2
Working Memory Interventions in Adults: A Systematic Review

2.1
Abstract

Impairments in working memory (WM) can contribute to a range of significant problems that can affect everyday life. This memory comprises attentional and executive operations and constitutes the basis of several cognitive functions. The purpose of this systematic review is to identify designs, procedures, and results of empirical studies that performed neuropsychological interventions on WM in adults. A PubMed and LILACS (Latin-American and Caribbean Health Sciences Literature) literature search was conducted using the following keywords: *working memory* AND (*training* OR *rehabilitation* OR *intervention*) AND *adult*. Studies were reviewed according to the following inclusion criteria: (1) presence of neuropsychological pre- and post-program assessments, (2) adequately specified interventions, and (3) samples composed of adult individuals. A total of 643 articles were found, 40 from Lilacs and 603 from PubMed. After analyzing the inclusion criteria in each abstract, only seven articles from PubMed were eligible for this review. Among the selected articles, two were global interventions, and five were specific. The effectiveness of the WM interventions was more evident in studies that employed specific interventions for samples with neurological disorders than in those based on global programs with healthy adults. From these seven studies, three were randomized controlled trials, two were case reports, one was a clinical trial, and one was an evaluation study. Because of the negative impact of WM impairments on individuals, these results indicate the need for more evidence-based theoretical and empirical studies to verify the effectiveness of WM interventions and provide adequate guidance for clinical neuropsychologists and future research.

Keywords: working memory, intervention, rehabilitation, training, adult.

2.2
Background

This paper systematically reviews one of the most promising and emergent evidence-based practices in clinical neuropsychology—the neuropsychological rehabilitation of working memory (WM). Studies on neuropsychological assessment (e.g., Busch and Chapin, 2008; Peña-Casanova et al., 2009) and multiple-memory-system processing (e.g., Baddeley and Hitch, 1974; Baddely et al., 2000, 2009) have been developed. However, intervention processes and WM have not been sufficiently explored, especially with regard to their interaction.

Neuropsychological rehabilitation is concerned with the improvement of cognitive, behavioral, emotional, and psychosocial deficits that result from brain injury. Furthermore, it is a process in which damaged individuals work together with a professional team to remediate or alleviate acquired cognitive impairments (Wilson, 2008).

The origins of historical rehabilitation, despite being a relatively new field, can be found in Ancient Egypt (2500-3000 B.C.). One of the rehabilitation milestones was World War I, during which time this intervention helped in the recovery of several soldiers with head injuries. Probably also at this time modern rehabilitation began. To some extent, many of the procedures developed at military hospitals during World War I are still being employed today. Other contributors to the development of rehabilitation were Israeli programs and the tremendous increase in victims of traffic accidents which have spurred the growth of several specialized rehabilitation centers (Wilson, 2002).

With regard to different types of cognitive rehabilitation, including all of its possible features and related variables, no consensual taxonomy can be found in the literature. Regarding the number of and targeted cognitive domains to be improved, neuropsychological rehabilitation can be divided into two main groups: global and specific. According to Francés et al. (2003), global rehabilitation seeks to ameliorate several cognitive domains, such as memory, attention, and executive function, whereas specific rehabilitation seeks to improve a particular cognitive function, such as memory.

The present article focuses on WM intervention, and the concepts and theoretical aspects of this mnemonic system are reviewed. Working memory is fundamental to the individual processing of complex cognitive thoughts, such as problem solving, language, decision-making, and the execution of actions. It is a multicomponent system used not only for temporary storage under attentional control, but also for the manipulation of information. Regarding WM processing, different theoretical models of WM have been proposed in the context of neuroscience. The most influential of these models was proposed by Baddeley and Hitch (1974) and Baddeley (2000). In this model, WM consists of three subsystems: the central executive and two others subsidiary slave systems (i.e., the phonological loop and visuospatial sketchpad). The central executive, an attentional controller, is the most important subsystem of the WM multicomponent model, coordinating and scheduling mental operations, processing the capacity to focus, dividing and switching attention, and providing a link between the two slave systems and long-term memory (Baddeley, 1996; Baddeley et al., 2007). According to recent studies, this component appears to have two forms of control. One is automatic, such as consolidated habits (e.g., riding a bike) that require almost no attention, and the other depends on the limited attention of the central executive (Baddeley, 1996; Baddeley, 2009).

