016), in Battle, Mexicana, Deactivated, and League, they used the essay strategy to recall numbers. In the Bingo and Lottery routines, they said that they have made frequent use of the strategy to draw patterns as stimuli appeared. Finally, on the steps of Dancing, and on the arrows in Deactivated, they used parts of their bodies to memorize, oriented towards the promulgation effect, which suggest that several attributes in the motor and perception systems of the body may have an impact on the ability to remember.

CONCLUSION

Except for the small size of the samples, the guidelines recommended by training literature were followed: using an active control group instead of a passive one, not naming intervention as brain training, applying several measurements of intermediate transfer, and assigning a time and daily mean therefor.

From the originally stated objectives, it is concluded that differences between the groups in the post-test may be due to treatment and not to the effects of other variables, because of similar scores of both groups, prior to the intervention. Additionally, with regards to the main objective, significant differences were obtained for several tasks, mainly to those of the visuospatial domain, and the figurative inductive reasoning. Using routines comprised by structurally different tasks to those employed to measure, with a greater variability of action and stimuli, may have contributed to the results.

In respect to the second of the objectives, no intermediate or far transfer was obtained in most of the tests, except for those of the visuospatial nature. Similar to the studies reviewed, training time was not associated to the level of improvements, nor was this one associated with the motivation scheme, since the most motivated group obtained lower gains.

In respect to the third objective, training routines with greater difficulty were those that required to keep and update visuospatial patters, as well as to quickly decide whether this is an eligible one. Instead, those with less complication were those that required memorizing and processing simple stimuli.

On the last objective, strategies reported were, on the whole, similar to those of the studies which also obtained them. Finally, it is required that the results be held confidentially because of the size of the sample employed; therefore, as a future line of work, additional interventions are proposed where, in addition to increasing its size, a request is made to increase the difficulty of the easiest routines, that a larger number of sessions and a variety of routines are applied, with the purpose of reducing repetition of strategies and that, furthermore, intermediate transfer measurement is enriched with OM updating tasks, and far, with additional reasoning measurements.

REFERENCES

Adam, C. S. & Vogel, E. K. (2018). Improvements to visual working memory performance with practice and feedback. *PloS one*, *13*(8), e0203279. https://doi.org/10.1371/journal.pone.0203279

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 & Review*, 22, 366-377. https://doi.org/10.3758/s13423-014-0699-x

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

Cohen, J. (1988). *Statistical power analysis for the behavioral science*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Conway, A.; Kane, M.; Bunting, M. F., Hambrick, Z.; Wilhelm, O. & Engle, R. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769-786. https://doi.org/10.3758/BF03196772

De Simoni, C. & von Bastian, C. (2018). Working memory updating and binding training: Bayesian evidence supporting the absence of transfer. *Journal of Experimental Psychology: General*, *147*(6), pp. 829-858. https://doi.org/10.1037/xge0000453

Ellingsen, V. J. & Engle, R. W. (2019). Cognitive Approaches to Intelligence, en R. J. Sternberg (ed.), *Human intelligence: An introduction*. Cambridge University Press.

Esquivel-Gámez, I.; Martínez-Olvera, W.; Galvez-Buenfil, K. E.; Barrios-Martínez, F. L.; López-Azamar, B.; Córdoba-Del Valle, R. y Medina-Cruz, H. (2018). NeuronsWorkOut: experiencias en su aplicación para medir la capacidad de la memoria operativa, en I. Esquivel-Gámez, G. Aguirre, R. Edel y J. Balderrama (coords), *Memoria operativa: medición y propuesta para su desarrollo, apoyadas en TIC*. Ciudad de México: Porrúa Print.

Esquivel-Gámez, I.; Aguirre-Aguilar, G.; Barrios-Martínez, F. L. y Gálvez-Buenfil, K. E. (2020). Entrenamiento de la memoria de trabajo: propuesta basada en tareas automatizadas, en R. I. García López, J. A. Armenta, A. L. Rodríguez y M. A. M. Varela (coords.), *Investigaciones sobre ambientes educativos mediados por tecnología*. Ciudad de México: Clave editorial.

