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Scientific Research on Verbal Fluency Tests: A Bibliometric Analysis

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Abstract

Verbal fluency tests are easy and quick to use in neuropsychological assessments. The aim of this study is to explore their relevance through a bibliometric analysis. We performed a search in the Web of Science, involving documents published between 1960 and 2021. We used bibliometric indicators to explore articles distribution, doubling time, and annual growth. We calculated the participation index of the different countries and institutions. Through bibliometric mapping, we explored the co-occurrence networks for the most frequently used terms in verbal fluency research. 1718 articles were found, distributed in two different periods (1960–1995 and 1995 to 2021), the second one containing more than 88% of the documents. Price's law shows an exponential growing. Literature on verbal fluency has grown at a rate of 6,7% per year, doubling its size every 10.7 years. Bradford's law shows a high concentration of articles published in a small core of specialized journals. Finally, the map network visualization shows a change in the most important topic related to verbal fluency during the most recent period analysed. Verbal fluency task has undergone an exponential growth. Its easy application, its sensitivity to different brain dysfunction, the possibility of implementation with neuroimaging studies, and the potential analysis of more complex components (clustering or switching) might have played a key role in its growing interest.

Keywords

Verbal fluency; Bibliometric; Neuropsychology; Assessment

Introduction

Finding a simple, accessible and sensitive test has been one of the main goals of the neuropsychological assessment. Verbal fluency tests are usually included in neuropsychological assessments and it may be one of the possible candidates. This task depends on lexical retrieval from memory, which requires executive control over cognitive processes such as selective attention, selective inhibition, mental set shifting,

internal response generation, and self-monitoring (Patterson, 2011), and evaluate an individual's ability to retrieve specific information within restricted search parameters (Lezak et al., 2012). It seems to be influenced by demographic variables such as age, gender, ethnicity, educational, intellectual or reading levels (Strauss et al., 2006).

The two forms of verbal fluency commonly assessed are phonemic (letter guided) and semantic (category guided). In a limited timeframe (generally one minute), the participant has to provide responses that start with a specified letter or belong to a target category. In phonemic/letter verbal fluency, "F, A, and S" are the most commonly employed letters, although other combinations are also used; for example, "P, M and R" had been proposed as the most appropriate letters in Spanish (Casals-Coll et al., 2013; Peña-Casanova et al., 2009). In semantic/category verbal fluency, the most common category is "animals", but "fruits or vegetables", "things in the kitchen", or "first names" have also been used (Lezak et al., 2012).

Since seminal studies about verbal fluency were performed in healthy and clinical populations around the 1940s (Fruchter, 1948; Thurstone, 1938), verbal fluency tasks have been tested in detail in different populations and also with the aim to obtain descriptive and normative data. *The Controlled Oral Word Association Test* (COWAT) (Benton & Hamsher, 1989) was one of the first validated phonemic verbal fluency tests, and large sample of comprehensive norms across age, education, gender, and IQ has been improved lately (Heaton, 2004; Loonstra et al., 2001; Mitrushina, 2005). In addition, verbal fluency tasks have been also included in the majority of neuropsychological batteries as *The Delis-Kaplan Executive Function System* (D-KEFS) (Delis et al., 2001), a battery specifically designed to assess the component processes of executive functioning, or *The Repeatable Battery for the Assessment of*

Neuropsychological Status (RBANS) (Randolph, 1998), that brief evaluates of cognitive function in adults with neurological disturbance.

The relationship between verbal fluency and specific cognitive processes has been deeply explored. It has been mainly linked with general executive functions (Aita et al., 2019) and particularly with cognitive flexibility (Jaimes-Bautista et al., 2017), working memory (Ojeda et al., 2010), or updating information (Laisney et al., 2009). Not surprisingly, verbal fluency has been found to be associated with language performance (Whiteside et al., 2015), including lexical access skills and vocabulary knowledge (Sauzéon et al., 2011; Shao et al., 2014). In addition, it has been related with processing speed abilities (Elgamal et al., 2011). Other studies have investigated the differential executive and language functions involved in phonemic and semantic forms of verbal fluency (Biesbroek et al., 2016).

Moreover, in recent decades the use of more qualitative methods of analysis, beyond the measure of total words recalled, has become popular. Troyer et al. (1997, 1998) proposed the quantification of clustering and switching behaviours as relevant parameters related to cognitive function. Clustering refers to the extent that adjacent response items are produced in bursts of related words (e.g., farm animals in the animal fluency task) and switching refers to the capacity to change from one cluster to another (e.g., from farm animals to insects). Clustering has been proposed to be more closely related to semantic memory capacities, and switching to executive function, although such distinction might not be so straightforward (Mayr, 2002).

Verbal fluency tests have been commonly used in neuropsychological assessment of children (Jacobsen et al., 2017; Pastor-Cerezuela et al., 2016). In adult population, it has been applied to healthy adults as well as in several clinical environments, being a useful instrument to explore and characterize different

pathologies. It has been widely employed in neurodegenerative diseases, such as Alzheimer (Bertola et al., 2014; Fagundo et al., 2008; see Henry et al., 2004, for a review) or Parkinson (Farzanfar et al., 2018; Galtier et al., 2017), as well as in mood disorders, such as depression (Akiyama et al., 2018; see Henry & Crawford, 2005a for a review) and psychotic disorders (Helmes & Hall, 2016), specially schizophrenia (Brébion et al., 2018; Egeland et al., 2018; see Henry & Crawford, 2005b, for a review). Additionally, verbal fluency tests are really frequent as a part of the neuropsychological assessment of patients with acquired brain injury, giving clinicians valuable information regarding important cognitive characteristics of patients who have suffered a stroke (Schmidt et al., 2019) or a traumatic brain injury (Kavé et al., 2011; see Henry & Crawford, 2004, for a review).

