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Article

Comparing Traditional and Technology-Based Method for Executive Function and Attention Training in Moderate Alzheimer's Dementia

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ABSTRACT

Background: This study investigates the effects of cognitive interventions on executive functions and attention in patients with moderate Alzheimer's, comparing traditional and technology-based methods with a control group. **Method**: A randomized controlled trial was conducted with 112 participants, divided into three groups: traditional intervention, technology-based intervention, and control group. Sixteen sessions were carried out, assessed using standardized tests and applying hierarchical linear mixed models to adjust for confounding factors and random effects. **Results**: The interventions proved effective in improving executive functions. The model for backward digits and categorical fluency was optimized with MMSE scores, highlighting the benefits of good cognitive performance and the negative impacts of age on categorical fluency. The similarity-abstraction variable demonstrated the beneficial effects of education and cognitive performance. **Conclusions**: Cognitive training is a valuable tool for improving executive functions and attention in moderate Alzheimer's, indicating significant practical benefits. Future research should focus on the mechanisms of skill transfer to optimize interventions and improve the quality of life for those affected.

Comparación de Método Tradicional y Basado en Tecnología para el Entrenamiento de las Funciones Ejecutivas y Atención en la Demencia de Alzheimer Moderada

Palabras clave:
Entrenamiento cognitivo
Intervención
Demencia de Alzheimer

RESUMEN

Antecedentes: Este estudio investiga los efectos de intervenciones cognitivas en funciones ejecutivas y atención en pacientes con Alzheimer moderado, comparando método tradicional y basado en tecnología con un grupo control. **Método**: Se realizó un ensayo controlado aleatorio con 112 participantes, divididos en tres grupos: intervención tradicional, intervención basada en tecnología y grupo control. Se llevaron a cabo 16 sesiones, evaluando mediante pruebas estandarizadas y aplicando modelos lineales jerárquicos mixtos para ajustar factores confusos y efectos aleatorios. **Resultados**: Las intervenciones mostraron ser efectivas en la mejora de funciones ejecutivas. El modelo para dígitos hacia atrás y para la fluidez categórica se optimizó con MMSE, resaltando los beneficios de un buen rendimiento cognitivo y los impactos negativos de la edad en la fluidez categórica. La variable de abstracción de similitudes mostró efectos beneficiosos de la educación y el rendimiento cognitivo. **Conclusiones**: El entrenamiento cognitivo se revela como una herramienta valiosa para mejorar funciones ejecutivas y atención en Alzheimer moderado, sugiriendo beneficios prácticos significativos. Futuras investigaciones deberían centrarse en los mecanismos de transferencia de habilidades para optimizar las intervenciones y mejorar la calidad de vida de los afectados.

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An underlying principle within cognitive aging theories of executive functions (EF) posits that EF will be among the initial cognitive capacities to deteriorate with advancing age, and this impairment in EF is anticipated to be more pronounced compared to other facets of cognitive decline (Reuter-Lorenz et al., 2021). Furthermore, age-related alterations in attention become apparent, evidenced by worse performance in intricate attention-demanding assignments such as selective or divided attention. As individuals age, their proficiency in handling these more intricate attentional tasks gradually diminish. However, simple attention tasks such as digit span are maintained in normal subjects up to age (Lezak et al., 2012). In a prospective longitudinal study in a large sample of patients with different types of dementia, Smits et al. (2015) reported that Alzheimer's disease (AD) patients declined in all cognitive domains, including EF and attention. In recent years, it has been observed that EF are impaired in the early stages of AD (Levy et al., 2002), primarily due to the degeneration of the prefrontal cortex (Salat et al., 2001). Specifically, inhibitory abilities are compromised (Amieva et al., 2004), which, in conjunction with alterations in attentional skills required for solving complex tasks, can disrupt the performance of everyday activities (Guarino et al., 2019).

