The potential role of neurotechnology-based cognitive training for older adults: A scoping review

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ABSTRACT

Background: There is a considerable variety of neurotechnology-based cognitive training using immersive and computerized technologies, although this wide variety of training is not well explored by the literature in manuscripts that describe what types of approaches exist and what training is most appropriate for certain individuals' necessities, especially for perceptual and cognitive outcomes. Aim: To synthesize neurotechnology-based cognitive training interventions for healthy older adults. Methods: We followed the guidelines set forth for conducting systematic scoping reviews proposed by Peters et al. (2015). Consistent with this methodology, our review was conducted in five steps (developing the specific research questions, identifying relevant studies, selecting studies, charting data, and summarizing and reporting results). Results and Discussion: The initial search of electronic databases yielded 417. After the removal of duplicates, 328 studies were screened. After abstract and title screening, we assessed 36 full texts for eligibility and included 13 studies in the final synthesis. From our first specific research question, the most frequently mentioned type of training in recent literature is computer-based cognitive training. From our second specific research question, the most frequently mentioned cognitive outcomes in healthy older adults are global cognition, inhibitory control, and processing speed. Conclusion: The results of this brief scoping review show the importance of evaluating the impact of neurotechnology-based cognitive training to verify its effects on the cognitive performance of healthy older adults.

Keywords: Geriatrics, Gerontology, Health, Aging, Neuroscience.

1 BACKGROUND

The world population is aging more quickly than ever before, as a result, the proportion of people aged 65 years and older is increasing at different rates in different parts of the world. The number of older adults has risen more than threefold since 1950, from approximately 130 million in 1950 to 419 million in 2000 [1]. Additionally, epidemiological studies show that 11% of the world's population is over 60 years of age and is projected to increase by 2050 to 22% of the population [2]. Furthermore, increasing life expectancy and the consequences of demographic change have led to considerable challenges in nearly all areas of the health sciences, with the proportion of individuals in their late adulthood steadily growing [3].

Aging in humans is accompanied by stereotypical structural neurophysiological changes in the brain and variable degrees of cognitive decline [4]. The decline in cognitive function is a major concern for older adults, and it is already well documented in the literature that cognitive functioning declines in older age [5]. Due to the rapid neurotechnological expansion in the health sciences, developments in neuroimaging techniques and related mathematical tools, many technology-based interventions (e.g., neurotechnology-based cognitive training) have been used to reverse cognitive decline, especially for older adults [6,7].

Cognitive training interventions that harness neuroplasticity mechanisms for cognitive enhancement in impaired neural systems or delaying cognitive decline due to aging show promise as evidence-based interventions in the health sciences. In terms of types of training, there is a considerable variety of neurotechnology-based cognitive training using immersive and computerized technologies. This wide variety of trainings is not well explored by the literature in manuscripts that describe what types of approaches exist and what training is the most appropriate for certain individuals' necessities, especially for perceptual and cognitive outcomes.

Although the outcome literature on effective interventions applied to older adults is uneven across conditions and treatment approaches, there are some particular intervention methods that have received consistent research support (e.g., the use of experimental paradigms of experimental psychology applied to user-friendly digital interfaces; see Legault et al. (2012)[8]). To investigate and summarize this gap, we conducted a brief scoping review to identify and describe the range of types of training on neurotechnology-based cognitive training interventions for healthy older adults. The specific research questions were described below (see Table 1).

TABLE 1. Specific research questions descriptions.

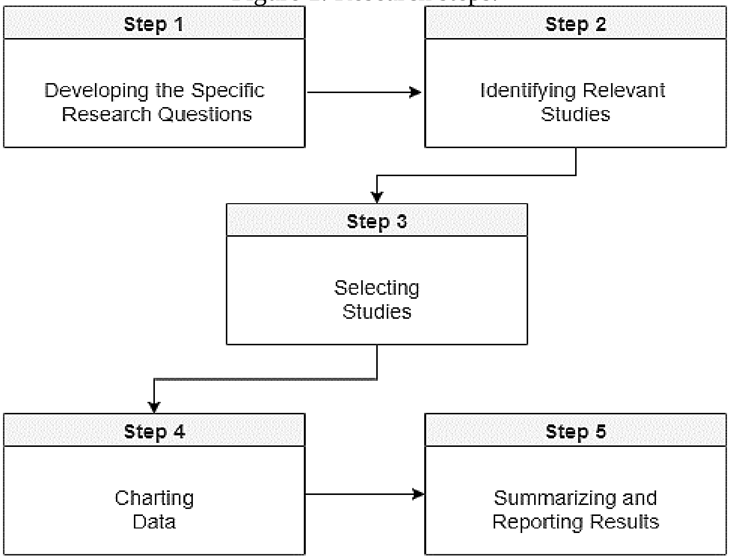
Specific Questions
SQ1 -What types of neurotechnology-based cognitive training are most mentioned in the scientific literature?
SQ2 -What are the main cognitive outcomes of neurotechnology-based cognitive training for the elderly adult population?

