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Alfredo Ardila [a] , Feggy Ostrosky-Solís [b] & Byron Bernal [c]

[a] Florida International University, Miami, FL, USA

[b] Universidad Nacional Autónoma de México, Lomas de Reforma, Mexico

[c] Miami Children's Hospital, FL, USA

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Cognitive testing toward the future: The example of Semantic Verbal Fluency (ANIMALS)

Alfredo Ardila

Florida International University, Miami, FL, USA

Feggy Ostrosky-Solís

Universidad Nacional Autónoma de México, Lomas de Reforma, Mexico

Byron Bernal

Miami Children's Hospital, FL, USA

We are proposing that, in the future, tests included in psychological and neuropsychological batteries should fulfil the following criteria. (1) Have a large enough normative database (''normative criterion''). Performance of subjects of different ages and different educational levels, including illiterates, should be well established. Normative data from different countries and cultural contexts should be available. (2) Know the effects of brain damage on different characteristics on the test (''clinical criterion''). (3) Know how the brain is activated when the test is performed (''experimental criterion''). (4) Know how this test correlates with other cognitive tests (''psychometric criterion''). Few contemporary tests fulfil all these criteria. A notable exception is Semantic Verbal Fluency test using the category ANIMALS. This test requires the generation of words corresponding to a specific semantic category, such as animals, fruits, vegetables, etc. Typically, the number of correct words produced in 1 minute is counted. Semantic verbal fluency taps lexical knowledge and semantic memory organization. Using regional cerebral blood flow measures, it has been reported that both frontal and temporal activation are observed while performing this test. Optimal fluency performance involves generating words within a subcategory and, when a subcategory is exhausted, switching to a new subcategory. Although different semantic categories have been used in this test, ANIMALS is the most frequent due to some significant advantages: (1) it is a clear enough semantic category across languages and cultures; (2) it is a relatively easy semantic category with only minor differences among people living in different countries, different educational systems, or belonging to different generations; and (3) it is an easy-to-administer, short, and common test included in different neuropsychological test batteries. It is concluded that obtaining similar information for other cognitive tests represents a huge research endeavour for psychology and neuropsychology during the 21st century.

Nous proposons, qu'à l'avenir, les tests inclus dans le testing psychologique et neurologique doivent remplir les critères suivants: (1) avoir une base de données normatives assez grande («critère normatif»). La performance des sujets d'âge et de niveaux d'éducation différents, incluant les illétrés, doit être bien établie. Les données normatives provenant de pays et de contextes culturels différents doivent être disponibles; (2) connaître les effets du dommage cérébral sur les différentes caractéristiques sur ce test («critère clinique»); (3) savoir comment le cerveau est activé quand le test est exécuté («critère expérimental»); et (4) savoir comment ce test est corrélé avec d'autres tests cognitifs («critère psychométrique»). Peu de tests contemporains remplissent tous ces critères. Une exception remarquable est la Fluence Verbale Sémantique utilisant la catégorie ANIMAUX. Ce test requiert la génération de mots correspondant à une catégorie sémantique spécifique, tel que les animaux, les fruits, les végétaux, etc. Typiquement, la quantité de mots produits en une minute est comptée. La fluence verbale sémantique capte la connaissance lexicale et l'organisation de la mémoire sémantique. En utilisant des mesures régionales de débit sanguin cérébral, il a été rapporté qu'une activation frontale et temporale est observée en exécutant ce test. La performance optimale au test de fluence implique la génération de mots à l'intérieur d'une sous-catégorie et, lorsqu'une sous-catégorie est épuisée, le passage à une nouvelle sous-catégorie. Même si

Correspondence should be addressed to Alfredo Ardila, PhD, ABPN, Florida International University, Department of Communication Sciences and Disorders, HLS144, Miami, Florida 33199, USA (E-mail: ardilaa@fiu.edu).