While managing prominent symptoms such as memory loss has traditionally been the central focus of treating individuals affected by AD, the importance of addressing impairments in executive functions and attention, crucial for their quality of life, is increasingly gaining recognition (Clare et al., 2019; Raz et al., 2010). It is evident that EF and attention play a central and complex role in neurocognitive aging, being negatively affected, but some authors point out that they are a source of possible support and maintenance of effective cognitive and behavioral functioning due to their compensatory character when preserved (Tucker & Stern, 2011). Therefore, interventions that address these functions can be important to slow down the alterations associated with the disease and maintain independence in daily life.

One of the most widely employed non-pharmacological interventions for individuals with dementia is cognitive intervention therapy (Gavelin et al., 2020). This approach is rooted in the hypothesis that maintaining an active cognitive engagement can attenuate cognitive decline by stimulating preserved areas and preventing deterioration due to disuse. Among these interventions, cognitive training (CT) stands out, involving the repetitive practice of structured tasks targeting specific cognitive functions across varying difficulty levels, tailored to individual performance (Bahar-Fuchs et al., 2019). CT operates under the assumption that continuous practice aids in sustaining the functioning of the trained cognitive domains and potentially correlates with a decelerated clinical progression immediately post-treatment and in the medium term.

The field of cognitive training raises fundamental questions about its generalization and the cognitive processes involved. The capacity-efficiency model suggests that CT can facilitate transfer by either expanding cognitive capacity or increasing efficiency in using existing capacity. Increases in overall cognitive processing capacity are expected to lead to broader transfer effects, while improvements in efficiency might be more specific to the task and training context (von Bastian et al., 2022). According to these authors, the majority of studies on cognitive training aimed to enhance capacity based on the common element's theory. The underlying transfer hypothesis posited that improvements would generalize maximally to untrained outcomes when knowledge components were identical across tasks. However, this hypothesis has been reconsidered in favor of the process or functional overlap theory, suggesting that if two tasks share cognitive processes, any improvement in these underlying processes should transfer from training one task to performing the other.

However, diversity in outcomes and observed clinical variations suggest that there could be statistical heterogeneity in the effect estimates from individual trials. Bahar-Fuchs et al. (2019) highlighted that CT could offer modest to moderate improvements in global cognition for individuals with mild to moderate dementia, with benefits that might extend up to twelve months after treatment. Although improvements across various cognitive domains were observed, the overall level of evidence remains low. The effectiveness of CT is questioned in studies such as those by Simons et al. (2016), which demand more rigorous evidence standards and a critical evaluation of the promised cognitive benefits. Farah (2015) underscores our limited understanding of who specifically benefits from CT and the associated risks, while von Bastian et al. (2022) investigate cognitive improvement through behavioral training, focusing on skill transfer to untrained tasks.

These debates highlight the need for meticulous scrutiny of interventions and a focus on identifying the cognitive mechanisms underlying improvements. Hill et al. (2017) identified the combination of various intervention methods as one of the problems that could cause conflicting results in CT interventions. Their findings indicate that although the impact of CT on individuals with dementia showed a generally weak pattern, clinically significant results were notable in studies that employed non-traditional CT approaches. This emphasizes the potential of alternative CT methods to provide more stimulation and engagement than traditional paper-and-pencil methods, suggesting that the evolution toward digital platforms could introduce benefits previously inaccessible.

Irazoki et al. (2020) further the argument for the use of new technologies in cognitive training, emphasizing the distinct advantages these modern approaches offer over classic methods. The use of technology in CT allows for precise targeting of cognitive functions, the ability to dynamically adjust training based on participant performance, designs that encourage greater engagement and reward, the provision of immediate feedback, and improved accessibility. This shift towards integrating advanced technologies and non-traditional methodologies in cognitive training suggests a promising direction for enhancing effectiveness, not only by addressing limitations highlighted by previous studies but also by leveraging the potential for greater personalization and engagement in training programs.

Combining these perspectives with the previous discussion, it becomes evident that while traditional CT methods have shown modest benefits, the incorporation of innovative approaches and technology could potentially overcome existing challenges. These insights underscore the need for a critical and methodological reevaluation of cognitive training interventions, emphasizing the importance of diversity in approach and the integration of new technologies to achieve more significant and clinically relevant outcomes.

