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Effectiveness of computerized cognitive stimulation in Chilean older adults

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Summary

Cognitive stimulation in older adults can improve cognitive performance and help reduce the risk of developing cognitive decline.

Objective: *To analyze the effectiveness of computerized cognitive stimulation (CCS) on memory, attention, processing speed, and problem-solving in cognitively healthy older adults (OA).*

Method: *The sample consisted of an intervention group (IG = 47, M = 76.02, SD = 3.37 years) subjected to 42 CCS sessions using Lumosity software three times per week, and a control group (CG = 52, M = 74.12, SD = 2.86 years) from the community, who did not receive any intervention. Both groups were medically evaluated and assessed using the Modified Mini-Mental State Examination (MMSEm), the Photo Test (PT), the Clock Test (CT), and the Trail Making Test (TMT A and B), before and after training.*

Results: *At baseline, significant intergroup differences favored the CG in all cognitive tests (MMSEm: d = 0.92; TMT-A: d = 1.12; TMT-B: d = 1.14; PT: d = 0.55; CT: d = 0.50). Despite these disparities, post-intervention analysis showed significant improvements in the IG across all domains except the CT (t = -1.43, p = ns), with large effects in MMSEm (d = 0.86) and moderate effects in PT, TMT-A and B.*

Conclusions: *CCS improved the cognitive performance of the evaluated older adults, demonstrating its feasibility and relevance as a digital strategy for cognitive health.*

Keywords: *computerized cognitive stimulation, lumosity, older adults, healthy aging, cognitive training.*

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INTRODUCTION

During aging, a series of cognitive (Rabbitt & Lowe, 2000), functional (Graciela et al., 2011) and neurophysiological (Elwan et al., 2003), changes occur, which manifest as declines in processing speed (Kuznetsova et al., 2016), attention (Correia-Delgado, 2010) and memory (Vega Ramírez et al., 2010), as well as a decrease in motor and functional abilities (Zanto & Gazzaley, 2019). On the other hand, there are alterations in the anatomy, biology, and biochemistry of the nervous system that are not part of healthy aging and are associated with neurodegenerative disorders (Kumar et al., 2018), leading to progressive cognitive decline (Bereczki et al., 2018; Gómez-Gómez & Zapico, 2019).

For both scenarios, Computerized Cognitive Stimulation (CCS) emerges as an effective intervention alternative to improve cognitive performance and reduce the risk of dementia (Fiatarone Singh et al., 2014). This strategy is characterized by its wide accessibility and low cost, as it relies on digital platforms that can be complemented with pharmacological treatments in combined care approaches (Jessen, 2020).

CCS utilizes various digital resources, such as tablets, mobile devices, computers, and virtual reality, as cognitive training tools. Its application promotes learning through the acquisition of skills and novel experiences, allowing users to engage in a set of tasks designed to strengthen cognitive abilities(Wang, 2022). These tasks, with varying levels of difficulty, have the potential to improve cognitive performance both generally and in specific domains (Djabelkhir et al., 2017; Vanova et al., 2018).

Lumosity (Lumos Labs, 2010), is a digital application designed to train and enhance cognition through 12 games based on task execution that strengthen memory, attention, inhibition, processing speed, and problem-solving. Available evidence supports the benefits of cognitive stimulation based on digital systems in domains such as memory, attention, and response speed (McDonnell et al., 2017).

Likewise, it has been identified as an effective intervention strategy to improve overall cognitive performance in individuals with and without cognitive impairment (Liang et al., 2018). However, the transfer of cognitive skills through this application remains a topic of debate, as clear evidence has so far only been demonstrated in cognitive flexibility (Bainbridge & Mayer, 2018). Despite its global use, there is a lack of studies contextualized to Latin American populations, where evaluating digital cognitive stimulation tools like Lumosity may offer valuable insight for public health strategies targeting aging and cognitive decline.

In this context, it is essential to continue evaluating the effects of Lumosity on cognitive training. In Chile, our research team has previously analyzed the impact of this program on overall cognitive performance, processing speed, and cognitive flexibility in older adults. To further explore these findings, it is necessary to develop sustained case-control studies that rigorously examine the program's effectiveness. Therefore, we set out to assess the efficacy of Lumosity's memory, attention, processing speed, and problem-solving tasks in a group of Chilean older adults who do not participate in cognitive stimulation activities.

