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REVIEW ARTICLE

Assessment of cognitive instrumental activities of daily living: a systematic review

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ABSTRACT

Purpose: Cognitive instrumental activities of daily living are particularly related to executive functions, such as scheduling appointments, monthly payments, managing the household economy, shopping or taking the bus. The aim of this systematic review was to determine the available tests for the assessment of executive functions with ecological validity to predict individuals' functioning.

Materials and methods: An electronic search was conducted in MEDLINE, Cochrane Central, PsyCInfo and IEEE Xplore until May 2019, in addition to a manual search. The PRISMA criteria and the Covidence platform were used to select articles and extract data.

Results: After applying the search selection criteria, 76 studies were identified. They referred to 110 tools to assess instrumental activities of daily living. Those that have received most attention are related to menu preparation and shopping. Performance-based measures are the most widely used traditional methods. Most tests were aimed at the adult population with acquired brain damage, cognitive impairment or dementia. There was a predominance of tests based on the Multiple Errands Test paradigm.

Conclusions: In recent years, it has increased the number of tools that assess the instrumental activities of daily living based on technologies such as personal or environmental sensors and serious games.

➤ IMPLICATIONS FOR REHABILITATION

- Assessment of Instrumental Activities of Daily Living through performance-based measures is especially useful for the early detection of dysfunctions or preclinical disability.
- Difficulties in performing instrumental activities of daily living are closely associated with deficits in executive functions and prospective memory.
- Activities of Daily Living can be understood as multitasks.
- The use of virtual reality-based tests was shown to be sensitive to the detection of cognitive deficits in Activities of Daily Living.
- An advantage of using virtual reality in assessments is that it can help to predict the level of personal autonomy in patients who are in an institutional environment and could be a first approximation to the real environment.

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Activities of daily living; virtual reality; ecological validity; systematic review; executive functions

Introduction

Activities of daily living (ADLs) can be defined as the activities that people have to perform daily to be able to live in an autonomous way, be integrated in their usual environment and fulfill their social role [1]. The performance of activities of daily living also contributes to develop a sense of positive competence, self-efficacy, self-confidence and self-esteem when responding to various demands of the environment [2]. ADLs require motor, cognitive and socio-emotional skills. They can be classified as *basic activities of daily living* (BADLs), which refer essentially to personal care, or *instrumental activities of daily living* (IADLs), which involve a greater interaction with the social environment and higher cognitive demands. IADLs also are known as complex activities of daily living [3]. IADLs require less automatic actions than BADLs do [4].

According to the American Association of Occupational Therapy [5], 11 IADLs can be identified: (1) care of others, including the selection and supervision of caregivers; (2) care of pets; (3) child-rearing activities, involving the care and supervision of children; (4) communication management, involving the use of communication devices, such as mobiles, computers, tablets and others; (5) driving and mobility in the community, involving the use of public or private transport, transit through the community or neighborhood, and so on; (6) financial management, such as planning expenses and income to face daily or monthly payments, use of a cashier, electronic banking and similar activities;

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Supplemental data for this article can be accessed here.

(7) health management and maintenance, such as maintaining a healthy routine, taking physical exercise, having adequate nutrition and annual health checkups, avoiding health risk behaviors and handling medication if necessary; (8) home establishment and management: for example, searching for a home and taking care of it, repairing clothes and personal belongings or cleaning the home; (9) meal preparation and cleanup: it includes planning a balanced and nutritious diet, cooking and cleaning after meals; (10) religious and spiritual activities and expression; (11) safety and emergency maintenance: knowing and developing processes to prevent accidents and responding to unexpected hazards or emergencies; and (12) shopping: it incudes making a shopping list, selecting the goods and payment method and purchasing the goods.

Two major factors have been differentiated in IADLs: (1) activities of daily living with a high physical demand; and (2) cognitive instrumental activities of daily living, such as scheduling appointments, organizing monthly payments or budgets, economic management of the monthly salary and similar activities [6,7]. Cognitive IADLs can be understood as everyday cognition, which has been defined as the ability to solve cognitively complex tasks of everyday life [8,9] in the real world [10]. Recently, other authors have also referred to cognitive instrumental activities of daily living as *functional cognition*. This is understood as the performance of complex ADLs, which occurs thanks to the dynamic interaction of motor, cognitive and social skills, the demands of the activity and the context of performance of the activity [11]. These complex cognitive demands have led instrumental activities of daily living to be understood as multitasking skills, that is, skills involving various integrated cognitive processes and taking place in an unstructured context [12–14].

Burgess reported that multitasking activities have eight main characteristics [12]: (1) many tasks must be completed; (2) it is necessary to intersperse one task with another; (3) due to cognitive or physical limitations, only one task can be performed at a time, which sets them apart from the dual task paradigm, in which participants are instructed to perform two tasks at the same time; (4) unforeseen interruptions/unexpected results may occur; (5) the accomplishment of the different tasks requires prospective memory; (6) the different tasks vary in terms of priority, difficulty and duration; (7) the objectives of the tasks are defined by the person who is going to perform them; (8) and there is no continuous performance feedback during the performance of the task. Multitasking is related to a broad variety of cognitive functions and particularly to those associated with executive functioning and prospective memory. In this regard, it is easy to understand why IADLs have been mainly associated with cognitive components. Moreover, the performance of IADLs is sensitive to early cognitive decline [15,16]. Cognitive processes and particularly executive functions (EFs) are essential for the performance of IADLs [17]. Indeed, difficulties performing IADLs have been closely associated with deficits in executive functions, which increase the need to develop effective compensatory strategies to meet the demands of IADLs [3,18]. Deficits in executive functions are a predictor of participation and functional outcomes of various pathologies [19]; they occur in over 66% of patients having had a mild stroke [20] and predict functional outcomes at three, six, nine and twelve months in stroke patients [21,22]. EF has been found to explain 37% of the variance of functional status in individuals with mild cognitive impairment, unlike other cognitive processes [23]. Among EFs, flexibility accounts for 63% of the variance of functional status, followed by inhibitory control (32%), planning (25%) and reasoning and initiation (11% each) [15,24].

Other authors have reported that self-regulation of behavior and attentional control are crucial determinants for the independent performance of IADLs [22]. Actually, executive dysfunction tends to be more easily observed in everyday life in non-routine situations, where self-regulation and self-initiation of activities are relevant, than in traditional neuropsychological tests [25,26].

Standard cognitive tests do not usually assess multitasking skills; in fact, most assess a specific cognitive function in a well-structured and controlled environment. Indeed, it has been argued that there is a double dissociation between standard cognitive measures and multitasking skills, suggesting that the brain processes of multitasking skills may be independent of those of laboratory tests evaluating isolated cognitive processes [27]. This has led to growing criticism about the lack of clinical/ecological validity of some tests aimed at assessing cognitive IADLs, either because they use self-reports as a methodology – and in some cases patients are not aware of their deficits – or because they use reports by others and there is a discrepancy between the reports of informants and actual performance [28].

It has also been observed that some of these tests do not make it possible to determine which underlying processes affect functional performance beyond functional mobility [29,30]. In this regard, Burgess [29] has suggested that most traditional neuropsychological tests alone are insufficient to evaluate ADLs because they try to split the functions into components without including multitasking or significant familiar environments [31]. Cognitive tests and executive functions are often performed with standardized instruments in structured environments, without distractions and under the supervision of a clinician, which does not reflect the complexity that characterizes behavior in everyday activities in the real world [25]. Standard cognitive laboratory tests may overestimate functional difficulties, since individuals can apply compensatory strategies in their daily life or show behavioral patterns that increase their functionality [32] because they are highly familiar with these tasks. The ecological perspective is useful and of great interest in the evaluation of the various cognitive processes when the aim is to determine the causes of limitations in participation in the various activities of daily living that occur naturally in the real world taking multitasking skills into account [33]. In this context, a test is considered to have ecological validity when it is able to predict functional behavior in everyday life [26,34,35]. Parsons [36] suggested four key criteria to ensure that evaluations have ecological validity. They are (1) correspondence: tasks must correspond to the relevant aspects of the real-world activity and environment; (2) representativeness: tasks must be representative of the people who perform them; (3) convenience: tasks must be about real-world situations and the test results should reflect and predict real world phenomena; and (4) relevance: tasks must be relevant from a neurocognitive point of view.

