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REVIEW

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A comprehensive review of attention tests: can we assess what we exactly do not understand?

Ehsan Nasiri[1,2], Mohammad Khalilzad[1], Zahra Hakimzadeh[1], Ashkan Isari[1], Sajjad Faryabi-Yousefabad[3], Saeed Sadigh-Eteghad[2*] and Amirreza Naseri[1,4*]

Abstract

Attention, as it is now defined as a process matching data from the environment to the needs of the organism, is one of the main aspects of human cognitive processes. There are several aspects to attention including tonic alertness (a process of intrinsic arousal that varies by minutes to hours), phasic alertness (a process that causes a quick change in attention as a result of a brief stimulus), selective attention (a process differentiating multiple stimuli), and sustained attention (a process maintaining persistence of response and continuous effort over an extended period). Attention dysfunction is associated with multiple disorders; therefore, there has been much effort in assessing attention and its domains, resulting in a battery of tests evaluating one or several attentional domains; instances of which are the Stroop color-word test, Test of Everyday Attention, Wisconsin Card Sorting Test, and Cambridge Neuropsychological Test Automated Battery. These tests vary in terms of utilities, range of age, and domains. The role of attention in human life and the importance of assessing it merits an inclusive review of the efforts made to assess attention and the resulting tests; Here we highlight all the necessary data regarding neurophysiological tests which assess human attentive function and investigates the evolution of attention tests over time. Also, the ways of assessing the attention in untestable patients who have difficulty in reading or using a computer, along with the lack of ability to comprehend verbal instructions and executive tasks, are discussed. This review can be of help as a platform for designing new studies to researchers who are interested in working on attention and conditions causing deficits in this aspect of body function, by collecting and organizing information on its assessment.

Keywords Attention, Cognition, Attention tests, Cognitive processes, Sustained attention, Selective attention, Neuropsychological tests

*Correspondence:
Saeed Sadigh-Eteghad
saeed.sadigetegad@gmail.com
Amirreza Naseri
Amirx2eza@gmail.com; naseria@tbzmed.ac.ir
[1] Student Research Committee, Tabriz University of Medical Sciences, Golgasht Street, Tabriz 5166/15731, East Azerbaijan, Iran
[2] Neurosciences Research Center (NSRC), Tabriz University of Medical Sciences, Golgasht Street, Tabriz 5166/15731, East Azerbaijan, Iran
[3] Yuksek Ihtisas University, Ankara, Turkey
[4] Research Center for Evidence-Based Medicine, Iranian EBM Centre: A Joanna Briggs Institute (JBI) Center of Excellence, Tabriz University of Medical Sciences, Golgasht Street, Tabriz 5166/15731, East Azerbaijan, Iran

Introduction

Cognition is the general term used to refer to the process of gaining knowledge [1]. Cognition encompasses several domains, including attention, language, learning, memory, perception, and higher reasoning [2]. These domains are highly interconnected, for instance, attention and memory cannot function with another lacking operation; as memory capacity is limited comes attention to filter what gets to be encoded [3]. As a domain of cognition, attention can be defined as a crucial process for keeping thoughts organized, but psychologists and philosophers have always tried to define attention.

By the 1950s several models for attention were proposed [4]. Now an acceptable definition for Attention is a cognitive process matching data from the environment to the needs of the organism [5]. Being able to focus on one thing and ignore other stimuli is another definition provided by some [6]. Despite these definitions Bernhard Hommel and colleagues, after a discussion about the concept of attention, the difference between attention and intention, and the synthetic approach to attention found that "*no one knows, or can ever know, exactly what attention is*" [7]. This was in contrast with the prior belief about attention which was defined by William James who mentioned *"Everyone knows what attention is."*

There are several aspects to attention including tonic alertness (defined as a process of intrinsic arousal that varies by minutes to hours), phasic alertness (defined as a process that causes a quick change in attention as a result of a brief stimulus), selective attention (defined as a process differentiating multiple stimuli), and sustained attention (defined as a process maintaining persistence of response and continuous effort over an extended period) [8–11]. Attention is also divided based on where it functions: "bottom-up" which refers to guidance that stems from external stimuli and "top-down" which refers to guidance that comes from intrinsic factors rooted in previously acquired knowledge [12].

It is generally agreed that attention can be focused on voluntarily using "top-down" signals derived from knowledge of the current task (finding your lost keys), and automatically using "bottom-up" signals captured by salient sensory events in the sensorium (a flashing fire alarm)[13, 14]. Studies in neuroimaging and neurophysiology have discovered that a large network, involving the posterior parietal cortex, temporoparietal junction (TPJ), superior temporal sulcus, and dorsal areas of the frontal cortex, supports the orienting of attention [14–16]. Although there are neural correlations between both types of attention in the frontal and posterior parietal cortex, and both can modulate processing in sensory processing regions; prefrontal neurons reflected the target location first during top-down attention, whereas parietal neurons signaled it earlier during bottom-up attention [13, 17]. According to studies, involuntary attention is highly related to ventral regions (temporoparietal junction) and can be engaged more rapidly, and is more resistant to interference than voluntary attention which is related to more dorsal segments of the frontal and parietal lobes [14].

