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REVIEW ARTICLE

Cognitive estimation abilities in healthy and clinical populations: the use of the Cognitive Estimation Test

Gabriela Peretti Wagner · Sarah E. MacPherson · Maria Alice M. P. Parente · Clarissa M. Trentini

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Abstract Estimation abilities are a group of processes that involve functions such as planning, attention, abstract reasoning, and also mnemonic processes, like semantic and working memory. They are allocated in order to solve problems for which the answers are not readily available. Estimation abilities can be measured using the Cognitive Estimation Test (CET). The aim of this article was to review the use of the CET and other tests of cognitive estimation in healthy and pathological populations. We discussed studies examining correlations between the CET and other measures of executive functions and the importance of the standardization of measures that assess estimation abilities.

Keywords Cognitive estimation test · Estimation abilities · Executive functions

Introduction

Estimation abilities are a group of cognitive functions allocated when an immediate answer is not available, but the response can be guessed using general knowledge from semantic memory [35]. For example, these processes can be required when an individual needs to estimate the distance between two streets in order to give someone directions or when a host has to estimate if the food s/he is preparing is enough for his/her guests. This group of functions can be assessed in different ways, including neuropsychological tests.

One such neuropsychological test is the Cognitive Estimation Test (CET), originally devised by Shallice and Evans [35] in order to investigate estimation abilities in frontal brain damaged patients. Shallice and Evans [35] created the CET after evaluating a patient, J.S., who suffered a brain lesion after an explosion. J.S. was extensively investigated and, despite having preserved general cognitive abilities, showed a "gross inability to produce adequate cognitive estimates" [35, pp. 294–295]. For example, patient J.S. answered that the largest fish in the world was a trout, estimating its length at three feet. Based on this case study, the authors devised the CET and administered it to a sample of frontal brain damaged patients due to different aetiologies.

The frontal lobes are localized in the anterior part of the brain and are described as playing a role in processing executive abilities. Often executive abilities and frontal lobes are erroneously used as synonymous [42, 43]. Executive processes are functionally more complex, as the frontal lobes have connections with almost all other areas of the brain. Each of these circuits plays a role in other cognitive abilities, generating a multidimensional and multicomponential construct–executive functions [20]. Executive functions allow individuals to evaluate their situation in order to achieve their goal, and then carry out a plan to achieve that goal and include processes such as problem solving, decision making, planning, initiation, inhibition and monitoring [42]. These executive processes are thought to play an important role in CET performance

G. P. Wagner (✉) · M. A. M. P. Parente · C. M. Trentini
The Institute of Psychology and the Psychology Post-Graduate Program, Universidade Federal do Rio Grande do Sul – UFRGS, Porto Alegre, Brazil
e-mail: gabrielapwagner@gmail.com

S. E. MacPherson
Centre for Cognitive Ageing and Cognitive Epidemiology, Human Cognitive Neuroscience, Department of Psychology, University of Edinburgh, Edinburgh, UK

and Shallice and Evan's [35] study demonstrated deficits on the task in the frontal group.

Since the original study was published [35] several other studies have been conducted in order to investigate cognitive estimation abilities in different clinical populations (for example, [4, 13, 44]). The aims of the present review were to discuss the use of different versions of the CET for both adaptation and standardization purposes, and the assessment of clinical samples of neurological patients.

Cognitive estimation abilities and executive functions

Cognitive estimation abilities rely on cognitive processes such as attention, reasoning, cognitive flexibility, imagery and in particular problem solving [39]. One might be asked, "What is the length of one dollar bill?" In order to answer this question, an individual must allocate attention to the main components of the problem, search for previous knowledge that could help answer the question, use reasoning abilities to select the appropriate problem solving strategy, make a decision about which one should be used, and put it into practice for later evaluation. For example, the individual has to think about the main information related to the question, reflecting on the length of monetary notes, imagining them and perhaps comparing them with the length of a ruler or hand (for example), choosing the most appropriate strategy, and then answering the question by putting the strategy into practice.

The CET is also thought to rely upon executive abilities, which are a multi-dimensional entity [20, 42, 43], involving mainly working memory, inhibition, shifting [19], attentional set [11], and verbal fluency [15]. It has long been established in the scientific literature that the frontal lobes of the brain play a role in executive functions [43]. Several studies have demonstrated that patients with frontal brain lesions show impairments on tasks tapping executive functions such as the Wisconsin Card Sorting Test (WCST—[2, 5], the Tower of London [34], and the Stroop Color Word Test [41]).