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différentes catégories sémantiques ont été utilisées dans ce test, les ANIMAUX est celle la plus utilisée à cause des avantages significatifs suivants: (1) il s'agit d'une catégorie sémantique assez claire à travers les langues et les cultures, (2) c'est une catégorie sémantique relativement facile, avec seulement des différences mineures entre les gens vivant dans des pays différents, des systèmes éducatifs différents ou appartenant à des générations différentes, et (3) il s'agit d'un test qui est facile à administrer, bref et commun, inclus dans différentes batteries de tests neuropsychologiques. Nous concluons que l'obtention d'informations similaires pour d'autres tests cognitifs représente un défi de taille pour la recherche en psychologie et en neuropsychologie durant le 21ème siècle.

Se propone que en el futuro, las pruebas utilizadas en la evaluación psicológica y neuropsicológica deberían cubrir los siguientes criterios: (1) Contar con un base de datos normativa lo suficientemente grande. Establecer claramente el desempeño de sujetos de diferentes edades y niveles educativos. Contar con datos normativos de diferentes países y contextos culturales (''criterio normativo''); (2) conocer los efectos del daño cerebral en diferentes aspectos de la prueba (''criterio clínico''); (3) conocer la activación cerebral ante la ejecución de la prueba (''criterio experimental''); y (4) conocer cómo se correlaciona la prueba con otras pruebas cognitivas (''criterio psicométrico''). Pocas pruebas contemporáneas cubren estos criterios. Una excepción es la prueba de fluidez verbal semántica con la categoría ANIMALES. Esta prueba requiere la generación de palabras correspondientes a una categoría semántica como animales, frutas, vegetales, etc. Generalmente la cantidad de palabras correctas generadas en un minuto es contabilizada. Usando medidas del flujo sanguíneo cerebral se ha reportado una activación frontal y temporal mientras se ejecuta esta tarea. El desempeño óptimo en esta prueba implica la generación de palabras dentro de una subcategoría y cuando ésta se agota, cambiar a una nueva. Aunque diferentes categorías semánticas han sido utilizadas en esta prueba, la categoría ANIMALES es la más frecuente debido a algunas ventajas significativas: (1) es una categoría clara entre idiomas y culturas, (2) es una categoría relativamente sencilla con pequeñas diferencias entre personas de diferentes países, sistemas educativos o entre personas pertenecientes a distintas generaciones, y (3) es una prueba sencilla de administrar, corta e incluida en varias baterías neuropsicológicas. Se concluye que el obtener información semejante para otras pruebas cognitivas representa un enorme reto para la psicología y neuropsicología durante el siglo XXI.

During the last decades, psychology and neuropsychology have been significantly interested in developing reliable and valid enough cognitive testing procedures (e.g., Lezak, 2004; Mitrushina, Boone, & D'Elia, 1999; Spreen & Strauss, 1998; Wechsler, 1997). Important controversies, however, have been frequent (e.g., Ardila, 1999). We are proposing that in the future, in addition to the fundamental psychometric test properties (e.g., reliability), cognitive tests should fulfil at least the following four criteria.

1. *Normative criterion*. That is, to have a large enough normative database *to understand the variables impacting test performance*. Performance in subjects with different ages and educational levels, including illiterates (about one fifth of the world population; www.portal.unesco.org), should be well established. As a matter of fact, norms in illiterates are crucial in order to understand cognition without education as a confounding variable. Developmental data and performance in elderly populations are also necessary. Normative data from different countries and cultural contexts should also be available. This information will be most important to identify variables affecting the test performance. For some tests (e.g., language tests), educational level plays a major role; for others (e.g., memory tests), age may be most significant; in other tests (e.g., spelling), language may be crucial, etc.

2. *Clinical criterion*. That is, to know reasonably well the effects of different types of brain pathology on this test: right, left, anterior, posterior, cortical, and subcortical. In addition, information regarding test performance in major pathological conditions (dementia, traumatic brain injury, Parkinson's disease, etc.) is highly desirable.

3. *Experimental criterion*. That is, to know reasonably well how the brain is activated in normal individuals when this particular test is performed. fMRI and/or PET studies are required to know how different brain areas participate when performing the test.

