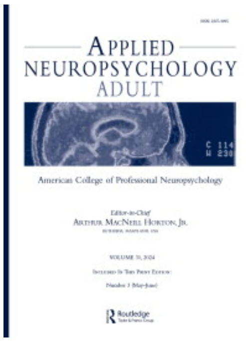

Applied Neuropsychology: Adult

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/hapn21

Ecological validity of neuropsychological interventions: A systematic review

Joana O. Pinto, Diogo Pontes, Bruno Peixoto, Artemisa R. Dores & Fernando Barbosa

To cite this article: Joana O. Pinto, Diogo Pontes, Bruno Peixoto, Artemisa R. Dores & Fernando Barbosa (08 Apr 2024): Ecological validity of neuropsychological interventions: A systematic review, Applied Neuropsychology: Adult, DOI: 10.1080/23279095.2024.2328694

To link to this article: https://doi.org/10.1080/23279095.2024.2328694

Published online: 08 Apr 2024.

APPLIED NEUROPSYCHOLOGY: ADULT
https://doi.org/10.1080/23279095.2024.2328694

Ecological validity of neuropsychological interventions: A systematic review

Joana O. Pinto[a,b,c], Diogo Pontes[a], Bruno Peixoto[c,d,e], Artemisa R. Dores[a,b,f] and Fernando Barbosa[a]

[a]Laboratory of Neuropsychophysiology, Faculty of Psychology and Education Sciences, University of Porto, Porto, Portugal; [b]ESS, Polytechnic of Porto, Porto, Portugal; [c]Department of Social, Behavioral Sciences of University Institute of Health Sciences – CESPU, Gandra, Portugal; [d]Associate Laboratory i4HB – Institute for Health and Bioeconomy, University Institute of Health Sciences – CESPU, Gandra, Portugal; [e]UCIBIO – Applied Molecular Biosciences Unit, Translational Toxicology Research Laboratory, University Institute of Health Sciences, (1H-TOXRUN, IUCS-CESPU), Gandra, Portugal; [f]Center for Rehabilitation Research, ESS, Polytechnic of Porto, Porto, Portugal

ABSTRACT

Background: The concept of ecological validity (EV) in neuropsychological interventions (NI) has been consistently advocated, but there is a lack of reviews focused on how EV is operationalized in NI programmes. This review aims to address this gap by exploring the outcome measures more commonly used for assessing EV and to understand the main characteristics of programmes with good EV.

Method: A literature search was conducted to identify studies that examined the EV of NI programmes, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the Cochrane Collaboration Guidelines.

Results: A total of twenty-seven studies were included in this review. Among these, only three studies explicitly described the procedures used to assess EV. Additionally, almost half of the studies assumed that interventions had good EV based on the characteristics of the programmes. The inconsistent assessment of EV of NI programmes prevented the identification of specific characteristics of programmes demonstrating good EV.

Conclusion: This systematic review reveals a significant gap in the literature concerning the operationalization of EV within the field of NI. Further research is required to establish a consistent definition of EV in the context of NI and to develop criteria for its effective operationalization.

KEYWORDS
Ecological validity; neuropsychological intervention; systematic review; PRISMA

Introduction

In recent years, ecological validity (EV) has attracted considerable interest from researchers in neuropsychology, particularly concerning neurocognitive assessment (Pinto et al., 2023a; Tarnanas et al., 2013). However, it has been advocated since 1990 that neuropsychological interventions (NI) should also be ecologically valid (Tupper & Cicerone, 1990) because EV plays a critical role in improving the cost-effectiveness of these interventions (Moreau & Conway, 2014).

In the field of neuropsychological assessment, EV refers to "the attributes of neurocognitive tests that make them representative of a given cognitive instrumental activity of daily living, in a certain real-world context, allowing the test results to be generalized to related activities" (Pinto et al., 2023a, p. 14). In the context of NI, EV can be evaluated by analyzing generalization, which pertains to the contribution of NI results in increasing autonomy in activities of daily living (Parenté et al., 1994). It is worth noting that the concept of generalization is sometimes confused with transfer. Transfer can be conceptualized as: (a) near transfer, which involves assessing the transference of NI effects to tasks that require the same neurocognitive function; and (b) far transfer, which involves assessing the transference of NI results to untrained neurocognitive functions (Guye et al., 2016; Noack et al., 2009; Sala et al., 2019).

Indeed, EV is a requirement for more comprehensive and holistic interventions, such as neurocognitive and neuropsychological rehabilitation, as they involve setting functional goals (Pinto et al., 2023b) and addressing instrumental activities of daily living (Gómez & Rodríguez, 2021). One proposed method to enhance EV of NI interventions in NI is to include virtual reality simulations of activities of daily living (Tarnanas et al., 2013). Therefore, an intervention model called the Activities of Daily Living model was created to organize technology-based interventions with higher EV, employing four hierarchical structures: (a) defining the target activity of daily living; (b) identifying the sub-activities within the target activity; (c) dividing of the task into task states, representing segments necessary for task completion; and (d) defining pathways based on stimuli, interactions with them, and feedback related to each interaction (e.g., admissible or non-admissible) (Martínez-Moreno et al., 2016). Notably, this model seems to be useful not only for technology-based interventions but also for non-technological interventions, which commonly use paper-and-pencil tasks and incorporate strategies like goal management (Winson et al., 2017).

CONTACT Joana O. Pinto joanafftopinto@gmail.com Laboratório de Neuropsicofisiologia, Faculdade de Psicologia e Ciências da Educação, Universidade do Porto, Rua Alfredo Allen, 4200-135, Porto, Portugal.

In light of the aforementioned points, it becomes paramount to understand the key attributes that enhance the EV of NI for various compelling reasons: (a) allows to set meaningful goals for patients (Dekker et al., 2020); (b) contributes to better real-world functioning; and (c) in mild cognitive impairment it has potential to delay the progression to major neurocognitive impairment, which is characterized by a decline in performance in instrumental activities of daily living.

EV in neuropsychological assessment has been extensively explored in several literature reviews (Acker, 1990; Chaytor & Schmitter-Edgecombe, 2003). However, only one systematic review has specifically addressed the ecological effects of NI, examining the impact of virtual reality-based cognitive training on activities of daily living in patients with mild cognitive impairment and Alzheimer's disease (Son & Park, 2022). Therefore, to the best of our knowledge, no previous review has thoroughly examined the characteristics of NI programmes with good EV and the operationalization of EV within those programmes. The main purposes of this review are to explore how EV is operationalized and assessed in NI programmes and to understand the main characteristics of programmes with good EV. The review will be guided by the following question regarding the EV of NI:

Question 1 (Q1): Which outcome measures are more commonly used to assess EV of NI?

Question 2 (Q2): What are the main characteristics of programmes with good EV?

Method

The systematic review protocol was developed in accordance with the recommendations of the *Preferred Reporting Items for Systematic Review and Meta-analysis* (PRISMA; Page et al., 2021).

Search strategy

Studies were selected by searching databases such as *EBSCO*, *PubMed*, *ISI Web of Knowledge*, and *Scopus*. The following *EBSCO* databases were included: *PsycInfo*, *PsycArticles* e *Psychology and Behavioral Sciences Collection*. Additionally, the reference lists of selected studies were reviewed to identify other relevant studies. A manual search was performed to prevent source selection bias.

The keywords and search string were: ecological* valid* – AB; cognitive training OR cognitive therapy OR rehabilitation – AB. Animal studies were eliminated, and the search was limited to papers written in English.

Study selection

The inclusion criteria were empirical studies focused on the EV of NI programmes. The exclusion criteria comprised the following: (a) studies written in a language other than English; (b) literature reviews, editorials, dissertations, comments, and book chapters; (c) case studies; and (d) studies not relevant to the topic. Duplicate studies were eliminated. Abstracts were selected by two independent reviewers according to the *Cochrane Collaboration's recommendations* (Higgins & Green, 2011). In cases of disagreement, a third reviewer, an expert in the field, was consulted to decide about the selection of the studies.

Results

The initial search conducted in the databases yielded a total of 1059 studies (see Figure 1). Additionally, eleven papers were identified through a manual search. After excluding duplicate studies using *Rayyan* (Ouzzani et al., 2016), the titles and abstracts of 591 papers were analyzed by the reviewers. Among these, 547 articles were excluded based on the following reasons: (a) were not relevant to the topic ($n = 417$); and (b) were other publication types than empirical study ($n = 174$). A total of 55 full-text papers were then analyzed, and 27 of them met the eligibility criteria for inclusion in this systematic review. The assessment of titles and abstracts showed an almost perfect agreement between reviewers, with a Cohen's κ coefficient of .814 (Landis and Koch, 1977).

Study characteristics

The methodological quality of the studies was assessed using the classification system of Cicerone et al. (2000). Among the included studies, fourteen were classified as in Class I (prospective, randomized, and controlled experimental design), two were included in Class Ia (prospective, quasi-randomized in treatment conditions); seven were classified in Class II (prospective, non-randomized and cohort studies; retrospective studies with non-randomized control group; or clinical series with control group); and the remaining four studies were included in Class III (clinical series without control group) (Cicerone et al., 2000) (see Table 1).

The studies included 1178 participants ($M = 43.63$ participants, $SD = 38.98$, $Min = 6$, $Max = 176$). In terms of gender distribution, 402 participants were female (34.8%), and 473 were male (41%). Four studies did not provide information about the participants' gender (Grewe et al., 2013; Lansford et al., 2016; Lo Priore et al., 2003; Strobach & Huestegge, 2017). The age of participants ranged from 6 to 86 years old. Five studies did not report the age range (Câmara et al., 2023; Dehn et al., 2018; Jiang et al., 2022, Park, 2022; Rosenblau et al., 2020), and two did not report any information about the age of the participants (Lansford et al., 2016; Lo Priore et al., 2003).