Verbal fluency tests are quick and simple (they take about five minutes) and do not require specific materials other than a timer. Unlike most other tests, verbal fluency tasks do not have low ceilings when used in neurologically intact populations, making them popular for use in a variety of testing situations. General scoring is also easy—the total correct is the sum of all admissible words for the three letters and the sum of all admissible words for the semantic category. Moreover, a deeper evaluation of the performance, considering kind of errors and other qualitative aspects—such a clustering or switching (Troyer et al., 1997), gives the professional valuable information in regard with the cognitive processes involved in this task (Strauss et al., 2006). Consequently, they have been broadly used in research and clinical practice, and the literature addressing verbal fluency tests is large and has increased during last decades, being a very important topic in neuropsychology research.

Bibliometric analyses are a useful tool to examine the research activity related to a specific domain or construct, or a more general investigation field. Bibliometric

approach has been used to analyse the evolution of scientific literature in different areas of neurosciences, involving diverse mental disorders and related characteristics (López-Muñoz et al., 1996, 2019; López-Muñoz, Alamo, et al., 2008; López-Muñoz, García-García, et al., 2008). Moreover, bibliometric indices have been recently used to evaluate research activity in the field of neuropsychological rehabilitation (Mojgani et al., 2020).

Bibliometrics includes the collection, processing and management of quantitative bibliographic data from scientific publications (Moed et al., 1985). The Organization for Economic Co-operation and Development (OECD) refers to it as a tool by which the state of science and technology, through the global production of scientific literature in a given specialty, can be observed (Okubo, 1997). Accordingly, the term bibliometrics refers to a group of bibliographic searches and scientific information that allows analysis of production and dispersion of a specific topic in a statistically quantitative way (Price, 1963). Bibliometrics statistical indicators allow measurement of the amount of scientific publications and their characteristics. Neuropsychology has undergone profound changes through the 20th century and the first decades of the 21st. In parallel, verbal fluency tests have not only been a key tool in neuropsychological assessment, but also a topic of research for long decades. While a narrative review might offer an informed assessment of the relevance of verbal fluency tests for neuropsychology, it would be provided from a qualitative point of view. However, bibliometrics might offer information on its impact, on the main institutions contributing to development, and on its relationship with other related topics from both a quantitative and qualitative perspective. The aim of this study is to explore the ways in which verbal fluency has been addressed so far in cognitive research by using bibliometrics. Here, we have used different indices to study the growth rate of publications about verbal fluency, their impact factor, the main institutions contributing

to research, and the journals concentrating more information on the topic. Moreover, a bibliometric mapping analysis of the scientific landscape was performed to identify clusters and trends in research on verbal fluency among healthy and clinical population. Bibliometric mapping allows visualizing how a given term, such as “verbal fluency”, relates to others by their cooccurrence in publications. These data help us address in a quantitative manner how the interest in the area has evolved, its presence in specific journals, and its current status within neuropsychological research.

Methods

Data Source

The initial data search was conducted through Web of Science (WoS, Thomson Scientific). We selected this data base because it indexes journals with a high scientific quality and provides a unique citation report function. In addition, it is the most frequently used database in bibliometric studies (Yang & Meho, 2007).

Search Strategy

Remote downloading techniques were used to select papers published between 1960 (year in which continuity in publication arises) and 2021, which contained in the article title the descriptors *“verbal fluency” or “fluency task” or “phonemic fluency” or “semantic fluency” or “action fluency” or "letter fluency” or “category fluency".* To minimize the inclusion of off-topic items, we searched only in the “title”.

Data were extracted from WoS at one day (February 11, 2021) to avoid bias because of daily updating in the database.

Data Analysis and Categorization

After downloading the metadata and extracting bibliographic details of all verbal fluency publications, the results were analysed according to the criteria of chronological

distribution, country of origin, affiliation, sources of the documents, keywords, and descriptors used. The methodology applied in this study was comparable to recent bibliometric studies (López-Muñoz et al., 2018, 2021; Okoroiwu et al., 2018; Povedano-Montero et al., 2018; Redondo et al., 2017). For this study, the most common bibliometric indicators used were: Price Index, doubling time, annual growth rate, and the Bradford Zones. In addition, an analysis of production by countries and institutions was included.

Among the possible production indicators, we chose to apply the Price´s law (Price, 1963). This law is the most used indicator in the analysis of the productivity of a specific discipline or a particular country, and reflects a fundamental aspect of scientific production, namely its growth. For this purpose, a graph is constructed, with the chronological distribution of the documents, applying the linear and exponential trend lines. Thus, according to the correlation index, it is checked whether the growth of literature is more similar to a linear or to exponential growth.

To assess whether the scientific production on verbal fluency follows the Price´s law, a linear trend curve expressed in the following way y = 1.7342x - 3425 was created. Similarly, an exponential trend line was created according to the equation $y = 1E\text{-}81e^{0.0946x}$.

Doubling time and the annual growth rate are related to the growth of a subject of study. It allows comparisons on the literature growth rate in the different scientific fields. The former is the amount of time required by the subject of study to double its production. To estimate the doubling time (D) of the scientific literature, the following equation is used:

$$D = \frac{LN(2)}{LN(g)}$$

The form of growth was studied from the equation of Egghe and Rao (1992):

$$C(t) = cg^t$$

Where, C (t) is the total number of documents produced at time t; c and g represent estimated constants of the observed data, taking into account that c> 0, g> 1, and t ≥0; t is the number of chronological years studied in the research period (t = 0, 1, 2, ..., n). The model not only provides an average rate of growth, but also offers a rate of doubling.