One of the main inputs clinicians usually need to know is the restrictions or limitations in functional capacity that are caused by a certain disease, disorder or deficit and, therefore, what impediments to the performance of ADLs it causes. To be able to predict future functioning and/or improve participation, independence and personal autonomy through an intervention program, it is essential to perform a comprehensive assessment to determine the patient's profile, strengths, weaknesses and needs [18]. Identifying difficulties in cognitive IADLs could reduce hospital admissions, use of emergency services and caregiver overload [3]. All these aspects highlight the importance of knowing what tests are available, whether they have ecological validity and how to determine any existing gaps; it is important to encourage the

development of this type of assessments to predict their functioning in the real world and demonstrate their predictive value regarding personal autonomy.

Considering the criticisms about the lack of ecological validity of tests assessing executive functions from the traditional neuropsychological perspective, the aim of this systematic review was to determine what instruments with ecological validity are available to assess instrumental cognitive activities of daily living including executive functions.

Materials and methods

We conducted a comprehensive search of the literature between 2 May 2018 and 31 May 2019 to identify the ecologically-valid instruments available for assessing cognitive instrumental activities of daily living that conform to the PRISMA statement (see Figure 1). The review was registered in PROSPERO with code CRD42018111599.

The search was conducted in the following databases: MEDLINE, SCOPUS, Cochrane, IEEE Explorer and PsycInfo. The search strategy included the MeSH terms ("Activities of Daily Living" AND "Executive Functions" OR "Everyday Executive Skills") AND ("assessment" OR "evaluation") AND ("ecological validity") in the title or abstract and articles published between 2014 and 31 May 2019.

Inclusion criteria

Studies reported in English and Spanish were included according to the following criteria:

- Design: systematic reviews and specific original articles on the assessment of activities of daily living.
- Participants: individuals with executive dysfunctions or with delays in the development of executive functions that affect their participation in activities of daily living regardless of their age;
- Intervention: assessments and tools with ecological validity aimed at identifying deficits in cognitive instrumental ADLs.

To determine when a test had ecological validity, we followed similar tests to those used by Chevignard et al. [37]:

- Tests requiring the performance of a multitasking, open-ended activity in a naturalistic environment or a virtual environment simulating a naturalistic environment.
- Questionnaires focused on the performance of cognitive instrumental activities of daily living.

The inclusion of articles comprised two stages. In the first stage, we selected systematic reviews and original articles on the

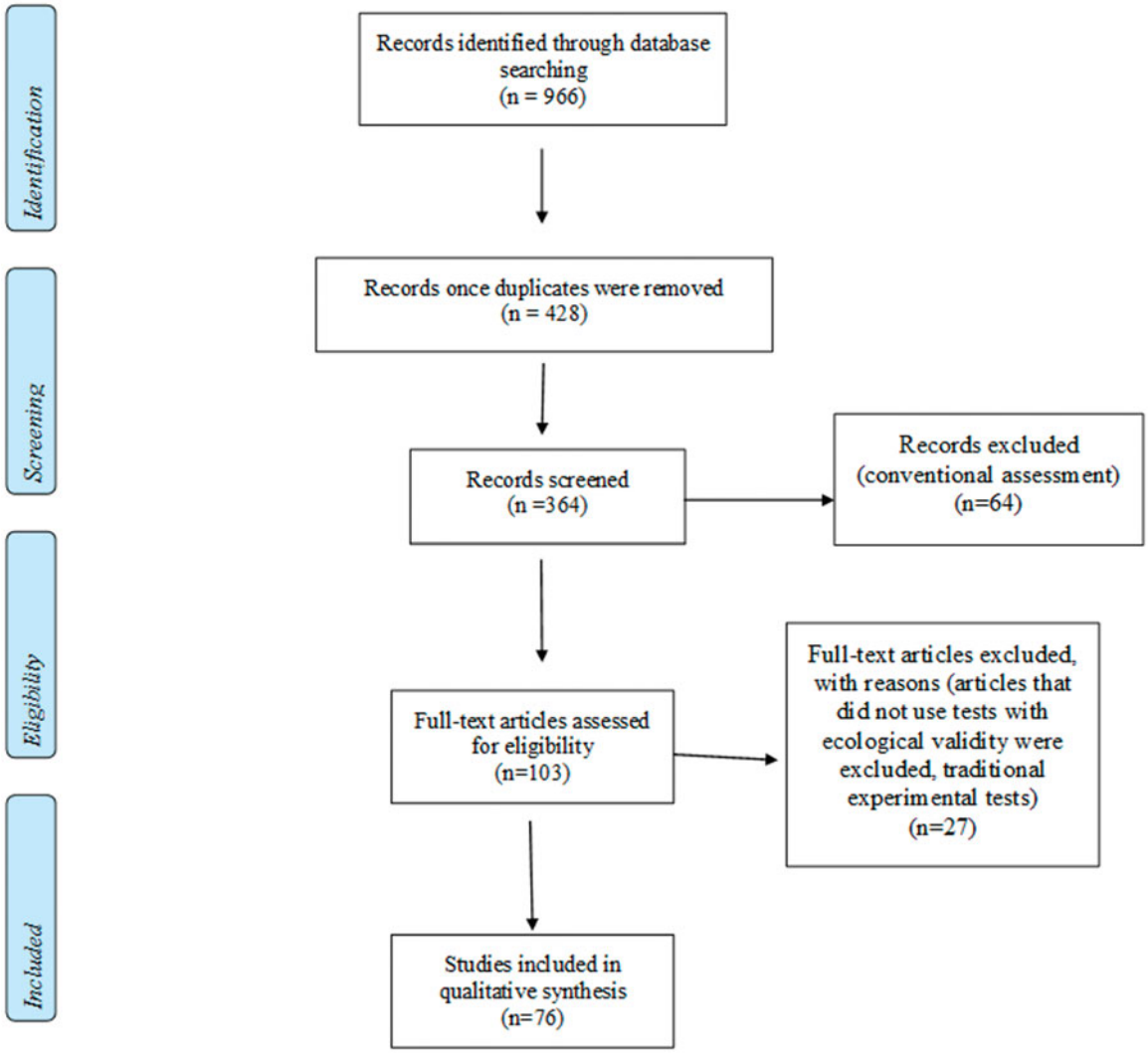

Figure 1. Prisma 2009 Flow Diagram.

evaluation of executive functions from an ecological perspective, considering the impact of such functions, that is, how they affected participation in instrumental cognitive activities of everyday life. In the second stage, if necessary, a specific search was made of each instrument or assessment task used to determine its psychometric properties and other possible applications.

Exclusion criteria

The following studies were excluded:

- Questionnaires that only included the performance of IADLs without considering the underlying executive processes (e.g., Functional Activities Questionnaire [38] and questionnaires that only focused on executive functions (e.g., Dysexecutive Questionnaire [29].
- Tests that evaluated executive functions but did not do so from an ecological perspective or in relation to IADLs (e.g., Ball Search Field Task [39].
- Tests or tasks that only focused on one cognitive process, such as prospective memory (e.g., the Virtual Week Task, [40,41], Prospective Execution Task [42] or Virtual Environment Grocery Store [43]) or other cognitive processes such as prospective memory or spatial orientation, even if it was in an everyday environment (e.g., EXPANSES, Episodic, Museum Task/Virtual Make [44], tests of everyday action semantics [45], Allen Cognitive Level Screen, (ACLS-5/LALCs-5) [46], Picture Interpretation Test, or solving problems in everyday life (Everyday Problems Test).
- Virtual tests performed in everyday scenarios but aimed at measuring only one cognitive process, such as inhibitory control (e.g., Virtual Apartment Stroop Task, [47] Virtual Reality Moral Dilemma Scenarios [48], Virtual Anticipating Consequences Task [49]; Beach/Sorting beach apparel and refreshments [50] with no multitasking demands.
- Narrative reviews, letters to the editor, dissertations and articles that were not peer-reviewed.