In relation to the slave subcomponents, the phonological loop is responsible for the temporary storage of verbal-acoustic information. This system comprises two subcomponents: (1) the phonological store, in which representations of verbal material, such as word lists, are kept and (2) a subvocal rehearsal mechanism that maintains information in the phonological loop (Baddeley, 2009). The visuospatial sketchpad is responsible for processing visual and spatial information and consists of two components: (1) “passive” visual storage and (2) an active mechanism that maintains the contents of visuospatial storage.

The current model of WM underwent two important changes: (1) connection of the phonological loop and visual-spatial sketchpad to long-term memory and (2) the addition of a fourth component, the episodic buffer, which was assumed to have a limited capacity to directly obtain information from the other WM subcomponents and long-term memory, transforming it into coherent episodes (Baddeley, 2009). The episodic buffer can be defined as an interface between a number of other different cognitive sources, such as visual, verbal, and perceptual codes, and long-term, semantic, and episodic memories. The episodic buffer, which is temporary in nature, differs from long-term episodic memory and has been hypothesized to act as a workplace in conscious awareness (Baddeley et al., 2007).

Different neurological and psychiatric pathologies may affect WM, resulting in substantial impairments and affecting an individual's life. Recent degenerative disease studies found that WM is affected during the early stages of Alzheimer's disease (Huntley et al., 2010; Lim et al., 2008; MacPherson et al., 2007; Sebastian et al, 2006) and in numerous studies of multiple sclerosis (Chiaravalloti et al., 2005; Hildebrandt et al, 2007). Deficits in WM are quite common in brain injury and stroke (Philipose et al, 2007; Serino et al, 2007; Vallat-Azouvi et al., 2007; Vallat-Azouvi et al., 2009; Westerberg et al., 2007). Neuropsychological deficits in **affective disorders** have been a topic of increasing research. Initially, research was focused mainly on depression, which found psychomotor slowing and deficits in attention, verbal memory, WM, and executive function (Marquand et al., 2008; Mondal et al., 2007). In schizophrenia, deficits in WM and executive function are frequently observed (Green 2006; Sánchez-Morla, 2009; Pae et al., 2008; Pachou et al., 2008). Similarly, evidence is beginning to emerge that WM may also be a core feature of bipolar disorder (Green, 2006).

Based on the relevance of theoretical and methodological issues, the consequences of WM impairments on an individual's life, and the sparse evidence-based studies on WM interventions available in the scientific literature, systematic reviews in this area have become increasingly important. To our knowledge, no systematic reviews have been written on WM interventions. Only one non-systematic review about training of the executive component of WM was found in the PubMed database (Dahlin et al., 2009). This previous article investigated issues that are different from the present paper and explored the neural basis, transfer effects, and age-related changes after training.

The aim of the present systematic review is to present a spectrum of empirical studies on WM interventions in adults, describing and analyzing their designs, procedures, and results. This knowledge may contribute to evidence-based guidance for clinical practice and future research. The following research questions are answered in this review: (1) Which evidence-based studies in the national and international literature, if any, have investigated neuropsychological interventions to improve WM in adults? (2) What are the main methodological features of designs, samples (healthy and clinical), and assessment and intervention procedures, and are such procedures based on a theoretical framework? (3) What are the main results, and did they show WM improvements? (4) Considering the types of interventions and the study designs, which of the research studies present clear evidence of neuropsychological intervention effectiveness? The hypotheses for each research question are the following: (1) Few studies in the national and international literature have investigated neuropsychological interventions to improve WM in adults. (2) The methodological features will consist mostly of randomized controlled trials and single-case studies with healthy and clinical samples and WM assessments and intervention procedures based on a theoretical framework. (3) Working memory training can improve WM performance in neuropsychological tests. (4) Considering the global and specific types of interventions, the clearest evidence of neuropsychological intervention effectiveness will be attributable to specific approaches. Additionally, with regard to study design, randomized controlled trials are hypothesized to present the most informative findings.