Regardless of definition, a need for assessing attention, as one of the components of human cognition, leads to designing different attention tests. Testing attention is included in assessing the neuropsychological function of a subject [18]. Besides a few exceptions, such as the Test of Everyday Attention for Children (TEA-Ch), most attention tests evaluate attention in a wide range of ages (as young as a 4-year-old to as old as one can get) [19]. Traditionally most of the tests were taken on paper. With the invention and widespread use of computers, many tests are now conducted via the computer, although some remain only on paper or in the form of cards. Using audio tapes are also used as a way of evaluating attention and specifically to assess the auditory domain of attention [20–23].

Attention dysfunction is a symptom that is associated with multiple disorders [24, 25]. In addition to attention deficit hyperactivity disorders (ADHD), Schizophrenia [26], anxiety disorder [27], depression [28], posttraumatic stress disorder [29], epilepsy [30], dementia [31], hearing loss [32], even heart disease [33] and anemia [34], can cause impairment in attentive function. Studies suggested that episodic memory loss, which is the characteristic symptom of Alzheimer's disease (AD) type dementia, may be secondary to failures of attentional processes [35]. Also, a recent study found overlapping cognitive profiles between mild cognitive impairment (MCI) and ADHD [36]. Attention has a vital role in determining one's ability in dealing with problems, planning, organizing thoughts and behavior and choosing targets and acting towards them. Hence deficits in this domain of cognition can herald difficulties in many everyday activities in subjects suffering aforementioned conditions. Therefore, assessing attention seems necessary in evaluation of these conditions [37].

Studies on patients with AD revealed that with progressive dysfunction of prefrontal cortex (PFC) and medial temporal lobe, signs of cognitive impairment and inattention appear. Thus, a part of attention circuit consists of PFC and medial temporal lobe [38]. It is also believed that information related to bottom-up attention comes from visual cortex and is directed toward PFC. It has also been seen that when differentiating stimuli with different color and shape, PFC is activated. PFC and posterior parietal cortex (PPC) are origins for signals responsible for top-down attention. Role of PFC and PPC in maintaining attention was further established by studies stimulating these two areas during an attention-requiring activity which resulted in shorter latency of detecting and responding. PFC is activated earlier in top-down attention than PPC. Deactivation of PFC also impaired performance in all attentive tasks while PPC disruption was noticeable only in more difficult tasks. Timing and difficulty differences give the idea of a more important role for PFC in this aspect of attention [39].

Previous research has demonstrated a connection between attention dysfunction and several mental and neurological conditions. This association may be

explained by the role of immune dysregulation, inflammation, anxiety, and stress in the development of ADHD, which can lead to a wide range of chronic illnesses, including cardiovascular, and metabolic diseases (due to inflammation), as well as psychiatric (such as schizophrenia and neurodegenerative diseases (due to immune dysregulation and increase in kynurenic acid (KYNA) as a result of the activation the tryptophan (TRP)-kynurenine (KYN) metabolic pathway) [38, 40, 41]. Stressors can induce inflammation and inflammation in turn can affect multiple brain sites resulting in impairment of cognitive function. Studies support stress role in inattention by showing a meaningful connection between childhood trauma and severity of ADHD. It has been also shown that in a stressful condition the levels of the proinflammatory cytokines rise in the brain [40]. Therefore, it is crucial to diagnose and treat attention deficit disorders early on. This makes the assessment of attention function even more important. The interaction between cognition and emotion is also considerable. Biases in attention are identified as central characteristics of depression and anxiety [42]. Emotions also impact cognition and their effect on attention has been illustrated by studies assessing reaction times under different emotions such as fear [43, 44].

In this review, our main objective to pursue is to summarize the different neurophysiological tests which assess human attentive function and investigate the evolution of attention tests over time. We have searched PubMed and Google Scholar databases for articles and studies that evaluated attention assessment methods and tests using the "attention tests" keywords. We have considered those which were relevant to the objectives in hand and reviewed the included.

Results

In this review, we have summarized the available cognitive tests for assessing attentive function. Table 1 briefly presents the results of this review. The table is sorted by the date each test was established and contains brief information on the setting each test is undertaken. The duration of each test, the domain(s) assessed, and the age of each test targeted are also noted. The details of the tests are mentioned afterward.

Digit Span Test (DGS)

The Digit Span Test along with the reaction time test is thought to be among the very first tests assessing cognition and attention used by psychologists. The first time DGS has been introduced and put into work was in 1716 by Gottfried Leibniz [45]. The most current version which has been used since 2008 is embedded in Wechsler Adult Intelligence Scales IV [46–48]. This test is also a part of the Wechsler Intelligence Scale for Children and the Working Memory Index [47, 49, 50]. DGS is at large a measure of working memory but is also described to be of importance in evaluating everyday simple attention [51–53]. DGS in its latest version includes 3 subtasks: Digit Span Forward, Digit Span Backward, and Digit Span Sequencing [47]. In this task the subject is presented with a series of random digits, then the subject is required to repeat the digits in the same sequence or backward [54].