SQ – Specific question.

2 METHODS

In this scoping review, we synthesized neurotechnology-based cognitive training interventions for healthy older adults. We focused on a survey of the main types and methods of cognitive training mentioned in the scientific literature in the last five years (i.e., time frame between 2019 and 2023). We followed the guidelines set forth for conducting systematic scoping reviews proposed by Peters *et al.* (2015)[9]. Consistent with this methodology, our review was conducted in five steps (see Figure 1).

Figure 1. Research steps.



2.1 SEARCH STRATEGY

We conducted the review from the electronic literature databases of PubMed/MEDLINE (https://pubmed.ncbi.nlm.nih.gov/) and Lens (https://www.lens.org/) to identify peer-reviewed English original research studies published between January 2019 and June 2023. To elaborate the search strategy, we used the open-source software 2D Search (www.2dsearch.com), in which queries are formulated by manipulating objects on a two-dimensional canvas. The search strategy and filters adopted on both platforms is illustrated below (see Table 1).

Table 1. Search strategy.

Eletronic Database	Search Strategy	Filters
Pubmed/MEDLINE	(elderly OR "older people" OR aged) AND (cognition) AND ("cognitive therapy" OR "cognitive training" OR "brain training")	Clinical Study, Clinical Trial, Clinical Trial, Phase I, Clinical Trial, Phase II, Clinical Trial, Phase III, Clinical Trial, Phase IV, Controlled Clinical Trial, Multicenter Study, Randomized Controlled Trial, Aged: 65+ years, 80 and over: 80+ years, Humans.
Lens	Scholarly Works (252) = (elderly OR ("older people" OR aged)) AND ((cognition) AND ("cognitive therapy" OR ("cognitive training" OR "brain training")))	Year Published = (2019 - 2023) Publication Type = (journal article) MeSH Heading = (Cognition , Aged)

2.2 ELIGIBILITY CRITERIA

We included articles that met the following criteria:

Inclusion

- Experimental peer-reviewed clinical trials;
- Multimodal/Multicentre/Combined modalities of interventions;
- Intervention sample with older adults (age ≥ 60 years old);
- Studies Published between January 2019 to June 2023.

Exclusion

- Intervention sample diagnosed with dementia/cognitive impairment of any type or other;
- Reviews, Protocol or not experimental studies;
- Intervention not characterized as a neurotechnology-based cognitive training;
- Studies without clearly cognitive outcomes;
- Studies not in English.

2.3 DATA EXTRACTION AND SYNTHESIS

We extracted the trials using the open-source software Zotero - version 6 (https://www.zotero.org/). For the screening process, the open-source, free web-tool software Rayyan (http://rayyan.qcri.org) was used. For the synthesis, the following data were extracted and inserted into a spreadsheet: Authors, Year, CT type, and Cognitive Outcomes. The analysis has been primarily focused on studies clearly reporting details about neurotechnology-based cognitive training, a clear intervention description (e.g., digital interfaces, possible experimental paradigms), evidence of cognitive outcomes, and an experimental group composed of older adults (i.e., age ≥ 60 years old).

3 RESULTS AND DISCUSSION

The initial search of electronic databases yielded ∑n = 417 studies (PubMed/MEDLINE: ∑n = 165, Lens: ∑n = 252). After the removal of duplicates, ∑n = 328 studies were screened. After abstract and title screening, we assessed ∑n=36 full-texts for eligibility and included ∑n = 13 studies in the final synthesis (see Figure 2).

The population ages of participants (final synthesis) ranged between 65 and 88 years old. The studies came from the Netherlands [10], Finland [11], Taiwan [12], Belgium [13] , United States of America [14–17], Canada [18], China [19], Switzerland [20], Japan [21] and Spain [22]. The main characteristics of individual studies were summarized (see Table 2).

From our first specific research question (i.e., what types of neurotechnology-based cognitive training are most mentioned in the scientific literature?) the most mentioned type of training in recent literature is computer-based cognitive training. This type of training is one such application of digital health in which individuals can access gamified, engaging, cognitive exercises from their own computers or mobile devices anytime, anywhere, and these exercises can be targeted to improve overall cognition or specific domains [23]. Furthermore, perhaps the recurrent use of this type of computerized training is justified by the rapid advances in computerized digital interfaces developed in recent years, especially during the period of the COVID pandemic.