2.3
Method

Two databases were consulted: LILACS (Latin American and Caribbean Health Sciences Literature) for national studies and PubMed for international studies. A search of LILACS was conducted without a limitation on the year of publication using the advanced search form with the following Portuguese keywords: *memória* AND *trabalho* AND (*intervenção* OR *reabilitação* OR *treinamento*) AND adulto. In PubMed, the English terms used were the following: *working memory* AND (*intervention* OR *rehabilitation* OR *training*) AND adult. The abstracts were selected according to the following inclusion criteria: (1) WM neuropsychological interventions, (2) WM stimulation procedures clearly specified, (3) pre- and post-intervention assessments, (4) sample with adult participants, (5) empirical designs, (6) English, French, Spanish, or Portuguese written languages, and (7) publication date between 2000-2010.

2.4
Results

Although only a small number of studies was found in this systematic review of WM interventions, summarizing several methodological aspects and the theoretical and data features is very relevant in this section of results. Table 1 shows the number of Latin American (LILACS) and international (PubMed) studies found after the initial search. Moreover, the table also presents the number of investigations selected for this review based on the inclusion criteria.

Table 1: Number of national and international studies that investigated neuropsychological working memory interventions in adults.

	Number of studies	
Database	***Initial search***	***After inclusion criteria analysis***
LILACS	40	0
PUBMED	603	7
Total	643	7

As shown in Table 1, after the analyses of the inclusion criteria, no national studies were included. Among the international investigations, only 1.08% of the initial abstracts were selected for the final analysis. Two additional abstracts were selected after the first screening. However, after the corresponding articles were analyzed, they too were excluded because one was a study that presented a case report whose original version was already included in this review, and the other presented WM in its title but had no explicit neuropsychological assessment procedure or WM intervention. Among the excluded studies, the main features that did not meet the inclusion criteria were pharmacological and non-empirical interventions, music listening, and samples composed of children and adolescents.

In Table 2, the seven studies selected from PubMed were organized into two groups: (1) intervention type (global and specific) and (2) study design (randomized controlled trial, clinical trial, evaluation study, and case report).

Table 2: Distribution by publication type and intervention type of the publications selected from PubMed.

Intervention Type	**Publication Type**				**Total**
	Randomized Controlled Trial	***Clinical Trial***	***Evaluation Study***	***Case Report***	
Global	1	1	0	0	2
Specific	2	0	1	2	5
Total	3	1	1	2	7

In summary, the data presented in Table 2 show that the majority of the intervention studies used a specific approach and were based on a randomized controlled trial design, followed by case reports.

Tables 3 and 4 describe the studies based on global and specific intervention categories, respectively. The main features of each study are summarized according to the research questions of this review.

Table 3: Description of global interventions studies.