Among the bibliometric indicators of dispersion, we have applied the Bradford Zones. It reveals the distribution of the scientific literature in a particular discipline, with a model of concentric zones of productivity (Bradford Zones). Bradford explained that the highest percentage of a bibliographical output in a particular subject tends to concentrate in a small number of journals, which indicates a decrease in the usefulness of expanding the reference searches away from its nucleus (Bradford, 1934). In this way, this model allows us to establish which journals are preferred by researchers for publishing and therefore, the most specific ones on a research domain or field of investigation, where the number of journals in the nucleus and in the successive zones is in a ratio of 1: n: n^2.

To assess the influence of publications, the Impact Factor (IF) is used. This indicator is calculated taking into account the times a journal has been cited in the Science Citation Index database in the last two years and the total number of articles published in this journal in those same years. Despite its limitations (see Brembs et al., 2013 for an extensive review and discussion on the limits of impact factor and journal ranks), IF has been traditionally considered an index of journal's prestige (Garfield, 1979).

Statistical Analysis

Statistical analysis tests were performed using the Statistical Package for the Social Sciences (SPSS) version 23.0. Linear and exponential regression adjustments were compared to explore the trend in publication.

Bibliometric mapping is an important research topic in the field of bibliometrics (Börner et al., 2003). VOSwiever: 1.6.15 (van Eck & Waltman, 2010) was used to study the keywords, and the cooccurrence networks for the most frequently used terms in the titles and abstracts of the publications were studied over the time interval. Each term is demonstrated by a circle, where its diameter and the size of its label illustrate the frequency of the term, and its color reflects most frequently encountered topics in this field (van Eck & Waltman, 2010).

Results

Using the search criteria, we retrieved 1,718 research publications in a 62-year period, from 1960 to 2021. The chronological distribution of the publication showed a notable increase in the number of articles generated in the area of verbal fluency research (Figure 1).

[INSERT FIGURE 1 HERE]

As reflected in Figure 1, the mathematical adjustment to a linear curve reveals a correlation coefficient of 0.884 (R^2=0.787), indicating that a 11.60% cannot be explained by this adjustment. On the other hand, the exponential adjustment of the measured values provides a 0.930 coefficient (R^2=0.866) and therefore, a residual variability percentage of 7%. These results suggest that the repertoire analysed is more in keeping with an exponential fitting than with a linear one, therefore complying with the postulates of the Price´s Law.

Additionally, two different periods can be distinguished in the chronological chart. In the first period, from 1960 to 1995, the number of documents remained stable. However, from 1995 to the present we found a great increase in research documents.

Table 1 shows the parameters and values obtained from the application of the exponential model by the non-linear regression method. The value of c is 2.212 and that of g is 1.067. With these values the Egghe and Rao (1992) equation can be established, and thus, predict the growth of the published literature on verbal fluency:

$$C(t) = 2.212 * 1.067^{t}$$

According to this method, literature on verbal fluency has grown at a rate of 6.7% per year with a production that doubles its size every 10.7 years. This model is explained at 92.3%.

[INSERT TABLE 1 HERE]

The geographical and affiliation distribution of the documents is presented in Figure 2. This analysis shows that 10 countries represent 79.10% of production, with the United States being the largest producer with 27.71% of the documents. Regarding the most productive institutions, it should be noted that most of them belong to the university context, the University of California and the University of London being the ones with the highest number of documents and together comprise 17% of the global production.

[INSERT FIGURE 2 HERE]

The maps presented in Fig. 3a and 3b show the most frequently used terms in the titles and abstracts of the publications related to verbal fluency from two specific publication time periods (1994–1960 and 2021–1995). While the first period only present three terms (verbal fluency, patient and effect) poorly connected between them, the second one presented in Figure 3b shows the generated term map detailing on

clusters of closely related terms in complex network visualization. The larger the circle, the higher the frequency of occurrence of the specific term and the smaller the distance between two terms/circles, the higher the co-occurrence of the terms. Colours indicate clusters of closely related terms. Cluster analysis based on term co-occurrence identified five major clusters (green, red, purple, blue, and yellow) and two minor (orange and light blue); the main term (verbal fluency task) being situated in the blue cluster and highly connected with terms from the other clusters. Important terms are related with characteristics of the verbal fluency task, such semantic fluency or phonological fluency. Additionally, others important aspects of verbal fluency test also appear such as clustering or switching, and also other cognitive processes related (memory, attention, vocabulary or executive control). Diseases associated with an important cognitive decline, which have been measured with this kind of tasks, also appear as significant clusters (Alzheimer, Parkinson, schizophrenia, dementia, depression or traumatic brain injury). The common use in recent decades of neuroimaging techniques is reflected in the high number of important terms in the red cluster (near-red spectroscopy, functional connectivity, fmri…).

[INSERT FIGURE 3 HERE]

Table 2 shows the distribution of journals per Bradford Zone. Fifteen (3.01%) of the journals made up the core zone, while 77 (5.46%) and 406 (81.53%) made up zones 1 and 2, which implies a high concentration of articles published in a small core of more specialized journals. Seven of the ten journals in the core zone have an IF over 3, with three of them having an IF over 4, including one journal with more than 13, which may be considered an index of the significant interest that verbal fluency arouses as a research topic. Table 3 displays data about journals with highest number of publications on the topic.

[INSERT TABLE 2 HERE]

[INSERT TABLE 3 HERE]

Table 4 refers to the indicator of the IF of the articles, which corresponds to the number of citations received from subsequent publications. In this sense, the most cited article is "*Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming"* by Tombaugh et al. (1999) with 2.11% of total citations.