Identification and selection of studies

The Covidence platform was used to identify and select the studies (https://www.covidence.org/home). Initially, duplicates were removed from the total of identified articles. Two authors reviewed the remaining article titles and abstracts to determine whether they met the inclusion criteria. Next, an independent reviewer screened the articles that had not been selected to ensure they should be excluded. Any article eliciting doubts or disagreement was fully reviewed by the independent reviewers until a decision was finally reached on its inclusion or exclusion (see Figure 1 for a flow diagram adapted from the PRISMA methodology).

Once the measures, scales or tasks had been identified, a second electronic search was performed in the same databases. This search was performed using the full name of the measures in order to obtain the psychometric properties of each instrument.

Data collection and methodological quality of studies

A data extraction sheet was developed and the data collection included the name of the instrument, the executive function dimensions it assessed, the assessment methodology, the population to which it applied, the type of context in which the test was performed and its psychometric properties. For each eligible assessment tool, two researchers extracted all relevant data. In case of disagreement, discussions were held to reach a consensus, with a third reviewer if necessary.

Results

The search yielded a total of 966 abstracts. Figure 1 shows both the selection process and how many articles were considered in each stage of the process. Of the 76 articles selected, we found references to 110 tools aimed at identifying the executive functions underlying IADLs. In order to broadly show the results found, they have been classified according to different dimensions. First, the instruments found for each type of instrumental activity of daily living are presented following the classification of ADL of the American Association of Occupational Therapy (see Table 1). Second, the different instruments are showed according to the methodology used for the evaluation of ADLs: (1) traditional methodologies, which include performance-based measures, behavior rating scales and self-reports; and (2) methodologies involving the use of technologies, such as virtual reality systems, serious games, environmental sensors and others. Third, the paradigms used for the evaluation of ADLs are presented: Performance-based naturalistic tasks, the Multiple Errands Test (MET) and the dual-task paradigm. The fourth section of the results shows the specific instruments that have been found for different clinical groups with cognitive, mental or neurodevelopmental problems. In addition, the available instruments for children, adolescents, adults and the elderly are compiled in each section. Overall, 32 of these tools were virtual or technological assessments, 20 were tests aimed at assessing cognitive IADLs in children or adolescents and 58 were tests aimed at assessing IADLs in adults or older people. Results also showed 11 performance-based measures for children or adolescents and 44 performance-based measures for adults or older people. In addition, there were six behavior rating scales and two self-reported measures for children or adolescents. There were eight behavior rating scales and four self-reports aimed at adults and older people. Only one of these instruments was a performance-based measure specifically aimed at adolescents; it was focused on planning activities (see Tables 1, Supplementary Table S1 and S2).

Types of tests according to the type of IADLs

As regards tests aimed at adults, most instruments assessed activities related to meal preparation and cleanup, followed by activities related to financial and communications management, health management and maintenance, mobility in the community and shopping (see Figure 2).

In children and adolescents, the IADLs assessed by most instruments were related to other types of activities not classified according to the American Occupational Therapy Association. Some examples are academic activities, which in some cases were related to communication skills, such as writing. There were also instruments aimed at assessing the skills for the planning of daily activities such as organizing a party. Of the IADLs classified by the American Occupational Therapy Association, the most frequent ones were meal preparation and cleanup, activities related to tidying up clothes and maintaining order at home (i.e., home establishment and management) and community mobility (i.e., assessing the skills of deciding when to cross the street or not in children with autism).

Regarding virtual tasks, the most numerous ones were aimed at shopping, money management and community mobility activities, followed by meal preparation and cleanup and

Table 1. Instruments to assess cognitive AIDL according the American Occupational Therapy Association.

AIDL	Instruments for Children and Adolescents	Instruments for Adults and Elderly	Virtual task
1) Care of others		• (a)-ADL [121]	
2) Care of pets			
3) Child-rearing activities		• Routine Task Inventory – Expanded [122]	
4) Communication management	• School AMPS [123]	• Performance Assessment of Self-care skills [124] • Kohlman Evaluation of Living Skills [125] • Executive Function Performance Test [92,126] • Multiple Object Test [28] • Sydney Test of Activities of Daily Living in Memory Disorders [127] • Multiple Errand Test – Hospital Version [128] • Baycrest Multiple Errands Test [129] • Complex Task Performance Assessment [20] • Actual Reality Task (digital) [130] • Performance-Based Skills Assessment [131] • Performance-based Skill Assessment—brief versión [132] • Hotel Task [133] • Observed Tasks of Daily Living Revised [134] • Erlangen Test of Activities of Daily Living [135] • (a)-ADL [121] • Applied Cognition Scale Activity Measure for Post-Acute Care [136] • Routine Task Inventory – Expanded [122] • Everyday cognition [83] • Disability Assessment for Dementia Spanish Version [137] • Daily Living Questionnaire [138] • Rivermead Extended ADL Assessment [139] • Task of eight activities [140] • Timed Instrumental Activities of Daily Living [141] • Observed Tasks of Daily Living [141]	• Virtual Multitasking Test [213] • Virtual Reality Shopping Task [142] • Virtual Library Task [55] • Towi videogame [143] • Smart Aging [71] • Real life Shopping Test [118,144]
5) Driving and mobility in the community	• Towi videogame (Rosetti et al. 2017) For children between 5–13 years	• Executive Function Route Finding Task [81] • Amap Task [145] • Multiple Errand Test – Hospital Version [128] • Multiple Errands Test – Contextualized version [146] • Baycrest Multiple Errands Test [129] • Erlangen Test of Activities of Daily Living [135] • Day Out Task [147] • Performance-Based Assessment of Instrumental Activities of Daily Living [148] • Activities of Daily Living Profile [149] • Independent Living Scales [150,151] • Escala Cognitiva de las Actividades de la Vida Diaria [152] • (a)-ADL [121] • Activities of Daily Living-International Scale [170] • Routine Task Inventory – Expanded [122] • Everyday cognition (Ecog) [83] • Disability Assessment for Dementia Spanish Version [137] • Daily Living Questionnaire [138] • Rivermead Extended ADL Assessment [139] • Walking Response and Inhibition Test [153]	• Virtual Action Planning Supermarket [154] • Virtual Multiple Errands Test [63,155–157] • Virtual Human Object Memory for Everyday Scenes [158] • Virtual Action Planning Supermarket [159] • Multitasking in the City Test [160] • Edinburgh Virtual Errands Test [161] • Virtual Reality Pedestrian Environment – for children [162] • Virtual Reality Pedestrian Environment [131] • Road Crossing Virtual Apparatus [163] • Virtual Park [164] • Virtual reality Cognitive Performance Assessment Test [165] • Towi videogame [143]
6) Financial management		• Performance Assessment of Self-care skills [124] • Kohlman Evaluation of Living Skills [125] • Multiple Errands Test [26] • Intellectual Disability Multiple Errand Test [166] • Executive Function Performance Test [92,126] • Sydney Test of Activities of Daily Living in Memory Disorders [127] • Multiple Errand Test – Hospital Version [128]	• Virtual reality Cognitive Performance Assessment Test [165] • Virtual Park [164] • Ice Cream Seller Test [170] • Virtual Town [171] • Edinburgh Virtual Errands Test [161] • Multitasking in the City Test [160]

(*continued*)

Table 1. Continued.