Most of the studies focused on patients with psychiatric and/or neurological conditions, including: (a) acquired brain injury (Lorentz et al., 2023; Ownsworth & McFarland, 1999), specifically traumatic brain injury (Galbiati et al., 2009; Jacoby et al., 2013; Keegan et al., 2022) and stroke (Faria et al., 2016, 2020); (b) acquired prosopagnosia (Corrow et al., 2019; Davies-Thompson et al., 2017); (c) mild cognitive impairment (Hampstead et al., 2008; Park, 2022); (d) focal epilepsy (Grewe et al., 2013, 2014); (e) chronic aphasia (Giachero et al., 2020);

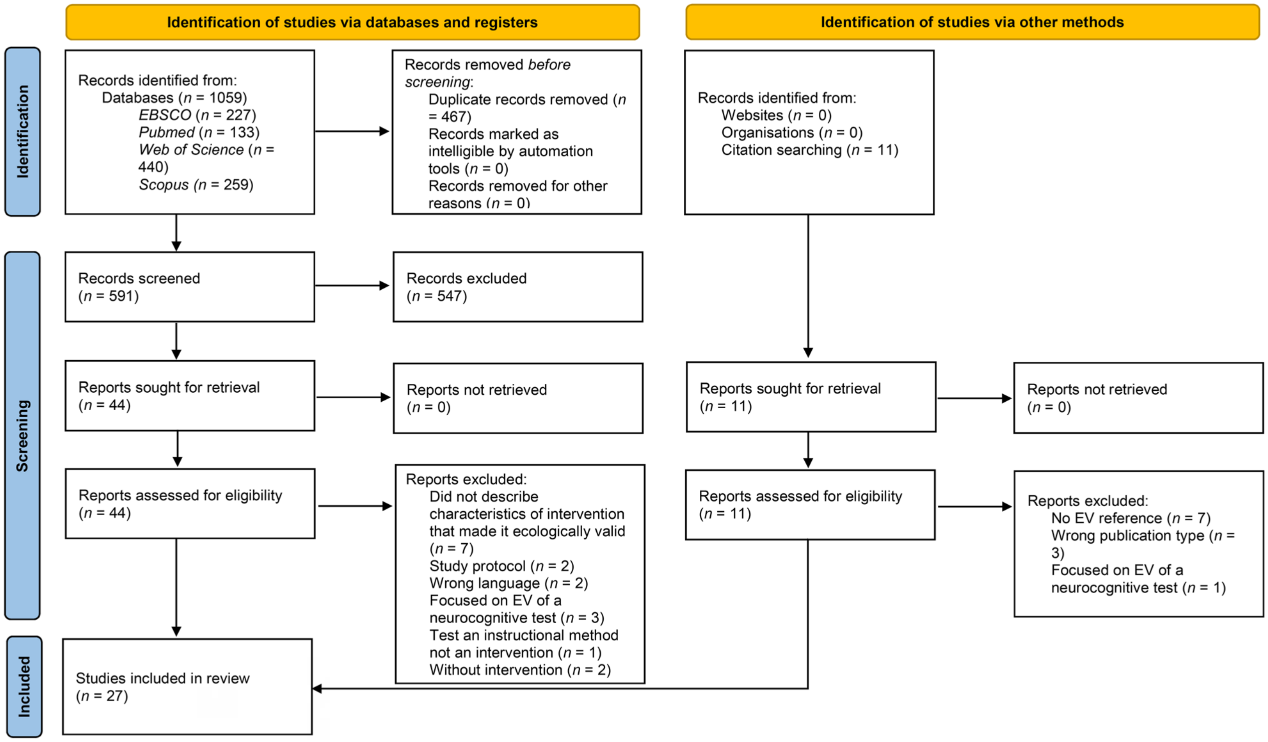

Figure 1. Flow diagram of literature search.

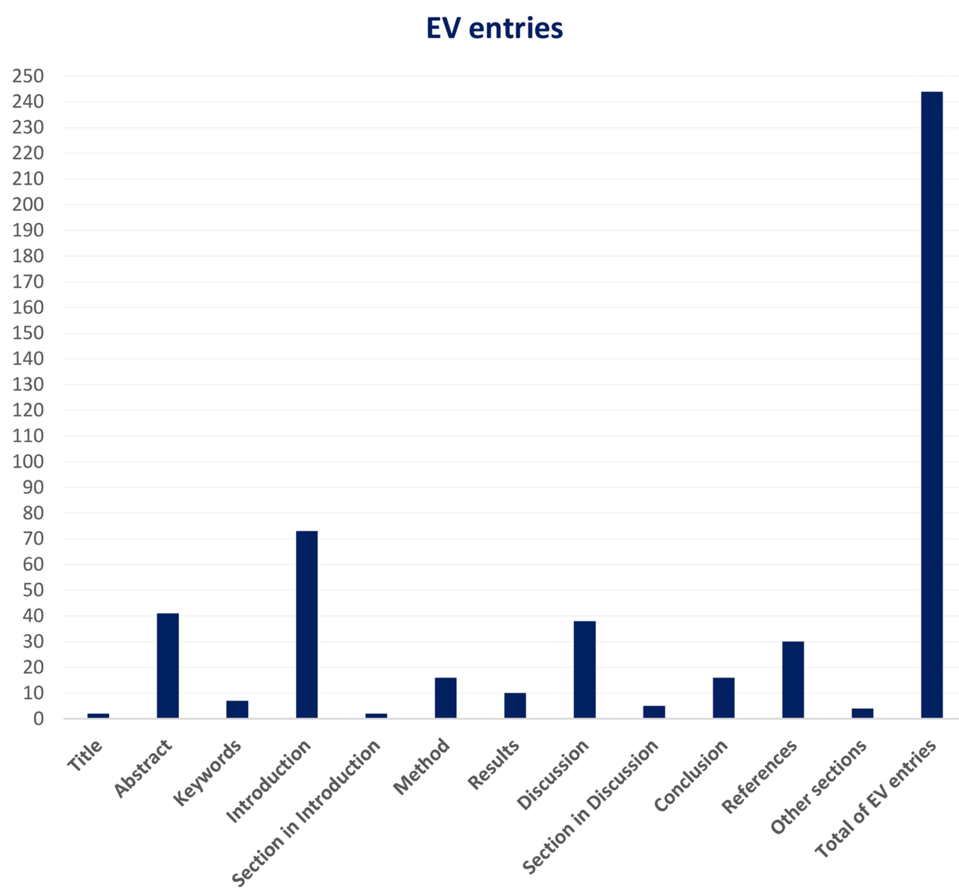

Figure 2. EV entries throughout the studies.

(f) schizophrenia (Gomar et al., 2015; Hodge et al., 2010; Kim et al., 2020); (g) high-functioning adults with autism spectrum disorder (Rosenblau et al., 2020); (h) depression (Dehn et al., 2018); and (i) mental and behavioral disorders not specified (Câmara et al., 2023). Five studies included healthy participants, such as older participants (Chen et al., 2018;

Table 1. Neuropsychological intervention programmes referring EV: Main characteristics and effects.

No.	First author	Class	Etiology	Center	Age *M* ± *SD* [*Min*, *Max*]	Education Level Years - *M* ± *SD*	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
1	Câmara (2023)	I	Patients with mental and behavioral disorders	Female mental health institution	55.93 ± 11.57	5.55 ± 4.24	Attention, memory, language, executive functions	Cognitive training: • VR-based intervention: the Reh@City v2.0 • Paper-and-pencil intervention: the task generator	Individual	2 x wk	30 min	3 mo	24	Pre Post Follow-up (2 mo)	Global cognitive functioning Processing speed Sustained and selective attention Verbal memory Visual memory Executive functions Depressive symptomatology Quality of life	MoCA Digit Symbol and Symbol Search WAIS III Toulouse-Piéron Verbal Paired Associates I subtest of WMS-III RCFT Semantic and Phonemic Verbal Fluency Tests BDI-II WHOQOL-BREF	Reh@City: • pos > visual memory and depressive symptomatology > pre • follow-up > global cognitive function, language, visuospatial and executive functions > pos TG: • pos > processing speed, verbal memory, and quality of life > pre • follow-up > attention > pos Reh@City < depressive symptomatology < TG TG > social relationships aspects of quality of life > Reh@City
2	Lorentz (2023)	III	Patients with ABI acquired brain injury and mild to moderate attention deficits	Inpatient neuroreh- abilitation centers	51.66 ± 17.8 [13, 81]	NA	Attention	Virtual journey around the world (*VR Traveller*)	NA	Once	20-30 min	Once	1	Pre Post	Tonic Alertness, Selective Attention or Divided Attention Memory Verbal and nonverbal intelligence Acceptability Feasibility Tolerability	TAP Subtests *Digitspan* and *Blockspan For- wards* and *Backwards* from the WMS-IV subtest *Matrices* from the WAIS-IV and the Mehrfachwahl-Wortschatz-Intelligenztest Ver- sion B UEQ Self-constructed feasibility questionnaire VRQS	Good acceptance, feasibility and tolerability
3	Keegan (2022)	III	Mild to severe TBI and cognitive communication difficulties	Local doctors' offices and rehabilitation facilities	[32, 59]	High school – College NA	Communication	Virtual INSIGHT programme (Improving Natural Social Interaction: Group rehabilitation after Traumatic brain injury)	Group (using zoom)	NA Only refer 2 h/wk	NA Only refer 2 h/wk	8 wks	NA	Pre Post	NA	RBANS Update TASIT-R LCQ SWLS PARTO-17 GAS	↑GAS scores Treatment – feasible and ecologically valid
4	Jiang (2022)	I	Typically developing children	Public kindergarten (classroom)	EG: Neurocognitive training with no teacher positive feedback (NCT) - 5.86 ± 0.34 Neurocognitive training with teacher positive feedback (NCT-TPF) - 6.23 ± 0.32 CG: 5.95 ± 0.31	Kindergarten NA	Executive functions	EG: • NCT • NCT-TPF • CG: • - No-training	Group	2 x wk	NA	3 wks	6	Pre Post	ADHD Symptoms Scale Inhibitory Control Task Switching task Working memory task Subjective Acceptance of the Training Agents Attention level	Chinese version of the SNAP-IV Conners Index Questionnaire IOWA Conners rating scale Go-no-go task Sort objects by a sorting dimension (i.e., color or shape) into one of two locations Locating a person behind a number of doors Answer two questions EEG record	EG: Post - ↑ untrained inhibitory control task Pos = working memory task = Pre NCT-TPF: Post - ↓ reaction time in Colour and Shape trials NCT: Post - ↑ reaction time in Switch trials Teachers' subjective acceptance supported including positive feedback as part of neurocognitive training