Simple and choice reaction time (RT)

This test has been used to measure an individual's reaction time to an illustrated stimulus since the nineteenth century. This test has two major parts, one in which the participant is timed responding to a predictable single stimulus (simple RT) and another in which the participant is expected to respond appropriately to one of several stimuli (choice RT) [55, 56]. RT task is a common test evaluating a subject's central processing speed which correlates with cognitive efficiency, namely sustained attention and alertness [57, 58]. This test is both a simple single-choice and a multiple-choice RT task which consists of five steps, each a more complex chain of reactions than the previous one. In each scenario, the participants have to respond whenever a yellow dot shows up. The dot may show up in one of five designated places, and the subjects have to respond either by pressing a pad, touching the screen, or sometimes doing both. There are 4 pieces of results to the RTI which are categorized into RT and movement time, each including a simple and a five-choice task [56].

Stroop Color and Word Test

The Stroop Color and Word Test is originally a test that was used to measure the ability to inhibit cognitive interference [21]; but studies suggested the Stroop test as a measure of attentive function, especially selective attention, too [59–64]. The standard Stroop Test includes words typed in different colors. Participants are initially asked to read the colored names and they are timed doing so. Following this step, they are asked to identify the printed color of each word. Normally, the required time for naming the color is more than that of reading the color's name.

The emotional Stroop test

The emotional Stroop, known as the E-Stroop test, employs target and control lists that incorporate variably colored words [65]. E-Stroop is the most commonly utilized test for measuring attentional biases [66]. Attentional bias refers to hyper-attention to threatening material [67]. The sensitivity of the e-Stroop sufficiently differentiates between neutral and emotionally charged

Table 1 Summary of available attention tests

Test name	Established date	Assessed attention domain	Type of assessment	The age range of the assessment	Estimated time
Digit Span Test	1716	Simple attention mainly used to assess working memory	Audio tapes and online computerized tests are available	4 +	1–3 min
Reaction Time	1873	Sustained attention and alertness	Mechanical at first, computerized now CANTAB version: Presented on digital screens	No limits	3 min
Stroop Color and Word Test	1935	Selective attention	Paper-based, computerized version are also available	3–75 +	5 min
Wisconsin Card Sorting Test	1948	Executive function, namely selective attention	Printed on cards, a computer-based version is also available	6.5–89	12–30 min
The Mackworth Clock Test	1948	Vigilance and Sustained attention	Printed on and performed by a physical box, a computerized version is also available	15 +	2 h
Match to sample visual search task	1950	Visual selective attention	CANTAB version: Presented on digital screens	4 +	7 min
The rapid visual information processing	1953	Sustained attention	CANTAB version: Presented on digital screens	4 +	4–7 min
Dichotic listening test	1956	Selective auditory attention	Voices are presented to the subject	5 +	
The continuous performance test	1956	Vigilance and sustained and visual selective attention	Presented on digital screens	8 +	15–20 min
Motor screening test	1964	Selective attention	CANTAB version: Presented on digital screens	4 +	2 min
CANTAB	1988	–	Presented on digital screens	4 +	RTI: 3 min RVP: 7 min MOT: 2 min MTS: 7 min
The Ruff 2 and 7 Test	1992	Sustained and visual selective attention	Paper-based	16–70	5 min
Test of variables of attention	1993	Sustained attention	Computer-based	4–80 +	23 min
Test of everyday attention	1994	Sustained, visual and auditory selective and divided attention and also attentional switching	A combination of papers and audio tapes	18–80	45–60 min
The Psychomotor Vigilance Task	1997	Sustained attention and alertness	Computer-based, also available on smartphones	4 +	2 versions of 10 and 3 min
Test of everyday attention for children	1998	Sustained, visual and auditory selective and divided attention and also attentional switching	A combination of papers and audio tapes	6–16	55–60 min
AX-Continuous Performance Test	1999	Vigilance and sustained and visual selective attention	Presented on digital screens	8 +	20 min
The Conners Continuous Performance Test—2	2000	Vigilance and sustained and visual selective attention	Computer-based	4 +	14 min
The Madrid Card Sorting Test	2003	Executive function, namely selective attention	Printed on cards	–	–
Concentration CogniFit General Cognitive Assessment	2011	-	Online multi-platform	7 +	15–20 min

CANTAB Cambridge Neuropsychological Test Automated Battery, *RTI* reaction time, *RVP* rapid visual information processing, *MOT* motor screening task, *MTS* match to sample visual search

words. In the E-Stroop test, participants are required to name the ink color of words with emotional or neutral valence, which is the main difference between the traditional Stroop and E-Stroop. Specifically, the words do not represent names of colors but contain words varying in accordance with their emotional valence [68]. In the other words in the E-Stroop test, the emotional meaning of the word tends to capture and hold the participant's attention and cause a slowdown in reaction time, regardless of the ink color in the traditional test [69].