4. *Psychometric criterion*. To know how this specific test correlates with other cognitive measures; i.e., the communality existing with other assessment procedures.

Few contemporary tests fulfil these optimal criteria. A notorious exception, however, is Semantic Verbal Fluency for ANIMALS. This paper analyses the three last criteria in the Semantic Verbal Fluency test when the category ANIMALS is used. The analysis of the first criterion was presented elsewhere (Ardila, Ostrosky-Solís, & Bernal, 2005).

SEMANTIC VERBAL FLUENCY (ANIMALS)

Controlled oral word association or word or verbal fluency has become one of the most popular tests in neuropsychology (Lezak, 2004; Spreen & Strauss, 1998). Two different conditions can be used: (1) phonemic fluency (words beginning with a particular letter, usually in English F, A, and S); and (2) category or semantic verbal fluency (words corresponding to a specific semantic category, such as animals, fruits, vegetables, etc.). Typically, the number of correct words produced in 1 minute is counted. A normal person can produce about 12 words beginning with a specific letter, and about 16 words corresponding to a semantic category, within 1 minute (Spreen & Strauss, 1998). The level of productivity, however, depends upon the letter or the semantic category. A very strong educational effect has been demonstrated in both conditions, especially in the phonemic condition (Ostrosky-Solís, Ardila, & Rosselli, 1999; Ostrosky-Solís, Ardila, Rosselli, López, & Mendoza, 1998; Ostrosky-Solís, Ramírez, Lozano, Picasso, & Vélez, 2004; Rosselli, Ardila, & Rosas, 1990). Ardila, Ostrosky-Solís, Rosselli, and Gomez (2000) found that the educational level accounted for 38.5% of the variance in the phonemic condition and for 23.6% of the variance in the semantic condition. A moderate to middle correlation (around .30–.60) between scores in both conditions has also been reported (Ardila, Rosselli, & Bateman, 1994; Ardila, Galeano, & Rosselli, 1998; Matute, Rosselli, & Ardila, 2004; Ostrosky et al., 1999).

Verbal fluency tests have often been interpreted as executive functioning tests (Bruyer & Tuyumbu, 1980; Parks et al., 1988; Perret, 1974; Ramier & Hecaen, 1970; Ruff, Allen, Farrow, Niemann, & Wylie, 1994). Difficulties in performing this test are found in cases of frontal lobe damage, usually left and bilateral frontal lesions. In general, it is assumed that phonemic verbal fluency is superior to semantic fluency as an executive functioning test. Semantic verbal fluency is rather tapping lexical knowledge and semantic memory organization. Using regional cerebral blood flow measures, it has been reported that frontal and temporal activation are both observed while performing this test. PET studies have demonstrated that the frontal lobe is activated in phonemic generation while the temporal lobe is more active in semantic generation of words (Warburton et al., 1996). Several investigators have observed that words tend to be produced in semantic clusters on the semantic fluency task and in phonemic clusters on the phonemic fluency task. The clusters are defined by bursts of words over time, which are semantically or phonemically related. Optimal fluency performance involves generating words within a subcategory and, when a subcategory is exhausted, switching to a new subcategory. Troyer, Moscovitch, and Winocur (1998a) devised a method to quantify these processes as switches and average cluster size. These components are differentially affected by various neurological disorders. Clustering is related to temporal lobe functioning, while switching is related to frontal functions (Testa, Tröster, Fields, Gleason, Salmon, & Beatty, 1998; Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998b).