SUBJECTS AND METHODS

Intervention study, case-control (Argimon Pallás & Jiménez Villa, 2013), in which the effectiveness of Lumosity software tasks was evaluated. The data were analyzed based on statistical distribution and normality in the intergroup and intragroup variation of the pre- and post-intervention assessment, using Student's t-test for independent samples. To account for the effect size in the inter- and intragroup mean differences, Cohen's d was estimated based on the proposal by Thalheimer and Cook (Thalheimer & Cook, 2002), which defines a small effect (0.15-0.40), medium effect (0.40-0.75), and large effect (+0.75).

Participants

A non-probabilistic sampling was conducted, initially including 195 older adults from the community, aged between 65 and 80 years, residing in the city of Osorno, Chile. The participants underwent a medical and cognitive evaluation to select a sample free of cognitive impairment, dementia, depression, and other neuropsychiatric disorders (see flow diagram).

The final sample consisted of 99 participants. Of these, 52 were part of the intervention group (IG), composed of members of the Diana de Rob Older Adults Association from the Osorno community. The remaining 47 were part of the control group (CG), consisting of older adults from the community who were not affiliated with any organization. Both the IG and CG participants stated that they had not previously engaged in any form of cognitive training.

Figure 1 shows the flow diagram describing the composition of the groups, as well as the moments when cognitive stimulation and the respective evaluations were conducted.

Instruments and digital application

All participants took the Preventive Medicine Examination for Older Adults (EMPAM), a comprehensive, periodic, and monitoring medical assessment that includes health, cognitive, and functional evaluation. With the formed groups, a sociodemographic questionnaire and a brief neuropsychological assessment protocol were used, including the Modified Mini-Mental State Examination (MMSEm) (Quiroga L. et al., 2004), the Photo Test (TF), the Clock Test (TR), (López et al., 2014) and the Trail Making Test (TMT A and B) to assess overall cognitive performance.

Lumosity is a cognitive training application developed by the Lumos Lab foundation(Lumos Lab, n.d.), available on *Google Play Store* (Lumos Labs, 2014) and the *App Store* (Lumos Labs, 2018). Its design includes a series of games specifically created to strengthen key