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min*, *Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
5	Park (2022)	I	Mild cognitive impairment	Local senior centers	> 65 yrs EG: 72.25 ± 5.13 CG: 70.88 ± 4.51	NA EG: 7.56 ± 3.93 CG: 7.50 ± 2.89	Visual memory, attention, spatial navigation, planning, inhibition, multitasking	EG: • Virtual shopping training CG: • wait-list	NA	2 x wk	NA	8 wks	16	Pre Post	Executive functions IADL	EFPT-K K-IADL	GE > executive functioning and IADL > GC
6	Kim (2020)	I	Patients with schizophrenia	Mental-health welfare center	EG: 42.50 ± 10.59 CG: 46.80 ± 9.25 [19, 55]	EG: 11.80 ± 2.39 CG: 12.10 ± 1.66	Grocery shopping skill in a real situation	EG: Conventional rehabilitation (Physical exercise, social-skill training, and social-adaptation training) + grocery-shopping process components CG: Conventional rehabilitation	NA	2 x wk	50 min	4 wks	8	Pre Post	Executive functions IADL Global cognitive	EFPT-K K-IADL MoCA-K	Post EG - ↑ EFPT-K, K-IADL, and MoCA-K
7	Faria (2020)	I	Patients with stroke	Rehabilitation units working under the Physical Medicine and Rehabilitation department	VR: 59.14 ± 11.81 Paper-and-pencil: 65.00 ± 6.20 [18, 75]	VR: 8.00 ± 5.32 Paper-and-pencil: 5.50 ± 3.15	Memory, attention, executive functions, language	Cognitive training: EG: • VR-based intervention: the Reh@City v2.0 CG: • Paper-and-pencil intervention: the task generator	NA	NA	NA	1 mo	12	Pre Post Follow-up (2 mo)	General cognitive functioning Attention Memory Language Executive functions Patient-reported evaluation of cognitive state	MoCA TMT A and B WMS-III verbal paired associates WAIS-III vocabulary Digit Span from the WMS-III, and the Symbol Search and the Digit Symbol Coding from the WAIS PRECiS	Post: EG: • ↑ general cognitive functioning, attention, visuospatial ability, and executive functioning (MoCA) • ↓self-perceived cognitive deficits in different aspects of their everyday life CG: • ↑ orientation (MoCA) EG > general cognitive functioning, visuospatial ability, and executive functions (MoCA) > CG Follow-up: • CG – gains last over time
8	Giachero (2020)	I	Patients with chronic aphasia	Neurological departments of hospitals	59.75 ± 11.21 [32, 77]	11.25 ± 3.54 [5–18]	Language skills, communication efficacy, and psychosocial aspects (self-esteem, patient's emotional health, and humoral states)	Aphasia Rehabilitation: • Conversational training with VR • Conversational training without VR	Group (3 people)	2 x wk	2 h	6 mo	48	Pre Post	Language Communication Psychosocial aspects of the patient's disability Memory Attention	AAT CAPPA Visual Analogue Self Esteem Scale WHOQOL Digit span Corsi test TMT A and B	Post: Conversational training with VR = Conversational training without VR Conversational training without VR - ↑language tasks, psychosocial dimensions

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min*, *Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
9	Rosenblau (2020)	Ia	High-functioning adults with autism spectrum disorder	Autism outpatient clinic	32.4 ± 9.4	NA	Social cognition	Computer-based social-cognitive training (SCOTT) Non-social control training (NCT)	Self-paced training at home	3 h wk	NA	12 wks	NA	Pre Post	Verbal and non-verbal IQ Diagnostic instruments Close generalization Distant generalization Cortical thickness and functional activity during two social-cognitive tasks: mentalizing task and a facial affect recognition task	Vocabulary test MWT; strategic thinking test (LPS) ADI-R, ADOS Face Puzzle implicit and -explicit tasks Movie for the Assessment of Social Cognition fMRI	Post: EG > participants' facial emotion recognition accuracy on a close generalization task > CG EG > mentalizing abilities on a more distant generalization task > CG ↑ functional and structural neuroplasticity in midline and prefrontal areas of the brain
10	Corrow (2019)	II	Patients with acquired prosopagnosia	NA	[20, 61]	NA	Face perception	Face Training programme Control television task	Home training	NA	NA	11 wks	NA	Pre Post Follow-up (3 mo)	Colour perception Face recognition Visuo-perceptual Imagery Attention Memory Short-term familiarity for faces Perceptual discrimination of faces NA Autism spectrum disorders Acquired structural lesions Perceptual sensitivity Impressions of the subjects	Goldmann perimetry and the Farnsworth-Munsell 100-hue test Prosopagnosia Index Hooper Visual Organization, Benton Judgment of Line Orientation, Visual Object and Spatial Perception Mental rotation TMT, star cancellation, visual search Digit span-forward, spatial span-forward, word list (immediate recall), Warrington Recognition Memory Test for Faces and Words, Cambridge Face Memory Task Cambridge Face Perception Test Old/New faces test, Famous Faces Test Autism Questionnaire MRI scans Face perception task Participants were asked to describe the effects of training on their experience with faces in daily life	Post: EG > face sensitivity > CG EG: • ↑ generalized to untrained expressions and views of faces, transfer to new faces ↑ short-term familiarity ↑ daily life FU = Post

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age *M* ± *SD* [*Min*, *Max*]	Education Level Years - *M* ± *SD*	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
11	Dehn (2018)	II	Patients with depression	Clinic of Psychiatry and Psychotherapy (inpatient-treatment)	>18 yrs EG: 47.48 ± 9.40 CG: 42.29 ± 13.72	EG: 13.52 ± 2.21) CG: 13.06 ± 2.49	Grocery shopping	VR-environment (highly immersive) – OctaVis PC desktop VR-application (less immersive)	Individual	Training intervals:- trials 1-5 - 1 and 3 days - trials 6-8 consecutive days	NA	8 d	NA	Pre Post	Demographic and relevant clinical data Depression General cognitive abilities General immersion tendency Complaints in everyday life Alertness and selective attention Verbal short-term memory and verbal working memory Verbal learning and memory Visuo-spatial memory Semantic and lexical verbal fluency Visuo-spatial perception Shopping task (virtual and real): • verbal learning and memory • processing speed	Pre-structured interview (including weekly computer usage) BDI-II, Structured Clinical Interview for DSM- IV LPS ITQ Questionnaire for Complaints of Cognitive Disturbances TAP Digit Span Task of the WMS-R German version of the RAVLT RCFT RWT BRLD No. of correctly purchased products Walking distance, shopping time	VR-setting had no benefit compared to a PC-desktop
12	Chen (2018)	I	Healthy older adults	community	68.55 ± 5.7 [60, 83]	Elementary school to college	Memory and Reasoning	Cognitive training Low ecological memory training (LEM) High ecological memory training (HEM) Low ecological reasoning training (LER) High ecological reasoning training (HER)	Group	1 x wk	60 min	10 wks	NA	Pre Post	Visual acuity Normal color vision Hearing NA Mental abilities (Spatial working memory Numerical working memory Reasoning) Everyday problem-solving	NA NA NA MMSE See the paper for tasks description OTDL-C	EG - ↑ cognitive functions and everyday problem-solving HEM and HER = LEM and LER
13	Haeger (2018)	II	Healthy older participants	University campus and in the city, mailing lists, newspapers	71.46 ± 4.09 [65, 80]	EG: • A level – 8 • O level – 8 CG: • A level – 9 • O level – 12	Visual attention and executive functions	Driving-Simulator Training	NA	3 x wk	1 h	4 wks	NA	Pre Post	NA Distributed/spatial attention Selective and sustained attention Multistream divided attention Spatial working memory Executive flexibility Retrospective physical activity Gait and balance/ functional mobility	MMSE Precue task D2-Attention task Attention Window task Grid Span task Switching task PAQ-50+ Timed Up-and-Go task	EG: ↑ divided visual attention No training-induced transfer effects

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min, Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
14	Davies-Thompson (2017)	III	Acquired prosopagnosia	Web site	[60, 83]	NA	Perceptual learning	Experimental task: Face Training programme Control task: Watch episodes from a British television series of patient's choice	Individual (computer based – at home) Control task: NA	Experimental task: 3 x wk Control task: NA	Experimental task: 30-40 min Control task: 1.5 h	11 wks	NA	Pre - 6 online assessments (1 of them at the laboratory) Post training or the control task - 6 online assessments (+1 at the laboratory) Post completing the task they had not yet done - 6 online assessments (+1 at the laboratory)	Neuro-ophthalmologic history and examination	Goldmann perimetry and Farnsworth–Munsell 100-hue test	Experimental task: • perceptual discrimination of faces • ↑ transfer, generalization and maintenance of results • some patients perceived benefits in daily life
															Handedness	NA	
															Attention	TMT, Star Cancellation, Visual search	
															Memory	Digit span, Spatial span, Word list, CFMT	
															Visual-perceptual abilities	HVO, BJLO	
															Visual Object and Spatial Perception	Object: Screening, Spatial: Dot Counting	
															Imagery	Mental Rotation	
															Face Processing	BFRT, Familiarity: Famous faces d', WRMT, CFPT, Face imagery	
															Name Processing	Familiarity, Occupation sorting	
															Brain structure and functioning	MRI, fMRI (dynamic face localizer)	
															Perceptual sensitivity to morphed changes	Decision about morphed change (six online assessments, Tests 1 and 2 – trained views and expressions, Tests 3 and 4 – untrained views and expressions, Tests 5 and 6 - untrained expression of surprise)	
															Generalization	Task using new images of trained faces	
															Transfer	Task using new faces	
															Maintenance of results	Results in six online tests immediately after training vs results after another 3 months doing the control task.	
															Discrimination of changes in feature shape and the spatial relations	Interocular distance and the distance between the nose and mouth	
															Impressions of the Particppants	Description the effects of training on their experience with faces in daily life	

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age *M* ± *SD* [*Min*, *Max*]	Education Level Years - *M* ± *SD*	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
15	Strobach (2017)	I	NA	Websites, advertisements in newspapers, internet forums, and chats	45.1 ± 10.9 [21, 73]	86.8% - high school 52.6% -graduated	Working memory updating tasks and working memory span tasks Linguistic skills	Computerized home-based brain training (www. neuronation.com) EG CG	NA	NA	30-35 min	EG: 36.5 d CG: 32.5 d	21	Pre Post	• Criterion tasks: Working memory updating, concentration, and visuospatial attention	Shuffler	Pos EG: ↑ criterion and near-transfer tasks ↓reported cognitive failures
															Working memory span and task shifting	Memory Interrupted	
															• Near transfer: Episodic working memory span	Restorer	
															Working memory updating	Turning Tops	
															Episodic working memory span	Turnabout	
															Working memory storage capacity	Digit Span	
															• Far-transfer: Inhibition of prepotent, automatic responses	Stroop	
															Selective and sustained attention, and visual scanning speed	d2	
															Logical thinking, reasoning, and mental rotation	IQube, Missing Link	
															Visual attention and task switching	TMT	
															Frequency of minor everyday lapses	CFQ	