From our second specific research question (i.e., what are the main cognitive outcomes of neurotechnology-based cognitive training for the elderly adult population?), the most frequently mentioned cognitive outcomes in healthy older adults are global cognition, inhibitory control and, processing speed. Perhaps this is justified by the use of systematic tasks that allow the development of target variables that are built into friendly digital interfaces. In addition, many studies use neuropsychological tools that allow the tracking of specific outcomes related to cognition (e.g., stroop-task).

Figure 2. Flow-diagram of included and excluded studies.

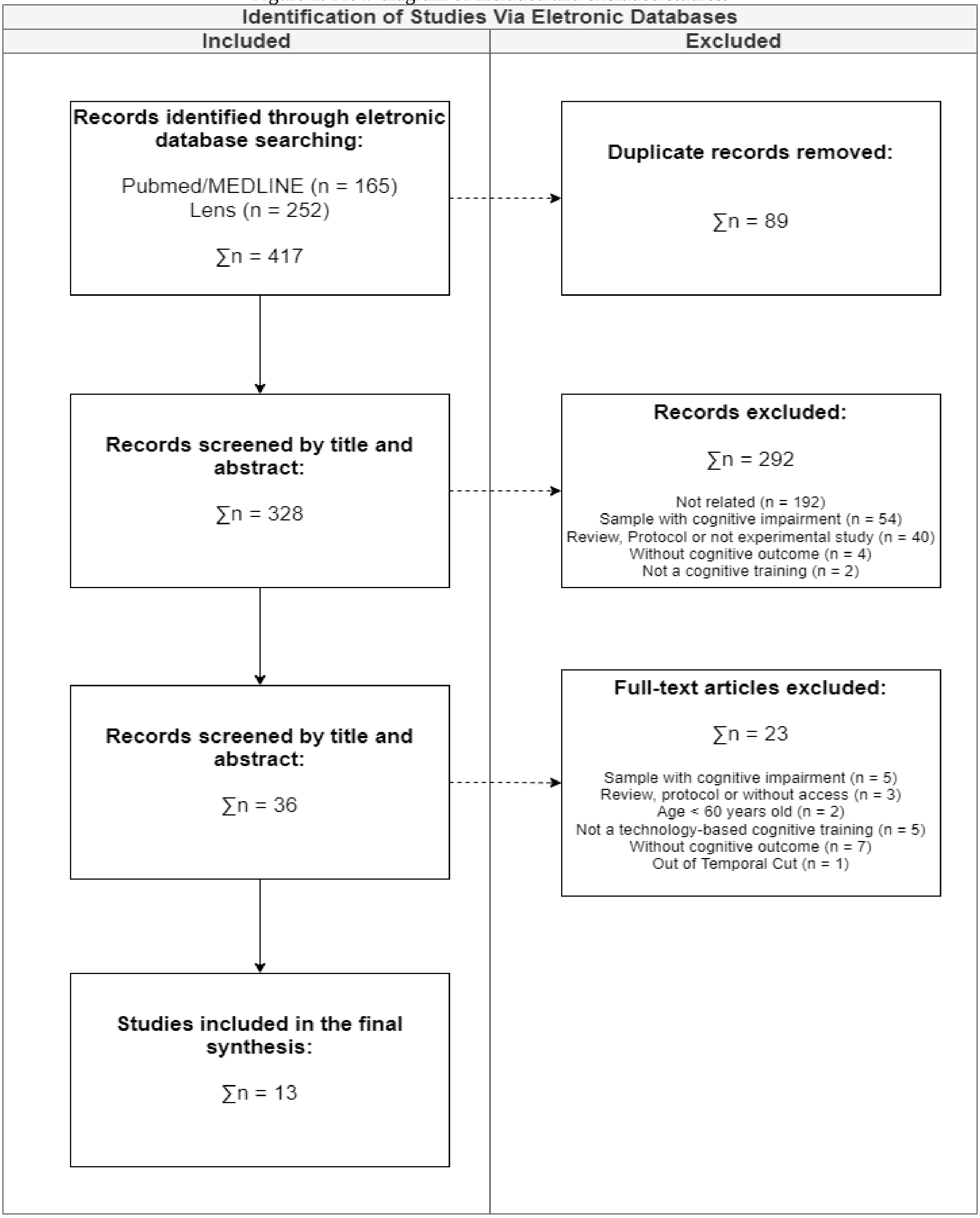


Table 2. Characteristics of individual studies.