The Wisconsin Card Sorting Test (WCST)

This neuropsychological test was first devised in 1948 and has been used to assess cognitive processes of higher levels since 1963 [54, 70]. These processes include attention, perseverance, working memory, abstract thinking, cognitive flexibility, and set-shifting. The test is made up of two card packs; each containing four stimulus cards and 64 response cards. The dimensions of each card are 7×7 cm and on them are various shapes of different colors and numbers. The subjects are required to sort the response cards with the stimulus cards using the feedback given to them by pre-established instructions. This study uses the Heaton technique with 128 cards. Each subject took the test separately and 12 sets of points were applied [71]. Due to the character of the test, carrying out a reliability study was not possible. However, validity studies, done on a Turkish sample, confirmed the credibility of this test [54]. This test has been used to assess cognitive function in subjects suffering from various disorders; including TBI, schizophrenia, chronic alcoholism, anorexia nervosa, autism spectrum, obsessive–compulsive disorder, and ADHD [70, 72–75].

The Mackworth Clock Test

This test was first devised in 1948 to assess vigilance in radar technicians of the British Air Force [76–80]. This test assesses sustained attention and was evaluated in two different time frames, one from 1962 to 1964 and another from 1980 to 1984 [77, 81–83]. Effects of alcohol hangovers, fatigue, and specific serotonin reuptake inhibition on the test results have been studied [84–87]. A metal box with a white face of 30.5 cm in diameter and on it a 15.25 cm long pointer, black in color, was used in this test. The face was divided into 100 3.6-degree steps and the pointer jumped one step each second. The target stimuli in this test were called double jumps, where the pointer traveled 7.2 degrees in one second. These stimuli occurred randomly in varying time intervals and each trial took 62 min to carry out. The box, or 'the clock' as it was referred to, was placed at a distance of 1.22 m but could be reduced to a minimum of 0.31 m if the subject had difficulty seeing the pointer sharply [76]. A computerized version of the test has been available since 2000 [76, 88].

Match to sample visual search task

This task is a benchmark measuring speed/accuracy trade. The task assesses how well the subject is in matching visual samples. A complex visual pattern appears in the center of the screen then after a short pause, a number of similar patterns appear at the edge of the screen. Of all these patterns only, one matches that of the center. Efficient performance is defined as the ability to reject all unintended patterns and to recognize and point out the correct ones. Percent correct is the variable of interest in this task. A subject with a better performance gets a better score[89, 90].

The rapid visual information processing (RVP)

The RVP task is a 4-min-long visual continuous performance task (CPT). This test was devised by modifying and simplifying Wesnes and Warburton task and is designed to analyze sustained attention [56]. The test has been utilized in schizophrenic patients and subjects having ADHD and social anxiety disorder [56, 91–93]. In the test process numbers from 2 to 9 appear in the center of a screen without any specific arrangement at a rate of 100 numbers/min. Subjects are required to press a specific button whenever the pattern of the numbers is 2–4-6, 3–5-7, or 4–6-8. Seven factors were quantified: (1) number of misses (times in which there is no response despite the pattern being shown); (2) probability of hits (h, times when the subject responds accurately), calculated by dividing the number of hits by the number of hits and misses; (3) total correct rejections (times when subject correctly ignores other patterns); (4) probability of false alarms (f, times 0 when the subject responds inaccurately), calculated by dividing false alarms by total false alarms and correct rejections; (5) A' (calculated as$0.5 + [(h - f) + (h - f)2]/[4 \times h \times (1 - f)]$), a signal detection measure of sensitivity to the target, regardless of response tendency; (6) B" (calculated as$[(h - h2) - (f - f2)]/[(h - h2) + (f - f2)]$), a signal detection measure of the strength of trace needed to cause a response (Sahgal, 1987); and (7) mean latency (mean time needed to react in correct responses) [56].

Dichotic listening test

This test was first designed to assess auditory function and measure hemispheric asymmetry [94]. It is also used as the standard basis for all the tests studying selective auditory attention. In this test, subjects are provided with two sound sequences. Sequences are played in the same ear in one instance while in the other instance, each sequence is played in a different ear. The subject is

then required to only focus on one of the formerly played sequences while rejecting the other. In the instance of dichotic listening, a male voice is presented to one ear and a female voice to the other. On the other hand, in the biotic instance, both ears are presented with both sequences [95]. This test has been used to evaluate the effect of the attentional deficit on the elderly affected by AD [96].

The continuous performance test

The continuous performance test that was first introduced in 1956 is administered to assess sustained attention and selective visual attention [97–99]. In the first round of testing, three tests were undertaken; the Continuous Performance Test, Identical Pairs version (CPT-IP), the Attention Span Task, and the Information Overload Task. The entire round of testing took 1.5 h to carry out. In the initial home visit the Quick Test a demographic questionnaire, and an inventory of perceived attentional styles were also administered. In the second run which is executed for confirming the reliability of the first run over time, only information-processing aspects are re-evaluated [98]. This test has been used on subjects with schizophrenia, ADHD, mania, and alcoholism [100–104].