The citation index represents the number of times that an article has been referenced in other documents and is one of the most used tools to analyse research productivity. The number of total citations for this field of research is 43,163, so the average citation index per article is 25.14 and represents an h index of 103.

[INSERT TABLE 4 HERE]

In order to contextualize the growth of publication of verbal fluency, we compared it with two related neuropsychological assessment test, namely the Trail Making Test (Reitan, 1958) and the Wisconsin Card Sorting Test (Grant & Berg, 1948). We also used "executive function" as a general concept of neuropsychology to provide a more general reference in a broader field. All topics presented a general growth. However, publication around verbal fluency was greater than that around Trail Making Test and Wisconsin Card Sorting Test (higher annual growth and doubling time). Executive function, as a broader concept, presents even greater growth. It allows us to observe the general growth within the field of neuropsychology, and evidences a particular growth of publication on verbal fluency among neuropsychological assessment tests (See Table 5).

[INSERT TABLE 5 HERE]

Discussion

According to the results obtained in the bibliometric analysis, the interest for this topic has undergone an exponential growth from the 90s onwards, especially from 1995. The exponential growth in literature related to verbal fluency is surely influenced by conceptual and historical changes in the area of neuropsychology. The development of a cognitive neuropsychology focused more on processes and less on location. The first historical role of neuropsychology was to infer the presence and location of brain damage from behavioral measures (Gronwall, 1989). With this purpose, specific tests and batteries emerged, designed to be administered in a highly standardized way and interpreted to infer the presence or absence of brain damage and try to localize it. This approach came under criticism in the 1980s on both empirical and conceptual grounds. The possibility of localizing brain lesion accurately using structural and functional imaging techniques decreased the use of neuropsychological evaluation for this purpose (Mapou, 1988). Besides, the development and understanding of brain systems and the related cognitive processes changed the paradigm of neuropsychological assessment from the assessment of localized lesions to the assessment of cognitive skills (Alfano & Satz, 2000).

Thus, the focus has changed gradually from lesion localization to using the test analysis to understand an individual's functional status (Lezak et al., 2012). This does not mean that neuropsychologists are not interested anymore in how specific tasks might reveal the dysfunction of particular brain networks or areas. An important interest remains on how verbal fluency is related to structural and functional brain damage. Many important studies in the 90s and 2000s are concerned with changes in verbal fluency depending, for example, on lesion location for focal brain damage (Baldo et al., 2001; Henry & Crawford, 2004a). Concurrently, studies about verbal fluency impairment in different neurodegenerative (Barbosa et al., 2017; Benjamin et al., 2015;

Chi et al., 2014; Farzanfar et al., 2018) and psychiatric disorders (Bauer et al., 2015; Egeland et al., 2018) have proliferated, along with studies on more diffuse brain damage, such as traumatic brain injury (Henry & Crawford, 2004b).

Part of the high interest in verbal fluency performance might thus reside in how it is related to many aspects of cognitive function, particularly executive control but also memory and language (Aita et al., 2019; Kavé & Sapir-Yogev, 2020; Vinogradov et al., 2003; Whiteside et al., 2015), and thus, to subtle dysfunction of cognitive brain networks across many pathological conditions. Even if low fluency scores, by themselves, might not be really discriminative about a specific lesion or pathology, part of their growing interest in these decades comes from its sensitivity to dysfunction across many conditions related to functional and structural brain impairment, and also to specific cognitive processes which are of utmost importance for the clinician. In this regard, research from 1995 onwards has also addressed how qualitative aspects of task performance, such as clustering and switching, might differentially associate to executive and memory components of the task. Some of these studies have been widely cited, in fact (Troyer et al., 1997, 1998), though it might not be easy to dissociate those components in a simple way (Mayr, 2002).

In addition, an important turning point by the end of the 20th century in neuropsychology and cognitive neuroscience is the generalization in the use of functional brain imaging. Part of the increase in literature about verbal fluency from the final of 90s' decade could be related to the possibility of using verbal fluency test in neuroimaging studies. Other classical assessment tools in neuropsychology, such as many of the classic paper and pencil tests, could be difficult to implement for neuroimaging research, but it is not the case for phonemic and semantic verbal fluency tasks.

Moreover, and giving its utility (even as a screening tool) in important pathologies with a significant increase of research literature (as Alzheimer disease or Parkinson); the publication of normative data with large samples by the end of the 90s (Gladsjo et al., 1999; Tombaugh et al., 1999; Troyer, 2000) had allowed clinicians to use a free neuropsychological tool, with the possibility to compare the results obtained with normative data. The availability of such data might have also promoted the use of verbal fluency as a clinical research tool and therefore, the exponential growing in related literature.

A closer inspection of the most cited articles among those published in the period of time between 1995 and 2005 seems to support this hypothesis. Some of them assessed pathological samples such as, people with brain injury (Henry & Crawford, 2004a; Troyer et al., 1998), Alzheimer's Disease (Henry et al., 2004) and schizophrenia (Frith et al., 1995), and finally two of them presented normative data (Gladsjo et al., 1999; Tombaugh et al., 1999), moreover, an article include neuroimaging techniques (Frith et al., 1995). These results also highlight the importance of the clustering and switching aspects of verbal fluency test (Troyer et al., 1997, 1998). Apart from the total number or words, the possible analysis of this other components more specifically related with executive functions, probably made the tool even more attractive, according to the above-mentioned change in interest from lesion localization to the analysis of functional processes, as could be additionally confirmed in the second term map during the period from 1995 to 2021.