Esquivel-Gámez, I.; Barrios-Martínez, F. L. y Gálvez-Buenfil, K. E. (2020). Memoria operativa, ansiedad matemática y habilidad aritmética en docentes de educación básica en formación. *Revista de Educación Matemática*, *32*(2), 121-149. https://doi.org/10.24844/em3202.05

Fellman, D.; Soveri, A.; Waris, O. & Laine, M. (2017). Training of Verbal Working Memory at sentence level Fails to show Transfer. *Frontiers in Communication*, *2*(14). https://doi.org/10.3389/fcomm.2017.00014

Foster, J. L.; Harrison, T. L.; Hicks, K. L.; Draheim, C.; Redick, T. S. & Engle, R. W. (2017). Do the effects of working memory training depend on baseline ability level? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(11), 1677. https://doi.org/10.1037/xlm0000426

Guye, S.; De Simoni, C. & von Bastian, C. (2017). Do individual differences predict change in cognitive training performance? A latent growth curve modeling approach. *Journal of Cognitive Enhancement*, *1*(4), 374-393. https://doi.org/10.1007/s41465-017-0049-9

Green, S. C.; Bavelier, D.; Kramer, A.; Vinogradov, S.; Ansorge, U.; Ball, K. & Witt, C. (2019). Improving methodological standards in behavioral interventions for cognitive enhancement. *Journal of Cognitive Enhancement*, *3*(1), 2-29. https://doi.org/10.1007/s41465-018-0115-y

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

Linares, R.; Borella, E.; Lechuga, M. T.; Carretti, B. & Pelegrina, S. (2019). Nearest transfer effects of working memory training: A comparison of two programs focused on working memory updating. *PloS one*, *14*(2), e0211321. https://doi.org/10.1371/journal.pone.0211321

Maraver, M. J.; Bajo, M. T. & Gomez-Ariza, J. C. (2016). Training on working memory and inhibitory control in young adults. *Frontiers in human neuroscience*, 10, 588. https://doi.org/10.3389/fnhum.2016.00588

Melby-Lervåg, M.; Thomas 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*, 512-534. https://doi.org/10.1177/1745691616635612

Minear, M.; Brasher, F.; Guerrero, C. B.; Brasher, M.; Moore, A. & Sukeena, J. (2016). A simultaneous examination of two forms of working memory training: Evidence for near transfer only. *Memory & Cognition*, *44*(7), 1014-1037. https://doi.org/10.3758/s13421-016-0616-9

Miyake, A. & Shah, P. (eds.). (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. New York, NY: Cambridge University Press.

Morrison, A. B.; Rosenbaum, G. M.; Fair, D. & Chein, J. M. (2016). Variation in strategy use across measures of verbal working memory. *Memory & Cognition*, *44*, 922-936. https://doi.org/10.3758/s13421-016-0608-9

Redick, T. S.; Wiemers, E. A. & Engle, R. W. (2019). The role of proactive interference in working memory training and transfer. *Psychological Research*, 1-20. https://doi.org/10.1007/s00426-019-01172-8

Von Bastian, C. & Eschen, A. (2016). Does working memory training have to be adaptive? *Psychological research*, *80*(2), 181-194. https://doi.org/10.1007/s00426-015-0655-z

Von Bastian, C. & Oberauer, K. (2013). Distinct transfer effects of training different facets of working memory capacity. *Journal of Memory and Language*, *69*(1), 36-58. https://doi.org/10.1016/j.jml.2013.02.002

Von Bastian, C. & Oberauer, K. (2014). Effects and mechanisms of working memory training: a review. *Psychological Research*, *78*, 803-820. https://doi.org/1007/s00426-013-0524-6

Raven, J. C. & Court, J. H. (1998). *Manual for Raven's progressive matrices and vocabulary scales*. Oxford: Oxford Psychologists.

Soveri, A.; Antfolk, J.; Karlsson, L.; Salo, B. & Laine, M. (2017). Working memory training revisited: A multi-level meta-analysis of n-back training studies. *Psychonomic Bulletin & Review*, *24*, 1077-1096. https://doi.org/10.3758/s13423-016-1217-0

Zhao, X.; Xu, Y.; Fu, J. & Maes, J. H. R. (2018). Are training and transfer effects of working memory updating training modulated by achievement motivation? *Memory & cognition*, *46*(3), 398-409. https://doi.org/10.3758/s13421-017-0773-5

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