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min, Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
16	Faria (2016)	I	Stroke	Hospitals (out and inpatients)	EG: $M = 58$ [48, 71] CG: $M = 53$ [50.5, 65.5]	EG: 4 [4–10.5] CG: 9 [4–9]	Memory, attention, visuo-spatial abilities and executive functions	Cognitive training: EG: • VR-based simulation of ADL's: the Reh@City v2.0 CG: • Conventional training (puzzles, calculus, problem resolution and shape sorting)	NA	NA	20 min	4-6 wks	12	Pre Post	Hemi-spatial neglect Minimum cognitive function Language comprehension Global cognitive functioning Attention Executive functions Subjective general health status Satisfaction and usability with the Reh@City system	LBT MMSE Token Test ACE TMT PAT from WAIS-III SIS 3.0 SUS	Post: VR-based intervention: • ↑ global cognitive functioning, attention, memory, visuo-spatial abilities, executive functions, emotion CG: • ↑ self-reported memory and social participation VR-based intervention > global cognitive functioning, attention, and executive functions > CG
17	Lansford (2016)	I	Laboratory Listeners Crowdsourcing listeners	University Crowdsourcing	NA	NA	Perception	EG: Perceptual training using dysarthric speech CG: Perceptual training using non-dysarthric speech	NA	NA	NA	NA	1	Post	NA	Transcription task	EG > mean percent words correct > CG Results = 2 training settings (lab and at-home computer-based scenario)
18	Gomar (2015)	I	Patients with schizophrenia	Inpatient rehabilitation services of hospitals and rehabilitation centers for community-dwelling patients	EG: 46.68 ± 9.97 TAU: 45.40 ± 9.77 CG: 46.13 ± 10.11 [20, 65]	EG: 9.30 ± 2.86 TAU: 10.33 ± 2.65 CG: 9.53 ± 3.08	Attention, memory, and executive function NA NA	EG: Computerized online training drawn from the FesKits programme CG: computerized typing programme TAU: daily rehabilitative activities	Group Group Individual	2 x wk 2 x wk NA	45 min 45 min NA	6 mo	NA	Pre Post	Schizophrenia or schizoaffective disorder Diagnosis Symptoms Premorbid IQ Current IQ Executive functions Memory function Performance-based daily living skills Memory and Executive failures in daily life	DSM-IV criteria based on interview and review of clinical history PANSS WAT WAIS-III BADS, Stroop Test, TMT, FAS test RBMT, WMS: digit span, logical memory immediate, immediate memory for faces, and letter-number sequencing UPSA DEX, MCL	EG: • ↑ training tasks • No transfer to memory (RBMT) and executive functions (BADS) • No benefit on daily life cognitive failures rated by careers • - Computerized online training is not effective in schizophrenia

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age *M* ± *SD* [*Min, Max*]	Education Level Years - *M* ± *SD*	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
19	Grewe (2014)	II	Patients with focal epilepsy	Hospital	EG - 31.29 ± 9.44 [19, 51] CG - 31.21 ± 14.26 [19, 62]	NA	Visual–spatial cognition of memory and navigation	VR training programme (supermarket)	NA	Sessions 1-5 - maximum interval of 48 h between training sessions Sessions – 6, 7, and - maximum interval of 24 h between training sessions	NA	14 d	8	Pre Post	IQ	LPS	No. of correct products per time across all VR learning trials was correlated with the no. of correct products per time in the reality check task No. of correct products per distance across all VR learning trials was correlated with the no. of correct products in the reality check task ↓VR scores correlated with ↓ estimations of cognitive abilities
															Depression	BDI-II	
															Subjective memory complaints	MAC-Q	
															Use of computer	Likert scale	
															Visuo- construction, planning, intermediate and long-term visual memory	RCFT	
															Verbal learning and memory	VLMT, German version of the RAVLT	
															Verbal short-term and working memory	Digits Span Tasks of WMS-R	
															Semantic and lexical verbal fluency	RWT	
															Spatial-cognitive abilities	BRLD	
															Participants' subjective cognitive disabilities	FLEI	
															Memory performance in VR task	No. of correctly bought products	
															Navigational performance	Time (in seconds) and the lengths of movement trajectories (in meters)	
															Memory-related spatial navigation	No. of correct products in relation to the movement path for each trial; no. of correct products in relation to the required time for each trial	
															Verbal learning and memory (outside the VR)	No. of verbally recalled correct products after presentation of the target list prior to starting the VR task	
															General learning score	Summing up all correctly bought products across all six trials	
															Shopping performance in a real-life supermarket task	No. of correct products, no. of correct products in relation to the length of movement paths, and no of correct products in relation to time	

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min, Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
20	Grewe (2013)	II	Healthy university students and patients with focal epilepsy	NA	EG: 23 ± 3.45 [19,28] CG: 35.04 ± 8.08 [25,47]	NA	Real-life cognitive abilities	360°- VR supermarket – "Octavis"	NA	NA	NA	EG: 8 d CG: 5 d	NA	During the intervention Post	IQ Perceived level of presence during the shopping situation in the virtual supermarket General tendency to get immersed into a virtual environment Cybersickness Usability of both the task and the technical apparatus Figural memory Behavioral measures of performance in the virtual supermarket	Not reported PQ Immersive Tendencies Questionnaire Asked the participants whether they experienced symptoms of vertigo Self-constructed explorative questionnaire RCFT Time required to buy all the shopping items they remembered, no of correctly picked items, adjusted no of correctly picked items from the respective list ("product-score, i.e., number of correct items minus false positives minus repetitions), LMT (distance travelled in the VR supermarket)	EG: Day 7 > items > Day 1 Day 6 > required time for shopping > Day 8 CG: ↑ correct items, product score ↓ LMT Day 1 < PQ-subscale "immersion/adaptation" < Day 5 • Immediate recall of the RCFT correlated with: • product-score on day 5 • Delayed recall of the RCFT correlated with: • product score on day 5 • no of correct products on 5
21	Jacoby (2013)	Ia	Adults With TBI	Department of Brain Injury Rehabilitation at Hospital	EG: 27.83 ± 12.06 CG: 30.67 ± 13.13 [19, 55]	EG: 13 ± 1.1 CG: 12 ± 1.67	Motor, cognitive and executive functions during the practice of IADL Planning, initiation, time management, monitoring performance, meta-cognitive strategies	Virtual Mall (VMall) -virtual environment of a supermarket Occupational therapy intervention	NA	3-4 x wk	45 min	NA	10	Pre Post	Basic cognitive abilities Executive functions NA	Neurobehavioral Cognitive Status Examination—Cognistat BADS, MET-SV, EFPT GCS	EG > ↑ EF > CG

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [*Min, Max*]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
22	Hodge (2010)	I	Patients with schizophrenia	Intervention outpatient centers, chronic inpatient rehabilitation centers, and chronic community outpatient centers	31.33 ± 9.08 [17, 50]	11 ± 1.16	Sustained attention, processing speed, memory, and executive functions	EG: Neuropsychological Educational Approach to Remediation (NEAR) CG: wait-list	Individual	2 x wk	1 h	10-15 wks	30	Baseline Pre Post Follow up (4 mo)	Premorbid IQ Positive and negative symptoms Processing speed Set shifting Sustained attention Verbal learning and verbal memory Visual memory Reasoning/cognitive flexibility Patients' social and occupational functioning Functioning in patients with schizophrenia Quality of Life Self-esteem Depression	WRAT-R PANSS TMT A TMT B CCPT RAVLT RCFT DKEFS SOFAS LSP-39 WHOQOL-Bref RSES CDS	EG: FU = Pos > verbal and visual memory, sustained attention and executive functioning; social and occupational outcomes > Pre
23	Galbiati (2009)	II	TBI patients	Intensive rehabilitation unit	EG: 13.9 ± 3.75 CG: 15.5 ± 3.30 [6, 18]	EG: 5.95 ± 3.75 CG: 5.68 ± 3.30	Attention	Tabletop tasks (computerized tasks such as the Rehacom programme (Schuhfried, 1996) and the Attenzione e Concentrazione programme (Di Nuovo, 1992)	Individual	4 x wk	45 min	6 mo	NA	Pre Follow-up (1 yr)	IQ Attention Adaptive behavior	WISC-R or WAIS-R CPT II VABS	EG - ↑ CPT II and VABS > CG
24	Hampstead (2008)	III	Mild cognitive impairment	University Alzheimer's Disease Research Center and Veterans Affairs Medical Center	75 ± 6.7 [63, 86]	15.3 ± 1.8	Memory	Face-name association modified Biographical Information Module from the Ecologically Oriented Neurorehabilitation of Memory programme (Stringer, 2007)	NA	NA	60 min	2 wk	3	Pre Post Follow-up (1 mo)	Cognitive functioning NA Memory Test Performance Memory confidence ratings NA	DRS-2 GDS Face-name test (Recognition accuracy and response latencies for trained and untrained lists) 4-point scale Use of Cues During Training	Pos - ↑ recognition accuracy and ↓ reaction times for trained face-name pairs > untrained face-name pairs Follow-up - ↑ accuracy persisted for trained face-name pairs; trained list > more confident in selecting the correct names > untrained list
25	Lo Priore (2003)	I	Young normal subjects without neurological or psychiatric problems	NA	NA	NA	Executive funcions	EG: VR-based rehabilitation tool, V-Store CG: non-immersive (flat screen) sessions of V-Store	NA	NA	34 min	NA	NA	During sessions	Sense of presence	Changes in skin conductance Incidental recall memory test related to auditory information coming from the "real" environment Count of breaks in presence ITC-SOPI questionnaire (spatial presence; engagement; ecological validity/ naturalness; negative effects)	EG > skin conductance > CG EG = EC – self-report questionnaire

(*Continued*)

Table 1. Continued.

No.	First author	Class	Etiology	Center	Age $M \pm SD$ [Min, Max]	Education Level Years - $M \pm SD$	Neurocognitive functions targeted	Treatment	Modality	Frequency of sessions	Sessions lenght	Intervention lenght	Total number of sessions	Assessment moments	Variables measured	Instruments	Main results
26	Villa (2000)	I	Healthy elderly individuals	Recruited through advertisements in a local paper	67.37 ± 7.39 [55, 81]	15.16 ± 2.74	Prospective memory	Psychoeducation (impact of mood on memory), relaxation training, behavior modification and cognitive restructuring of automatic thoughts EG: ecologically valid stimuli CG: laboratory-generated stimuli	Group	NA	75-90 min	NA	7	Pre Post	Medical history and medication NA NA NA Prospective memory	MAI MMSE Storandt Brief Dementia Battery BDI or GDS RBMT and PROMS	Pos > prospective memory > Pre employing ecologically valid stimuli = using laboratory-generated stimuli
27	Ownsworth (1999)	II	ABI	EG: Local brain-injury community support group CG: University	EG: 43.1 CG: 28.1 [23, 65]	EG: 11.6	Memory	Diary and Self-Instructional Training (DSIT) approach - compensation using higher cognitive skills of self-awareness and self-regulation Diary Only (DO) approach – compensation using a task specific learning	NA	NA	NA	4 wks	NA	Pre During the treatment	Memory	RBMT, WMS-R, memory questionnaire, and a daily memory checklist	DSIT > diary entries > DO DSIT < memory problems < DO DSIT > positive ratings associated with treatment efficacy > DO DSIT - ↑ skills to self-regulate in addition to learning simple behaviours associated with diary use