With the aim of contributing substantial evidence to this realm of research, the primary objective of this study is to investigate the effects of cognitive training interventions on executive functions and attention in individuals with moderate Alzheimer's disease. By comparing interventions based on traditional methods (pencil and paper) and new technologies with a control group, we hypothesize that both cognitive training methods will result in significant improvements in the preservation of executive functions and attention compared to the control group. Additionally, we hypothesize that the technology-based group will outperform the traditional group. This approach allows for a detailed evaluation of the efficacy of the intervention modalities, underscoring our contribution to the existing body of knowledge on the treatment and management of Alzheimer's disease.

Method

Participants

We conducted a randomized controlled study to compare the effects of two interventions of 16 cognitive training sessions administered through either traditional methods and technology-based, with a control group.

Eligible participants, aged over 60 years, met the criteria for probable AD according to the National Institute on Aging-Alzheimer's Association workgroup (NIA-AA; McKhann et al., 2011). Inclusion criteria specified a Mini-Mental State Examination (MMSE; Folstein et al., 1975) score range of 16 to 20 during the screening process, aligning with NICE guidelines, which classify individuals scoring between 10 and 20 as having moderate dementia. Additionally, a Global Deterioration Scale (GDS; Reisberg et al., 1982) score of 4 was required for inclusion.

Exclusion criteria included individuals with neurodegenerative diseases other than AD dementia, severe psychiatric symptoms, high dependency levels, and those anticipating relocation during the study period.

All participants were associated with 12 centers managed by organizations representing relatives of individuals with Alzheimer's and other dementias (AFAS) in Valencia province, Spain. Initially, 15 centers were approached, but three declined to participate.

To ensure baseline comparability and minimize unintended imbalances, we employed a randomized block design. Centers were allocated to either the two intervention groups or the control group through block randomization, utilizing a 2:1 ratio. This ratio was chosen to optimize statistical power while still allowing for a sufficient number of participants in the intervention groups. Additionally, rural and urban geographical locations served as strata to further enhance the randomization process and ensure diversity across settings. It's important to note that assessment of participants was conducted by psychologists who were external to the centers. These psychologists were not involved in the allocation process and were thus blinded to the intervention assignments and implemented at each site. This blinding helped mitigate potential biases in outcome assessment.

Out of the 12 centers that agreed to participate, 162 patients were initially contacted for potential inclusion in the study. Following the screening process, which involved checking the inclusion and exclusion criteria, a total of 29 participants were excluded. Four individuals were excluded due to an MMSE < 16 and GDS = 5, one had an MMSE > 22 and GDS = 3, and three declined to participate. Additionally, 21 participants were excluded due to an MMSE > 20, all of whom had a GDS score of 4, indicating significant functional decline despite relatively higher cognitive test scores. Subsequently, the remaining 133 participants were randomized into the traditional intervention group, technology-based intervention group, and the control group.

Throughout the intervention and follow-up period, twenty-one participants dropped out of the study. Among these, three participants passed away, two were hospitalized, and five declined to continue their participation. Additionally, eleven participants were identified as having experienced cognitive decline during the intervention, as measured by decreases in MMSE scores below 16 and GDS scores reaching 5. Consequently, the final sample at the study's conclusion consisted of 112 participants who completed all assessments.

To address concerns regarding potential bias introduced by these dropouts, we conducted additional analyses comparing baseline characteristics and outcomes between participants who dropped out and those who completed the study. Specifically, we compared demographic variables and baseline cognitive scores between the two groups (completers and non-completers) with no significant differences. These results suggest that the decision to drop out of the study was not influenced by factors related to difficulties adhering to the intervention.

At the conclusion of the intervention and follow-up period, the final sample comprised 112 participants who completed the study. The research received approval from the Ethics Committee of Research in Humans of the Ethics Commission in Experimental Research of University of Valencia with register code 2601758. A flow chart of the study is shown in Figure 1.