Although different semantic categories have been used in this test, ANIMALS is the most frequent. Using ANIMALS has some significant advantages. (1) It is a clear enough semantic category across languages and cultures. The semantic field of other categories can vary across different languages. For example, the semantic field of the English word "vegetables" is only partially coincidental with the semantic field of the Spanish word *vegetales*. Furthermore, in Spanish, *vegetales* may be a confusing semantic category, whereas "vegetables" is a clear one in English. In Spanish, trees or grass can be considered as vegetables. Interestingly, many English-speaking people include some fruits as vegetables (e.g., tomatoes are indeed fruits, but many people consider them to be vegetables). Furniture, clothes, and other categories can be different in different countries and different languages. ANIMALS do not present these ambiguities. (2) ANIMALS is a relatively easy semantic category with only minor differences among people living in different countries, exposed to different educational systems, or belonging to different generations (for example, a generation effect can be conjectured for the category "tool"). The brain activity, therefore, is not expected to vary as much as it could with a task based on phonological clues when used in different languages (Chinese and Spanish, for example). Nell (2000) has suggested that Semantic Verbal Fluency using ANIMALS represents a reliable test for adults with low education. Lopera (n.d.), using 16 different semantic categories in a 3000-participant sample, found that the easiest semantic categories were BODY-PARTS, THINGS TO EAT, and ANIMALS (Table 1). That is, there is a hierarchy of difficulty when finding elements corresponding to a particular semantic category. (3) ANIMALS Verbal Fluency is an easy to administer, short, and common test included in different neuropsychological test batteries (e.g., Boston Diagnostic

TABLE 1
Average number of words generated by Spanish speakers in 1 minute in different semantic categories (n=3000) (Lopera, n.d.)

Category	*Words in 1 minute*
Body-parts	18
Things to eat	17
Animals	16
Kitchen elements	14
Fruits	13
Colours	13
Places or sites	12
Adjectives	12
Parts of the house	12
Transportation means	11
School elements	11
Verbs	11
Tools	10
Personal care elements	10
Furniture	10
Flowers	8

Aphasia Examination, Goodglass & Kaplan, 1972; CERAD neuropsychological test battery, Morris et al., 1989; Neuropsi, Ostrosky-Solís et al., 1999). Instructions are simple, and no special instruments (except a stopwatch, a pencil, and paper) are required. It is also a cheap test, accessible anywhere.

CLINICAL CRITERION

A number of brain conditions can affect the performance in verbal fluency tests: focal brain damage, especially frontal lobe pathology (Herrmann, Ehlis, & Fallgatter, 2003; Ravnkilde, Videbech, Rosenberg, Gjedde, & Gade, 2002), Parkinson's disease (Donovan, Siegert, & McDowall, 1999; Troyer et al., 1998a), schizophrenia (Chen, Chen, Chan, Lam, & Lie-Mak, 2000; Curtis et al., 1998), subcortical dementia (Testa et al., 1998; Troster et al., 1998), traumatic brain injury (Bradley, Torner, Fisher, & Aharon-Peretz, 2001), Huntington's disease (Ho et al., 2002; Suhr & Jones, 1998), depression (Crowe, 1992; Okada, Okamoto, Morionobu, Yamawaki, & Yokota, 2003; Ravdin, Katzen, Agraval, & Relkin, 2003), vascular and degenerative dementias (Cooper et al., 2001; Troyer et al., 1998a), and amyotrophic lateral sclerosis (Abrahams et al., 2000).

Two major conclusions can be drawn: (1) in general, Semantic Verbal Fluency is a task that is quite sensitive to diverse types of brain abnormalities, particularly those involving the left hemisphere; (2) in addition to quantitative scores, a diversity of pathological phenomena may be observed: intrusions, perseverations, difficulties in maintaining instructions, etc. Qualitative analysis should complement the quantitative scoring.

EXPERIMENTAL CRITERION

Diverse studies have been published, analysing the brain areas involved in semantic verbal fluency (Abrahams et al., 2003; Fama et al., 2000; Gaillard et al., 2003; Hugdahl et al., 1999; Lurito, Kareken, Lowe, Chen, & Mathews, 2000; Pihlajamaki et al., 2000; Schlosser et al., 1998; Tucha, Smely, & Lange, 1999; Vingerhoets et al., 2003; Weiss et al., 2003). There is converging evidence that verbal fluency activates the left posterior aspect of the middle temporal gyrus, and other brain areas can additionally participate, such as the left dorsolateral prefrontal convexity and the hippocampus. Pihlajamaki et al. (2000) observed that the medial temporal lobe is required for the process of retrieval by category.