Reference	Objective	Method: *Sample*	Method: *Neuropsychological Assessment*	Method: *Intervention*	Results
Study 1 (Buiza et al., 2008)	To investigate the effectiveness of cognitive intervention in elderly individuals	(a) Healthy older adults, age > 65 years (b) Experimental group 1 (*n* = 85), experimental group 2 (*n* = 68), control group (*n* = 85); no sample loss reported (c) Inclusion criteria: no dementia or memory impairment, adequate intellectual functioning (d) Exclusion criteria: degenerative neurological disorder; severe psychotic traits, depression, agitation, or behavioral problems; history of alcohol or substance abuse; systemic disease	(a) Functions: attention; working memory; immediate execution, logic, recent word list, and short-term memories; learning potential; designation, repetition, auditory, written, and reading language; visuo-constructive ability; planning; bimanual coordination; visuo-manual coordination speed; phonetic and semantic fluency; abstraction; categorization (b) Six assessments of 6 months each: four with the same neuropsychological battery and two with ADAS-COG.	(a) Design: randomized clinical trial; double-blind; longitudinal; quasi-experimental (b) Type of rehabilitation: group modality; worked with all cognitive functions; experimental group 1 (training: cognitive, social skills, alternative therapies, musical therapy, culture); experimental group 2 (similar to group 1, but not following an organized timetable); control group (untrained) (c) Theoretical framework: Braak and Braak's model of Alzheimer's staging (d) Procedures: cognitive training of attention and orientation, memory, language, visuo-constructive ability, executive function, visuo-manual coordination, and praxia (e) Duration: 2 years, 180 sessions, 1.5 h per session twice per week	• Significant improvements in immediate memory in experimental group 1, particularly in the second year • Recent logic execution memory was significantly improved in all three groups • Working memory was only statistically significant in experimental group 1 at the second year
Study 2 (Craik et al., 2007)	To verify the effects of a multimodular cognitive rehabilitation training program on memory in older adults	(a) Healthy independent-living elderly adults, with ages ranging from 71 to 87 years (b) Experimental group: early training (*n* = 29); control group (late training, *n* = 20) (c) Inclusion criterion: subjective complaints of cognitive or memory dysfunction	(a) Functions: working memory, primary and secondary memory (b) Pre- and post-intervention assessments separate by 3 months each with a 6 month follow-up after training; four different but equivalent batteries	(a) Design: clinical trial (b) Type of rehabilitation: group modality, 3 modules: (*i*) memory skills, (*ii*) goal management, and (*iii*) psychosocial training. Both groups were subjected to the same training but at different times. (c) Theoretical framework: Jacoby (1991); difference between two major components of remembering: one more automatic and familiarity-based and the other more controlled and recollective (d) Procedures: memory skills learning and organization, external and internal techniques (e) Duration: 12 weeks, one session per week	• No training-related improvement in working, primary, or recognition memory • Positive results were restricted to the experimental group

Table 3 shows that both studies had the same objective, which verified the effectiveness of neuropsychological interventions in healthy elderly adults by employing a group modality. Moreover, both studies had common inclusion criteria (i.e., self-report of memory complaints). However, the studies differed in several respects, such as sample size (study 1 had a much larger sample than study 2), the number of cognitive functions evaluated (study 2 was limited mainly to memory domains), length of time of the program (study 1 lasted twice as long as study 2), and assessment frequency (study 2 included follow-up and used different versions of the same evaluation battery). Furthermore, these investigations also differed with regard to their methodological designs, training of cognitive domains, length of time (which varied from three months in study 2 to 24 months in study 1), frequency of sessions (from once per week in study 2 to twice per week in study 1), and theoretical framework. The results related to WM improvement were restricted to study 1, which provided other cognitive domain stimulations in the experimental group, in addition to memory training.

Table 4. Description of specific interventions studies.

Reference	Objective	Method			Results
		Sample	*Neuropsychological Assessment*	*Intervention*	
Study 3 (Buschkuehl et al., 2008)	To investigate the effect of WM training on WM and episodic memory performance	(a) Octogenarians (b) Experimental group (WM training, *n* = 13), control group (physical training, *n* = 19) (c) Inclusion criteria: absence of acute heart, psychiatric, or debilitating problems; arthrosis problems; independent and healthy elderly adults	(a) Functions: WM, episodic memory (b) Pre- and post-intervention, with 1 year follow-up; the same battery was administered	(a) Design: randomized control trial (b) Type of intervention: three computerized WM training task variants (c) Theoretical framework: process-specific approach (Park et al., 2007) (d) Procedures: (*i*) passive activation, warm-up and cool down task, (*ii*) WM training, (*iii*) reaction time task (e) Duration: 3 months, 45 min sessions twice per week	• Experimental group showed overall increased visual WM performance and, to a lesser degree, visual episodic memory performance • No differences between groups in the 1 year follow-up
Study 4 (Duval et al., 2008)	To describe and evaluate a program of neuropsychological rehabilitation	(a) A case of a 23-year-old, right-handed student, bilingual (French) at an academy of music (b) Deficits: WM impairment as a result of cerebral tumor surgery on his left temporal lobe	a) Functions: memory, language, constructional praxis, intellectual abilities, attention, executive functions (b) Four assessments with the same tests: pre-evaluation, intermediate, post-immediate, and post 3 months	(a) Design: case report, multiple baselines (b) Type of rehabilitation: cognitive program (training of three WM subcomponents; executive central) complemented by an ecological approach (c) Theoretical framework: non-passive storage by slave systems (Emerson and Miyake, 2003), complemented by an ecological approach (WM model; Baddeley, 1986) d) Procedures: (*i*) cognitive rehabilitation (exercises divided into three subprograms: central executive, visual sketchpad, and phonological loop), (*ii*) ecological rehabilitation (analyses of scenarios and simulations of real-life situations) (e) Duration: 6 months, 90 min sessions four times per week	• Effectiveness for all three WM components • Generalization to everyday life, and effects were maintained after 3 months