Table 1 shows the primary data and comparison tests performed between the three groups. The characteristics of the groups were similar.

Table 1
Means (and SD) and Percentages of Demographics Indices Comparing Groups

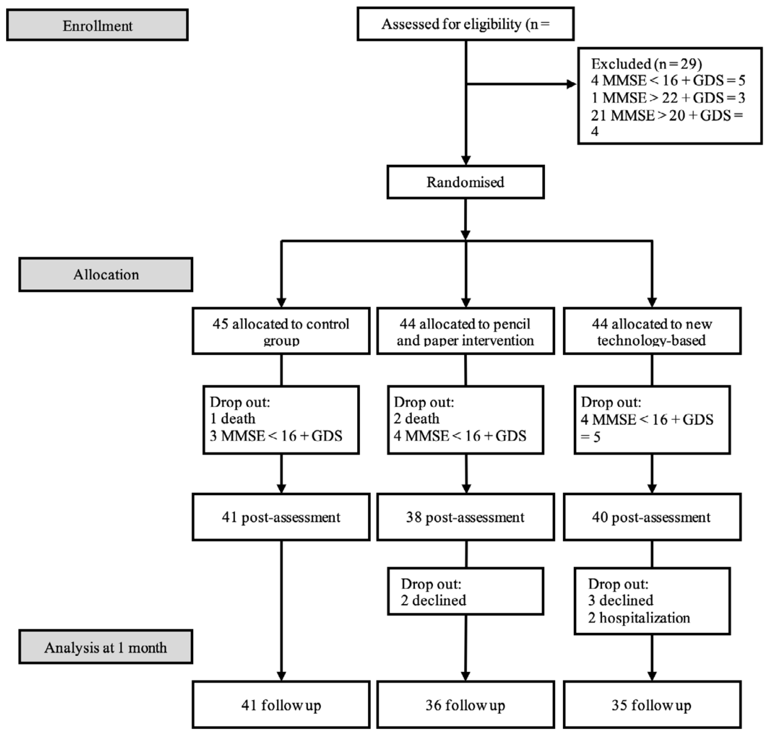
	CG	TIG	TBIG	*p*
Gender % (W/M)	58.5/41.5	61.1/38.9	65.7/34.3	.813
Age (SD)	79.59 (5.9)	78.97 (7.1)	78.89 (6.6)	.887
Marital status % MR/SI/WI	43.9/7.3/48.8	38.9/5.6/55.6	37.1/5.7/57.1	.763
Years of Educational (SD)	8.21 (2.6)	8.36 (2.8)	9.05 (2.9)	.389
MMSE (SD)	18.02 (1.3)	18.63 (1.4)	18.11 (1.5)	.131

Note. CG = control group; TIG = traditional intervention group; TBIG = technology-based intervention group; W = women; M= men; MR = married; SI = single; WI = windowed.

Instruments

To determine patient eligibility, we employed two assessment tools: Mini-Mental State Examination (MMSE; Folstein et al., 1975) and Global Deterioration Scale (GDS; Reisberg et al., 1982). The MMSE serves as a cognitive screening test designed to detect the presence of cognitive impairment, with a maximum achievable score of 30 points. Scores falling below 23 were considered indicative of cognitive impairment, with a maximum achievable score of 30 points. Scores falling below 23 were indicative of cognitive impairment. GDS is a global measure of cognitive function originally developed to gauge cognitive decline in various forms of dementia. It categorizes patients into seven clinically distinguishable

Figure 1
Flow Diagram of Trial Profile



global stages, ranging from a normal state (Stage 1) to severe AD (Stage 7). Also considers patients' functional capacity, including their ability to perform daily activities and instrumental tasks.