Note: No. = Number; M = Mean; SD = Stead deviation; Min = Minimum; Max = Maximum; VR = Virtual Reality; min = minute; mo = month; MoCA = Montreal Cognitive Assessment; WAIS = Wechsler Adult Intelligence Scale III; WMS-III = Wechsler Memory Scale-III; RCFT = Rey-Osterrieth Complex Figure Test; BDI-II = Beck Depression Inventory II; WHOQOL-BREF = World Health Organization Quality of Life abbreviated; ABI = Acquired Brain Injury; NA = Not Available; TAP = Testbatterie zur Aufmerksamkeitsprüfung; WMS-IV = Wechsler Memory Scale – Fourth Edition; WAIS-IV = Wechsler Adult Intelligence Scale–Fourth Edition; UEQ = User Experience Questionnaire; VRQS = Virtual Reality Symptom Questionnaire; TBI = Traumatic Brain Injury; h = hour; wk = week; Pre = Pre-Intervention; Post = Post-Intervention; RBANS Update = Repeatable Battery for the Assessment of Neuropsychological Status Update; TASIT-R = The Awareness of Social Inference Test Revised; LCQ = La Trobe Communication Questionnaire; SWLS = Satisfaction with Life Scale; PARTO-17 = Participation Assessment with Recombined Tools-Objective—17 item revision; GAS = Goal attainment scale; EG = Experimental group; CG = Control group; EEG = Eletroencephalography; EFPT-K = Korean version of the Executive Function Performance Test; IADL = Instrumental Activities of Daily Living; K-IADL = Korean Instrumental Activities of Daily Living; MoCA-K = Korean version of the Montreal Cognitive Assessment; TMT = Trail Making Test; PRECiS – Patient-Reported Evaluation of Cognitive State; h = hour; AAT = Aachen Aphasia Test; CAPPA = Conversation Analysis Profile for People with Aphasia test; IQ = Intelligence Quotient; MWT = Mehrfach-Wortschatz-Test; ADI-R = Autism Diagnostic Interview – Revised; ADOS = Autism Diagnostic Observation Schedule; fMRI = Functional magnetic resonance imaging; MRI = Magnetic resonance imaging; d = day; LPS = LPS: Leistungsprüfungssystem; ITQ = Immersive tendencies questionnaire; TAP = Test Battery for Attention Performance; RAVLT = Rey Auditory Verbal Learning Test; RWT = Regensburg Verbal Fluency Test, Regensburger Wortflüssigkeitstest; BRLD = Bergen Right-Left Discrimination Test; OTDL-C - Chinese version of the Observed Task of Daily Living; MMSE = Mini-Mental Status Exam; CFMT = Cambridge Face Memory Test; HVO = Hooper Visual Organization; BJLO = Benton Judgment of Line Orientation; BFRT = Benton Face Recognition Test; WRMT = Warrington Recognition Memory Test; CFPT = Cambridge Face Perception Test; ADL = Activities of Daily Living; ACE - Addenbrooke Cognitive Examination; CFQ = Cognitive Failure Questionnaire; LBT = Line Bisection test; PAT = Picture Arrangement test; SIS 3.0 = Stroke Impact Scale 3.0; SUS = System Usability Scale; TAU = Treatment as Usual; DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; BADS = Behavioral Assessment of the Dysexecutive Syndrome; RBMT = Rivermead Behavioral Memory Test; UPSA = University of California Performance Skills Assessment; DEX = Dysexecutive Questionnaire; MCL = Memory Checklist; WAT = Word Accentuation Test; PANSS = Positive and Negative Syndrome Scale; MAC-Q = Memory Assessment Clinics Questionnaire; VLMT = Verbaler Lernund Merkfähigkeitstest; FLEI = Questionnaire for Complaints of Cognitive Disturbances; IADL = Instrumental Activities of Daily Living; PQ = Presence Questionnaire; LMT = length of movement trajectories; MET-SV = Multiple Errands Test—Simplified Version; EFPT = Executive Function Performance Test; GCS = Glasgow Coma Scale; WRAT-R Wide Range Achievement Test-Revised; PANSS = Positive and Negative Syndrome Scale; CCPT = Conners' Continuous Performance Test; DKEFS = Delis-Kaplan Executive Function System; SOFAS = Social and Occupational Function Scale; LSP-39 = Life Skills Profile—39; RSES = Rosenberg Self-Esteem Scale; CDS = Calgary Depression Scale; CPT II = Continuous Performance Test II; VABS = Vineland Adaptive Behavior Scales; yr = year; DRS-2 = Dementia Rating Scale-2; GDS = Geriatric Depression Scale; MAI = Multilevel Assessment Inventory; PROMS = Prospective Memory Screening Test

Haeger et al., 2018; Villa & Abeles, 2000), typically developing children (Jiang et al., 2022), and young normal subjects without neurological or psychiatric problems (Lo Priore et al., 2003). One study only provided information about the sample recruitment procedures (Strobach & Huestegge, 2017), while another categorized the group based on the characteristics of the intervention setting (Lansford et al., 2016).

The studies included in this review were published in 21 different journals. Among these journals, those with a higher number of publications were *Journal of NeuroEngineering and Rehabilitation* ($n=3$), *Asian Journal of Psychiatry* ($n=2$), *Journal of Aging Research* ($n=2$), *Schizophrenia Bulletin* ($n=2$), and *Virtual Reality* ($n=2$).

Intervention characteristics

Most of the studies in the review focused on specific neurocognitive functions, targeting between one (e.g., Jiang et al., 2022; Keegan et al., 2022) to four neurocognitive functions (e.g., Câmara et al., 2023; Faria et al., 2020). Most studies targeted one neurocognitive function ($n=11$; Corrow et al., 2019; Davies-Thompson et al., 2017; Galbiati et al., 2009; Hampstead et al., 2008; Jiang et al., 2022; Keegan et al., 2022; Lansford et al., 2016; Lorentz et al., 2023; Lo Priore et al., 2003; Ownsworth & McFarland, 1999; Villa & Abeles, 2000), with memory being the most trained neurocognitive function ($n=11$; Câmara et al., 2023; Chen et al., 2018; Faria et al., 2016, 2020; Gomar et al., 2015; Grewe et al., 2014; Hampstead et al., 2008; Hodge et al., 2010; Ownsworth & McFarland, 1999; Park, 2022; Villa & Abeles, 2000). In addition to memory, other neurocognitive functions were targeted in the reviewed studies. For example, one study targeted multitasking (Park, 2022), while others addressed social cognition (Rosenblau et al., 2020), real-life performance of daily activities (Kim et al., 2020) or in a simulated situation (Dehn et al., 2018), language and psychosocial aspects (Giachero et al., 2020), training motor and cognitive functions during the practice of instrumental activities of daily living and training of meta-cognitive strategies (Jacoby et al., 2013). One study did not explicitly specify the neurocognitive functions being targeted (Grewe et al., 2013).

Regarding the treatment, virtual reality-based interventions were applied in twelve studies (Câmara et al., 2023; Dehn et al., 2018; Faria et al., 2016, 2020; Giachero et al., 2020; Grewe et al., 2013, 2014; Jacoby et al., 2013; Keegan et al., 2022; Lo Priore et al., 2003; Lorentz et al., 2023; Park, 2022). These interventions employed various virtual reality scenarios, including: (a) shopping or supermarket contexts ($n=5$; Dehn et al., 2018; Grewe et al., 2013, 2014; Jacoby et al., 2013; Park, 2022); (b) a city environment ($n=3$; Câmara et al., 2023, Faria et al., 2016, 2020; Giachero et al., 2020); (c) different locations within the virtual world ($n=1$; Lorentz et al., 2023); and (d) an internal goods store ($n=1$; Lo Priore et al., 2003). Virtual reality-based interventions were compared to several interventions, including: (a) paper-and-pencil interventions ($n=2$; Câmara et al., 2023; Faria et al., 2020); (b) the same task without the use of virtual reality ($n=2$; Giachero et al., 2020; Lo Priore et al., 2003); (c) conventional training involving tasks such as puzzles and problem-solving tasks ($n=1$; Faria et al., 2016); (d) the same task trained in virtual-reality intervention using a computer desktop virtual reality-application ($n=1$; Dehn et al., 2018); and (e) occupational therapy intervention ($n=1$; Jacoby et al., 2013).

Computer-based interventions were applied in three studies (Galbiati et al., 2009; Gomar et al., 2015; Rosenblau et al., 2020; Strobach & Huestegge, 2017). To evaluate the effectiveness of the computer-based interventions, the results were compared to different control conditions: (a) nonsocial control training (Rosenblau et al., 2020); (b) computerized typing programme; and (c) usual daily rehabilitative activities (Gomar et al., 2015).

One study performed the intervention in a local grocery shop within the community (Kim et al., 2020). The study aimed to compare the results between two groups: the first group received the intervention in the grocery shop, along with a conventional rehabilitation programme that included physical exercise and social skill training, while the second group only underwent the conventional rehabilitation programme without the additional grocery shop intervention (Kim et al., 2020). Another study included interventions categorized by the authors as low ecological and high ecological based on the inclusion of tasks that resemble activities performed in participants' everyday life (Chen et al., 2018).

Other interventions implemented in the studies included the following: (a) face training programme with a television task as control intervention (Corrow et al., 2019; Davies-Thompson et al., 2017); (b) face-name association training using the Ecologically Oriented Neurorehabilitation of Memory Programme (Hampstead et al., 2008); (c) online group rehabilitation focused on communication (Keegan et al., 2022); (d) neurocognitive training with and without positive feedback from a teacher, compared to no training (Jiang et al., 2022); (e) driving-simulator training (Haeger et al., 2018); (f) perception training using dysarthric and non-dysarthric speech (Lansford et al., 2016); (g) neuropsychological educational approach to remediation compared (Hodge et al., 2010); (h) prospective memory intervention programme using ecologically valid stimuli or laboratory-generated stimuli (Villa & Abeles, 2000); and (i) remediation of everyday memory using diary training programmes (Ownsworth & McFarland, 1999).

Most interventions were delivered in group ($n=6$; Chen et al., 2018; Giachero et al., 2020; Gomar et al., 2015; Jiang et al., 2022; Keegan et al., 2022; Villa & Abeles, 2000), while a fewer number of studies used individual intervention formats ($n=5$; Câmara et al., 2023; Davies-Thompson et al., 2017; Dehn et al., 2018; Galbiati et al., 2009; Hodge et al., 2010). Sixteen studies did not specify whether the interventions were delivered individually or in a group (Corrow et al., 2019; Faria et al., 2016, 2020; Grewe et al., 2013, 2014; Haeger et al., 2018; Hampstead et al., 2008; Jacoby et al., 2013; Kim et al., 2020; Lansford et al., 2016; Lo Priore et al., 2003; Lorentz et al., 2023; Ownsworth & McFarland, 1999; Park, 2022; Rosenblau et al., 2020; Strobach & Huestegge, 2017), although two of these studies mentioned that the intervention took place at home (Corrow et al., 2019; Rosenblau et al., 2020).