Semantic fluency tasks differ somewhat in their application from the regular manner in which they are applied in the clinical neuropsychology context. The tasks are applied with some changes, which are summarized in Table 2. Vascular responses of the brain coupled to the task have to be switched *on* and *off* several times to obtain enough statistical power to demonstrate activation. The duration of the free retrieval is shortened, as the generation decays considerably in the second half of the minute. Since a second attempt to generate nouns within the same category would add some difficulty, as the subject may run out of salient nouns, the generation of animals is usually followed by other categories. Usually an fMRI

TABLE 2
Task differences between regular and fMR laboratories

Test type	*Duration*	*Off period*	*Several items*	*Motion restriction*	*Speech*	*Controlled*
Regular laboratory	1 min	None	Not necessarily	No	Overt	Yes
FMR laboratory	20–40 s (usually 30 s)	20–40 s	Yes	Yes	Covert	No

consists of three or four *on* epochs, preceded, ended, and separated by *off* epochs of the same duration. Thus, generating only animals during three different periods would require division of this category; for example, asking for the retrieval of wild animals in the first attempt, then insects in the second, and birds for the third.

Semantic fluency, phonological fluency, and verb generation activate left lateral frontal areas. Left Brodmann's 44, 45, 46, 9, 7, and 8 are activated most frequently, with other areas varying among different subjects. These ancillary areas are the supplementary motor area (SMA), posterior temporal areas, cingulate gyrus, contralateral frontopolar area, and visual areas. Figures 1 and 2 show activation obtained with a semantic fluency task and a verb generation task in the same subject. The similarities are limited to the activation of areas directly related to fluency (Brodmann's 44, 9, and SMA). However, some differences appear: Verb generation also elicited activation in Wernicke's area, left caudate nucleus, and contralateral Broca's area. Not all subjects show the same differences, but there are cases in which the activation is almost identical.

No differences according to language or gender have been reported in this task. Vingerhoets et al. (2003) analysed activation patterns in 12 multilingual right-handed men performing a word fluency task, a picture naming task, a comprehension reading task, and their respective control tasks in three languages (Dutch, French, and English) while whole-head fMRI was applied. In general, all language tasks revealed predominantly overlapping regions of activation for the different languages. Weiss et al. (2003) observed that men and women who did not differ significantly in

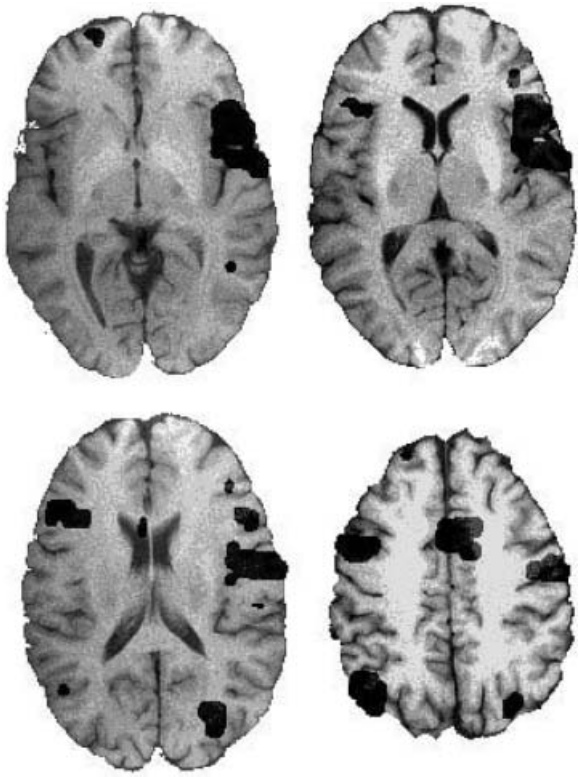

Figure 1. Brain activation of semantic fluency. These clusters were obtained from a paradigm consisting of 3 *on* epochs alternating with 3 *off* epochs. During *on* the subject was silently generating names of animals, vegetables, and fruits (respectively). The volunteer was asked to think of a blue sky during the *off* periods. The largest clusters of activation are located in left Broca, left mouth premotor area, and SMA. Some activation also appears in the left interparietal sulcus, right Brodmann's 7, and contralateral Broca's area (from the Miami Children's Hospital, department of radiology; www.mch.com/clinical/radiology/fmri).