Further, the results related with the most frequently used terms in verbal fluency´s publications show an important change after this critical period around 1995. In the first period (1965-1995), the most significant topics in relation to verbal fluency were "effect" and "patient". This reflects that, during that period, the use of this task

was primarily focused on the assessment of pathology, with a clear applied perspective, as discussed above. The scene evolved into one rather complex from 1995, when topics such as "cognition", "attention", "memory", or "executive control" becoming important topics (see figure 3b). This change reflects a shift in the area towards a more comprehensive use of the verbal fluency tests that goes beyond a purely applied or clinical one. Verbal fluency tests started then to be considered important measures of cognitive processes, particularly executive functions, as revealed by the emergence of "clustering" and "switching" as important themes of research. Notwithstanding, our analysis also shows that verbal fluency tests were still used for the assessment of brain pathology (indexed by the occurrence of terms such as "Alzheimer", "Parkinson", "Dementia", "Schizophrenia", "Depression" or "Traumatic Brain Injury") but probably from a more complete perspective that include in-vivo brain imaging (i.e. "Near-infrared Spectroscopy", "fMRI" or "Functional Connectivity") and even brain stimulation (i.e. "Deep Brain Stimulation").

Overall, this evolution reflects a shift in the research interest that, rather than a change, seems to be more compatible with a progressive adoption of complementary perspectives that complemented and enriched the applicability of verbal fluency tests.

Verbal fluency, as an interesting neuropsychological assessment tool, has been broadly used in research that had been published in renowned prestigious journals with high IF. The majority of them are journals specialized in neuroscience (*Archives of Clinical Neuropsychology*, *Journal of Clinical and Experimental Neuropsychology*, *Journal of the International Neuropsychology Society*, *Clinical Neuropsychologist*, *Neuropsychologia*, *Neuropsychology*), but also in more general journals (*Neurology*), in those focusing on a specific clinical population (*Schizophrenia Research*, *Biological Psychiatry*), and even on journals devoted to the use of neuroimaging to study of

structure-function relationships (*Neuroimage*). This distribution highlights the relevance of the topic in clinical research as well as in that more related with neuroimaging techniques.

With the increased availability of PET and fMRI during the 90s, a wide amount of studies assessed the pattern of brain activity related to verbal fluency tasks. Both letter and semantic fluency seem to commonly and consistently recruit a complex fronto-temporo-parietal network, including predominantly increased activation at anterior cingulate and left dorsolateral and ventrolateral prefrontal areas, as well as deactivation over mesial parietal regions (Phelps et al., 1997; Schlösser et al., 1998). Letter fluency seems to induce more activation over dorsal portions of the left inferior frontal gyrus, in congruence with its supposed role in phonological and articulatory processing. In contrast, semantic fluency seems to recruit to a higher extent more anterior regions of the left inferior frontal gyrus as well as temporal areas related to semantic processing (Birn et al., 2010; Costafreda et al., 2006; Gourovitch et al., 2000).

The adaptation of verbal fluency protocols to fMRI settings, however, is not unproblematic. The standard protocol requires overt free recall of exemplars, while the motionless and noisy fMRI setting might require either covert recall or experimenter-paced overt recall. Moreover, the election of the more adequate baseline to reveal the task-related effects of interest might require careful consideration. However, different authors have investigated and proposed solutions in this regard (see Allen & Fong, 2008; Basho et al., 2007). Functional near-infrared spectroscopy (fNIRS) allows for overt responses during free recall, more akin to the usual verbal fluency assessment protocol, and has been also widely used to investigate patterns of brain activity related to verbal fluency tasks (Herrmann et al., 2003).

Functional neuroimage of verbal fluency might be particularly interesting when frontal lobes are supposed to be involved, as in many psychiatric disorders (se Yeung & Lin, 2021, for a recent review of fNIRS data). For example, hypoactivation of frontal areas has been consistently reported in major depressive disorder, along with a failure to deactivate mesial parietal cortex (Hu et al., 2021; Takamura et al., 2016). Changes and de-regulation in frontal activation and mesial parietal deactivation have been also reported in people with schizophrenia and bipolar disorder, with differential patterns. For example, lower deactivations of the precuneus and other parietal areas are reported for both schizophrenia and bipolar patients alike relative to controls, but some results suggest that hyperactivation in right prefrontal areas (Costafreda et al., 2011) and lower functional connectivity across frontal task-related areas and striato-thalamic circuits (Vandevelde et al., 2018) might be specific for patients with schizophrenia. Hence, functional neuroimage of verbal fluency in psychiatric disorders might be useful to reveal shared and unique neurofunctional impairments. The possibility to adapt verbal fluency task to functional neuroimage protocols, in particular with fNIRS, and its applicability to the study of the pathophysiology of psychiatric disorders, might explain why these terms appear closely related in the bibliometric map, and the interest of journals related to psychiatry and neuroimage on the topic. Moreover, another state of affairs were the conjoint use of functional neuroimage and verbal fluency might be clinical useful is the study of hemispheric dominance for language prior to surgery, as in patients with intractable epilepsy or brain tumors. In a systematic review, Bradshaw et al., (2017) indicate that verbal fluency tasks provide consistently strong laterality indices (i.e., indices of the relative hemispheric dominance for language), particularly with regard to the participation of frontal areas.