For the evaluation of EF, we employed the backward digit span subtests of the Wechsler Intelligence Scale for Adults-III (Wechsler, 2001) and the subtests categorical fluency and similarity-abstraction of the Barcelona Test Revised (Peña-Casanova, 2005). The backward digit span comprises a sequence of numbers of increasing difficulty, consisting of eight items with two items each. The maximum score is 16, the examiner reads a series of numbers that the patient must say in reverse order to those presented. Word fluency tests are widely used in neuropsychological research due to their ease of administration and sensitivity to various cognitive disturbances. To assess language ability, we used the Categorical fluency subtests from the Barcelona Test Revised (TBR; Peña-Casanova, 2005). In this test, participants were asked to name as many animals as possible in one minute, allowing the observation of their capacity to access and recall elements from the lexical and semantic storehouse Lastly, in the similarity-abstraction subtest, two concepts or words were presented and patients were tasked with identifying and explaining the abstract similarity between them, assessing their ability to establish abstract relationships between different concepts. The maximum score that can be obtained is 12.

The Stroop test (Golden, 2010) was employed to evaluate biased attention with regard to focusing on specific stimulus attributes while disregarding unrelated information. In this task, patients were initially presented with colored names written in black ink (e.g., red, blue, green, yellow) and were asked to read the words. Subsequently, the same colors were presented in strings of nonsense symbols (XXXX), and patients were required to name the colors. The third condition involved presenting words that were actually color names but were written in a different color than the word itself (e.g., the word "green" written in red ink). Patients were tasked with naming the color of the ink that disagreed with the word they read. For this study, the third condition was utilized (Stroop color–word).

Procedure

The cognitive training intervention, conducted by psychologists from participating centers, involved two formats: traditional, utilizing pencil and paper, and a program presented via technology-based methods. Despite differing formats, both interventions featured identical activities to ensure comparability. Sessions were conducted in groups of a maximum of eight participants, ensuring optimal engagement and individual attention. Each intervention comprised 16 sessions, scheduled twice a week, with a duration of 50 minutes per session (see table 2). To maintain ecological validity, daily tasks and relevant topics were integrated into the sessions.

The structure of each session remained consistent throughout the intervention. Initially, tasks were introduced, followed by time for completion, and concluded with a brief session wrap-up. Tasks aimed at enhancing EF and attention were integrated into every session.

To ensure consistency and reproducibility, interventions were designed to be identical in content and duration across both modalities. Presentation times for each task were standardized across both modalities to minimize potential confounding factors.

The intervention targeted various aspects of executive function. Participants engaged in activities such as identifying common elements in series of objects to stimulate abstraction capacity (for

Table 2
Number Sessions and Objectives Intervention

Sessions	Objectives
Sessions: 1, 3, 5, 7, 9, 11, 13, and 15.	Stimulate and exercise the cognitive function of abstraction. Stimulate and exercise the cognitive function of planning. Work on alternative attention.
Sessions: 2, 4, 6, 8, 10, 12, 14, and 16.	Activate and exercise the cognitive functions of problem solving. Stimulate and work on selective attention. Enhance working memory

example, participants were shown the words "rose", "daisy", and "carnation", and they were required to identify the category they belong to, which is flowers), repeating lists of words in reverse order to enhance working memory (for example, participants were given three words such as "April", "boot", and "house", and they were required to repeat the list in reverse order, that is, "house", "boot", and "April"), and solving hypothetical problems to improve problem-solving skills (for example, imagine you want to make an omelette, but you don't have any eggs. What would you do? Participants were required to provide logical responses and appropriate solutions, such as going to the supermarket to buy eggs). Additionally, planning capacity was addressed through the organization of calendars for fictitious characters (for example, if Maria needed to go to the supermarket, which is open from 9 AM to 8 PM, and also had to attend a one-hour yoga class available only in the afternoon from 3 PM to 6 PM, while her work hours were from 9 AM to 3 PM, participants were expected to indicate that Maria should go to work in the morning and until 3 PM, then she could attend the yoga class, and finally, go shopping at supermarket). Selective attention was developed by requiring participants to mark specific stimuli under certain conditions (for example, in a table filled with letters and numbers, participants were asked to cross out all the numbers), and alternating attention was practiced by prompting participants to switch focus between different stimuli (for example, in a table full of numbers and letters, participants were initially asked to mark only the numbers until a given moment when they were informed that they should mark only letters from that point forward). Importantly, tasks were carefully designed to avoid any resemblance to outcome measures, thereby minimizing the risk of introducing a practice effect bias during assessment tasks.