A relationship between cognitive estimation abilities and the frontal lobes, structures involved in processing executive functions, was first discovered by Shallice and Evans [35]. These authors assessed 96 participants, divided into four groups according to the location and the lateralization of their brain lesion. Twenty-one left anterior, 24 right anterior, 24 left posterior, and 27 right posterior brain lesion patients were compared with 25 controls with extracerebral tumors. All participants had to answer a list of 26 items devised to assess cognitive estimation abilities. However, as there was a large variance on 11 of the items, these were later excluded and only 15 items were finally analyzed. Shallice and Evans [35] demonstrated that the patients with left and right anterior lesions showed the poorest performance on the task. These participants provided more extreme over- or underestimates to the questions, which were classified as bizarre. For example, estimations of two meters for the length of a man's spine or 50 m for the height of Empire State building were considered bizarre.

Some other studies have also showed a relationship between estimation abilities measured by CET and executive functions. In these studies, other measures of executive functions were used in association with CET. For example, in Shoqeirat et al. [36], estimation abilities and executive functions tapped by FAS (COWAT—Controlled Oral Word Association Test—[40] both discriminated healthy participants from three clinical groups (CET—$F(1,60) = 18.2$, $p < 0.001$/FAS—$F(1,60) = 13.9$, $p < 0.001$), which included Korsakoff syndrome, ruptured anterior communicating artery aneurism, and post-encephalitis due to herpes simplex patients. The same pattern of results was found by Brand et al. [7] and Spencer and Johnson-Greene [38]. In the Brand et al. [7] study, performance on estimations abilities (bizarre estimation errors) and executive functions (assessed by FAS) was correlated ($r = -0.43$, $p = 0.02$). In the Spencer and Johnson-Greene [38] study, significant correlations between executive measures (FAS and Rey Complex Figure Test—RCFT—[26] and CET ($p < 0.001$) were found. For FAS, the correlation index was $r = -0.35$; for RCFT, it was $r = -0.48$. These findings suggest that the CET correlates with the planning (RCFT) and flexibility (FAS) components of executive functions.

Nonetheless, it is important to mention that the estimation abilities measured by the CET [35] are not always related to other measures of executive functions and/or to frontal brain lesions. For example, Taylor and O'Carroll [44] assessed a large group of patients with different neurological conditions. The authors did not find a significant difference on CET performance between anterior and posterior lesioned groups, weakening the evidence of the CET as a measure sensitive to frontal lobe damage. Such studies, e.g., Brand et al. [7], Shoqeirat et al. [36], Spencer and Johnson-Greene [38], and Taylor and O'Carroll [44] will be discussed later in more detail in the clinical samples section.

In summary, there is some evidence showing that frontal lobe lesions impair cognitive estimation abilities [35] and the literature has provided evidence to establish the role of the frontal lobes in executive processing [2, 5, 43]. Some other studies have shown a relationship between other executive measures and estimation abilities [7, 36, 38]. At the same time, some studies have failed to provide confirmation of the association between estimation abilities and executive functions (for example, Taylor and O'Carroll [44]). Based on these findings, one might say that executive functions and estimation processes can be related.

Assessing cognitive estimation abilities

As we have just discussed, some studies have shown associations between cognitive estimation abilities and executive functions. Executive functions are a concept that involves a group of processes [24], and these can be assessed using a number of different tasks [12, 43]. To assess estimation abilities, three main tests have been adopted in the scientific literature: the Cognitive Estimation Test (CET—[35]); *Test Zum Kognitiven Schätzen* (TKS—[6]) and Biber Cognitive Estimation Test (BCET—[9]). Shallice and Evans's [35] version of the CET consists of a list of two types of questions: quantitative (e.g. "How fast do race horses gallop?") and qualitative (e.g. "What is the largest fish in the world?"). In order to score the task, the authors used a four-point scale (normal, quite extreme, extreme and very extreme), based on the answers of the control group. This scale was used to score patients' answers, which were evaluated as being greater or smaller than the correct answer. "Considering responses greater than the correct one, any answer greater than any of the estimates given by the control group was rated as very extreme, other answers greater than all-but-one of the control group's ones were rated as extreme and those greater than all-but-two as quite extreme" [35, p. 298]. The same procedure was adopted for responses smaller than the correct answer. Omissions were scored as extreme [35].

The *Test zum kognitiven Schätzen* (TKS—[6] is a 16-item test, with four questions for each dimension. These dimensions are size, weight, quantity, and time. Unlike the CET [35]), in the TKS, participants must answer the questions based on pictures of objects presented on cards (one picture per question). The range of correct answers was developed using means and standard deviations (one S.D. of the solution of the normative group—[8]. The procedure of presenting the cards helps to separate executive processes from some of the memory functions because it reduces the mnemonic load. This can be a useful procedure to assess different groups of amnesic patients, like Korsakoff syndrome and Alzheimer's Disease (AD), for example [7, 8].