Considering these points, the exponential growth of publication around verbal fluency seems to be probably due to a multifactorial process. The ease of use in any population, even with patients for whom other tests are more complex, in combination with its sensibility to detect cognitive impairment (used as screening), are probably behind the multifactorial nature of the growth of its scientific production. Likewise, the possibility of employing verbal fluency tasks in structural and functional neuroimaging sets in a simpler way have probably made it an adequate tool for massive use in research. Finally, the emergence of the analysis of more complex components within the task itself, such as clustering or switching, gave added value to it. Accordingly, this exponential development of the scientific literature on verbal fluency has led to the publication of numerous studies with normative data in a multitude of languages and contexts, which are still being updated nowadays (Rivera et al., 2019; St-Hilaire et al., 2016; Vogel et al., 2020). Clearly, there are many countries—from varying continents that use different languages (English, Japanese, German, Portuguese, Spanish, French, etc.)—that have contributed to the scientific production in this discipline. Despite this international interest in verbal fluency, figure 2 displays clearly how USA and England concentrate most of the research output. This is surely related to the high investment in research in these countries and also to their long-standing tradition of research and practice in neuropsychology. This is also reflected in the fact that Universities are the institutions with higher rates of publications (in all of the most active countries), demonstrating the great utility and tradition of verbal fluency tasks in research on neuropsychological processes.

Moreover, scientific production has experienced an important growth in many fields, and particularly in health science and neuroscience. Thus, it is critical to contextualize the exponential growth of publications around verbal fluency by

comparing it with production around other equivalent neuropsychological tools, and even broader topics within the field of neuropsychology. Our results showed that scientific production around verbal fluency was greater than that experienced by other test such as the Trail Making Test or the Wisconsin Card Sorting Test. Features of verbal fluency tests such as its availability, its easy and short time application, and its informative value, among others, may account for this advantage in relation with more complex or commercial tools. Notwithstanding, production around the concept of executive function showed the largest increase, confirming that neuropsychology and cognitive neuroscience is a field under expansion.

Considering the progressive aging of population in developed countries, it seems reasonable to suggest that verbal fluency will become even more relevant in the coming future. Recent evidence has probed its utility for predicting risk of cognitive impairment, dementia, and conversion of the first to the latter, and these associations were independent of age, gender, education, race, ethnicity, and APOE risk status (Sutin et al., 2019). Their predictive value in combination with its easy administration might make verbal fluency test an important screening tool to be implemented in most neurological context for screening and prevention strategies within the healthcare systems.

Despite of its interest in analysing and assessing trends in scientific activity, bibliometrics are not exempt of certain limitations, as those imposed by the lack of standardization of authors' names. Also, although citations are used as an index of the importance of a given study in the scientific field, citations themselves may be considered an indicator of its visibility, rather than a measure of quality. Additionally, the search strategy applied was just in manuscript´s titles, therefore it is possible that some articles were not included, for example the ones which use neuropsychological

batteries such us D-KEFS or RBANS. Still, the combination of a large number of bibliometric indicators on data collected using a very powerful database (i.e., Web of Science) allows to offer an informative picture of the development of scientific activity on the field of verbal fluency.

Bibliometric studies are important as an effective complement for the opinions and judgements of experts in a specific field, as a useful and objective measure for evaluating the results of scientific activity. They provide a more realistic view of the complete picture, and reveal the research trends in a specific discipline, as well as predict how the research activity might evolve for a given scientific speciality. In summary, this study provides an opportunity to reveal the development and evolution of publications involving research into the verbal fluency literature, a fundamental tool in neuropsychological context.

The results of this bibliometric study provide a comprehensive overview of the development of the scientific literature in the verbal fluency field. Nowadays, many of these free and classic "pencil and paper" tests are often undervalued by new generations of professionals who are impressed by recent computer/digital tests. The conclusions reached by this study are far from this. Verbal fluency tests are particularly relevant today. They are accessible and offer relevant information for both research and clinical practice. They are simple and quick tasks that require activation of multiple cognitive processes. They may be used in almost all situations with all kind of participants and do not require specific assessment tools. Thus, the cost-benefit of these tasks have made the verbal fluency test probably the most used tool in current and probably future neuropsychological assessment.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Tables

Table 1

Values of the parameters obtained with the exponential model

Parameter estimates				
Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
c	2.7212	.447	1.318	3.106
g	1.067	.004	1.059	1.075

ANOVA[a]			
Source	Sum of Squares	df	Mean Squares
Regression	112488.552	2	56244.276
Residual	5385.448	60	89.757
Uncorrected Total	117874.000	62	
Corrected Total	70268.774	61	

Dependent variable: Docs

a. R squared = 1 - (Residual Sum of Squares) / (Corrected Sum of Squares) = .923

Table 2

Distribution of journals in Bradford's zones

	Nº of journals	% of journals	Nº of articles	% of articles	Bradford multiplier
Core	15	3.01	576	33.53	
Zone 1º	77	5.46	563	32.77	5.13
Zone 2º	406	82.53	579	33.70	5.27
Total	498	100.00	1718	100.00	5.2

Table 3

Journals with highest number of publications on verbal fluency

Source	No of documents	Productivity Index	Impact Factor*	Country of origin	Category	Quartile
ARCHIVES OF CLINICAL NEUROPSYCHOLOGY	113	6.58	2.813	United Kingdom	Psychology	Q2
SCHIZOPHRENIA RESEARCH	69	4.02	4.939	Netherlands	Psychiatry	Q1
JOURNAL OF CLINICAL AND EXPERIMENTAL NEUROPSYCHOLOGY	63	3.67	2.475	Netherlands	Clinical Neurology	Q3
CLINICAL NEUROPSYCHOLOGIST	47	2.74	3.535	Netherlands	Clinical Neurology	Q2
NEUROPSYCHOLOGIA	38	2.21	3.139	United Kingdom	Behavioral Sciences	Q2
NEUROLOGY	35	2.04	3.139	United States	Clinical Neurology	Q1
JOURNAL OF THE INTERNATIONAL NEUROPSYCHOLOGICAL SOCIETY	31	1.80	2.892	United States	Clinical Neurology	Q3
NEUROPSYCHOLOGY	27	1.57	3.295	United States	Neurosciences	Q3
BIOLOGICAL PSYCHIATRY	24	1.40	13.382	United States	Neurosciences	Q1
NEUROIMAGE	24	1.40	6.556	United States	Neuroimaging	Q1