In the technology-based approach involved presenting tasks through projected onto a large screen. Responses in this format were given orally, with guidance from the psychologist to maintain order, while visual interaction was encouraged among participants. Here, the psychologist played an active role, not only presenting tasks but also utilizing technology to provide immediate feedback

In contrast, the traditional intervention, participants received tasks on paper, with the psychologist reading instructions that were consistent for the entire group. Participants then responded in writing to their assigned activities, while the psychologist provided individualized clarification as needed. Immediate feedback was not given in this format; instead, a final group reflection on activity solutions was conducted.

Meanwhile, the control group engaged in recreational activities such as board games and art projects, following the same structure and duration as the intervention sessions while on a waiting list. Although these activities were less focused on specific cognitive skills, they provided a valuable basis for comparison by fostering social interaction and emotional well-being without an explicit focus on cognitive improvement.

It is important to highlight that all involved centers received the necessary materials for both types of interventions, enabling their future application regardless of the participants' assignment in the study.

Data Analysis

Hierarchical linear mixed models were implemented, progressively increasing the model's complexity to adjust for confounding factors and random effects. Successive models added fixed variables and were compared using Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC) to assess the appropriateness of the fit. The analysis began with a baseline model (Model A) that included fixed effects of group and time and their interaction, as well as random effects by center. Additional variables, such as MMSE (Model AB), gender (Model ABC), age (Model ABCD), and years of schooling (Model ABCDE), were subsequently incorporated, refining the model specification at each step. The statistical analysis was conducted using the R software, specifically employing the lme4 package (Bates et al., 2023) for implementing hierarchical linear mixed models. This approach allowed for a detailed examination of temporal and group patterns, adjusting for random effects and multiple predictor variables, to provide a robust interpretation of the data.

Results

Hierarchical linear mixed models were implemented for each of the outcome variables, progressively increasing the model's complexity to adjust for confounding factors and random effects in table 3, the models and results for the backward digit variable are shown, considering that all models include random effects by center.

Table 3
Models and Results for Variable Backward Digit

Model	Significant Fixed Effects (Estimate; *p-value*)	AIC	BIC
Model A	Time (-0.5244; 4.32e-06), TIG: Time (0.5938; 0.000342), TBIG: Time (0.3958; 0.017188)	996.983	1027.520
Model AB (with MMSE)	Time (-0.40837; 0.000101), MMSE (0.08419; 2.25e-14), TIG: Time (0.50471; 0.000899), TBIG: Time (0.31348; 0.039534)	946.951	981.305
Model ABC (with gender)	Time (-0.41287; 8.11e-05), MMSE (0.08093; 2.88e-13), TIG: Time (0.50816; 0.000802), TBIG: Time (0.31667; 0.037038)	948.181	986.352
Model ABCD (with age)	Time (-0.417035; 6.87e-05), MMSE (0.077904; 3.08e-12), TIG: Time (0.511365; 0.000741), TBIG: Time (0.319625; 0.035256)	948.181	997.510
Model ABCDE (with years of education)	Time (-0.423745; 5.04e-05), MMSE (0.073035; 1.29e-10), TIG: Time (0.516520; 0.000632), TBIG: Time (0.324387; 0.032105)	948.181	1006

Model AB stands out as the best model for analyzing the variable backward digit due to its lowest AIC and BIC values, indicating a superior balance between simplicity and explanatory power. It demonstrates that backward digit typically decreases over time, yet higher MMSE scores result in increases. Notably, the TIG group exhibits a significantly more positive change over time than TBIG, highlighting that the effect of time on backward digit varies by group. TIG benefits the most, suggesting that intervention associated with this group have the most substantial positive impact.