The Biber Cognitive Estimation Test (BCET—[9]) is a 20-item test with five estimation questions for each of four categories—distance, quantity, weight, and time/duration. The main difference between CET [35] and BCET [9] is that the latter also stipulates the unit of measurement that the answer should be given in for each question. For example, when a participant is asked the length of a tablespoon, the answer must be in inches. The BCET was standardized by Bullard et al. [9], who evaluated demented patients on the task (like [8] but also other clinical samples, such as traumatic brain injury [37], and child development studies [18]). Despite the existence of these two other tests tapping cognitive estimation abilities, the focus of the current review is on the traditional CET and the versions that were devised subsequently from it. In the next section, we are going to discuss standardized versions of the CET and its use in healthy subjects.

Standardization of Cognitive Estimation Test and testing healthy individuals

The Cognitive Estimation Test (CET—[35]) has been used in several studies of healthy individuals. Some of these studies involve standardization of items to be used with individuals from different cultures [4, 13, 29] as collecting normative data and standardizing cognitive instruments is important for neuropsychological evaluation. Patients and participants must be compared with an individual from their own culture for a valid and reliable result (American Educational Research Association—AERA [1, 10]).

O'Carroll et al. [29] carried out a study in a British sample in order to test some psychometric properties of Shallice and Evan's CET. The authors tested 150 healthy participants in order to provide normative data for a 10-item version of original CET. They also investigated the relationship between variables such as age, gender, intelligence, social class, and education on CET performance. Gender differences emerged from their study, with women performing significantly more poorly (M $= 6.2$; SD $= 3.5$) when compared with men (M $= 4.5$; SD $= 3.5$) ($t = 4.04$; $p < 0.01$). The correlation between age and CET performance was low ($r = 0.14$) and not significant. Regarding the other demographic variables, CET significantly correlated with education ($r = -0.30$; $p < 0.01$), and social class ($r = 0.20$; $p < 0.05$). Finally, CET performance was correlated with IQ, as measured by the National Adult Reading Test (NART—[27] ($r = 0.30$; $p < 0.01$), which provides an estimate of pre-morbid intellectual ability by measuring reading abilities of regular and non regular words.

After examining the influence of demographic variables on CET performance in the sample, O'Carroll et al. [29] also investigated some psychometric properties. The authors analyzed the factor structure of the CET through a factor analysis (varimax rotation). They found a five-factor result, with each factor having an eigenvalue greater than one. The explained variance was 64.4%. Finally, O'Carroll et al. [29] also ran an internal reliability analysis where Cronbach's alpha was 0.40 and Guttman's split-half reliability coefficient was 0.35. The authors explain these low psychometric properties are a result of the variation of the items across the scale itself.

Other authors have also tried to standardize the CET. In the USA, Axelrod and Millis [4] carried out a study with an American adaptation of the instrument aiming to collect normative data. The authors assessed 164 adults (122 women) with a mean age of 39 years (SD = 16.1) on a 10-item version of the task. An important contribution from Axelrod and Millis's [4] study is the method used to develop the deviation score. The authors defined a score of 0 for answers between the 16th and 84th percentiles, and a score of 1 for responses that ranged from the 2nd to 16th percentiles and also for those from the 84th to 98th percentiles. Finally, a deviation score of two was used for responses less than the 2nd percentile and greater than the 98th percentile. A higher deviation score implied poorer performance on the CET.

Axelrod and Millis [4] found significant differences between the different educational groups where deviation scores were lower for individuals who were better educated. However, as in the O'Carroll et al. [29] study, Axelrod and Millis [4] did not find age effects on CET performance. Axelrod and Millis [4] also analyzed some psychometric properties of the instrument: item-total correlations and clinical validity. Regarding item-total correlations, the authors found values ranging from 0.22 to 0.57, with $p < 0.001$.

Clinical validity was also assessed comparing severe traumatic brain-injured (TBI) patients ($n = 30$) to healthy controls ($n = 30$) [4]. The groups did not significantly differ in age, but did in education, with the patient group having significantly fewer years of education [$t(58) = -2.8$, $p = 0.008$]. The results confirmed the hypothesis—patients showed a lower performance on the CET (M = 8.1; SD = 3.2) when compared with healthy controls (M = 4.5; SD = 2.0). However, due to the differences in education, it is not possible to say that the differences on CET performance are exclusively caused by TBI.

Della Sala et al. [13] provided normative data for an Italian version of the CET. These authors assessed a sample of 175 healthy Italian participants aged between 18 and 87 years. They were divided into three age groups, which did not significantly differ in terms of educational level. Participants answered a 21-item version of the CET. Again, the authors found no affect of healthy adult aging on CET performance [4, 29].