*Data of JCR 2020

Table 4

Top 10 most cited articles

Article	Authors	Source	Cited	%	Year
Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming	Tombaugh, TN et al.	Archives Of Clinical Neuropsychology	911	2.11	1999
Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults	Troyer, AK et al.	Neuropsychology	707	1.64	1997
Comparisons of verbal fluency tasks in the detection of dementia of the alzheimer type	Monsch, AU et al.	Archives Of Neurology	498	1.15	1992
A meta-analytic review of verbal fluency performance following focal cortical lesions	Henry, JD et al.	Neuropsychology	450	1.04	2004
What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults	Shao, Z et al.	Frontiers In Psychology	443	1.03	2014
Verbal fluency performance in dementia of the Alzheimer's type: a meta-analysis	Henry, JD et al.	Neuropsychologia	443	1.03	2004
Clustering and switching on verbal fluency: the effects of focal frontal- and temporal-lobe lesions	Troyer, AK et al.	Neuropsychologia	411	0.95	1998
Childrens production on verbal and non-verbal fluency tasks	Regard, M et al.	Perceptual And Motor Skills	392	0.91	1982
Norms for letter and category fluency: Demographic corrections for age, education, and ethnicity	Gladsjo, JA et al.	Assessment	367	0.85	1999
Regional brain activity in chronic-schizophrenic patients during the performance of a verbal fluency task	Frith, CD et al.	British Journal Of Psychiatry	355	0.82	1995

Table 5

Comparison between the growth in verbal fluency and other concepts

	Number of articles	Type growth	Annual Grown %	Doubling time*
Verbal fluency	1,344	Exponential	6.7	10.7
Trail making test	474	Exponential	5	14.2
Wisconsin card sorting test	563	Linear	2.2	31.8
Executive function	5,236	Exponential	11.1	6.6

* Years

Caption of figures

Figure 1

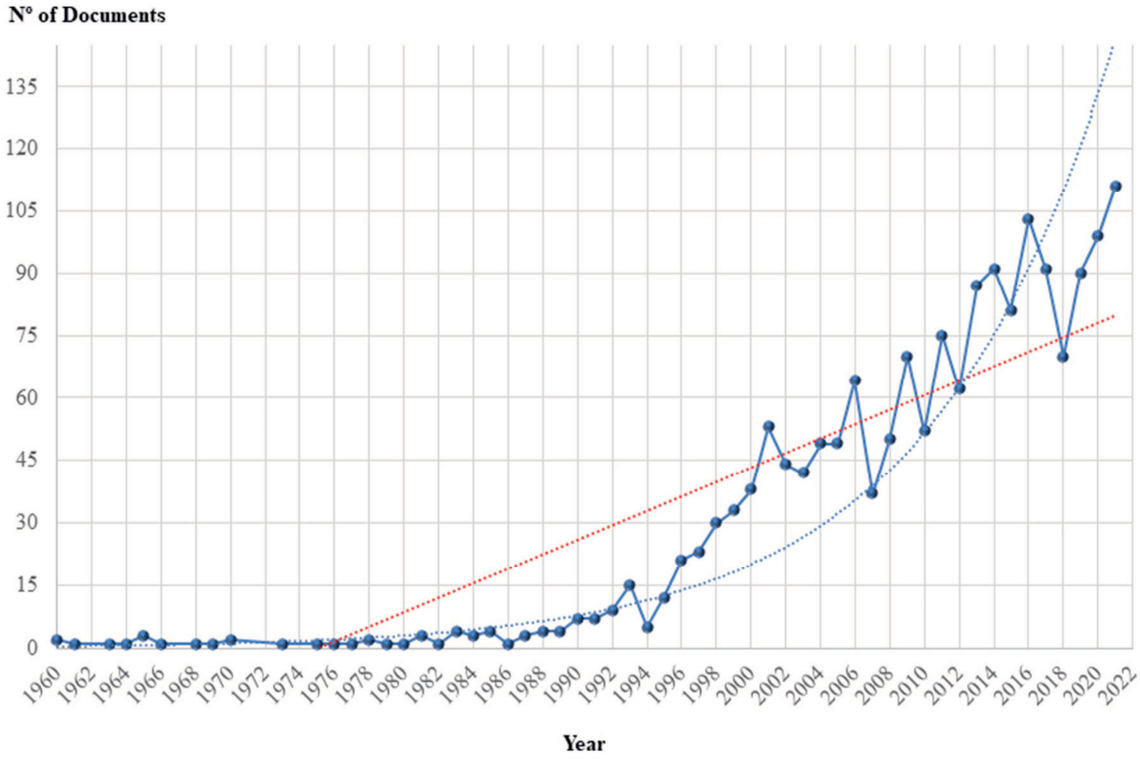
Chronological distribution. Linear adjustment (red): y = 1,7342x – 3225 (R^2=0.7871). Exponential adjustment (Blue): y = 1E-81$e^{0.0946x}$ (r = 0.866).