Table 4 outlines the analysis for the categorical fluency variable, where each model incorporates center-based random effects.

The optimal model for the categorical fluency variable is Model ABCD which achieves the best balance between model complexity and accuracy, as indicated by its lowest AIC value. This model shows that the MMSE score positively influences the outcome, suggesting higher cognitive function is associated with better outcomes. Gender and age are also significant predictors, with a particular gender category and older age linked to lower outcomes. Additionally, the interaction between the TBIG group and time indicates that changes in the categorical fluency variable outcome over time vary by group, with TBIG experiencing a more pronounced effect. This highlights the importance of cognitive performance, gender, and age in influencing the dependent variable.

Table 5 presents the analysis of the similarity-abstraction variable, incorporating center-based random effects in each model.

The Model ABCDE is identified as the best for analyzing the similarity-abstraction variable due to its lowest AIC and BIC values, indicating optimal balance between model complexity and fit. This model shows that higher cognitive performance (MMSE scores) and years of education positively influence similarity-abstraction scores, while age has a negative effect. Additionally, the TBIG group exhibits a significant positive trend over time, highlighting the nuanced impact of group, cognitive ability, age, and education on similarity-abstraction variable outcomes.

In the analysis of the Stroop C-W variable, none of the models demonstrated a significant effect of group/intervention over time. This indicates that the intervention does not significantly influence the performance of this variable

Discussion

The primary objective of our study was to investigate the effects of cognitive training interventions on EF and attention in individuals with moderate AD. By comparing traditional (pencil-and-paper) and technology-based intervention to a control group, we aimed to understand the distinct impacts of these approaches. Our findings offer valuable insights into the effects of cognitive training for individuals affected by this challenging condition.

The results of this study reveal a series of significant findings regarding the effects of cognitive training on various measures of cognitive performance. Firstly, the AB model emerges as the most optimal for analyzing the backward digit variable, highlighting the positive influence of MMSE scores on task improvement and the variability in changes over time among the intervention groups. Additionally, for the categorical fluency variable, the ABCD model reveals a positive association between cognitive performance, age, and education, while the TBIG intervention group shows a significant effect over time. However, in the analysis of the Stroop C-W variable, no significant effect of the intervention group is observed. These results suggest that cognitive training can have differentiated effects on different measures of cognitive performance, emphasizing the importance of considering individual and intervention factors when designing cognitive training programs.

Executive functions are essential for cognitive, behavioral, and emotional performance (Godefroy et al., 2018), and their alteration affects daily activities and social relationships. This underlines the importance of considering them for intervention, not necessarily with the ultimate goal of cognitively improving their performance, but perhaps because it can contribute to their activation and maintenance in emotional aspects or those related to daily activities.

Our results revealed significant changes in EF scores at the end of the interventions between both the traditional and technology-based intervention groups and the control group. This finding is in line with recent studies showing the efficacy of cognitive interventions to improve functions such as working memory, cognitive flexibility, and inhibition (Bahar-Fuchs et al., 2019; Clare et al., 2019; Diamond & Ling, 2016). EF involve higher-level neurocognitive processes

Table 4
Models and Results for Variable Categorical Fluency

Model	Significant Fixed Effects (Estimate; *p-value*)	AIC	BIC
Model A	Time (-0.9390; 0.0470), TIG: Time (1.2307; 0.0748), TBIG: Time (1.6962; 0.0150)	1943.04	1973.57
Model AB (with MMSE)	MMSE (0.42757; < 2e-16), TBIG: Time (1.27799; 0.0366)	1854.89	1889.24
Model ABC (with gender)	MMSE (0.40746; < 2e-16), Gender 2 (-1.51133; 0.000328), TBIG: Time (1.29765; 0.030752)	1843.84	1882.01
Model ABCD (with age)	MMSE (0.39184; < 2e-16), Gender 2 (-1.31841; 0.00174), Age (-0.09025; 0.00490), TBIG: Time (1.31293; 0.02721)	1842.95	1884.93
Model ABCDE (with years of education)	MMSE (0.38806; < 2e-16), Gender 2 (-1.31848; 0.00176), Age (-0.08881; 0.00606), TBIG: Time (1.31662; 0.02701)	1848.13	1893.94