In addition, the Italian version of the CET [13] compares two methods of CET scoring; an absolute error score and a bizarreness score. For the absolute error score, each response is awarded a score of 0, 1 or 2, with higher scores indicating the worst performance. When an estimate is between 0 and 30% above or below the correct answer, it is awarded an error score of 0; responses between 31 and 90% above, or below the correct answer are awarded a score of 1; finally, estimates of more than 90% above, or below the correct answer are awarded 2 points. These authors also used a bizarreness score which was produced by five judges. The judges had to specify maximum and minimum cut-off scores for each question, based on the range of responses provided by Alzheimer's disease patients and healthy controls. Then, the responses were classified as non bizarre (score 0) or bizarre (score 1). As in the case of the absolute error score, the greater the bizarreness score, the worse the performance on the CET.

In a second study, Della Sala et al. [14] assessed 175 healthy participants aged from 18 to 87 on CET performance and investigated the role of general knowledge (General Knowledge of the World test—GKW) on the task. The results did not show significant age effects on either CET performance or GKW test. However, GKW and CET were correlated suggesting that semantic knowledge plays a role on estimation abilities. This correlation was low ($r = -0.27$), but significant ($p < 0.0001$).

A final study by Gillespie et al. [15] investigated whether there are age effects on the CET. These authors used a shortened 10-item version of the original one. Each item was scored from 0 to 3, with a higher score again indicating poorer performance. The results did not show any correlation between CET performance and age. Gillespie et al. [15] also tried to verify possible relations among the CET and another two tasks of cognitive estimation (a task devised by the authors), the Novel Estimation Questions—n-EQ, and the estimation part of the Behavioural Assessment of Dysexecutive Syndrome (BADS—[48]), but no correlations reached significance.

The studies discussed above all included versions of the CET that involved standardization [4, 13, 29] and/or testing of healthy controls [15]. In the next section, we will present some studies using the CET to assess clinical samples. As a measure of executive functions, the CET has been administered to different neurological populations, in order to examine its use as a diagnostic tool of diverse diseases.

Using Cognitive Estimation Test to test clinical populations

Several studies have been carried out in order to test different clinical populations on the CET, such as stroke [38], Parkinson's disease [3], frontal lobe lesions, Alzheimer's disease [14, 17, 23], diencephalic amnesia due to different etiologies [22, 36], and many others, such as brain tumors, different dementias, and psychiatric conditions (Taylor and O'Carroll [44]). Assessing clinical populations is important as it provides evidence of validity (American Educational Research Association—AERA, American Psychological Association—APA, and National Council on Measurement in Education—NCME [1, 30, 45]).

Leng and Parkin [22] assessed patients suffering from organic diencephalic amnesia involving the frontal lobes. The authors investigated 13 patients: 7 with Korsakoff's syndrome, 5 suffering from encephalitis caused by Herpes Simplex, and one patient with an orbitofrontal lesion caused by an anterior communicating artery aneurysm (ACoAA). Patients' performance on tests of memory, IQ and executive function was compared with healthy controls. Regarding the CET [35], the post-encephalitic patients showed the worst performance (M = 11.6; SD = 3.8), followed by the patient with an orbitofrontal lesion (score of seven), Korsakoff patients (M = 4.0; SD = 1.3), and the controls (M = 2.9; SD = 3.8). As the patient with an orbitofrontal lesion had a similar performance to the post-encephalitic individuals on the CET, Leng and Parkin [22] argued that this was evidence of the CET being sensitive to orbitofrontal damage. This finding requires further investigation to be confirmed.

Shoqeirat et al. [36] conducted a study in order to replicate Leng and Parkin [22] results in a larger group of patients. Shoqeirat et al. [36] assessed patients from the same clinical groups as Leng and Parking's study (16 with alcoholic Korsakoff syndrome, 10 post-encephalitic by Herpes Simplex amnesic participants, and five amnesic individuals due to ACoAA), comparing them to 31 matching controls. Participants were evaluated using the same tasks—the modified WCST and the CET—and also by two additional tasks of executive functions—the full version of the WCST and FAS Word Fluency Test. Both versions of the WCST were given to patients in order to find out which version is more sensitive at differentiating the performance of post-encephalitic amnesic patients [36].

In contrast to Leng and Parkin [22], Shoqeirat et al. [36] found that all amnesic patients performed more poorly on the CET and FAS compared with controls, but the executive tasks did not discriminate between the three amnesic groups. In terms of the full and modified versions of the WCST, the post-encephalitis patients performed the tasks within normal limits, while the other two patient groups were impaired on both tests. Given that the post-encephalitis and ACoAA patients performed poorly on the CET, Leng and Parkin [22] suggested that the CET can be used to assess orbitofrontal functions. Nonetheless, further studies are needed to support this claim, especially as both studies [22, 36] do not provide specific lesion localization information for the three groups of patients.