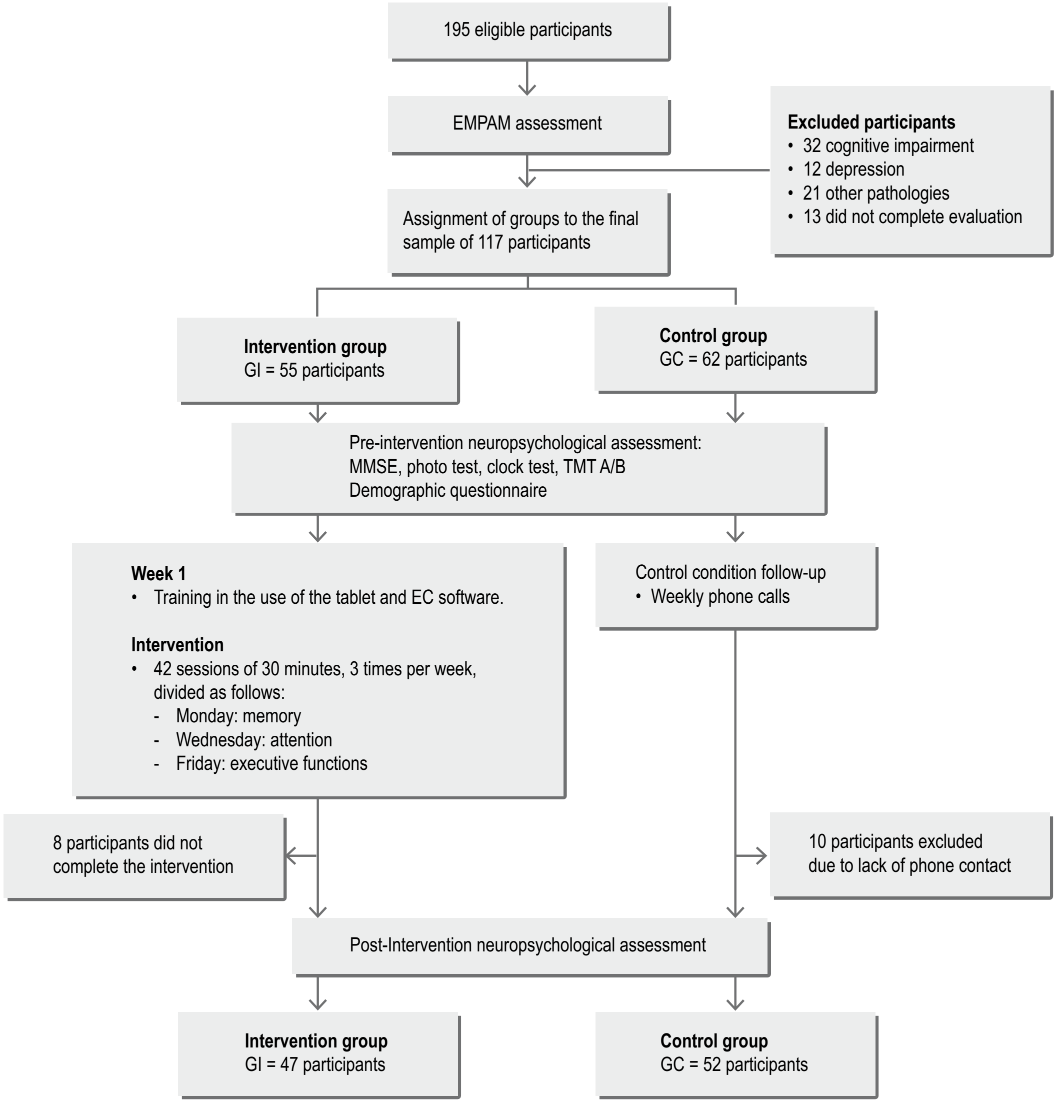

Figure 1. Flow diagram

cognitive skills such as memory, attention, processing speed, and problem-solving. Notable among these games are Color Comparison, Full Steam Ahead, Memory Matrix, Star Search, and Pet Detective, among others.

This platform is easily accessible and can be used on tablets and computers. Its exercises, based on game-like dynamics, feature progressively increasing difficulty levels as the user advances, allowing the training to be adapted to different performance levels. Additionally, Lumosity provides tools to evaluate and monitor user progress and is available in Spanish (Lumos Labs, 2010).

There are two versions of the application: a free version with limited access and a paid version with more advanced features. Studies worldwide have reported its effectiveness in improving cognitive performance in various populations (Hardy et al., 2015; Ho et al., 2022; Mam Khezri & Mikaeli Manieh, 2021). In Chile, it has been used as a training method for developing cognitive skills in children, demonstrating its potential as a cognitive stimulation tool across different age groups (Barrientos Jil et al., 2018).

Ethical aspects

The research was conducted within the framework of an interinstitutional agreement between the Behavioral Sciences Laboratory of the Universidad de Los Lagos and the Diana de Rob association. All participants were duly informed about the nature of the study and provided their informed consent. The study was approved by the institutional ethics committee (Ref. No. 06833/2023).

RESULTS

Table 1 presents the demographic and clinical characteristics of the groups, showing equivalence in terms of education, gender, and number of diseases, with a slight difference in age.

Prior to the implementation of computerized cognitive stimulation, significant intergroup differences were found in favor of the CG, showing better cognitive performance in the MMSEm and in the TMT-A and B, with large effect sizes (d = 0.92), (d = 1.12), and (d = 1.14), respectively. Additionally, medium effect sizes were observed in the Fototest (d = 0.55) and the Clock Test (d = 0.50). However, after the intervention, the IG averages leveled out, and the scores obtained in the cognitive tests surpassed those of the CG (see Table 2), except for the Clock Test (t = 6.90; $p < 0.05$), where the CG achieved a better result, with a medium effect size (d = 0.48).

As shown in Table 2, prior to the intervention, the CG showed significantly better performance than the IG in the MMSEm and TMT-A/B, with large effect sizes. Medium differences were also observed in the Phototest and Clock Test. After the intervention, the IG improved substantially, surpassing the CG in most tests, except for the Clock Test, where the CG maintained a better score with a medium effect size.