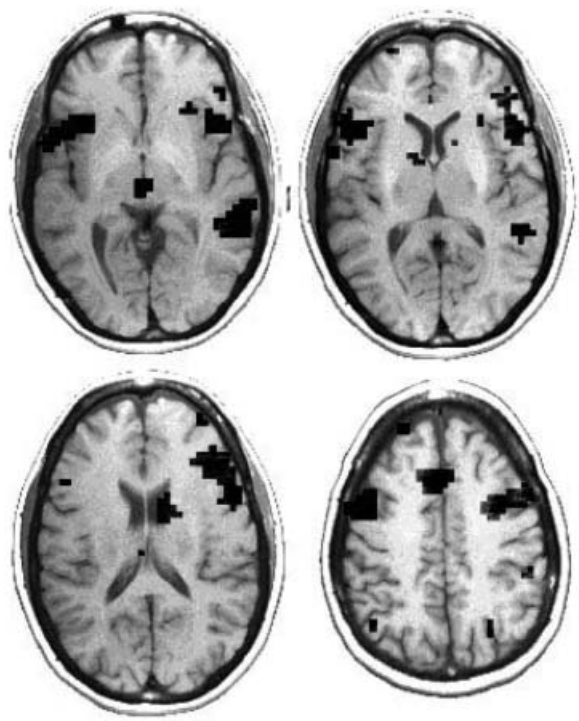

Figure 2. Brain activation of verb generation. This image was obtained with the same techniques utilized for the Semantic Fluency Task. The skull was not removed in the post-processing. During the *on* blocks, the subject was asked to think of verbs related to a list of nouns aurally presented at 0.2 Hz. In addition to the areas activated in the Semantic Fluency Task shown in Figure 1, there is activation the left caudate nucleus and stronger participation of contralateral Broca. Wernicke's area is expected to activate because of the stimulus delivery mode. Notice the small activation in the right frontopolar area (Brodmann's 10), which, strikingly is common to both tasks, and probably related to working memory or retrieving (from the Miami Children's Hospital, department of radiology; www.mch.com/clinical/radiology/fmri).

Verbal Fluency Task performance showed a very similar pattern of brain activation.

PSYCHOMETRIC CRITERION

Three studies were selected to analyse the Semantic Verbal Fluency pattern of correlations with other tests (Ardila et al., 1994, 1998; Ostrosky-Solís et al., 1999) (Tables 3, 4, and 5). It is observed that Semantic Verbal Fluency correlates with phonologic verbal fluency, verbal memory (immediate and delayed), backwards digits, and language comprehension. Correlation with naming is lower than correlation with language understanding. Interestingly, phonemic verbal fluency, but not Semantic Verbal Fluency, significantly correlates with the Finger Tapping Test (Ardila et al., 1994, 1998). Some correlation with arithmetic and, in general, with conceptual functions is also observed. These data suggest that attention, working memory, and immediate and delayed verbal memory are cognitive functions that contribute to semantic verbal fluency.