Study 5 (Serino et al., 2007)	To investigate the efficacy of a rehabilitation program (WM training) on WM and other cognitive functions dependent on this component system, such as divided attention, executive functions, and long-term memory; to verify whether the improvement generalizes to everyday activities	(a) Traumatic brain injury patients with severe WM deficits (b) *n* = 9, with ages ranging from 16 to 57 years and education ranging from 8 to 18 years (c) Inclusion criteria: ≥6 months post-injury; no other neurological disease, no emotional or psychiatric disturbances or communication problems	(a) Functions: speed processing, sustained and divided attention, WM, long-term memory, executive functions, psychosocial abilities, everyday functioning (b) Screening, intermediate, and final session of neuropsychological assessment with different versions of the same instruments	(a) Design: pilot study (b) Type of rehabilitation: general stimulation training (low executive demand) followed by WM training (c) Theoretical framework: WM model (Baddeley, 1986, 2003) (d) Procedures: Three WM tasks; (*i*) repeated administration of the Paced Auditory Serial Addition Test (PASAT, central executive), (*ii*) Davis et al. (2007) and (*iii*) alternate versions of PASAT (months task and words task) (e) Duration: 2 months (1 month for each intervention phase), four sessions per week	• WM training was effective in recovering central executive impairments • Some cognitive functions dependent on the central executive improved • Everyday life functioning improved • Significant improvement in WM, divided attention, executive functions, and long-term memory, but not in speed processing or sustained attention
Study 6 (Vallat et al., 2005)	To assess the efficacy and specificity of WM rehabilitation, focusing mainly on central executive and phonological loop	(a) A case of a 53-year-old right-handed male high school graduate computer scientist (b) Deficits: aphasia and WM central executive and phonological loop impairment as a result of a stroke; complaints of difficulties in everyday tasks	(a) Functions: oral language, attention, verbal and visual long-term memory (b) Two pre- and one post-intervention assessment sessions, with similar outcome measures and parallel versions of some tests	(a) Design: single-case with multiple-baseline-across-behavior with a control group (*n* = 10) that matched the case's age and education background; this control group performed all therapy tasks with a ceiling effect (b) Type of rehabilitation: training of WM storage and processing components; specific cognitive retraining of the central executive and phonological loop (c) Theoretical framework: WM model (Baddeley, 1986, 1998) (d) Procedures: Eight different tasks; (*i*) reconstruction of words from oral spelling, (*ii*) reconstruction of words from oral spelling with a letter omitted, (*iii*) oral spelling, (*iv*) odd or even number of a letters in a word, (*v*) reconstitution of words from syllables, (*vi*) alphabetizing, (*vii*) word sorting in alphabetical order, (*viii*) acronyms (e) Duration: 6 months, 1 h training sessions three days per week	• Case's forward digit span improved significantly compared with matched controls • Central executive and phonological store components of WM significantly improved after rehabilitation • Significant decrease in daily difficulties; return to full-time job at same position as before stroke