Motor screening (MOT)

This task screens for difficulties in the visual, movement, and comprehension zone. Results are stated in the form of two indices, the standard score of mean latency (MOT ML) and mean error (MOT ME) [105].

The Cambridge Neuropsychological Test Automated Battery (CANTAB)

Cambridge Neuropsychological Test Automated Battery (CANTAB), is a highly sensitive and objective measures series of cognitive tests developed at the University of Cambridge. Culturally neutral and requiring no technical knowledge or prior familiarity with computers make CANTAB suitable for usage in different studies. CANTAB also offered Web-based testing. Reaction Time (CANTAB-RTI), Rapid Visual Information Processing (CANTAB-RVP), Motor Screening Task (CANTAB-MOT), and Match to Sample Visual Search (CANTAB-MTS) are subtests of CANTAB which can assess the attention and psychomotor speed [106, 107].

The Ruff 2 and 7 test

This test was designed to assess sustained attention and visual selective attention [108, 109]. Using a pen and paper, sustained attention and its voluntary and intentional sides are evaluated using varying distractors. Assessments were done on four groups of patients suffering from a single lesion limited to the right or left anterior or right or left posterior region of the cerebrum. A greater fall in processing rate, independent of the processing mode (serial or parallel), was noticed in patients suffering from a right-hemisphere lesion than in subjects with a left-hemisphere lesion. Moreover, patients with anterior lesions showed a more noticeable contrast between serial and parallel processing, as was forecasted. This difference was the most prominent in subjects with a right frontal lesion [110]. This test has also been utilized on patients suffering from post-concussion syndrome [109]. Changes in the indices of this test by aging and depression have been studied [111, 112]. The validity of the test has been evaluated for outpatient schizophrenic subjects [113].

The Test of Variables of Attention (TOVA)

Test of Variables of Attention (TOVA) is derivative of CPTs and commonly administered to assess sustained attention [114–117]. Subjects in the TOVA are presented with a screen on which two signals are shown, a square in the upper half or a square in the lower half. The subjects are expected to react based on the location of the square, respond if the square is presented in the upper half ('go' signal), and ignore if the square is presented in the lower half ('no-go' signal). Each task includes two constellations of 'go' and 'no-go' trials, differing only in respect of the ratio of the two kinds. In the first constellation, the majority of the trials are 'go' trials assessing whether the subject is capable of denying responses when presenting with an occasional 'no-go' signal. A higher ratio of 'no-go' trials is shown in the later constellation and the subject is assessed whether he or she is capable of a swift response to the infrequent 'go' signals [114, 118–120]. TOVA has been used to diagnose ADHD and TBI [121–123].

Test of everyday attention (TEA)

The test of everyday attention (TEA) includes eight subtests, which are standardized to have an age-adjusted mean of 10 with a standard deviation of 3 for ages between 18 and 80, and by this, it is comparable to that of the Third Edition of Wechsler Adult Intelligence Scale and Wechsler Memory Scale–III [124, 125]. This test is designed to quantify sustained, selective, divided attention and attentional switching, both[20, 126, 127]. The subtest of the TEA is as follows:

TEA—map search

This subtest is devised to quantify visual selective attention, the subject looks at a tourist map of a city and looks for symbols representing different services. For example, a knife and a fork represent eating facilities.

TEA—elevator counting

This subtest is devised to quantify the sustained aspect of attention, asks the subjects to pretend they are in an elevator whose floor indication is not functioning, and by hearing a set of pre-recorded tapes they should guess which floor they have arrived.

TEA—elevator counting with distraction

A subtest of Elevator counting requires the subject to differentiate between high-tone and low-tone sounds as a means to evaluate auditory selective attention.

Visual elevator: subjects are required to count presented doors as a means to evaluate visual attentional switching.

TEA—auditory elevator with reversal

The same as the visual elevator subtest, evaluating auditory attentional switching.

TEA—telephone search

Subjects are required to look for symbols in a phone directory. This subtest assesses visual selective attention.

TEA—telephone search dual task

Subjects are required to do the same as a telephone search subtest but this time counting presented tones at the same time. This subtest assesses divided attention.

TEA—lottery task

Subjects are required to listen to the numbers announced on an audiotape, then write down the two letters preceding a specified number [124, 128–133].

The psychomotor vigilance task (PVT)

The psychomotor vigilance task (PVT), undertaken by a computer, is a test timing widely used to measure reduced fatigue-related changes in alertness due to sleep loss [134]. PVT is considered a validated task for measuring sustained attention [135–137], which is one of the primary components of processes of attention [138]. During the PVT test, the participant reacts to a particular minimal change in the labile environment [139]. In detail, participants monitor a fixed point on a display for the appearance of a millisecond counter and are taught to press a key on the computer when they want to react to a digital signal. Any error concerning missing a signal or pressing the key without a signal will be registered. Significant results which are called PVT performance lapses are those in which the subject reacts in more than 500 ms or does not respond at all [140]. The standard 10-min PVT is often considered impractical in applied contexts, so a modified brief 3-min version of the PVT (PVT-B) is suggested as a useful alternative to this test [141].