AIDL	Instruments for Children and Adolescents	Instruments for Adults and Elderly	Virtual task
		• Multiple Errands Test – Contextualized version [146] • Baycrest Multiple Errands Test [129] • Test of Grocery Shopping Skills [167] • Performance-based Skill Assessment—brief versión [132] • Hotel Task [133] • Observed Tasks of Daily Living Revised [134] • Erlangen Test of Activities of Daily Living [135] • Performance-Based Assessment of Instrumental Activities of Daily Living [148] • Activities of Daily Living Profile [149] • Independent Living Scales [150,151] • Escala Cognitiva de las Actividades de la Vida Diaria [152] • Applied Cognition Scale Activity Measure for Post-Acute Care [136] • Routine Task Inventory – Expanded [122] • Disability Assessment for Dementia Spanish Version [137] • Automatic Teller Machine [162] • Harvard Automated Phone Task [168] • Timed Instrumental Activities of Daily Living [141] • Everyday Cognition Battery • [169]	• Virtual Action Planning Supermarket [159] • Virtual Multiple Errands Test [63,155–157] • Virtual Action Planning Supermarket [154] • Virtual Reality Shopping Task [142] • Virtual Mall [62,172] • Real life Shopping Test [118,144]
7) Health management and maintenance		• Performance Assessment of Self-care skills [124] • Executive Function Performance Test [92,126] • Sydney Test of Activities of Daily Living in Memory Disorders [127] • Pillbox Test [173] • Observed Tasks of Daily Living Revised [134] • Erlangen Test of Activities of Daily Living [135] • Performance-Based Assessment of Instrumental Activities of Daily Living [148] • Escala Cognitiva de las Actividades de la Vida Diaria [152] • (a]-ADL [121] • Activities of Daily Living-International Scale [174] • Routine Task Inventory – Expanded [122] • Disability Assessment for Dementia Spanish Version [137] • Daily Living Questionnaire [138] • Task of six activities [140] • Automatic Teller Machine [162] • Harvard Automated Phone Task (APT) [168] • Timed Instrumental Activities of Daily Living [141] • Everyday Cognition Battery • [169] • Observed Tasks of Daily Living [175] • Timed Instrumental Activities of Daily Living [141]	
8) Home establishment and management	• Assessment of Motor and Process Skills AMPS [176]. For Children from 3 years old. • Chas-P/T [177]	• Performance Assessment of Self-care skills [124] • Amap Task [145] • Independent Living Scales [150] • (a)-ADL [121] • Activities of Daily Living-International Scale [174] • Routine Task Inventory – Expanded [122] • Everyday cognition [83] • Rivermead Extended ADL Assessment [139]	• Virtual Multitasking Test [216] • Virtual Apartment [178] • Therapeutic Virtual Kitchen [179] • ECO-VR [69] • Towi videogame [143]
9) Meal preparation and cleanup	• Children's Kitchen Task Assessment [180]. For children between 8–12 years old • Assessment of Motor and Process Skills AMPS [176].	• Performance Assessment of Self-care skills [124] • Cognitive Performance Test [184] • Kettle Test [185] • Executive Function Performance Test [92,126]. • Meal Preparation Scale [186] • Rabideau Kitchen Evaluation—Revised [186]	• Virtual Town [171] • Therapeutic Virtual Kitchen [179] • Cooking Task [193] • Meal-Maker [53] (For *children)* • ECO-VR [69] • EcoKitchen [21]

(*continued*)

Table 1. Continued.

AIDL	Instruments for Children and Adolescents	Instruments for Adults and Elderly	Virtual task
	For children from 3 years old. • Preschool Executive Task Assessment [181]. For children between 5–8 years old • DO-EAT [182] For children older 9 years old. • Children's Cooking Task [183] For children older 9 years old.	• Rabideau Kitchen Evaluation—Revised [186] • Kitchen Task Assessment [187] • Multiple Object Test [28] • Cooking Task [188] • Amap Task [145] • Multiple Errands Test – Contextualized version (MET-CV) [146] • Multi-Level Action Test [189] • Naturalistic Action Test [190] • Erlangen Test of Activities of Daily Living [135] • Performance-Based Assessment of Instrumental Activities of Daily Living [148] • Activities of Daily Living Profile [149] • Computerized Breakfast Task [191] • Prop- based Breakfast Task [192] • Escala Cognitiva de las Actividades de la Vida Diaria [152] • (a)-ADL [121] • Activities of Daily Living-International Scale [174] • Applied Cognition Scale Activity Measure for Post-Acute Care [136] • Routine Task Inventory – Expanded (RTI-E) [122] • Everyday cognition [83] • Disability Assessment for Dementia Spanish Version • [137] • Rivermead Extended ADL Assessment [139] • Task of six activities [140] • Everyday Cognition Battery [169] • Observed Tasks of Daily Living [175]	• Smart Aging [71] • Screen Based Simulated Cup of Tea [35]
10) Religious and spiritual activities and expression			
11) Safety and emergency maintain		• Performance Assessment of Self-care skills) [124] • Kohlman Evaluation of Living Skills [125] • Routine Task Inventory – Expanded [122]	
12) Shopping		• Performance Assessment of Self-care skills [124] • Cognitive Performance Test [184] • Kohlman Evaluation of Living Skills [125] • Multiple Errands Test [26] • Intellectual Disability Multiple Errand Test [166] • Rabideau Kitchen Evaluation—Revised [186] • Sydney Test of Activities of Daily Living in Memory Disorders [127] • Multiple Errand Test – Hospital *Version* [128] • Multiple Errands Test – Contextualized version [146] • Baycrest Multiple Errands Test [129] • Test of Grocery Shopping Skills [167] • Activities of Daily Living Profile [149] • Escala Cognitiva de las Actividades de la Vida Diaria [152] • Routine Task Inventory – Expanded [122] • "Let's Shop" [194] • Rivermead Extended ADL Assessment (READL) [139] • Timed Instrumental Activities of Daily Living [141]	• Virtual Mall [62,172] • Virtual Supermarket [195] • Virtual Reality Shopping Task [142] • Virtual Action Planning Supermarket [154] • Virtual Multiple Errands Test [63,155–157]. • Virtual Human Object Memory for Everyday Scenes [158] • Virtual Action Planning Supermarket [159] • Multitasking in the City Test [160] • Edinburgh Virtual Errands Test [161] • Virtual Town [171] • Virtual reality Cognitive Performance Assessment Test [165] • Real life Shopping Test [144]
Others activities without classification	• School AMPS [123] • Birthday Task [196]. For children between 8–16 years old. • Party Planning Task [197,198]. Adolescents between 12–16 years	• Behavioral Assessment of Disexecutive Syndrome [209] • Day Out Task) [147] • (a)-ADL [121] • Activities of Daily Living-International Scale [174] • Routine Task Inventory – Expanded [122] • Disability Assessment for Dementia Spanish Version [137] • Frontal Systems Behavior Scale or Frontal Lobe Personality Scale [210]	• Virtual Library Task [55] • Virtual Office Environment [212] • Virtual Executive Secretarial Task [213] • Virtual Office Assisstant or Jansari Assessment of Executive Functions [67] • Jansari assessment of Executive Functions for Children [54]

(*continued*)

Table 1. Continued.