Regarding the usual dose of sensory stimulation programmes, the frequency of intervention ranged from once a week (Lorentz et al., 2023) to four times a week (Galbiati et al., 2009). The information that gathered more consensus was twice a week ($n = 7$; Câmara et al., 2023; Giachero et al., 2020; Gomar et al., 2015; Hodge et al., 2010; Jiang et al., 2022; Park, 2022; Kim et al., 2020). Ten studies did not provide information on the frequency of stimulation (Corrow et al., 2019; Faria et al., 2016, 2020; Grewe et al., 2013; Hampstead et al., 2008; Lansford et al., 2016; Lo Priore et al., 2003; Ownsworth & McFarland, 1999; Strobach & Huestegge, 2017; Villa & Abeles, 2000). The duration of sessions varied from twenty minutes (Lorentz et al., 2023) to two hours (Giachero et al., 2020). Greater consensus was achieved for sessions lasting thirty minutes ($n = 4$; Câmara eta al., 2023; Lorentz et al., 2023; Davies-Thompson et al., 2017; Strobach & Huestegge, 2017) and sixty minutes ($n = 4$; Chen et al., 2018; Haeger et al., 2018; Hampstead et al., 2008; Hodge et al., 2010). Ten studies did not report the length of the sessions (Corrow et al., 2019; Dehn et al., 2018; Faria et al., 2020; Grewe et al., 2013, 2014; Jiang et al., 2022; Keegan et al., 2022; Lansford et al., 2016; Ownsworth & McFarland, 1999; Rosenblau et al., 2020). The duration of the intervention ranged from one session (Lorentz et al., 2023) to six months (Gomar et al., 2015). The information most widely agreed upon was four weeks ($n = 3$; Haeger et al., 2018; Kim et al., 2020; Ownsworth & McFarland, 1999) and six months ($n = 3$; Galbiati et al., 2009; Giachero et al., 2020; Gomar et al., 2015). Four studies did not report the length of the intervention (Jacoby et al., 2013; Lansford et al., 2016; Lo Priore et al., 2003; Villa & Abeles, 2000). The intervention programmes included from one (Lorentz et al., 2023) up to forty-eight sessions (Giachero et al., 2020). The information that garnered the highest level of agreement was a single session ($n = 2$; Lansford et al., 2016; Lorentz et al., 2023), eight sessions ($n = 2$; Grewe et al., 2014; Kim et al., 2020), and twelve sessions ($n = 2$; Faria et al., 2016, 2020). The total number of sessions was not provided in eleven studies (Chen et al., 2018; Corrow et al., 2019; Davies-Thompson et al., 2017; Dehn et al., 2018; Galbiati et al., 2009; Gomar et al., 2015; Haeger et al., 2018; Keegan et al., 2022; Lo Priore et al., 2003; Ownsworth & McFarland, 1999; Rosenblau et al., 2020).

Ecological validity entries

The term "EV" was mentioned in the studies between two and twenty-five times ($n = 244$) across the different sections of the papers (see Figure 2). Most of the references to EV were found in the introduction, followed by abstract and discussion. Only sixteen studies referred to EV in the method section, and ten studies referred to it in the results.

Assessment procedures

The most consensual times of assessment include pre-intervention and post-intervention ($n = 17$, Chen et al., 2018; Davies-Thompson et al., 2017; Dehn et al., 2018; Faria et al., 2016; Giachero et al., 2020; Gomar et al., 2015; Grewe et al., 2014; Haeger et al., 2018; Jacoby et al., 2013; Jiang et al., 2022; Keegan et al., 2022; Kim et al., 2020; Lorentz et al., 2023; Park, 2022; Rosenblau et al., 2020; Strobach & Huestegge, 2017; Villa & Abeles, 2000). Additionally, four studies performed follow-up assessments (Câmara et al., 2023; Corrow et al., 2019; Faria et al., 2020; Hampstead et al., 2008), ranging from one month (Hampstead et al., 2008) to three months (Corrow et al., 2019). Other studies performed: (a) baseline, pre-intervention, post-intervention, and follow-up assessment (Hodge et al., 2010); (b) pre-intervention and follow-up assessments (Galbiati et al., 2009); (c) pre-intervention and during the treatment assessments (Ownsworth & McFarland, 1999); (d) during intervention and post-intervention assessments (Grewe et al., 2013); (e) assessment only during the sessions (Lo Priore et al., 2003); and (f) assessment only post-intervention (Lansford et al., 2016).

Regarding the assessment instruments, studies used several interviews, questionnaires, tests, and other measures to characterize the sample and evaluate the effects of the intervention on various aspects such as neurocognitive functions, depressive symptomatology, quality of life (Câmara et al., 2023), acceptability, feasibility and tolerability of virtual reality (Lorentz et al., 2023), among others.

Only three studies explicitly outlined the procedures to evaluate EV. These included: (a) teachers' subjective acceptance questions (Jiang et al., 2022); (b) description of the effects of training on experience with faces in daily life (Davies-Thompson et al., 2017); and (c) the Vineland Adaptive Behavior Scales (Galbiati et al., 2009). The remaining studies did not provide information on how EV was assessed, but the authors seemed to indirectly infer about the EV of interventions using the following measures/instruments: (a) goal attainment scale (Keegan et al., 2022); (b) self and other report scales such as Korean Instrumental Activities of Daily Living (Park, 2022), Patient-Reported Evaluation of Cognitive State (Faria et al., 2020), Dysexecutive Questionnaire and Memory Checklist (Gomar et al., 2015), ecological validity/naturalness factor of ITC-Sense of Presence Inventory (Lo Priore et al., 2003), teachers reports addressing Subjective Acceptance of the Training Agents (Jiang et al., 2022), self-reported memory and social participation through a questionnaire not specified (Faria et al., 2016); (c) performed-based measures, including a transcription task in both laboratory and real-life settings (Lansford et al., 2016), an everyday problem-solving task (Chen et al., 2018), and a face perception task using trained and untrained expressions and views of faces (Corrow et al., 2019); and (d) real-life tasks including a shopping task (Dehn et al., 2018; Grewe et al., 2014) combined with a self-report measure, the Questionnaire for Complaints of Cognitive Disturbances (Grewe et al., 2014). Two studies focus on generalization and used tasks such as: (a) a face puzzle and a movie to assess close and distant generalization of social cognition improvements, respectively (Rosenblau et al., 2020); (b) the Social and Occupational Function Scale (Hodge et al., 2010). One study focused on near-transfer to untrained tasks, testing training skills, and far-transfer by evaluating untrained skills, including the use of Cognitive Failure Questionnaire

(Strobach & Huestegge, 2017). Another study targeted transfer effects on functional mobility by using Timed Up-and-Go task (Haeger et al., 2018).

The EV of NI or its effects on the functionality in activities of daily living were not assessed in one study of Class I (Villa & Abeles, 2000), one study of Class Ia (Jacoby et al., 2013), and two studies of Class II (Grewe et al., 2013; Ownsworth & McFarland, 1999).

Intervention outcomes

Class I studies

Only one Class I study provided information regarding the assessment of EV (Jiang et al., 2022). This neurocognitive training programme targeting executive functions with teacher-positive feedback was assumed to have higher EV based on subjective acceptance by teachers (Jiang et al., 2022).

One study found improvements in instrumental activities of daily living following virtual shopping training (Park, 2022). However, five virtual reality interventions were assumed to be ecologically valid based on the use of this method, but there was no direct assessment of EV or the intervention impact on the functionality in activities of daily living (Câmara et al., 2023; Faria et al., 2016, 2020; Giachero et al., 2020, Lo Priore et al., 2003). However, one of these studies demonstrated a decrease in self-perceived cognitive deficits in various aspects of everyday life following a virtual reality intervention, which can be considered an indirect measure of its EV (Faria et al., 2020). The effects of virtual reality-based intervention on self-reported memory and social participation did not differ from those of conventional training (which included tasks like puzzles) (Faria et al., 2016). Similarly, another study did not find differences between the effects of a virtual reality-based shopping training and a non-immersive shopping training using a self-report presence questionnaire (Lo Priore et al., 2003).

One study observed improvements in instrumental activities of daily living following a real-life grocery shopping intervention, but no direct inferences were made regarding its EV (Kim et al., 2020). Another study assumed the EV of two interventions based on the inclusion of tasks similar to those performed in participants' everyday life. However, the effects of interventions with high EV on everyday problem-solving tasks did not differ from the effects of interventions with low EV (Chen et al., 2018).

A computer-based training that focused on improving working memory showed positive outcomes with near-transfer effects on untrained tasks assessing trained skills, as well as far-transfer effects on untrained skills, along with a decrease in self-reported cognitive failures (Strobach & Huestegge, 2017). In contrast, one study did not demonstrate the benefit of computer-based training programme that targeted attention, memory, and executive functions on daily life cognitive failures, as rated by careers, when compared to control interventions (Gomar et al., 2015).

The remaining Class I studies also indirectly inferred about the EV of two interventions. One study found that a perception training using dysarthric speech resulted in higher intelligibility scores, as assessed by a transcription task, compared to the same training programme using non-dysarthric speech. This outcome was consistent regardless of whether the training to took place in a lab or real-life setting (Lansford et al., 2016). Another study focused on Neuropsychological Educational Approach to Remediation, which targeted sustained attention, processing speed, memory, and executive functions. The intervention led to the generalization of improvements in neurocognitive abilities to social and occupational functioning from baseline to post-intervention, which was maintained during the follow-up (Hodge et al., 2010).

Class Ia studies

One study applied virtual-reality training in a supermarket environment, assuming its EV based on the use of this methodology. However, this study only assessed cognition (Jacoby et al., 2013). A computer-based social cognitive training led to improvements in both closely related tasks, such as face puzzle implicit and explicit tasks (close generalization) and distantly related tasks involving social cognition (distant generalization) (Rosenblau et al., 2020).

Class II studies

The Class II study that identified the procedures to assess EV, demonstrated that a computer-based intervention targeting attention led to improvements in the adaptive behavior as directly assessed with Vineland Adaptive Behavior Scales from pre-intervention assessment to follow-up (Galbiati et al., 2009).

Concerning virtual reality-based interventions, one study made assumptions about the EV of a virtual reality shopping task based on its characteristics, without assessing EV or the impact on the activities of daily living (Grewe et al., 2013). The effect of a virtual reality-based grocery shopping programme on post-intervention real-life shopping did not show significant differences compared to the effects of a computer desktop-virtual reality application intervention (Dehn et al., 2018). However, another virtual-reality shopping training programme demonstrated its EV through correlations with both real-life shopping task performance and subjective estimations of cognitive abilities (Grewe et al., 2014).