Test of everyday attention for children (TEA-Ch)

The Test of Everyday Attention for Children (TEA-Ch), designed for ages 6–16, measures different aspects of attention in children. This test compares a subject's performance to the average score of his age group[128]. This test has been utilized to assess children with ADHD and traumatic brain injury [19, 142–144]. The test provides a means for evaluating selective attention, sustained attention, and executive control [145]. TEA-Ch tests oriented toward sustained attention are the following:

TEA-Ch—Score!

Subject children are asked to mutely count the tones they hear on an audiotape of 15 min. 10 trials are undertaken and the number of tones in each trial ranges between 9 and 15. Intervals between tones are different, and each successfully undertaken trial is counted as one point.

TEA-Ch—Sky Search dual task

A 'dual-task' in which children are required to do Sky Search and Score! subtests at the same time. Therefore, the scores obtained in this subtest measure both sustained and selective attention.

TEA-Ch—Score dual task

A 'dual-task' in which the child is required to do the Score! subtest combining it with another auditory task where the child needs to listen to a news report on an audiotape and look for an animal's name. By the completion of the 10 trials, the child has to give the number of tones heard and the animal's name.

TEA-Ch—Walk, Do Not Walk

Children are required to note down the path on a piece of paper with a pen every time a tone is heard on the audiotape but do not make a mark if a second tone is immediately heard after the first. There are 20 trials in this subtest and the rate of the tones is increasing as the child is going through them. Each point represents one successfully completed trial.

TEA-Ch—code transmission

An audiotape is played for the children and they are required to listen for two '5 s' in a row. After the two '5 s' are heard the child must tell the number just before the two '5 s'.

TEA-Ch tests oriented toward selective attention are the following:

TEA-Ch—Sky Search

Children are tutored to look for specific spaceships on a large piece of paper that is filled with analogous ploy spaceships. In the second part, there is no ploy spaceship, and rules out motor dysfunction.

TEA-Ch—map mission

Children have 1 min to look for target symbols on a map full of distractors.

TEA-Ch tests oriented towards Attentional Control/Switching Focused are the following.

TEA-Ch—Creature Counting

Children start counting numbers until a visual stimulus, which is a creature in a tunnel, is shown. By seeing that stimulus, the child should start counting backward. This process is repeated and both speed and accuracy are considered.

TEA-Ch—Opposite Worlds

The 'Same Worlds' subtest requires the children to say 'one' and 'two' when they see their respective characters. In the later 'Opposite Worlds' subtest children are required to say 'one' when the character for 'two' is visualized and vice versa [128].

AX-Continuous Performance Test (AX-CPT)

Like TOVA, AX-Continuous Performance Test (AX-CPT) is also a derivative of CPTs and is commonly administered to assess sustained attention [114–117]. The AX-CPT is a comparable task in which subjects are required to respond as swiftly as possible to a stimulus or ignore one considering the prior stimulus [114, 146].

The Conners Continuous Performance Test—2

Attention problems, most notably in the sustained domain of attention, are assessed using The Conners Continuous Performance Test—2, utilizing a computer [147–149]. The Conners' CPT is a helpful measure in diagnosing ADHD and has been studied on other disorders such as schizophrenia, TBI, and idiopathic epilepsy [147, 150–155]. 360 stimuli trials are performed on the screen, in letters presented 1, 2, or 4 s apart (ISI: Inter-Stimulus Interval). 18 blocks of 20, is the established division method for the trials. The ISIs are evened out across these blocks. The participation instructions require pressing the spacebar or the appropriate key on the mouse for any letter that appears, excluding the letter "x". Aside from the suggested practice test, it takes fourteen min for the CPT to be put into practice. Non-X stimuli appear 324 times, and the letter "X" (nontarget) appears 36 times during the test. One of the prominent advantages of this paradigm is putting a high quantity of targets to the test; ensuring a larger response database for producing the statistical output [148].

The Madrid Card Sorting Test

This test is the simplified version of the WCST and is done on the computer [156]. This test also features the possibility to undertake an ERP study. The test stimulus battery utilizes 24 response cards of the original 64 in the WCST and the subject is required to match these cards with the 4 stimulus cards based only on one criterion. This can be either the color, shape, or number on the card. A sensitive measure of sorting errors and set-shifting ability was possible only by using unequivocal cards. These sets of cards were used in 137 trials and put into 18 series in a semi-random manner. The intended sorting rule for each series differed and was initially unrecognized by the subjects. The stimuli were designed on the STIM package developed by NeuroScan Inc.; however, can be done in any format that supports at least 256 colors and 40 pixels/cm of resolution. Trials started with a compound stimulus displaying 4 key cards above one choice card showing up on an NEC monitor containing 10,243,768 pixels. The cards were fixed at a horizontal angle of 48 and a vertical angle of 3.58 and 1.5 m apart from the monitor. It was not proven that using smaller stimuli would make a meaningful change in EEG considering eye movement artifacts. Moreover, it is thought to be a deteriorating factor in the acuity of vision in the elderly or subjects suffering from neurological issues. The ideal contrast was achieved by using a black outline for shapes on a completely white background, while card stimuli were illustrated upon a dark one. The brightness of both the cards and the background was fixed at all times. Sequence control of the stimuli was provided by the STIM package but was tested successfully with other similar software such as MEL v1.0 and Presentation v0.50. An IBM computer was used for carrying out different parts of the trials [157].