Study 7 (Westerberg et al., 2007)	To examine the effects of WM training in adult patients with stroke	(a) Stroke patients with ages ranging from 34 to 55 years (b) Experimental group (trained, *n* = 9), control group (untrained, *n* = 9) (c) Inclusion criteria: time post-onset between 12 and 36 months; access to internet connection at home; self-reported deficits in attention (d) Exclusion criteria: IQ < 70, motor or perceptual handicap that would prevent use of computer, medication changes during the study period, major depression, known history of alcohol abuse or illicit drugs	(a) Functions: WM, attention, reasoning and problem-solving, declarative memory, inhibition, learning (b) Pre- and post-intervention sessions with the same assessment battery	(a) Design: randomized pilot study (b) Type of rehabilitation: computerized training on various WM tasks (c) Theoretical framework: not reported (d) Procedures: complete training on a computer at home and daily internet report to a server at the hospital (e) Tasks employed: (*i*) reproducing a light sequence in a visuo-spatial grid, (*ii*) indicating numbers in reverse order, (*ii*) identifying letter positions in a sequence, (*iv*) identifying a letter sequence in pseudo words, (*v*) finding mismatched letters, (*vi*) reproducing a light sequence in a rotated grid, (*vii*) reproducing a light sequence in a three-dimensional visuo-spatial grid (f) Duration: 5 weeks, 40 min sessions 5 days per week, 90 trials per day	• Statistically significant training effects on non-trained tests for WM and attention • Significant decrease in symptoms of cognitive problems in daily living • Some evidence that 1 to 3 years after stroke, intensive training can improve an individual's WM and attention performance

Table 4 summarizes the results of specific intervention studies included in this review and outlines the evidence of several aspects of WM-specific interventions. The main objective of these studies was generally to evaluate the effectiveness of WM interventions. Some studies went further and examined other cognitive functions, such as language (studies 4 and 6), attention (studies 4, 5, 6, and 7), executive function (studies 4, 5, and 7), psychosocial ability (study 5), and everyday functioning (study 5). With regard to study design, two studies described single cases (studies 4 and 6), two had experimental and control groups (study 3 had physically trained, and study 7 had untrained), and one had the experimental group as its own control (baseline intragroup comparison in study 5). Most of the studies had samples of adults with WM impairments (studies 4, 5, 6, and 7), with the exception of one study that investigated healthy and independent octogenarians (study 3). All samples of these investigations had a small *n*, averaging 11 individuals per group (studies 3, 5, and 7), and two of the studies had just one subject based on single cases (studies 4 and 6). To complete the sample features, most of the eligibility criteria varied according to the type of impairment (studies 4, 5, 6, and 7).

Considering the neuropsychological evaluations, all of the studies evaluated the individuals during pre- and post-interventions. Two of the studies also had follow-ups (studies 3 and 4), and one study provided assessments during the intervention (study 5). Three studies in Table 4 used the same battery to retest individuals (studies 3, 4, and 7), and the other two employed different test versions (studies 5 and 6). All of the rehabilitation programs described by the studies had WM as the principal cognitive domain. However, in some studies, other cognitive domains were also trained (studies 6 and 7). Moreover, the majority of the interventions were executed in a group modality (studies 3, 5, and 7), and two of the studies used computerized training (studies 3 and 7). Referring to the theoretical framework, the majority of the investigations used the model proposed by Baddeley and Hitch (1974) or more recent versions (Baddeley, 2000) (studies 4, 5 and 6).

High variability was found in the total duration of the programs, from 5 weeks (study 7) to 6 months (studies 4 and 6). Additionally, the frequency of sessions ranged from three times per week (studies 6 and 7) to five times per week (studies 4 and 5), and the session duration ranged from 40 to 90 min.

Considering the results, all studies demonstrated gains in WM training. Furthermore, four investigations presented a generalization effect to everyday life (studies 4, 5, 6, and 7), and one demonstrated a transfer effect to cognitive domains related to WM (study 7). After 3 months, follow-up assessment still showed maintenance of WM improvement as a result of two interventions (studies 4 and 6).