Authors	Year	CT Type	CT Outcome
Brinke *et al.*	2021	Computer-based Cognitive Training	Inhibitory Control
Lenze *et al.*	2020	Computer-based Cognitive Training	Global Cognitive Performance and Functional Cognition
Mao *et al.*	2021	Multi-Component Computer-based Cognitive Training	Global Cognition and Attention
Sipila *et al.*	2021	Computer-based Cognitive Training	Inhibitory Control
Fu et al.	2020	Computer-based Cognitive Training	Working Memory
Yu et al.	2021	Computer-based Cognitive Training	Global Cognition
Estrada-plana *et al.*	2021	Computer-based Cognitive Training	Semantic and Phonemic Verbal Fluency
Nouchi et al.	2020	Videogame-based Cognitive Training	Processing Speed and Working Memory
Bonnechère et al.	2021	Videogame-based Cognitive Training	Processing Speed
Krebs *et al.*	2021	Computer-based Cognitive Training	Selective and Divided Attention; and Global Cognition
Lee *et al.*	2020	Computer-based Cognitive Training	Processing Speed, Inhibitory Control and Working Memory
Acevedo *et al.*	2022	Videogame-based Cognitive Training	Memory, Verbal Memory and Processing Speed
Hardcastle *al.*	2022	Computer-based Cognitive Training	Inhibitory Control, Divided Attention and Processing Speed

CT – Cognitive training.

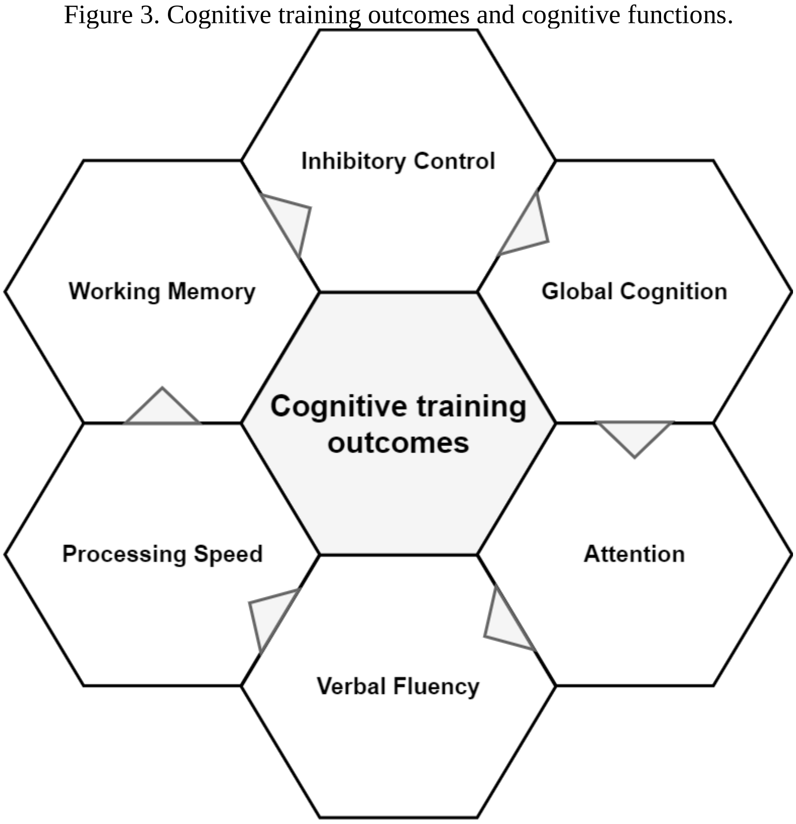
3.1 IMPLICATIONS FOR MEDICAL AND NURSING PRACTICE

Neurotechnology is not only about technology in general; rather, it is more about using technology to understand how the human nervous system works, particularly in order to comprehend the processes involved in both health and sickness [26]. Thus, considering the different technologies applied to the large field of health sciences are relevant to the clinical practice of different health professionals (e.g., physicians and nurses).

In line with our findings, neurotechnology-based cognitive training may be applied in different contexts for older patients. Perhaps the greater recurrence of findings in computer-based training is justified by the exponential growth of technologies applied in health. Numerous lives have been prolonged and have been given a higher quality because of advancements in medical technology, including diagnostic imaging technologies, treatments, medical gadgets, and new prescription medications [27].

Based on the evidenced cognitive outcomes, our findings demonstrate the wide applicability of different cognitive training modalities focusing on different cognitive functions (Figure 3). More precisely, it implicates in clinical/health neuroscience research, an emerging field focused on understanding how the brain affects and is affected by physical health [28].

Figure 3. Cognitive training outcomes and cognitive functions.



4 CONCLUSION

The results of this brief scoping review show the importance of evaluating the impact of neurotechnology-based cognitive training (types of training and cognitive outcomes) to verify its effects on the cognitive performance of healthy older adults. However, further investigations are needed to assess the effectiveness of different types of training in clinical and non-clinical populations (e.g., Alzheimer's disease and Parkinson 's disease).

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