The Cognitive Assessment Battery (CAB)

In recent years, online mobile-based cognitive assessments developed. One of them is CogniFit General Cognitive Assessment Battery (CAB). Although CAB does not identify the presence or absence of clinical diagnoses, studies found CAB a useful tool for distinguishing between controls and MCI as well as MCI and dementia [158]. The Concentration Cognitive Assessment (CAB-AT) is a tool for assessing attention. Resolution Test REST-SPER, Processing Test REST-INH, Equivalencies Test INH-REST, and Simultaneity Test DIAT-SHIF are subtests of CAB-AT which are development were inspired by CPT, classic Stroop test, TOVA, and Hooper Visual Organization Task, which was originally

developed as a screening instrument for neurological dysfunction but subsequently has been used as a test of visuospatial skills [159].

Table 1 is a summary of the characteristics of cognitive tests concerning the attentive function in humans. All the mentioned tests are developed for assessing attention in patients with stable conditions and without significant disabilities. The conventional tests, which typically require the ability to read or use a computer, along with the ability to comprehend verbal instructions and executive tasks, are incompatible with some populations due to significant intelligence deficits or low cognitive and social functioning, which have been considered "untestable"[160]. Such characteristics are common in people with Intellectual Disability or Autism Spectrum Disorder (ASD), who are identified with limited abilities to understand instructions and perform tasks [161]. Cooperation and communication impairment are two significant factors in the difficulty of testing people with intellectual disability or ASD who have trouble understanding and responding to instructions [162, 163]. Ho has trouble understanding and responding to instructions. Hence, in some previous studies, examiners invited examinees to engage in a game to improve their motivation by creating a playful test environment [164–167].

Evaluating unstable patients

It is noteworthy that only a few tests are compatible with the needs of individuals who exhibit such characteristics. According to a systematic review study, three tests and three batteries are appropriate for assessing people with intellectual disability or ASD. The tests mentioned were the Test of Auditory Discrimination, the Integrated and Visual and Auditory Continuous Performance Test (IVA-CPT), and Posner's Paradigm, while the batteries identified were the Cognitive Assessment System (CAS), TEA, and the Leiter international performance scale–revised (Leiter-R)[161].

Integrated and Visual and Auditory Continuous Performance Test (IVACPT)

The Integrated Visual and Auditory (IVA) CPT is made up of 22 subscales that provide information on inattention, inhibition, response consistency, attention diversity, and overall reaction time discrimination. It can assess inattention and impulsivity in the visual and auditory domains on the same task. When a computer screen displays a target stimulus, the individual must hit a button. However, when non-target stimuli flash, the user must not press the button. The IVA can be administered to individuals aged 5 and above. The IVA-CPT was created to aid in the measurement of ADHD symptoms; however, it has been used to assess attention and impulsivity in several neurodevelopmental disorders. The test evaluates sustained attention, processing speed, and attention consistency over time [168–171].

Test of auditory discrimination

This test assesses auditory distractibility, attention, and discrimination by asking the participant to detect speech sounds in both quiet and distracting (background noise) listening environments. It can be used on people aged 44 months to 70 years and older [170, 172].

Posner's paradigm

The Posner paradigm is a computer task that takes roughly 45 min to complete. This entails identifying a target (for example, a star, letters, or other symbols). The target is preceded by a cue that is either valid (indicates the target location correctly), invalid (indicates the target location incorrectly), or neutral (no indication of target location). Invalid trials necessitate the participant to disengage from the incorrectly cued location and shift to the proper one [173, 174].

Cognitive Assessment System (CAS)

CAS consists of three attention subtests, including expressive attention (The task for children aged 5 to 7 years includes pictures of ordinary animals; they must determine whether the animal depicted in real life is large or small, regardless of the relative size of the screen image; and those aged 8 to 18 are asked to name the color of the ink used to print the word rather than read that word), number detection (The aim is to identify specific numbers on a page (for ages 5 to 7 years) or specific numbers in a particular font (for ages 8 to 18 years) by underlying them), as well as receptive attention (The task is to underline pairs of objects or letters that either are identical in appearance or are the same from a lexical perspective.) [175, 176].

Test of everyday attention (TEA)

As previously stated, it was used to evaluate the capacity for selective or focused attention. This test involves quickly scanning a telephone directory page for specific symbols. The summary score is calculated by dividing the amount of time it took to search the page for symbols by the number of symbols correctly identified [177, 178].