The remaining Class II studies also indirectly deduced the EV of interventions. In one study, the EV of a driving simulator training was assumed based on its characteristics. However, the driving simulator training did not induce transfer effects on functional mobility (Haeger et al., 2018). A face training programme resulted in improvements in face sensitivity for both trained and untrained expressions and views of faces, as well as improvements in daily life experience with faces measured by self-report (Corrow et al., 2019). Another study suggested that self-instructional training had greater EV than a task specific learning, based on the higher number of diary entries recorded during the treatment in the self-instructional training (Ownsworth & McFarland, 1999).

Class III studies

The procedure to assess EV was described in a Class III study, found that some patients perceived the benefits of a face training programme in daily life, but did not provide the specific percentage of patients who experienced these benefits (Davies-Thompson et al., 2017). Additionally, it was found generalization of improvements to new images of trained faces and transfer to untrained faces (Davies-Thompson et al., 2017).

A virtual communication programme was considered ecologically valid by the authors due to its effectiveness in achieving improvements in individualized goals as measured by using goal attainment scale (Keegan et al., 2022).

Two studies made assumptions about the EV of the interventions based solely on task requirements (Lorentz et al., 2023) or characteristics (Hampstead et al., 2008). In one of the studies, a virtual reality-based intervention required moving the head constantly to monitor the entire situation (Lorentz et al., 2023). In the other, it was used a face-name association task from the Module of the Ecologically Oriented Neurorehabilitation of Memory programme (Hampstead et al., 2008; Stringer, 2007).

Discussion

The ultimate goal of NI programmes, such as neurocognitive rehabilitation and neuropsychological rehabilitation, is to improve functional performance in the activities of daily living (Clare et al., 2019; Pinto et al., 2023b). Therefore, it is important to understand the attributes of programmes that contribute to enhancing their EV, allowing for the generalization of improvements from therapy sessions to real-life activities (Parenté et al., 1994; Pinto et al., 2023b). Given the acknowledged importance of considering EV of NI programmes, the main objective of this review was to explore the operationalization and assessment of EV of NI programmes, and to identify the main features of programmes with good EV. For the reasons described above, we conducted a systematic review following PRISMA guidelines (Page et al., 2021) and the Cochrane Collaboration's recommendations (Higgins & Green, 2011) to address the following questions: (Q1) Which outcome measures are more commonly used to assess EV of NI?; and (Q2): What are the main characteristics of programmes with good EV?

In terms of sample characteristics, the population most examined in studies on the EV of NI programmes consists of individuals with acquired brain injury. This focus on acquired brain injury patients can be explained by the historical emphasis on studying this specific population within the field of neuropsychological rehabilitation (Cicerone et al., 2000; García-Molina & Enseñat, 2019). Additionally, the vulnerability of adolescents and young adults to acquired brain injury (Doser et al., 2018) justifies the need for interventions that demonstrate observable effects in real-life.

Considering the characteristics of the intervention, most of the studies focused on specific neurocognitive functions and targeted only memory. Among the interventions, virtual reality-based programmes gathered the most consensus, aligning with the advocated in the existing literature (Parsons, 2015). Most studies did not specify whether the interventions were conducted in an individual or group format.

Regarding the usual dose of NI programmes, the most consensual information was as follows: (a) twice a week session; (b) session's duration of thirty and sixty minutes; (c) intervention's duration of four weeks and six months; and (d) a total of a single session, eight or twelve sessions.

Concerning EV entries in the studies, surprisingly, only 62% of the manuscripts mentioned EV in the method section, and less than 50% referred to EV in the results. Accordingly, only three studies described the procedures used to assess EV, using self and other report questionnaires. Other studies explored EV by examining instrumental activities of daily living, generalization, and transfer effects to other tasks. The variability in the methodology used to operationalize EV across studies seemed to stem from the lack of a consensual definition of EV in the field of NI. Moreover, the assessment of transfer effects to other tasks may have been influenced by the decision to target isolated neurocognitive functions in most studies, which contradicts a fundamental assumption of NI that cognition cannot be isolated (Sohlberg & Mateer, 2001), because of interdependence between neurocognitive functions (Luria, 1976).

It is important to highlight that among the included studies, only one study used goal attainment scale (Keegan et al., 2022) as a method to infer about EV. This finding suggests that most of the programmes did not adhere to one of the most widely accepted principles of NI, which emphasizes the establishment of meaningful goals based on the individualized formulation of the clinical case (Winson et al., 2017).

Regardless of the Class of the studies, it is noteworthy that 42% of the studies assumed interventions to have a good EV based on the characteristics of the programmes. Among these, 30% attributed the assumption of good EV to the use of virtual reality environments. However, despite assuming interventions to have good EV, some studies found no significant differences in the effects of high EV interventions compared to control interventions when using EV-related measures. For instance, while some studies using virtual reality-based interventions showed improvements in instrumental activities of daily living (Park, 2022) and real-life performance in the same task (Grewe et al., 2014), other studies did not observe significant differences between this intervention and control interventions in terms of self-reported memory and social participation (Faria et al., 2016), as well as in real-life task (Dehn et al., 2018).

Based on the previously exposed, the available data is insufficient to determine the most used outcome measures for assessing EV (Question 1). Furthermore, despite identifying the main characteristics of the interventions reviewed, it is not possible to describe the main characteristics of programmes with good EV (Question 2) due to their inadequate operationalization, i.e., studies did not provide detailed information about the considerations taken into account to improve the EV of interventions.

The main limitations of the studies reviewed were: (a) not describing the procedures used to assess EV; (b) assuming the EV of interventions without providing a definition of EV and the criteria used for its operationalization; and (c) lack of follow-up to examine the maintenance of the intervention outcomes in most of the studies. The main limitation of this review is that it only included papers published in the English language.

Future work will concentrate on proposing a definition of EV in the field of NI, along with the formulation of specific criteria and the development of a checklist to operationalize EV in the creation of new NI programmes or in the assessment of EV of existing ones. Similar approaches have been successfully undertaken in the realm of neurocognitive assessment (Pinto et al., 2023a), providing a potential model for guiding future work in this area.

In conclusion, it is evident that the available literature on the EV of NI programmes presents methodological limitations when it comes to operationalizing EV. Consequently, it is not possible to reach definitive conclusions regarding the measures used to assess EV of NI programmes, as well as the key characteristics of programmes exhibiting good EV. Finally, this has implications for the categorization of NI programmes across different levels of EV.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Artemisa Dores is a researcher of School of Health, Polytechnic Institute of Porto, Porto, Portugal, supported by FCT - Fundação para a Ciência e Tecnologia [Portuguese Foundation for Science and Technology] through R&D Units funding (UIDB/05210/2020).

ORCID

Joana O. Pinto http://orcid.org/0000-0002-0643-8439

References

Acker, M. B. (1990). A review of the ecological validity of neuropsychological tests. In Tupper, D. E. & Cicerone K. D. (Eds.), *The neuropsychology of everyday life: Assessment and basic competencies* (pp. 19–55). Springer.

Câmara, J., Ferreira, R., Teixeira, L., Nóbrega, J., Romeira, C., Badia, S. B. I., & Faria, A. L. (2023). Efficacy of adaptive cognitive training through desktop virtual reality and paper-and-pencil in the treatment of mental and behavioral disorders. *Virtual Reality*, *27*(1), 291–306. https://doi.org/10.1007/s10055-021-00559-6

Chaytor, N., & Schmitter-Edgecombe, M. (2003). The ecological validity of neuropsychological tests: A review of the literature on everyday cognitive skills. *Neuropsychology Review*, *13*(4), 181–197. https://doi.org/10.1023/B:NERV.0000009483.91468.fb

Chen, B., Wei, Y., Deng, W., & Sun, S. (2018). The effects of cognitive training on cognitive abilities and everyday function: A 10-week randomized controlled trial. *The International Journal of Aging and Human Development*, *86*(1), 69–81. https://doi.org/10.1177/0091415017697725

Cicerone, K. D., Dahlberg, C., Kalmar, K., Langenbahn, D., Malec, J., Bergquist, T., Felicetti, T., Giacino, J. T., Harley, J. P., Harrington, D. E., Herzog, J., Kneipp, S., Laatsch, L., & Morse, P. A. (2000). Evidence-based cognitive rehabilitation: Recommendations for clinical practice. *Archives of Physical Medicine and Rehabilitation*, *81*(12), 1596–1615. https://doi.org/10.1053/apmr.2000.19240

Corrow, S. L., Davies-Thompson, J., Fletcher, K., Hills, C., Corrow, J. C., & Barton, J. J. (2019). Training face perception in developmental prosopagnosia through perceptual learning. *Neuropsychologia*, *134*, 107196. https://doi.org/10.1016/j.neuropsychologia.2019.107196

Davies-Thompson, J., Fletcher, K., Hills, C., Pancaroglu, R., Corrow, S. L., & Barton, J. J. (2017). Perceptual learning of faces: A rehabilitative study of acquired prosopagnosia. *Journal of Cognitive Neuroscience*, *29*(3), 573–591. https://doi.org/10.1162/jocn_a_01063

Dehn, L. B., Kater, L., Piefke, M., Botsch, M., Driessen, M., & Beblo, T. (2018). Training in a comprehensive everyday-like virtual reality environment compared to computerized cognitive training for patients with depression. *Computers in Human Behavior*, *79*, 40–52. https://doi.org/10.1016/j.chb.2017.10.019

Dekker, J., de Groot, V., Ter Steeg, A. M., Vloothuis, J., Holla, J., Collette, E., Satink, T., Post, L., Doodeman, S., & Littooij, E. (2020). Setting meaningful goals in rehabilitation: Rationale and practical tool. *Clinical Rehabilitation*, *34*(1), 3–12. https://doi.org/10.1177/0269215519876299

Di Nuovo, S. (1992). *Attenzione e concentrazione*. Erickson.