2.5
Discussion

The small number of studies on WM interventions in the literature have large variability among the types of designs, theoretical frameworks, samples, assessments, interventions, and results. As a consequence, the literature has some limitations in providing clinical direction. This review presents findings of WM interventions in adults and have provided answers to the following research questions:

Which evidence-based studies in the national and international literature, if any, have investigated neuropsychological interventions to improve WM in adults? All of the studies presented in this review were restricted to the international PubMed database, demonstrating the need for these types of investigations in the Latin-American literature. This result partially supports the hypotheses that few studies would be found in the national and international literature investigating neuropsychological interventions to improve WM in adults. The small number of studies in this area may be related to the fact that both neuropsychological interventions and WM are relatively new constructs in the context of neuroscience, especially when considering their interaction.

What are the main methodological features of the designs, samples (healthy and clinical), assessment and intervention procedures, and are such procedures based on a theoretical framework?

The results presented in this review confirmed the hypothesis that the methodological features would consist mostly of randomized controlled trials and single case studies with healthy and clinical samples, and the WM assessment and intervention procedures would be based on a theoretical WM framework. This hypothesis derived from evidence-based reviews of cognitive interventions, which focused mainly on randomized controlled trials and seldom on other studies, such as single cases (only when providing unique results), for clinical guidance and suggestions for future research (Cicerone et al. 2000; Cicerone et al. 2005; Teasell et al., 2007; Zehnder et al., 2009). Despite the fact that randomized controlled trials are quite rigorous methodological designs, to minimize the heterogeneity of the samples and the effects of unconventional variables, three studies in the present review applied this method. Two others employed a single case design, which confirmed the hypothesis.

Deepening in regard to the methods strength**,** Cicerone et al. (2000) classified them into three classes of evidence: I, II, and III. Class I refers to prospective studies that are robustly designed, such as randomized controlled trials. Other investigations, such as quasi-randomized studies, can be classified as Class Ia. Class II includes prospective, nonrandomized cohort, and case-control investigations. Class III consists of studies with no control groups, including case studies (for further details, see Cicerone et al., 2000, p. 1598). According to this classification standard, three studies in the present review could be assigned to Class I (Buiza et al. 2008; Buschkuehl et al., 2008; Westerberg et al., 2007), one could be assigned to Class II (Craik et al. 2007) and three could be assigned to Class III (Duval et al., 2008, Serino et al., 2007; Vallat et al., 2005).

Considering the types of samples, among the seven investigations, only three verified the effectiveness of WM training in healthy older adults. The remaining studies examined brain-injured individuals. The literature provided many studies that evaluated the effectiveness of WM impairments in individuals who suffered some kind of brain injury (Azouvi et al., 2004; Cicerone et al., 2005; Cicerone et al., 2000; Cullen et al., 2007; Serino et al., 2007; Vallat et al., 2005; Westerberg et al., 2007). Other studies have stated that one of the most frequently investigated samples in cognitive stimulations, especially memory training, are healthy elderly adults (Dahlin et al., 2009; Zehnder et al., 2009). However , very few have verified the effectiveness of WM training in older adults.

The present review reveals that one of the major challenges of WM interventions is to obtain large sample sizes. Only one of the presented studies was able to accomplish this goal. Having a large sample size is a challenge, because giving adequate attention to all members of a group may be difficult when subjects differ in their levels of ability to perform tasks, learn, retain and recall information, or process other cognitive domains in addition to mnemonic ones. Even if these groups are homogenized and these problems are minimized, other challenges still exist.

With regard to the assessments, another issue concerns the test-retest effect which is oftentimes attributable to the lack of different versions of recommended neuropsychological tools in the literature. In fact, this effect becomes a notable issue in healthy participants, especially when the tools are administered in more than one follow-up because these individuals retain an intact cognitive ability to learn, process, retain, and retrieve information. However, having a control group in these studies can minimize this confound (Dahlin et al., 2009).

Finally, six of the seven studies used a theoretical approach. Of these six, three were based on the model proposed by Baddeley and Hitch (1974) and Baddeley (1986, 2000). According to Wilson (2008), the majority of neuropsychologists who practice or research rehabilitation believe that interventions should be guided by theory.

What are the main results, and did they show WM improvements?