As shown in Table 3, the IG exhibited significant improvements in all cognitive tests except for the Clock Test,

Table 1. Demographic and clinical characteristics of the study groups

		IG ME ± SD	CG ME ± SD	t	*p*
Number		47	52		
Age		76.02 ± 3.37	74.12 ± 2.86	3.041	< 0.01**
Gender	Male	18	20	0.408	> 0.05
	Female	32	30		
Years of Schooling		8.22 ± 2.28	8.01 ± 2.25	0.629	> 0.05
Diseases	0	3	4		
	1	15	19		
	2	32	26		
	3	0	1		

Note: IG – Intervention group; CG – Control group; ME – Mean; SD – Standard deviation.** $p < 0.01$.

Table 2. Intergroup comparisons before and after ECC

		GC $\bar{x}$ ± DE	GI $\bar{x}$ ± DE	t	*p*	Cohen's d
Pre-intervention	MMSEm	27.03 ± 1.67	24.83 ± 2.50	4.63	< 0.001***	0.92
	PT	33.68 ± 3.20	31.78 ± 3.74	2.44	< 0.05*	0.55
	CT	7.55 ± 1.45	6.90 ± 1.19	2.19	< 0.05*	0.50
	TMT A	89.53 ± 15.09	108.88 ± 19.18	-5.02	< 0.001***	1.12
	TMT B	115.78 ± 16.41	137.50 ± 21.37	5.10	< 0.001***	1.14
Post-intervention	MMSEm	26.97 ± 2.14	27.48 ± 1.78	-1.14	> 0.05	0.26
	PT	34.05 ± 3.77	34.92 ± 4.39	0.96	> 0.05	0.21
	CT	7.72 ± 1.40	7.10 ± 1.19	2.15	< 0.05*	0.48
	TMT A	91.60 ± 15.31	97.52 ± 17.61	-1.61	> 0.05	0.36
	TMT B	120.40 ± 14.82	120.78 ± 18.07	-0.10	> 0.05	0.21

Note: IG – Intervention group; CG – Control group; MMSEm – Mini-mental; PT – PhotoTest; CT – Clock test; TMTA – Trail making test form A; TMTB – Trail making test form B.** $p < 0.01$

Table 3. Intragroup comparisons between IG and CG before and after cognitive training

		Initial x̄ ± DE	Final x̄ ± DE	t	*p*	*Cohen's d*
Control Group	MMSEm	27.03±1.67	26.97±2.14	0.34	> 0.05	0.02
	PT	33.68±3.20	34.05±3.77	-1.86	> 0.05	0.07
	CT	7.55±1.45	7.72± .40	-1.48	> 0.05	0.08
	TMT A	89.53±15.09	91.60±15.31	-4.10	< 0.001***	0.10
	TMT B	115.78±16.415	120.40±14.82	-4.24	< 0.001***	0.21
Intervention Group	MMSEm	24.83±2.50	27.48±1.78	-11.62	< 0.001***	0.86
	PT	31.78±3.74	34.92±4.39	-7.12	< 0.001***	0.54
	CT	6.90±1.19	7.10±1.19	-1.43	> 0.05	0.12
	TMT A	108.88±19.18	97.52±17.61	7.63	< 0.001***	0.44
	TMT B	137.50±21.37	120.78±18.07	8.60	< 0.001***	0.60

Note: IG – Intervention group; CG – Control group; MMSEm – Mini-mental; PT – PhotoTest; CT – Clock test; TMTA – Trail making test form A; TMTB – Trail making test form B.*** p < 0.001

with large effect sizes in the MMSEm and medium effects in the TMT-A, TMT-B, and Phototest. In contrast, the CG showed significant changes only in TMT-A and TMT-B, but with small effect sizes, indicating limited cognitive gains in this group.

DISCUSSION

This study evaluated the effectiveness of cognitive training software in improving cognitive performance in a group of healthy Chilean older adults as a strategy to mitigate the risk of cognitive decline associated with neurodegenerative processes (Lyu & Burr, 2016).