Doser, K., Poulsen, I., Wuensch, A., & Norup, A. (2018). Psychological outcome after severe traumatic brain injury in adolescents and young adults: The chronic phase. *Brain Injury, 32*(1), 64–71. https://doi.org/10.1080/02699052.2017.1363408

Faria, A. L., Andrade, A., Soares, L., & I Badia, S. B. (2016). Benefits of virtual reality based cognitive rehabilitation through simulated activities of daily living: A randomized controlled trial with stroke patients. *Journal of NeuroEngineering and Rehabilitation*, *13*(1), 1–12. https://doi.org/10.1186/s12984-016-0204-z

Faria, A. L., Pinho, M. S., & Bermúdez I Badia, S. (2020). A comparison of two personalization and adaptive cognitive rehabilitation approaches: A randomized controlled trial with chronic stroke patients. *Journal of Neuroengineering and Rehabiliation*, *17*, 1–15. https://doi.org/10.1186/s12984-020-00691-5

Galbiati, S., Recla, M., Pastore, V., Liscio, M., Bardoni, A., Castelli, E., & Strazzer, S. (2009). Attention remediation following traumatic brain injury in childhood and adolescence. *Neuropsychology*, *23*(1), 40–49. https://doi.org/10.1037/a0013409

García-Molina, A., & Enseñat, A. (2019). La rehabilitación neuropsicológica en el siglo XX. *Revue Neurologique, 69*(09), 383. http://doi.org/10.33588/rn.6909.2019247

Giachero, A., Calati, M., Pia, L., La Vista, L., Molo, M., Rugiero, C., Fornaro, C., & Marangolo, P. (2020). Conversational therapy through semi-immersive virtual reality environments for language recovery and psychological well-being in post stroke aphasia. *Behavioural Neurology*, *2020*, 2846046–2846015. https://doi.org/10.1155/2020/2846046

Gomar, J. J., Valls, E., Radua, J., Mareca, C., Tristany, J., del Olmo, F., Rebolleda-Gil, C., Jañez-Álvarez, M., Álvaro, F. J., Ovejero, M. R., Llorente, A., Teixidó, C., Donaire, A. M., García-Laredo, E., Lazcanoiturburu, A., Granell, L., Mozo, C. P., Pérez-Hernández, M., Moreno-Alcázar, A., Pomarol-Clotet, E., & McKenna, P. J. & the Cognitive Rehabilitation Study Group A. (2015). A multisite, randomized controlled clinical trial of computerized cognitive remediation therapy for schizophrenia. *Schizophrenia Bulletin*, *41*(6), 1387–1396. https://doi.org/10.1093/schbul/sbv059

Gómez, C. S., & Rodríguez, E. J. F. (2021). The effectiveness of a training programme in everyday cognition in healthy older adults: A randomised controlled trial. *BMC Geriatrics*, *21*(1), 79. https://doi.org/10.1186/s12877-020-01998-7

Grewe, P., Kohsik, A., Flentge, D., Dyck, E., Botsch, M., Winter, Y., Markowitsch, H. J., Bien, C. G., & Piefke, M. (2013). Learning real-life cognitive abilities in a novel 360°-virtual reality supermarket: A neuropsychological study of healthy participants and patients with epilepsy. *Journal of NeuroEngineering and Rehabilitation*, *10*(1), 42. https://doi.org/10.1186/1743-0003-10-42

Grewe, P., Lahr, D., Kohsik, A., Dyck, E., Markowitsch, H. J., Bien, C. G., Botsch, M., & Piefke, M. (2014). Real-life memory and spatial navigation in patients with focal epilepsy: Ecological validity of a virtual reality supermarket task. *Epilepsy & Behavior: E&B*, *31*, 57–66. https://doi.org/10.1016/j.yebeh.2013.11.014

Guye, S., Röcke, C., Mérillat, S., von Bastian, C. C., & Martin, M. (2016). Adult lifespan. In T. Strobach, & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 45–55). Springer.

Haeger, M., Bock, O., Memmert, D., & Hüttermann, S. (2018). Can driving-simulator. Training enhance visual attention, cognition, and physical functioning in older adults? *Journal of Aging Research*, *2018*, 7547631. https://doi.org/10.1155/2018/7547631

Hampstead, B. M., Sathian, K., Moore, A. B., Nalisnick, C., & Stringer, A. Y. (2008). Explicit memory training leads to improved memory for face-name pairs in patients with mild cognitive impairment: Results of a pilot investigation. *Journal of the International Neuropsychological Society*, *14*(5), 883–889. https://doi.org/10.1017/S1355617708081009

Higgins, J., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions (Version 5.1.0)*. http://hand book.cochrane.org

Hodge, M. A. R., Siciliano, D., Withey, P., Moss, B., Moore, G., Judd, G., Shores, A., & Harris, A. (2010). A randomized controlled trial of cognitive remediation in schizophrenia. *Schizophrenia Bulletin*, *36*(2), 419–427. https://doi.org/10.1093/schbul/sbn102

Jacoby, M., Averbuch, S., Sacher, Y., Katz, N., Weiss, P. L., & Kizony, R. (2013). Effectiveness of executive functions training within a virtual supermarket for adults with traumatic brain injury: A pilot study. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *21*(2), 182–190. https://doi.org/10.1109/TNSRE.2012.2235184

Jiang, H., Johnstone, S. J., & Lu, J. (2022). Comparing the efficacy of two school-based approaches of neurocognitive training for enhancing executive functions. *Children*, *9*(10), 1501. https://doi.org/10.3390/children9101501

Keegan, L. C., Reilley, K., Stover, M., & Togher, L. (2022). Virtual INSIGHT: Improving natural social interaction: Group reHabilitation after traumatic brain injury. *International Journal of Language & Communication Disorders*, *59*(2), 532–542. https://doi.org/10.1111/1460-6984.12790

Kim, Y. S., Park, J. H., & Lee, S. A. (2020). Is a program to improve grocery-shopping skills clinically effective in improving executive function and instrumental activities of daily living of patients with schizophrenia? *Asian Journal of Psychiatry*, *48*, 101896. https://doi.org/10.1016/j.ajp.2019.101896

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310.

Lansford, K. L., Borrie, S. A., & Bystricky, L. (2016). Use of crowdsourcing to assess. The ecological validity of perceptual-training paradigms in Dysarthria. *American Journal of Speech-Language Pathology*, *25*(2), 233–239. https://doi.org/10.1044/2015_AJSLP-15-0059

Lo Priore, C., Castelnuovo, G., Liccione, D., & Liccione, D. (2003). Experience with V-STORE: Considerations on presence in virtual environments for effective neuropsychological rehabilitation of executive functions. *CyberPsychology & Behavior*, *6*(3), 281–287. https://doi.org/10.1089/109493103322011579

Lorentz, L., Simone, M., Zimmermann, M., Studer, B., Suchan, B., Althausen, A., Estocinova, J., Müller, K., & Lendt, M. (2023). Evaluation of a VR prototype for neuropsychological rehabilitation of attentional functions. *Virtual Reality*, *27*(1), 187–199. https://doi.org/10.1007/s10055-021-00534-1

Luria, A. R. (1976). The working brain: *An* introduction to neuropsychology. Basic Books.

Martínez-Moreno, J. M., Sánchez-González, P., Luna, M., Roig, T., Tormos, J. M., & Gómez, E. J. (2016). Modelling ecological cognitive rehabilitation therapies for building virtual environments in brain injury. *Methods of Information in Medicine*, *55*(1), 50–59. https://doi.org/10.3414/ME15-01-0050

Moreau, D., & Conway, A. R. (2014). The case for an ecological approach to cognitive training. *Trends in Cognitive Sciences*, *18*(7), 334–336. https://doi.org/10.1016/j.tics.2014.03.009

Noack, H., Lövdén, M., Schmiedek, F., & Lindenberger, U. (2009). Cognitive plasticity in adulthood and old age: Gauging the generality of cognitive intervention effects. *Restorative Neurology and Neuroscience*, *27*(5), 435–453. https://doi.org/10.3233/RNN-2009-0496

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews*, *5*(1), 210. https://doi.org/10.1186/s13643-016-0384-4

Ownsworth, T. L., & McFarland, K. (1999). Memory remediation in long-term acquired brain injury: Two approaches in diary training. *Brain Injury*, *13*(8), 605–626. https://doi.org/10.1080/026990599121340

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed.)*, *372*, n71. https://doi.org/10.1136/bmj.n71

Parenté, R., Twum, M., & Zoltan, B. (1994). Transfer and generalization of cognitive skill after traumatic brain injury. *NeuroRehabilitation*, *4*(1), 25–35. https://doi.org/10.3233/NRE-1994-4105

Parsons, T. D. (2015). Virtual reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. *Frontiers in Human Neuroscience*, *9*, 660. https://doi.org/10.3389/fnhum.2015.00660

Park, J. H. (2022). Does the virtual shopping training improve executive function and instrumental activities of daily living of patients with mild cognitive impairment?*Asian Journal of Psychiatry*, *69*, 102977. https://doi.org/10.1016/j.ajp.2021.102977

Pinto, J. O., Dores, A. R., Peixoto, B., & Barbosa, F. (2023a). Ecological validity in neurocognitive assessment: Systematized review, content analysis, and proposal of an instrument. *Applied Neuropsychology. Adult*. https://doi.org/10.1080/23279095.2023.2170800

Pinto, J. O., Peixoto, B., Dores, A. R., & Barbosa, F. (2023b). Proposal of a common terminology for the neuropsychological rehabilitation. *Journal of Neuropsychology*, *17*(3), 431–449. https://doi.org/10.1111/jnp.12310.

Rosenblau, G., O'Connell, G., Heekeren, H. R., & Dziobek, I. (2020). Neurobiological mechanisms of social cognition treatment in high-functioning adults with autism spectrum disorder. *Psychological Medicine*, *50*(14), 2374–2384. https://doi.org/10.1017/S0033291719002472

Sala, G., Aksayli, N. D., Tatlidil, K. S., Tatsumi, T., Gondo, Y., & Gobet, F.,. (2019). Near and far transfer in cognitive training: A second-order meta-analysis. *Collabra: Psychology*, *5*(1), 18. https://doi.org/10.1525/collabra.203

Strobach, T., & Huestegge, L. (2017). Evaluating the effectiveness of commercial brain game training with working-memory tasks. *Journal of Cognitive Enhancement*, *1*(4), 539–558. https://doi.org/10.1007/s41465-017-0053-0

Sohlberg, M. M., & Mateer, C. A. (2001). *Cognitive rehabilitation: An integrative Neuropsychological Approach*. Guilford Publications.

Son, C., & Park, J. H. (2022). Ecological effects of VR-based cognitive training on ADL and IADL in MCI and AD patients: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *19*(23), 15875. https://doi.org/10.3390/ijerph192315875

Stringer, A. Y. (2007). *Ecologically-oriented neurorehabilitation of memory therapist manual*. Western Psychological Services.

Tarnanas, I., Schlee, W., Tsolaki, M., Müri, R., Mosimann, U., & Nef, T.,. (2013). Ecological validity of virtual reality daily living activities screening for early dementia: Longitudinal study. *JMIR Serious Games*, *1*(1), e2778. https://doi.org/10.2196/games.2778

Tupper, D. E., & Cicerone, K. D. (Eds.). (1990). Introduction to the neuropsychology of everyday life. In *The neuropsychology of everyday life: Assessment and basic competencies* (pp. 3–18). Springer.

Villa, K. K., & Abeles, N. (2000). Broad spectrum intervention and the remediation of prospective memory declines in the able elderly. *Aging & Mental Health*, *4*(1), 21–29. https://doi.org/10.1080/13607860055937

Winson, R., Wilson, B. A., & Bateman, A. (2017). (Eds.). *The brain injury rehabilitation workbook*. Guilford Publications.