Table 5
Models and Results for Variable Similarity-Abstraction

Model	Significant Fixed Effects (Estimate; *p-value*)	AIC	BIC
Model A	Time (-0.6463; 0.00323), TIG: Time (0.6325; 0.04796), TBIG: Time (0.7892; 0.01447)	1943.04	1973.57
Model AB (with MMSE)	MMSE (0.20310; < 2e-16), TBIG: Time (0.59055; 0.0362)	1854.89	1889.24
Model ABC (with gender)	MMSE (0.20676; < 2e-16), TBIG: Time (0.58698; 0.0373)	1843.84	1882.01
Model ABCD (with age)	MMSE (0.19123; < 2e-16), Age (-0.05970; 0.000147), TBIG: Time (0.60216; 0.02971)	1842.95	1884.93
Model ABCDE (with years of education)	MMSE (0.17309; 9.44e-16), Age (-0.05325; 0.000602), Years of Education (0.13275; 0.000339), TBIG: Time (0.61991; 0.02305)	1848.13	1893.94

such as planning, decision-making, and mental flexibility (Diamond, 2013). These processes require the coordination of multiple underlying mental functions, making them more receptive to cognitive training interventions and potentially exhibiting increased neural plasticity.

Our study not only confirms the complexity of executive functions, but also highlights the need to consider multiple factors when designing and implementing cognitive interventions. The initial level of impairment is crucial in determining the effectiveness of these interventions, emphasizing the urgency of applying them as soon as possible. Additionally, it is essential to consider additional factors such as age and years of education, which can positively or negatively influence the outcomes of interventions targeted at specific executive functions.

It should be noted that, in the case of attention tasks, the results observed were not statistically significant. Attention is one of the first cognitive abilities to decline with age and especially in cognitive disorders such as AD (McDonough et al., 2019). The lack of residual capacity in this skill may make it challenging for cognitive training to even maintain this skill, highlighting the importance of initiating interventions as early as possible (Belleville et al., 2011). Furthermore, the non-significant results in the attention tasks underscore the need for further exploration.

It is important to recognize that this particular study focused on a sample of individuals with moderate cognitive impairment. This underscores a critical aspect of our findings, demonstrating that even in the presence of established impairment, working on these cognitive functions remains beneficial. Cognitive training has the potential to help individuals at various stages of cognitive decline, including those with moderate symptoms.

This study has some limitations that should be considered. Firstly, the selection of measurement variables was constrained, focusing solely on specific cognitive areas and neglecting to encompass the entirety of the neuropsychological profile. This limitation may restrict the generalizability of the findings. Furthermore, the absence of a combined approach integrating traditional and technological intervention modalities limits our understanding of potential synergistic effects. The lack of a mixed therapy group prevents determination of whether the convergence of both methods could enhance the observed cognitive benefits. The findings of this research appear to have practical implications that could extend to the clinical context. Improvements in executive functions could translate into a better quality of life for people with Alzheimer's. These cognitive skills play a central role in daily functioning, influencing an individual's ability to handle complex tasks and maintain independence. However, future research in cognitive training should focus on several key areas to advance our understanding of transfer effects and improve the efficacy of interventions. Investigating the underlying mechanisms of transfer, particularly how the expansion of cognitive capacity and improvements in efficiency translate into transferable skills, should provide valuable insights.

Author Contributions

Jesus González-Moreno: Conceptualization, Formal Analysis, Writing - Original Draft. **Gema Soria-Urios**: Data curation, Methodology, Writing – Review & Editing. **Encarnacion Satorres**: Conceptualization, Investigation, Writing – Review & Editing. **Juan C. Meléndez**: Supervision, Formal Analysis, Writing - Original Draft.

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Declaration of Interests

The authors declare that there is no conflict of interest.

Data Availability Statement

The data supporting the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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