The results indicate that, in the pre-intervention phase, the average scores on the cognitive tests were higher in the CG than in the IG. In particular, CG participants showed better overall cognitive performance, reflected in higher scores on the MMSEm and TF, as well as on the Clock Test and faster response times in the TMT A and B tasks. This initial difference posed a challenge for the research team, as the study groups were not homogeneous in their characteristics and pre-intervention results.

Despite this situation, the decision was made to continue the study, considering the known benefits of neuropsychological interventions in maintaining or improving cognitive abilities in older adults with or without dementia (Cavallo et al., 2016). This unforeseen situation allowed for the hypothesis that the intervention group could experience a significant improvement in cognitive performance as a result of the sessions and intervention approach, to the point of surpassing the cognitive averages of the control group. Furthermore, the difference in performance between the CG and IG would highlight the variability in the effectiveness of the intervention.

Although the intervention group showed post-intervention improvements, the lack of randomization and baseline equivalence limits any causal interpretation of these results. This finding was supported by the intragroup analysis, in which the CG did not show significant improvements in the administered tests, except for the time required to complete the TMT A and B tasks.

The TMT A and B. The TMT (Tombaugh, 2004), is designed for participants to complete the tasks as quickly and accurately as possible, penalizing errors with an increase in response time. In this regard, CG members took longer to complete parts A and B of the TMT after the intervention, suggesting a decrease in their response speed and attention in the post-measurement. Additionally, no learning effect was observed in this group compared to the first measurement.

On the contrary, the intervention group showed significant improvements in the results of the applied tests, except for the TR. However, this measure is not highly relevant, as Lumosity does not include specific stimulation tasks to strengthen visuospatial ability. These findings reinforce the effectiveness of ECC in overall cognitive performance, suggesting that the improvements are directly related to the tasks designed to target specific processes within their respective cognitive domains (Martínez-Alcalá et al., 2018). From this perspective, it is essential to analyze the magnitude of the benefits of a cognitive intervention and its potential generalization, allowing for an assessment of its impact on the execution of specific tasks (Gigerenzer & Gaissmaier, 2010).

Nevertheless, the results found point toward the benefits of cognitive stimulation through technological platforms in both healthy older adults (ten Brinke et al., 2018) and those with neurocognitive disorders (van Balkom et al., 2020). Scientific literature has established that neuropsychological interventions, such as cognitive training, cognitive rehabilitation, and cognitive stimulation, have the potential to maintain or improve cognitive and functional abilities in both healthy individuals and those with cognitive impairment and dementia (Djabelkhir et al., 2017; Robert et al., 2020; Sood et al., 2019).

Thanks to technological advances and software development, a set of tasks based on traditional cognitive interventions has been integrated, strengthening the evidence in favor of digital modalities as effective tools for the well-being and mental health of older adults(Franza, 2022; Senczyszyn et al., 2021). Significant improvements have been observed in memory, attention, executive components, inhibitory control, and processing speed (Thalheimer & Cook, 2002). Additionally, these interventions have demonstrated benefits in functionality and cognitive abilities in mild cognitive impairment (MCI) and dementia (Zając-Lamparska et al., 2019), as well as in adaptive behavior and, in some cases, mood in individuals with mild forms of dementia or MCI (Sood et al., 2019).

Despite the favorable results of this study, several limitations must be considered. First, the small sample size may affect the generalization of the findings. Second, the study groups were not fully matched in terms of overall cognitive performance, which could have influenced the results. Third, this is a pre-post cross-sectional design, which does not allow conclusions about the persistence of cognitive improvements over time. Finally, the generalization of the benefits observed with ECC is limited by the lack of follow-up studies, as this research was based on a cross-sectional measurement. To address these limitations, future studies should include a longitudinal design with repeated measures, incorporating groups with cognitive impairments, mild cognitive impairment (MCI), and dementia to more accurately assess the effects of cognitive training using Lumosity.

CONCLUSION

Considering these limitations, it can be concluded that ECC improves memory, attention, processing speed, and problem-solving in older adults. The intervention group showed significant progress, outperforming the control group after the intervention, confirming the usefulness of digital platforms such as Lumosity. ECC emerges as an accessible and cost-effective alternative to strengthen cognitive function and promote healthy aging. Future longitudinal studies will allow for the evaluation of the sustainability of these benefits and their applicability in populations with cognitive impairment.

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