A few years later, Taylor and O'Carroll [44] carried out a study involving 370 participants suffering from neurological conditions with different etiologies or psychiatric diseases: head injury ($n = 94$), brain tumor ($n = 15$), subarachnoid hemorrhage from ACoAA ($n = 22$), subarachnoid hemorrhage as a result of other aneurysms ($n = 17$), encephalitis ($n = 17$), early dementia ($n = 19$), dementia of unknown cause ($n = 22$), multiple sclerosis ($n = 38$), anxiety or depression ($n = 22$), and alcoholic Korsakoff's syndrome ($n = 18$). Their performance on the 10-item version of the CET used by Shoqeirat et al. [36] was compared with 150 healthy control participants. The results showed that the Korsakoff patients were the only patients who performed significantly more poorly in terms of CET performance. The poor performance of the Korsakoff patients in making cognitive estimations supports the Leng and Parkin [22] findings. However, as the patients with anterior brain lesions did not show deficits in CET performance, Taylor and O'Carroll [44] failed to provide evidence that the CET is a measure of frontal lobe dysfunction.

Since the publication of these earlier studies, the CET has became international in terms of assessing clinical populations, adopting different versions of the CET to assess Alzheimer's Disease in the United States [17], Italy [14], and Canada [23], non-demented Parkinson's disease patients [3] and stroke patients [38]. For example, Goldstein et al. [17] assessed 25 individuals diagnosed with probable AD and 16 control subjects with a modified version of the Shallice and Evans [35] CET. In their 15-item questionnaire, there were items that required either quantitative or qualitative answers, as well as an index card with a picture for each question to reduce memory load. Responses were classified as quite extreme, extreme, and very extreme according to Shallice and Evans [35] and qualitative and quantitative answers were scored according to a normative group. Both the patient and control groups were then compared with the normative one. AD patients performed significantly more poorly than the control group in terms of the number of extreme answers for both quantitative and qualitative answers on the CET ($p < 0.01$).

In a second experiment, Goldstein et al. [17] used a revised CET to test AD patients whereby they assessed the participants using the same questions but with four alternatives (choices) for answers where one was the target answer. Again, when compared with the control participants' answers, AD patients showed performance deficits, as patients chose nontarget answers more often than healthy participants, for both quantitative and qualitative questions.

After evaluating healthy older adults on CET performance, Della Sala et al. [14] also tested 27 AD patients and compared them with 27 controls matched by age and years of education. As in Goldstein et al. [17], the AD patients showed significantly poorer performance on the CET, providing more extreme answers than the healthy control participants ($p < 0.0001$). Therefore, Della Sala et al.'s [14] study confirms Goldstein et al.'s [17] findings that Alzheimer's disease impairs performance on the CET.

In a more recent study, AD patients and Mild Cognitive Impairment (MCI) patients were assessed on the CET as little is known about how MCI patients perform the task [23]. MCI is a neurological condition resulting in cognitive deficits that are not as severe as dementia [31]. Some authors consider MCI to be a pre-dementia condition, as 10–15% of patients diagnosed with MCI convert to dementia per year [32]. Therefore, the CET may be used as a clinical tool for early diagnosis of cognitive deficits. Levinoff et al. [23] conducted a study with a modified 23-item version of the CET based on both Shallice and Evans [35] and Axelrod and Millis [4], but also including their own items. The authors first assessed 69 healthy participants on a final version of the CET and 15 quantitative questions were generated.

After devising this new version of the CET, Levinoff et al. [23] assessed 40 normal elderly controls (NEC), 73 MCI patients, and 40 AD participants. The authors analyzed the results using analysis of covariance with age and education entered as covariates. The CET results indicated a significant group effect ($p < 0.001$), with AD patients performing worse than NEC and MCI participants. However, NEC and MCI group differences were not significant. Therefore, the CET discriminates between AD patients and healthy control participants but not MCI.

Della Sala et al. [14] also assessed frontal lobe damaged patients on their Italian version of the CET [13]. The patient group included 16 frontal patients due to traumatic brain injury and five due to stroke who were compared with 21 healthy control participants. Participants' performance was scored according to Della Sala et al. [13] procedure, including an error score and a bizarreness score. Patients with frontal lobe lesions were impaired on the CET performance when compared with healthy participants [14]. The differences between the groups were significant on error score ($p < 0.0001$) and the bizarreness score ($p < 0.0001$). Thus, Della Sala et al. [14] confirmed Shallice and Evans's [35] results that the CET is sensitive to frontal lobe damage.