AIDL	Instruments for Children and Adolescents	Instruments for Adults and Elderly	Virtual task
	• Behavioral Assessment of Disexecutive Syndrome for Children [199] • Functional Lowenstein Occupational Therapy Cognitive Assessment [94] • Complex Task Performance Assessment [20] • Actual Reality Task (digital) [130] • Performance –Based Skills Assessment [131] • Weekly Calendar Planning Activity [200] Children from 12 to 17 years old • Chas-P/T [177] • Behavioral Rating Inventory of Executive Function [201,202] • Childhood Executive Functioning Inventory [203] • My Child Play [204] • Questionnaire for Assessing Students' Organizaning Abilities [205] • Executive Function and Occupational Routines Scale [206] • Evaluación del Procesamiento sensorial y funcionamiento ejecutivo en la infancia [207] • Dynamic Occupation Assessment of Executive Function [208]	• Daily Living Questionnaire [138] • Inventario de Síntomas Prefrontales [211] • Computerized Meeting Preparation Task [14] • Adult Executive Functioning Inventory [102]	• Computerized Meeting Preparation Task [14] • Virtual Classroom// ***AULA*** [214] • Ice Cream Seller Test [170] • Virtual Week Task [40]

communications management. There were no virtual tasks for activities such as care of others, care of pets, child-rearing activities, religious or spiritual activities or safety and emergency maintenance.

Types of instruments according to the methodology used

Regarding the methodology used, we distinguished two major types of assessment methodologies: (1) traditional methodology and (2) technology-based instruments (e.g., virtual tasks, serious games, sensors) (see Supplementary Table S2 and S3). Several traditional methodologies have been used to assess IADLs: performance-based measures, behavior rating scales and self-reports. These methodologies correspond to three different perspectives: (1) tests aimed at assessing executive functions and determining their correlation with certain daily activities; (2) questionnaires or behavior rating scales of ADLs to determine the level of independence and support required, generally through proxies; and (3) performance-based measures aimed at identifying the underlying cognitive functions, especially executive functions and prospective memory through naturalistic tests and multitasking tests.

As regards virtual tasks, we found six tools for children, 26 for adults and only two for older people (see Figure 2, Supplementary Tables S1–S3). Results showed two types of systems using virtual reality to assess multitasking skills: 13 were based on virtual multiple errand tasks (i.e., shopping, community mobility and cooking) and 11 were based on the virtual office environment. Supplementary Table S3 summarizes the results, types of tasks and virtual scenarios found that made it possible to assess executive functions from an ecological perspective. The table shows the type of IADLs considered, the executive functions domain and the target population.

We found only one virtual global cognitive functioning assessment that addressed several daily activities (ECO-VR). As regards age, results showed only four virtual scenarios for children: two for children with ADHD, one for children with cerebral palsy and a test for adults adapted to children with executive dysfunction (*Jansari Assessment of Executive Functions for Children*). Two studies that used virtual reality to assess cognitive functions in children included the virtual classroom (AULA). AULA has been used to detect attention and inhibition deficits in children with attention hyperactivity deficit disorder [51] and acquired brain injury [52]. Another task supported by virtual reality that was developed for children is *Meal-Maker*, which involves preparing a menu [53]. In this case, the system collects information about the gestures and number of mistakes made by children with cerebral palsy, who show limitations in their movement. The *Jansari assessment of Executive Functions for Children* [54] is another specific virtual task designed to assess executive functions. In this task, the virtual scenario is a house with three bedrooms and a garden where children have to prepare a birthday party. They must organize it according to an instruction sheet that collects information about the guests and a letter from their parents with pending tasks to be performed.

Regarding adults and virtual reality, most evaluations were based on the Multiple Errands Test (MET). Six main virtual scenarios were identified. The Virtual Library Task [55] is a non-immersive virtual reality game and includes seven subtasks. In one of them subjects must perform several tasks following some preestablished rules, such as turning on the air conditioning in the library. In this case, when trying to turn it on, the machine warns them that it does not work so they have to solve the problem of cooling the library in a different way. The idea is to go to an adjacent room and pick up a fan there, take it to the library and turn it on. Other tasks are to photocopy three pages when there are only two pages available and not picking up the phone even though it is ringing, among others. Participants have between nine and 20 min to complete the task assigned, which can be assessed using the following factors: (1) analysis of the task; (2) generation of strategies and regulation; (3) prospective work memory; (4) inference and management of dual tasks; (5) inhibitory response; (6) prospective memory based on time; and (7) prospective memory based on events. The Multitasking in the City Test [56] is based on the same idea as the previously mentioned MET. In this case a virtual city is used. It includes a post office, drug store, stationary store, coffee shop, grocery store,

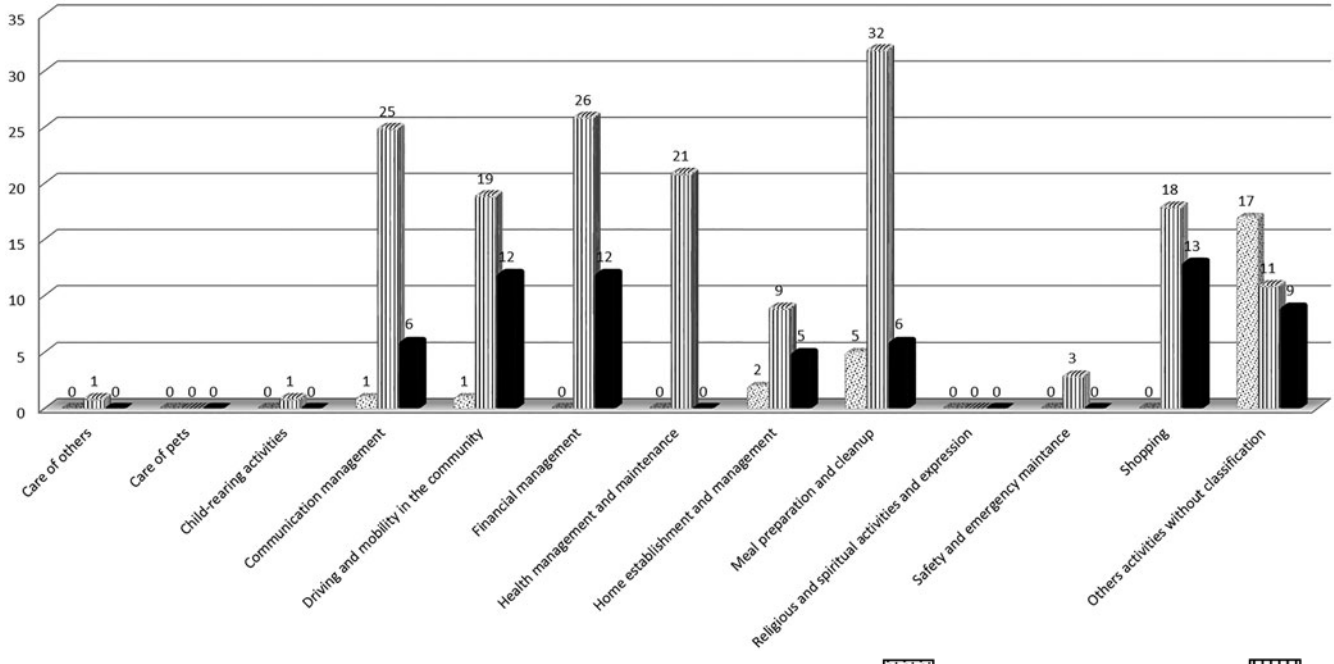

Figure 2. Instruments available for the assessment of the IADL. Instruments for children and adolescents . Instruments for adults and elderly . Virtual, serious games and new tecnological assessment .

optometrist's office, doctor's office, restaurant, bank, dry cleaners, pet store, and the participant's home. In this task participants must follow the following general rules: not traveling beyond a certain spatial boundary and not entering a store unless they intend to buy something, in order to explore behaviors that are not goal-directed. The Multitasking in the City Test was used to compare a sample of patients with acquired brain injury, a sample of patients with stroke and a sample of healthy individuals. This task revealed that the largest differences were found in the number of errors made by the clinical samples versus the healthy population. Other similar virtual tasks are the virtual city (Reh@City) [57], the virtual park and the virtual maze [58]. The last two scenarios were mainly used to assess orientation and spatial memory; the virtual maze was also used to assess trust and decision making [44].