Figure 2

More productive countries and institutions in the generation of scientific literature on verbal fluency

Figure 3

VOSviewer co-occurrence keywords map. A) Term map of title and abstract words in verbal fluency publications during 1994–1960 with research topics indicated (based on VOSviewer). B) Period 2021-1995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120
105
90
75
60
45
30
15
0
1960
1962
1964
1966
1968
1970
1972
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1984
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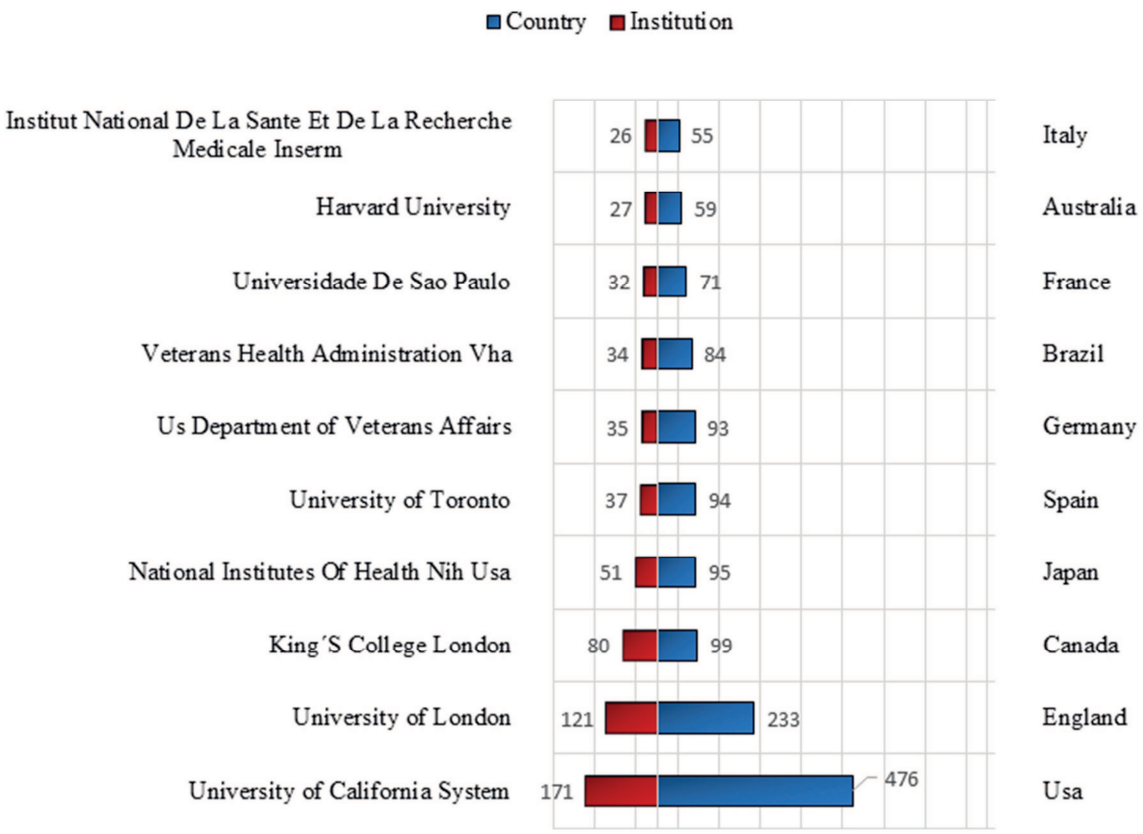
2018
2020
2022
Year

Figure 1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Institution
Institut National De La Sante Et De La Recherche Medicale Inserm
26
55
Italy
Harvard University
27
59
Australia
Universidade De Sao Paulo
32
71
France
Veterans Health Administration Vha
34
84
Brazil
Us Department of Veterans Affairs
35
93
Germany
University of Toronto
37
94
Spain
National Institutes Of Health Nih Usa
51
95
Japan
King´S College London
80
99
Canada
University of London
121
233
England
University of California System
171
476
Usa

Figure 2

Fig. 3a

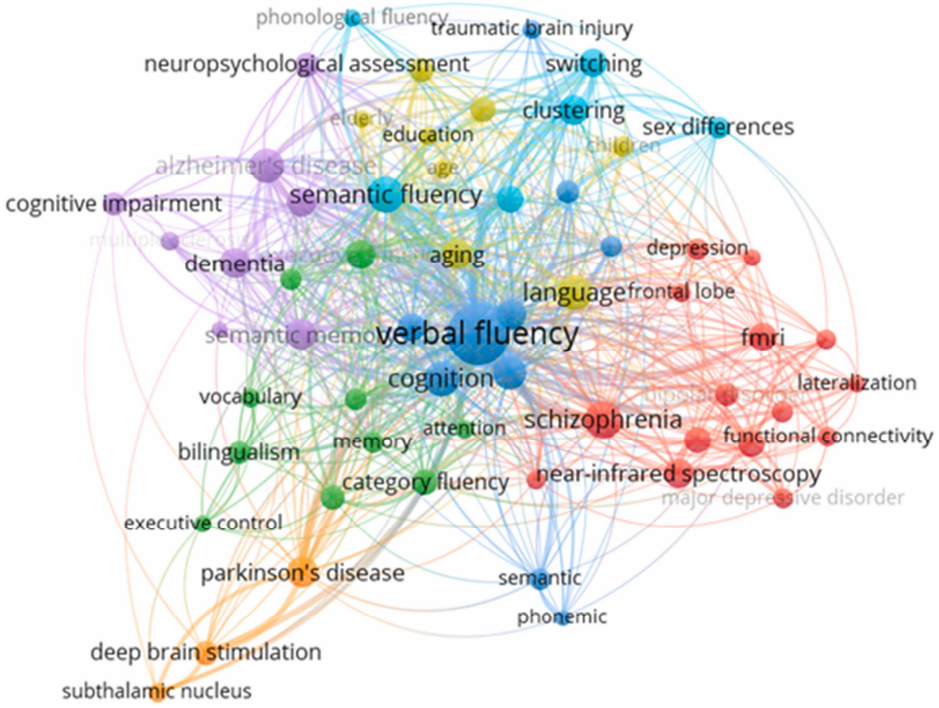

Fig. 3b

Figure 3