The present review found that six of the seven studies reported WM improvements in performance on neuropsychological tasks. However, one of the six investigations reported significant differences only in the WM visuospatial sketchpad (Buschkuehl et al., 2008). These results support the hypothesis of the present review in which WM training can improve WM performance in neuropsychological tests. Overall, the few evidence-based studies available in the literature are generally consistent with regard to the effectiveness of WM interventions (Buiza et al., 2008; Buschkuehl et al., 2008; Duval et al., 2008;

Dahllin et al. 2009; Serino et al., 2007; Vallat et al., 2005; Westerberg et al., 2007).

Healthy older adults appeared to require longer intervention times than brain-injured adults to obtain benefits from WM training. One explanation for this may be that the performance of healthy adults in neuropsychological tests are much closer to normal than brain-injured individuals who have much more room for improvement.

Considering the types of interventions and the study designs, which of the research studies present clear evidence of neuropsychological intervention effectiveness?

Referring to intervention types (global and specific) and study designs (randomized controlled trial, clinical trial, evaluation study, and case report), this fourth question can be answered according to this comprehensive review. Among the seven international studies, six provided clear evidence supporting the effectiveness of WM-specific training in adults. Furthermore, the study design that presented the most informative findings was the randomized clinical trial (Cicerone et al., 2000, 2005), which supports our initial hypothesis. According to other reviews, studies that employed specific WM interventions usually presented positive performance in the measurements. Specific cognitive interventions may act differentially on different memory domains, and more specific tasks that stimulate a specific WM component will result in greater improvements (Cicerone et al., 2005; Dahlin et al. 2009). Studies that use a robust methodological design, such as a randomized control trial, indeed show more detailed results. Therefore, valuable systematic reviews are usually based on such studies to guide clinical intervention (Cicerone et al., 2005).

With regard to the effectiveness of WM interventions, two main concerns can be derived from the literature: generalization and the transfer effect. Gains acquired during an intervention and applied to real-life situations are referred to as generalization. Several studies in the present review were successful in this regard. Notably, one case study reported that the subject returned to his previous full-time job after treatment (Duval et al., 2008; Serino et al., 2007; Vallat et al. 2005; Westerberg et al., 2007). One challenge is to maintain these gains. To achieve this, the individual may need to continue to stimulate the targeted cognitive domain on a day-to-day basis. Another challenge is the transfer effect, which occurs when an untrained task improves as a result of a trained task and is one of the most important aims in cognitive interventions (Dahlin et al, 2009). Some authors have indicated that not enough research has demonstrated this effect (Jaeggi et al., 2008). The present review supports this observation, presenting only one study that reported a transfer effect (Westerberg et al., 2007).

2.6
Conclusions

This review demonstrated that WM domains can be trained, especially when working with brain-injured individuals. However, these results need to be considered with caution because of the heterogeneity among the investigations in terms of the designs, samples, assessments, interventions, and availability of only a few robust methodological designs. Presently, insufficient evidence provides clinical guidance for WM training, especially when working with the elderly. One suggestion for future studies is to investigate clinical and healthy independent elderly individuals to generate more evidence-based clinical guidance, better understand the transfer effect, and generalize the gains to everyday activities. The benefits achieved during interventions can usually last only for a short period of time, especially when dealing with elderly individuals, who naturally experience a decrease in new challenges during daily life, due to retirement, the loss of family or friends, or other reasons. However, unless the elderly individual continues to challenge his or her cognition, maintaining the benefits can become quite difficult.

Additionally, research should focus on one type of cognitive intervention (e.g., WM in the present review). If several cognitive stimulations are used in the same program, then determining which ones were successful may be difficult, even with specific measurements of specific cognitive domains. One type of cognitive stimulation can possibly influence another. In real-life situations, this may not be the best solution because individuals are complex beings and may require several treatment approaches to improve their deficits. One solution may be to divide the training program into different modules and investigate and evaluate one particular cognitive target in the first module before commencing with subsequent training.

As a final suggestion for future studies, examining the ideal length of time of interventions, the ideal frequency of sessions per week, and the ideal number and types of training tasks is important in clinical and healthy samples to yield the most notable improvements in the WM domain (Dahlin, 2009). These procedures will also facilitate replication studies and will provide better guidance for clinical neuropsychologists and future research.

2.7
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