The CET was also used to assess non-demented patients with Parkinson's Disease [3]. The authors investigated the performance of 30 participants on the Italian version of the CET and also on STEP (*Stime dei Tempi e dei Pesi*—[28]). This latter test is composed of two 10-item sections, focusing on time and weight. These patients showed no significant deficits on the CET (only two patients—6%—showed a pathological performance on it). The same pattern of results was found on the STEP (three patients—10%—showed performance difficulties).

A recent investigation using the CET in clinical populations was conducted by Spencer and Johnson-Greene [38]. These authors examined 112 participants, all of whom were receiving rehabilitation care due to neurological conditions. Overall, 88 stroke patients (38 in the left hemisphere and 50 in the right hemisphere) and 24 participants with mixed neurological conditions were evaluated on Axelrod and Millis's [4] version of the CET. The authors also used other tasks of executive functions—Controlled Oral Word Association Test (COWAT—[40]) and Rey Complex Figure Test (RCFT—[26])—in order to investigate associations with CET performance. The results showed that the CET is significantly associated with gender and years of education, but not age. No significant differences emerged in CET performance between participants in different diagnostic groups ($p = 0.81$). Regarding the other executive measures, the correlation between COWAT and CET performance was low ($r = -0.35$) while the RCFT and CET had a medium correlation ($r = -0.48$). So, it seems that CET performance is more associated with executive components involving planning abilities than with the verbal fluency component of executive functions.

Another recent investigation using CET was published by Margraf et al. [25]. In this study, the authors investigated a group of patients suffering from subcortical ischemic vascular disease (SIVD). The SIVD causes ischemic damage to tissues from the brain stem, the basal ganglia and the subcortical white matter. According to the authors, as the disease can affect frontal connections and pathways, executive dysfunction can be disrupted. In order to evaluate the presence of dysexecutive symptoms, the authors assessed 17 patients and an equal number of healthy controls (matched for age, years of education, premorbid IQ and gender). The executive tests used were the clock drawing task (CLOX), the Tower of London task (ToL), tests of verbal and figural fluency, and the CET. Significant differences between the patients and controls emerged on all executive tests, except the CET. Other studies assessing executive abilities have also shown patients with impairments on some executive tasks but not others [21, 33, 46, 47]. Therefore, it may be that the CET is not sensitive to executive dysfunction due to SIVD, but is sensitive in other patient groups. Moreover, the results of Margraf et al. [25] may point to a lack sensitivity of the CET with subcortical lesions.

Finally, it is possible that cognitive estimation is a more complex function that reflects the diversity of executive functions and therefore devising a test of estimation abilities is complicated. As executive functions are a group of processes that control and regulate basic lower level cognitive functions, it is important to ascertain which basic abilities are being allocated to each question in the task. When questions are too difficult for the participant, they can be answered by guesses, resulting in impulsivity and/or lack of reasoning. On the other hand, if the questions are part of the individual's knowledge, s/he can answer the task using information stored in memory. Well developed questions must avoid these extremes and stay concentrated in the middle (in terms of level of difficulty), so the items of the task might allocate decision making, reasoning, working memory, and semantics. In this sense, depending on the items chosen for the task, the questions may or may not assess executive functions. So, developing a task with questions tapping pure executive abilities might be the next step.

Conclusion

In the last section, we attempted to provide evidence for the use of the CET for detecting impairments in clinical samples. As we have described, the CET has been show to be associated with frontal lobe injury and executive dysfunction in some studies [14, 22, 35, 36]. However, it remains unclear whether there is a specific area of the frontal lobes required to answer estimation questions successfully [22, 36]. The CET can also be a useful test to help to detect estimation difficulties in Korsakoff syndrome. Nonetheless, as these patients typically have memory deficits, it is not clear whether memory deficits or executive deficits underlie their impairments. Further studies are needed to investigate this issue.

The CET also shows estimation deficits in AD patients [14, 17, 23], especially as effects of healthy adult aging are not found on the task [13, 15]. Nonetheless, these studies have not investigated executive abilities in AD patients and their relationship with CET performance. Therefore, it would be useful to separate AD patients into those with dysexecutive and those without dysexecutive function to examine the underlying causes of poor CET performance in these patients.

The CET has also been used to assess estimation abilities in other neurological and psychiatric conditions. However, Taylor and O'Carroll [44] only found significant differences between Korsakoff syndrome and controls. However, it is possible to find very different patterns in terms of symptoms within the same condition. For example, brain tumors can proliferate in different areas of the encephalon where a left parietal brain tumor may evoke different symptoms from a right parietal one. The same issues can be addressed in the case of strokes where the hemisphere, the affected brain area, and the etiology (ischemic or hemorrhagic) can cause different cognitive symptoms. Such factors must be taken into account when attempting to understand the cognitive deficits associated with different conditions. Therefore, it is important to consider etiology and localization when comparing different clinical groups on their estimation and executive abilities.