Other virtual environments were used for the evaluation of ADLs such as shopping [59]; a few examples are the Virtual Action Planning-Supermarket [60], VMall [61,62] and the Virtual Multiple Errands Test [63].

In addition, using non-immersive systems, other studies included virtual tasks such as preparing coffee with an electric coffee maker [64,65]. They were developed to evaluate performance in IADLs, analyzing errors and validating them for populations with traumatic brain injury [65] and Alzheimer's disease [64]. Other virtual tasks related to community mobility were also developed, such as taking a bus [66]. Another type of instrument for measuring IADL in adults was the multitask known as the *Jansari assessment of Executive Functions* [67]. However, the activities to be performed were administrative and performed in an office (e.g., sending emails, preparing a room for a meeting).

Finally, there was also a battery (i.e., Systemic Lisbon Battery) aimed at assessing various cognitive processes using virtual reality. Specifically, it includes two tasks to assess executive functions: preparing breakfast and baking a cake [68]. The task of preparing breakfast required participants to use three ingredients in a certain sequence. To perform the second task, participants had to use five ingredients to bake the cake in the oven following a checklist. Another assessment tool that also includes both memory processes and executive functions is the ECO-VR task [69]. This task assesses five activities: watching the news on television; checking messages on an answering machine; organizing food and preparing the menu; finding items in a room; and remembering information related to TV news and the answering machine message.

In addition to virtual tasks, there were other methodologies used to evaluate ADLs by means of serious games platforms [70], combining game playing with a serious purpose such as that of assessing functional independence in older people through five ADL tasks in a family environment using the Smart Aging game [71]. Other types of assessments conducted with new technologies involve the use of sensors that collect data about participants' gestures, movements, location, interactions and actions [72]. For example, accelerometers are sensors that have been used to monitor the activity of getting dressed; magnetometers measure the strength of the magnetic field in three dimensions, provide guidance to users and detect and locate metallic objects within their detection radius. The location of the sensor (and of the person carrying it) can be determined based on its proximity to the objects detected. Finally, emerging studies are exploring the relationship between eye movement and changes in ocular fixation as predictors of cognitive and functional impairment [73].

Types of tests according to the paradigm

Some common aspects that must be considered in the tools available for the assessment of cognitive IADLs are the complexity of the activity, whether it requires a higher or lower level of attentional control, the subject's familiarity with the task (or its performance environment) and the novelty of the task. At least three paradigms can be found in this regard. Chronologically, the first paradigm is naturalistic tasks, which are performance-based measures. *Performance-based naturalistic tasks* are observable, rule-based, open tasks performed in an environment that mimics the real world or is the real world (e.g., in an apartment set up to conduct the assessment, a kitchen) [74,75]. As regards the instruments that use naturalistic tasks, we found three tests that used a cooking task in children (Children's Kitchen Task Assessment [52]; DO-EAT [56] and Children's Cooking Task [58] and one test aimed at preschool children (Preschool Executive Task Assessment) [55]. In addition, two instruments (i.e., Assessment Motor Process Skills and School- Assessment Motor Process Skills) were used while observing a significant activity of the child or adult, although intentional behavior, goal formulation or behavior monitoring were not among the executive functions considered. Furthermore, one instrument attempted to provide laboratory tasks with greater ecological value (Behavioral Assessment of Dysexecutive Syndrome), although it showed a low correlation with the behavior rating scale completed by parents and teachers. Supplementary Tables S2 and S3 show the tools found. The second paradigm is based on the *Multiple Errands Test* (MET). These tasks are multitasks that are oriented towards administrative or work-related activities such as working in an office. The Multiple Errands Test, with different variants, was the most frequently used multitask assessment. It involved tasks related to the hospital context, the therapeutic community or the supermarket (see Supplementary Table S1 and S2). This paradigm developed by Shallice and Burgess [75] attempts to address the limitations of common neuropsychology tests in identifying performance-based deficits in people with executive dysfunction. In addition to the MET paradigm and naturalist tasks, there is a *paradigm of dual tasks*, which combines walking and cognitive tasks (i.e., dual-task walking) [76]. This paradigm, exemplified by the *Complex Task Performance Assessment*, is a performance-based measure of executive functions developed from the MET and the action of the Supervisory Attentional System in complex multitasking situations [75]. The Complex Task Performance Assessment was designed to overcome the limitations of the MET in a clinical context [20]. An example of it is a task that simulates working in a library, which requires the completion of two tasks simultaneously: [1] control of current inventory and [2] telephone messaging.

Types of tools according to the diagnosis

There seem to be more tests aimed at older people, especially for the detection of cognitive impairment versus healthy aging, but most of them propose correlation studies between executive functions and ADLs. We identified 32 different tools.

A total of 22 different tests were found for adults with acquired brain injury. Eleven instruments were aimed at patients with schizophrenia, the most frequent of which were virtual tasks related to independence that were used in shopping activities such as the Test of Grocery Shopping Skills [77] and the Virtual Action Planning Supermarket [78] and pre-work activities such as the Computerized Meeting Preparation Task [14,79]. We found only three tests aimed at patients with addictive behaviors, one

aimed at patients with orthopedic surgical pathology (AM-PAC) and one aimed at patients with obesity (Let's Shop), related to shopping behavior (i.e., compulsive or not, shopping patterns and items purchased). Other authors also explored the impact of cognitive processes in ADLs in patients with glioma in the temporal lobe [79].

Discussion

The purpose of this review was to provide an overview of the current state of the art of IADL assessments with ecological validity focused on executive functions. This study also intended to rapidly map the key concepts underpinning this research area and to identify the aspects that require further research to improve the assessment of independence in activities of daily living.

The emphasis on the search for neuropsychological tests with ecological validity is the result of a paradigm shift in neuropsychology evaluations from a localizationist perspective to one focused on the prediction of functioning in everyday life [36]. Traditional neuropsychology assessment techniques have focused on measuring cognitive deficits rather than functional skills [80]. An important differential characteristic between traditional neuropsychological tests and ADLs is that the latter imply a high level of control and the absence of interruptions, which does not happen in the real world [81,82].

Types of tests according to the IADLs

It is possible to differentiate at least three types of approaches in the assessment of cognitive IADLs: (1) one essentially focuses on determining whether the person is independent or needs some kind of support for conduct ADL; (2) the second approach focuses on exploring the underlying cognitive processes in isolation and also in a highly controlled context with familiar materials; and (3) the third one is the result of merging the first two approaches to explore the underlying processes in the context of multistep/multitask ADL performance.

Regarding the first approach, most assessments of ADLs have attempted to identify whether the person needs some kind of help – either as a verbal or physical support – for the performance of the activities, mainly through a reliable informant. Others have looked for errors due to failures in the attentional control that the patient can exert. Although these scales are helpful in quickly assessing the amount of support the person might need, they are completely unspecific about what causes their dependence. They do not even help to dissociate whether patients are dependent due to physical or cognitive deficits. Therefore, they are probably insufficient to guide clinicians to plan targeted treatments for a given patient.

Some of the disadvantages of self-reports is that, in patients with a lack of awareness of their deficits and/or mood changes, the reliability and validity of the data are reduced [74]. Similarly, the information obtained through a key informant (e.g., family member, caregiver) has the disadvantage of depending on knowledge about patients, the number of hours spent with them and the type of activities carried out with them [83]. This may lead to bias in the information obtained about the participation and performance of ADLs [84]. Behavior rating scales of executive functions such as Behavioral Rating Inventory of Executive Function, Childhood Executive Functioning Inventory and the "Evaluación del Procesamiento Sensorial y Funcionamiento Ejecutivo en la Infancia" have a clear structure that usually depends on the exploratory or confirmatory factor analysis. Executive deficits can be related to other processes such as prospective memory deficit or motor cognition, which are not always well differentiated in the questionnaires (i.e., behavior rating scales).