TABLE 3
Statistically significant correlations over .15 ($p < .01$), Semantic Verbal Fluency and other cognitive tests (Ardila et al., 1998)

Test	*r*
Phonologic Verbal Fluency	.31
WAIS: Arithmetic	.27
Information	.22
Digits	.19
Perceptual speed: Similarities	.18
Verbal IQ	.18
Full Scale IQ	.19

TABLE 4
Correlations between Semantic Verbal Fluency (ANIMALS) and other neuropsychological tests in the NEUROPSI neuropsychological test battery (adapted from Ostrosky et al., 1999)

Subtest	*r*
Orientation: Time	.29
Place	.16
Person	.12
Attention: Digits backwards	.40
Visual detection	.38
20 minus 3	.37
Encoding: Verbal memory	.34
Copy of a semi-complex figure	.43
Language: Naming	.25
Repetition	.14
Comprehension	.45
Verbal fluency: Phonologic	.61
Reading	.30
Writing: Dictation	.14
Copy	.18
Conceptual functions: Similarities	.38
Calculation abilities	.33
Sequences	.41
Motor functions: Changing left-hand position	.22
Changing right-hand position	.21
Alternating movements	.39
Opposite reactions	.12
Memory: Words	.35
Cueing	.21
Recognition	.10
Semi-complex figure	.42

CONCLUSIONS

Recent decades have seen an exponentially growing interest in developing valid and reliable neuropsychological testing instruments that can be used in different clinical settings. An enormous diversity of tests has been developed (see, for example, Lezak, 2004). Simultaneously, the need to adapt these instruments to cultural and

TABLE 5
Correlations between semantic verbal fluency and other neuropsychological tests in 98 subjects aged 11–12 years (Ardila et al., 1994)

Subtest	*r*
Phonologic verbal fluency	.50
Wechsler Memory Scale:	
Information	.07
Orientation	−.17
Mental control	.01
Logical memory	.25
Digits	.22
Visual reproduction	.22
Associative learning	.05
Logical memory: delayed	.19
Associative learning: delayed	.05
Visual reproduction: delayed	−.10
Verbal memory	
Maximum	.44
Delayed recall	.46
Praxis	
Left hand	.05
Right hand	−.17
Tapping test	
Right hand	−.04
Left hand	−.19
Figure recognition	−.03
Token test	.11
WCST	
Correct responses	.25
Categories	.01
Boston Naming test	.13
Rey-Osterrieth Complex Figure	
Copy	.13
Immediate recall	.03

linguistic contexts other than the context for which they were originally developed has become evident. This effort has been observed in many different countries worldwide.

Until recently, test ability to detect brain pathology was enough. Today, sophisticated neuroimaging techniques are available, which could potentially contribute to extending our understanding of cognitive testing procedures. Furthermore, today we have extended databases for many neuropsychological instruments, which can be used to have a better understanding of the variables affecting test performance and the score dispersions that can be found.

We are proposing that neuropsychological tests should fulfil four different criteria: to have a large enough normative database; to know the effects of different types of brain damage on this test; to know how the brain is activated when the test is performed; and to know how this test correlates with other cognitive tests). This means that the test:

1. Has been administered to a diversity of populations, and diverse normative data are available. The test has been demonstrated to be appropriate to evaluate different populations (''normative criterion''). Simpler tests with simple instructions have a better chance of becoming widely used tests.
2. Has been demonstrated to be clinically useful (''clinical criterion''). This means that specific patterns of performance and error types on the test are known to be associated with specific brain pathologies.
3. Has been used experimentally in normal populations, and the pattern of brain activation correlated with the performance in this test is well known (''experimental criterion'').
4. Correlates with other assessment tests (''psychometric criterion''). Validity of the test would be established not only based on the intercorrelation with other tests, but also from the specific pattern of performance in the test found in individuals with different types of pathologies.

We have taken the example of Semantic Verbal Fluency using the category ANIMALS. But, potentially, the same type of analysis could be carried out with other basic neuropsychological tests; for example, the Token Test, the Wisconsin Card Sorting Test (using a simpler version), or the naming tests (assuming that it is possible to develop a good cross-cultural and cross-linguistic naming test). This type of analysis may advance our understanding of current neuropsychological instruments.

It can be anticipated that, in the future, some instruments may become relatively universal tests in neuropsychology. It can be also anticipated that some instruments may be usable only within certain cultural and/or linguistic contexts. This is an open question, and much more research is required.

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