Finally, it is important to think about the neuropsychological processes tapped by the CET when assessing the patients. As the estimation abilities and executive functions seem to rely on different cognitive functions, it is important to be sure what the patient really knows and what s/he is thinking when estimating the answer to certain questions. It might be the case that, when assessed with the CET, participants are using different cognitive resources, which means that the estimation component is not necessarily being assessed by the task. Further research is needed in order to explore exactly which cognitive abilities are requested when someone is trying to make an estimation. Also, isolating the executive components and developing specific questions to tap them might be useful to solve the controversies regarding the association between CET performance and other executive tasks.

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References

1. American Educational Research Association, American Psychological Association, & National Council on Measurement in Education (1999). Standards for Educational and Psychological Testing. AERA, Washington, DC
2. Anderson SW, Damasio H, Jones RD, Tranel D (1991) Wisconsin card sorting test performance as a measure of frontal lobe damage. J Clin Exp Neuropsychol 13(6):909–922
3. Appollonio IM, Russo A, Isella V, Forapani E, Villa ML, Piolti R, Frattola L (2003) Cognitive estimation: comparison of two tests in nondemented parkinsonian patients. Neurol Sci 24:153–154
4. Axelrod BN, Millis SR (1994) Preliminary standardization of the Cognitive Estimation Test. Assessment 1(3):269–274
5. Bechara A, Damasio H, Damasio AR (2000) Emotion, decision making and the orbitofrontal cortex. Cereb Cortex 10:295–307
6. Brand M, Kalbe E, Kessler J (2002) Test zum kognitiven Schätze. Hogrefe, Göttingen
7. Brand M, Fujiwara E, Kalbe E, Steingass HP, Kessler J, Markowitsch HJ (2003) Cognitive estimation and affective judgments in alcoholic Korsakoff patients. J Clin Exp Neuropsychol 25(3):324–334
8. Brand M, Kalbe E, Fujiwara E, Huber M, Markowitsch HJ (2003) Cognitive estimation in patients with probable Alzheimer's disease and alcoholic Korsakoff patients. Neuropsychologia 41:575–584
9. Bullard SE, Fein D, Gleeson MK, Tischer N, Mapou RL, Kaplan E (2004) The Biber Cognitive Estimation Test. Arch Clin Psychol 19:835–846
10. Cicchetti D (1994) Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in Psychology. Psychol Assess 6(4):284–290
11. Delaloye C, Moy G, Baudois S, De Bilbao F, Remund CD, Hofer F, Paquier CR, Weber K, Urben S, Giannakopoulos P (2009) The