Leiter International Performance Scale–Revised (Leiter-R)

The Leiter International Performance Scale–Revised (Leiter-R), includes 20 subtests in the visual function and reasoning battery (measuring nonverbal intelligence in the form of visual functioning, reasoning, and visuospatial skills) and the memory and attention battery (evaluating performance in memory and attention domains).

Leiter-R is approved for people aged 2 months and 0 months to 20 years and 11 months [179].

In addition, there are procedures and adaptations in the test set that make it more compatible with this population. Including the training sessions that necessitate more direct interaction between examiner and examinee, extra testing time, and the development of a device that allows the gradual discrimination of each test element. How instructions are communicated is also a significant factor in comprehending the instructions. Many authors point to the value of using short, simple as well as regularly repeating sentences, and speaking enthusiastically and encouragingly [161].

From another point of view, since the performance of conventional neuropsychological tests is multifaceted and often requires intact upper limb function, their administration is limited in patients with upper limb disability and compromised motor function who are referred to rehabilitation settings and outpatient follow-up clinics due to interpretation difficulty. Upper limb dysfunction resulting in a stroke can range from complete immobility, as in limb amputation and hemiparesis to more subtle motor impairment in neurological disorders such as multiple sclerosis (MS) and Parkinson's disease [180]. Therefore, two modified tests in this population group have been developed and widely used, which include:

The Oral Trail Making Test (OTMT)

In oral TMT, the subject counts as swiftly as they can from 1 to 25 (OTMT-A) and switches between numbers and letters (OTMT-B; 1-A-2-B-3-c, and so on). At number 13, the timing was stopped. The time to completion is the outcome measure for the OTMT-A and OTMT-B[181]. An oral TMT paradigm has the potential to be used in a clinical setting as an alternate measure of cognitive flexibility.

The Symbol Digit Modalities Test-oral (SDMT-oral)

Participants are given a written key of symbol-digit pairs with a number ranging from 1 to 9 in the oral format of SDMT. A list of 110 symbols is presented to the participant, who must provide verbal answers to the relevant number for as many of the symbols as possible within a time limit of 90 s[182]. Since its inception, the SDMT-oral has been utilized with varying degrees of regularity, most notably as part of neuropsychological assessment batteries in MS. The SDMT-oral is more recommended for clinical application[180].

It should also be mentioned that, due to the wide variety of available psychological tests, selecting the appropriate test for particular clinical groups is not challenging. For example, WCST or CANTAB, which we described before, appear to be appropriate in children with developmental language disorder who are classified as having language functional abnormalities in the absence of a definite etiology [183, 184].

Discussion and conclusion

There are multiple batteries for evaluating different parts of attention including, but not limited to, the Stroop test, continuous performance test, test of everyday attention for children, psychomotor vigilance test, and Wisconsin Card Sorting Test. Although the scientific study of attention, began in psychology, at this point, a debate about the different underlying mechanisms of these behavioral patterns is still ongoing. This review can be used for designing future studies regarding this domain of human cognition.

Beyond the historical definition of attention as a selection of wanted messages from unwanted ones (filter mechanism), another proposed mechanism for attention is to take up the level of the most important arriving signal [185–187]. Attention is vital for the proper functioning of the rest of our cognitive capacities. The application of attention in machine learning has added to its importance in recent years [188]. Improving the input–output models as well as adopting new primitives in deep learning methods is similar to what happens in the brain during the attention process; therefore, modeling complex systems with attention mechanisms, has multiple benefits such as focusing on a subset of elements and temporal dimensions [189].

Limitations and future directions

This study's limitations should be taken into consideration when interpreting its results. First, the strategy used to identify additional journals with the scope of untestable patients may have excluded studies published in scientific journals in which these terms do not appear as part of the title/abstract or scoping interests; which suggested getting focused in future studies. Second, we consulted one specialist database for locating papers and search reference lists of the included papers as well as reference lists of literature reviews that were discovered during the screening process. Additional web searches may yield more thorough descriptions of patients who have difficulty applying traditional tests. By properly establishing the search protocol and utilizing numerous pertinent datasets, such bias can be reduced.

Abbreviations

ADHD	Deficit hyperactivity disorders
AD	Alzheimer's disease
MCI	Mild cognitive impairment
DGS	Digit Span Test
RT	Reaction time
WCST	Wisconsin Card Sorting Test

RVP	Rapid Visual Information Processing
MOT	Motor screening
CANTAB	Cambridge Neuropsychological Test Automated Battery
TOVA	Test of Variables of Attention
TEA	Test of everyday attention
PVT	Psychomotor vigilance task
AX-CPT	AX-Continuous Performance Test
CAB	Cognitive Assessment Battery
ASD	Autism spectrum disorder
IVA	Integrated Visual and Auditory
CAS	Cognitive Assessment System
MS	Multiple sclerosis
OTMT	Oral Trail Making Test
SDMT-oral	Symbol Digit Modalities Test-oral

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