This systematic review focused essentially on performance-based tests for the evaluation of executive functions in everyday life. These results show a lack of instruments assessing people's independence in various cognitive IADLs (see Table 1). Results showed that the traditional tests and virtual tasks found either superficially considered some IADLs or failed to include them in the performance-based measures. Of the 11 IADLs described by the American Occupational Therapy Association, they only included the use of communication devices, financial management, health management and maintenance, community mobility and household management, and the preparation of menus [5]. The reason why there were no tools about the care of others or pets, child rearing and religious or spiritual activities may be that these types of activities are not general or carried out by the entire population, are more complex and can vary widely depending on the characteristics of the person or animal receiving the care. The same applies to driving activities. No driving assessments were found in this review either. This may be because driving is one of the most complex IADLs and has a specific assessment protocol [85]. Driving has also been strongly related to visual perceptual skills, motor skills and – when evaluated cognitively –, traditional neuropsychological tests such as the Montreal Cognitive Assessment, Clock Drawing Test, Useful Field of View test and Motor-Free Visual Perception Test and Trail Making Test A and B are used, among others. Specific tests to assess driving skills have been developed from the discipline of occupational therapy (e.g., OT-Driver Off Road Assessment, OT-DORA [86], and STISIM Drive simulator and simulator protocol [87,88]).

In addition, it is important to consider that there are several instruments related to performance in educational and work-related activities. In such activities, executive functions are essential and can be understood as instrumental activities since they are not conducted as an end in themselves but rather to achieve something (e.g., learning, earning a degree, obtaining an economic reward) [89].

One of the activities that have not been explored virtually is the evaluation of the maintenance of good health or use of medication, although there are different devices (e.g., apps) related to this activity for the general population, such as fitbit bracelets and accelerometers, among others. No scenarios assessed safety and response to emergencies both in the home and in other contexts, even though this is a very relevant activity in various clinical populations (e.g., patients with mild cognitive impairment or psychiatric or neurological disorders) in adults and children. The communication activities evaluated are very basic, such as making a phone call, sending a letter or filling in a form.

Finally, the classification of IADLs by the American Occupational Therapy Association is likely to be more adequate for adults than other populations and does not include other types of activities performed by children in an instrumental way in its taxonomy. Results showed a scarcity of instruments to assess children and adolescents. There are probably fewer tasks for evaluating multitasking in children because their development and the execution of IADLs progressively start at the age of 7 years in response to the demands of the environment [89]. Another important gap is the definition of IADLs for children from the age of 6 and for adolescents such as preparing the backpack for the next day, preparing clothes for the next day according to

the schedule, preparing a snack, using means of communication (e.g. mobile phones, tablets) and money management.

Types of tests according to the paradigm and technology

We found several types of performance-based measures: (1) measures that focused on a single IADL (mainly naturalistic tasks); and (2) multitasking measures. Performance-based measures have been developed to assess functional capabilities to perform IADLs more objectively [90]. There is a great heterogeneity between the aspects or components of executive functions included in performance-based measures. In general, most tests include attentional control (i.e., action supervision and error detection), planning, sequencing, cognitive flexibility and goal setting as shown in Supplementary Table S2 and S3. In addition, some performance-based measures based on multitasking instruments include results on the effectiveness of prospective memory, especially related to time in adults (i.e., Sydney Test of Activities of Daily Living in Memory Disorders, Baycrest Multiple Errands Test, Test of Grocery Shopping Skills) and events in children (i.e.: DO-EAT, Birthday Task). The study conducted by Vallejo et al. [80] confirmed previous findings that performance in multitasking in everyday life involves executive functions, prospective memory and retrospective memory. Thus, various processes work together in the performance of complex tasks. Among executive functions, planning is an essential component to accomplish novel tasks, as it is necessary to formulate an objective and establish the necessary actions to achieve it, with an appropriate sequence and taking into account personal strategies and specific rules. Prospective memory enables us to remember to conduct an activity planned for the future [91]. This is important because it implies that IADLs should not be examined as a set of cognitive processes only but rather considering how these processes work together as a whole, which may be more than the sum of its parts [80]. Conversely, in some tests performed in the real contexts of patients, such as the Assessment of Motor and Process Skills, School- Assessment of Motor and Process Skills or the Performance Assessment of Self-care Skills, errors and attentional control are not evaluated nor can they be considered multitasking, since they do not require prospective memory and are not self-initiated by the subject. Baum et al. [92] reported that an advantage of naturalistic tasks is that they allow us to know what level of support is necessary for each patient and to be able to choose the best treatment. Although some limitations of naturalistic tasks based on the MET paradigm have been pointed out (e.g., their time-consuming nature, the transportation of patients to the setting of the evaluation, the consent of companies required in the case certain establishments such as shopping centers, the cooperation of staff and clients and the fact that there may be too many variables to control). While assessments based on naturalistic tasks can be understood as laboratory tasks and have high ecological validity, they require patients' abstract thinking to conceptualize the task; by contrast, instruments assessing IADLs in a real context tend to be produced depending on the learning history and the execution context [14]. Therefore, the former may not fully reflect the functioning of the real world [93]. Nevertheless, naturalistic tasks tend to motivate subjects more and lessen the anxiety that a traditional pen and paper evaluation can cause.

Regarding complex tasks such as financial management, the existing proposals only consider the payment of products that are to be bought. In relation to home establishment and management, they only cover tidying up a part of the home, such as a closet, and picking up the utensils needed to cook or prepare tea or another simple hot beverage. With regard to the preparation of menus, only the making of very simple recipes is considered, which in some cases involves only heating a pizza or spreading something on toast. In addition, safety procedures are evaluated in very few tasks; in the few cases in which they are, they are very basic, such as not making a mistake when picking up a knife. In summary, is important to note that some tasks are very simple (e.g., preparing breakfast) and there is a ceiling effect, which makes it impossible to identify people with mild cognitive impairment [68].

Furthermore, some of these assessments do not consider the resolution of a problem in an emergency or dangerous situation. Some of them, such as the Assessment of Motor and Process Skills, the Kettle Test, some MET-based assessments and the Test of Actual Reality are based on the test paradigm and do not make it possible to determine the functional level of participants when they require help. By contrast, the Executive Function Performance Test [91,92] collects information on the type of help needed and how participants conduct their activity with the support they receive.

In naturalistic tasks there are a number of variables that can affect the performance of individuals and cannot be controlled (e.g., the amount of noise, people who spontaneously may or may not cooperate with the task, for example in a supermarket). Another limitation is that only a certain number of variables can be measured, since it is difficult for the observer to write everything down and it requires a lot of training and time and a high cost and involves poor control of several variables and lack of security [94,95]. Sometimes, if video recording is used it may affect the natural performance of the patient. In addition, in all these activities in the real world there is a great influence of the familiarity of the evaluated task, which affects the performance of executive functions. The scenarios evaluated using performance-based measures should be as complex as the real world and, at the same time, meaningful and of an everyday nature, with rules for the use of context and the execution of the activity. Therefore, there is a need for standardized tools that are accessible in a clinical setting and closely related to real-world activities, but at the same time place participants in new situations for them [14].

Virtual reality has been used to overcome some of these limitations. In fact, virtual reality is increasingly used in the evaluation of functional skills because of it has predictive value regarding functioning in daily life [55,65,96–99]. Tasks based on the MET paradigm that involve virtual reality are better at predicting the actual functioning of patients [100]. Virtual reality technology allows immersion in real situations, where the performance of the patient in IADLs can be observed. Virtual reality systems facilitate a three-dimensional presentation and the stimulation of dynamic environments, especially in evaluation scenarios that would be difficult to implement in real-world settings [72]. We found 32 references with virtual reality tasks (see Supplementary Table S1). Despite the importance of evaluating multitasking skills to predict the functioning of individuals in the real environment, their use is still infrequent, probably due to implementation difficulties in the laboratory [80].