contribution of aging to the understanding of the dimensionality of executive functions. Arch Gerontol Geriatr 49(1):e51–e59
12. Della Sala S, Gray C, Spinnler H, Trivelli C (1998) Frontal lobe functioning in man: the riddle revisited. Arch Clin Neuropsychol 13(8):663–682
13. Della Sala S, MacPherson SE, Phillips LH, Sacco L, Spinnler H (2003) How many camels are there in Italy? Cognitive estimates standardized on the Italian population. Neurol Sci 24:10–15
14. Della Sala S, MacPherson SE, Phillips LH, Sacco L, Spinnler H (2004) The role of semantic knowledge on the cognitive estimation task. Evidence from Alzheimer's disease and healthy adult aging. J Neurol 251:156–164
15. Fisk JE, Sharp CA (2004) Age-related impairment in executive functioning: updating, inhibition, shifting, and access. J Clin Exp Neuropsychol 26(7):874–890
16. Gillespie DC, Evans RL, Gardener EA, Bowen A (2002) Performance o folder adults on tests of cognitive estimation. J Clin Exp Neuropsychol 24(3):286–293
17. Goldstein FC, Green J, Presley RM, O'Jile J, Freeman A, Watts R, Green RC (1996) Cognitive estimation in patients with Alzheimer's disease. Neuropsychiatry Neuropsychol Behav Neurol 9(1):35–42
18. Harel BT, Cillessen AHN, Fein DA, Bullard SE, Aviv A (2007) It takes nine days to iron a shirt: the development of cognitive estimation skills in school age children. Child Neuropsychol 13(4):309–318
19. Huizinga M, Dolan CV, van der Molen MW (2006) Age-related chance in executive function: developmental trends and a latent variable analysis. Neuropsychologia 44:2017–2036
20. Jurado MB, Rosselli M (2007) The elusive nature of executive functions: a review of our current understanding. Neuropsychol Rev 17:213–233
21. Lamar M, Resnick SM (2004) Aging and prefrontal functions: dissociating orbitofrontal and dorsolateral abilities. Neurobiol Aging 25:553–558
22. Leng NR, Parkin AJ (1988) Double dissociation of frontal dysfunction in organic amnesia. Br J Clin Psychol 27:359–362
23. Levinoff EJ, Verret L, Akerib V, Phillips NA, Babins L, Kelner N, Chertkow H (2006) Cognitive estimation impairment in Alzheimer Disease and Mild Cognitive Impairment. Neuropsychology 20(1):123–132
24. Luria AR (1966) Higher cortical functions in man. Basic Books, New York, USA
25. Margraf N, Bachmann T, Schwandner W, Gottschalk S, Seidel G (2009) Bedside screening for executive dysfunction in patients with subcortical ischemic vascular disease. Int J Geriatr Psychiatry 24:1002–1009
26. Meyers JE, Meyers KR (1995) The Meyers scoring system for the Rey complex figure and recognition trial: professional manual. Psychol Assess Resour, Florida
27. Nelson HE (1982) National adult reading test. NFER-Nelson, Windsor, UK
28. Nichelli P, Leone M, Caronna A (2002) Taratura di un test di stime cognitive di impiego diagnostico in clinica: Stime dei tempi e dei pesi (STEP). Nuova Riv Neurol 12:37–42
29. O'Carroll R, Egan V, MacKenzie DM (1994) Assessing cognitive estimation. Br J Clin Psychol 33:193–197
30. Pasquali L (2001) Parâmetros psicométricos dos testes psicológicos. In: Pasquali L (ed) Técnicas de Exame Psicológico–TEP. Manual. Casa do Psicólogo, São Paulo, pp 111–136
31. Petersen RC, Smith GE, Waring SC, Ivnik RJ, Tangalos EG, Kokmen E (1999) Mild cognitive impairment: clinical characterization and outcome. Arch Neurol 56:303–308
32. Petersen RC, Stevens JC, Ganguli M, Tangalos EG, Cummings JL, DeKosky ST (2001) Practice parameter: early detection of dementia—mild cognitive impairment (an evidence-based review). Neurology 56:1133–1142
33. Rabbitt P, Lowe C (2000) Patterns of cognitive ageing. Psychol Res 63:308–316
34. Shallice T (1982) Specific impairments of planning. Philos Trans R Soc London 298:199–209
35. Shallice T, Evans ME (1978) The involvement of the frontal lobes in cognitive estimation. Cortex 14:294–303
36. Shoqeirat MA, Mayes A, MacDonald C, Meudell P, Pickering A (1990) Performance on tests sensitive to frontal lobe lesions by patients with organic amnesia: Leng & Parkin revisited. Br J Clin Psychol 29:401–408
37. Silverberg ND, Hanks RA, McKay C (2007) Cognitive estimation in traumatic brain injury. J Int Neuropsychol Soc 13(5):898–902
38. Spencer RJ, Johnson-Greene D (2009) The cognitive estimation test: psychometric limitations in neurorehabilitation populations. J Clin Exp Neuropsychol 31(3):373–377
39. Spreen O, Strauss E (1998) Executive functions. In: Spreen O, Strauss E (eds) A compendium of neuropsychological tests. Oxford University Press, Oxford, pp 171–198
40. Strauss E, Sherman EMS, Spreen O (2006) A compendium of neuropsychological tests. Oxford University Press, Oxford
41. Stroop JR (1935) Studies of interference in serial verbal reactions. J Exp Psychol 18(6):643–662
42. Stuss DT, Alexander MP (2000) Executive functions and the frontal lobes: a conceptual view. Psychol Res 63:289–298
43. Stuss DT, Levine B (2002) Adult clinical neuropsychology: lessons from studies of the frontal lobes. Annu Rev Psychol 53:401–433
44. Taylor R, O'Carroll R (1995) Cognitive estimation in neurological disorders. Br J Clin Psychol 34:223–228
45. Urbina S (2007) Fundamentos de testagem psicológica. Artmed, Porto Alegre
46. West R (1996) An application of prefrontal cortex function theory to cognitive aging. Psychol Bull 120:272–292
47. Wheeler MA, Stuss DT (2003) Remembering and knowing in patients with frontal lobe injuries. Cortex 39:827–846
48. Wilson BA, Alderman N, Burgess PW, Emslie H, Evans JJ (1996) Behavioural assessment of the dysexecutive syndrome. Thames Valley Test Company, Bury St. Edmunds