Assessments involving computerized tests provide accurate measurements in milliseconds. Such tests have the following characteristics: they are more sensitive to cognitive impairment and are usually faster to administer; the presentation of items in some batteries can be adapted to the levels of performance of the patient to avoid floor effects; they guarantee standardization and examiner effects are reduced; scores are automatic, which means that results are available immediately and human scoring error is

reduced; and they tend to have high portability [101]. According to other authors, the inclusion of real-world scenarios and virtual reality tasks in clinical studies can be a good means to demonstrate the impact of executive deficits on patients' lives [102,103], providing a sensitive measure of daily functioning [102,104]. Another advantage of this type of evaluation, particularly with children, is that it can assess them as if it were a game with a meaningful activity for them, decreasing their anxiety before the evaluation and the effects of feeling observed. In addition, such virtual reality tasks are similar to cognitive IADLs because they make it possible to easily include and design elements of the environment (e.g., familiar environment, more or fewer distractors or objects) through multitasking instruments [105]. A final advantage of using such assessments is that they can predict the level of personal autonomy in patients who are in an institutional environment and could be a first approximation to the real environment in patients with a mental disorder or drug abuse, for example. Based on the studies reviewed it can be stated that virtual environments and serious games for neurorehabilitation [105] and for the assessment of cognitive IADLs are increasingly being used in research to increase the ecological validity of assessments. However, results showed a very small number of virtual scenarios for the evaluation of executive functions in children and adolescents: only five instruments – two focused on kitchen tasks, one on office tasks, one on community mobility and one on attentional control in the classroom. Recent studies have started to include self-awareness as a parameter assessed with virtual reality [106]. In the future this could be of great interest for the assessment of IADLs. Virtual reality is even being considered to evaluate decision making regarding risk behaviors [107].

Some disadvantages of virtual reality tasks have been described: (1) they can cause dizziness (e.g., discomfort, nausea, vomiting, headache, fatigue) due to their inability to accurately simulate movements in the environment; (2) they involve costly technology, particularly if they are immersive; (3) they require regular maintenance; (4) their development requires multidisciplinary work involving computer engineers, neuropsychologists, occupational therapists and others; and (5) they have certain technical requirements such as lighting and broad spaces to be used. One of the pending tasks of virtual reality tests is to provide parallel versions of the task to avoid the learning effect in reassessments [35].

In conclusion, the main benefits of virtual reality for the evaluation of IADLs include affordability, safety, efficiency, applicability to a wide range of conditions and ease of data capture and qualification [21,34].

Many emerging technologies can be used for the evaluation of IADLs. A few examples are robots, depth cameras, event monitoring systems, body or environment sensors and serious games, among others, which make it possible to analyze movement and to predict and detect falls. In short, they make it possible to assess patients even when the therapist is absent, something known as Ecological Momentary Assessment. In an Ecological Momentary Assessment, a series of repeated measures are performed in various dimensions (e.g., cognitive, affective, physiological) while subjects perform IADLs without the need for a therapist to be present [108]. These new ecological paradigms provide a better understanding in the area of everyday multitasking and underline the importance of using virtual environments for exploring complex human cognition [80].

Finally, serious games have the potential to be used as multitasking assessment tools for cognition and performance in ADLs [80] as they improve motivation [109] and have shown to have ecological validity [110] and diagnostic value [111].

Tests according to the diagnosis

From a clinical perspective, several authors have indicated the interest of evaluating IADLs through performance-based measures for the early detection of dysfunctions in IADLs. This has also been called 'preclinical disability'. This is especially true in older or chronically disabled persons [112], who may not show a decrease in the overall number of activities carried out but may exhibit changes in the frequency and quality of their performance. Therefore, the assessment of cognitive IADLs becomes even more interesting given the trend in the population, which is increasingly aging and has a higher prevalence of diseases leading to cognitive impairments (i.e., dementia, Parkinson's, severe mental illness, substance use disorders and neurodevelopmental disorders). Of these, it is worth highlighting attention deficit disorders and autism spectrum disorders, which have a high impact on executive functions and personal autonomy [113].

In this review we selected the tests and instruments available to assess cognitive IADLs. We observed that many studies were aimed at assessing the relationship, correlation and predictive power of certain cognitive processes on performance or level of functioning in daily life rather than at developing specific tests to assess cognitive instrumental activities of daily living. Of the various cognitive processes, memory and executive functions were those found to be most related to the performance of IADLs [114].

Assessments with ecological validity show the patterns of performance of several pathologies. For example, when participants with mild cognitive impairment performed IADLs, they made more substitution than omission mistakes when they were interrupted [82,114]. Such assessments provide information about what spontaneous strategies patients use, whether such strategies are useful, what type of information they learn with greater ease and what kind of support will benefit them the most in real life [115].

Results showed that most of the instruments found used performance-based measures, followed by behavior rating scales for caregivers; self-report methodologies were the least numerous instruments. This is consistent with the lack of awareness of the deficits and scarce insight into problems of patients with cognitive and/or mental impairment, which results in a decrease in the reliability and sensitivity of self-reports in these populations [113].

There is some controversy about whether or not the assessment of cognitive IADLs with virtual reality makes it possible to determine the strategies and aids that patients use to perform the activities. Some authors report that it is possible [116], although other authors argue that virtual reality does not fully replicate all the demands of daily life nor the aids or compensatory strategies that patients use [117]. Studies that use virtual tasks need to expand the sample size and diversity of those of cognitive and neuropsychiatric disorders. Kitchen-related tasks may be gender oriented, which is a limitation for their use and validity and sensitivity, among others. In relation to the question about whether instruments with simulated tasks correlate well with performance in tests based on real performance, we found the following: a study conducted with patients with serious mental illness [118] showed that tasks simulated in controlled conditions were a strong predictor of performance in real-world tasks. This study also found that verbal memory correlated positively with independence in the community. According to these authors,

it is interesting to develop new systems for naturalistic evaluation, since most assessment tools available to date do not fully explain performance in the real world [118]. It is necessary to clinically validate all technologies and determine whether they have predictive validity over functional performance. Yet, the use of technology in the evaluation of IADLs is not without disadvantages, such as energy consumption and the limited use of wireless devices. In some cases, when it is necessary to record patient's performance and use environmental or personal sensors, this may threaten the privacy of patients.

So far, the use of various assessment tasks has been done mainly experimentally and few of the tests available have been the subject of studies with clinical validity reporting effect sizes [115]. One of the challenges of such evaluation systems is expanding them to make them appropriate for the entire population and available to clinicians in order to facilitate and improve the evaluation of IADLs. It is also necessary to conduct studies on the acceptability of technology both by therapists and patients and it would be good to make these IADL evaluation tools affordable for the entire population.

Thanks to the multidisciplinary work of computer engineers, occupational therapists and neuropsychologists, more solidly constructed tests will be available in the future [119]. Considering the knowledge obtained by the three disciplines can improve the quality of care and consequently the quality of life of the population.

Limitations of the study and implications for future research

This systematic review has certain limitations. First, the results shown were limited to the years on which the systematic review focused, and there may be other previous tests that were not found with the inclusion criteria. Second, as noted by other authors, the conclusions about convergent validity in daily life were limited because there is no gold standard measurement of cognitive IADLs against which these measures can be compared to [37]. Some authors compared the test with traditional measures of executive functions, such as the Stroop task, Wisconsin Card Sort Test or Continuous Performance Test [120], while others simply labeled their measure as ecological given the way they had designed and developed it.

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