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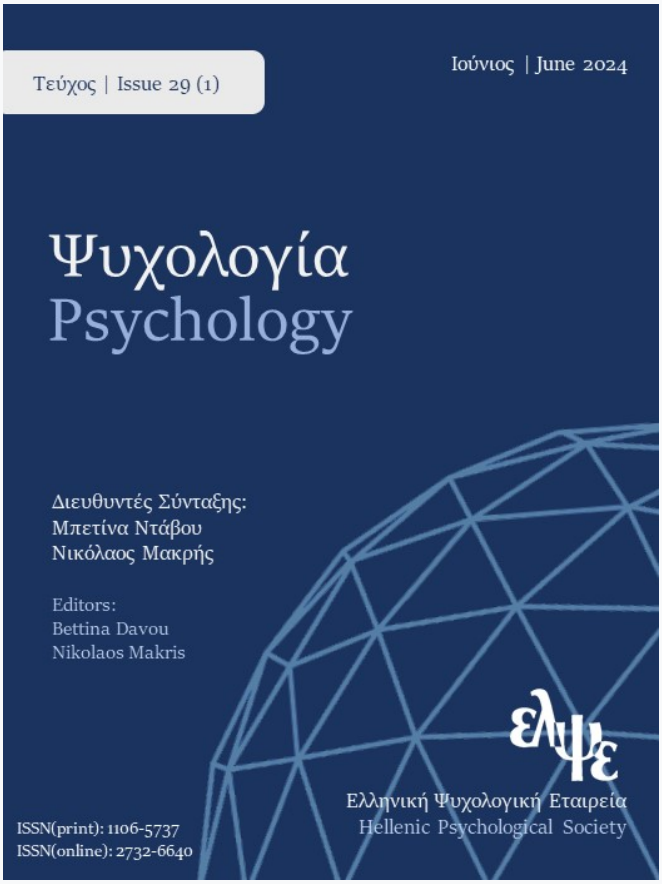


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ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER

# The importance of response times measures in verbal fluency tasks

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KEYWORDS

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ABSTRACT

Verbal fluency is a commonly used task in clinical and experimental neuropsychology. It assesses a person's ability to generate relevant words, according to a given category within a limited amount of time. Phonemic (PF) and semantic (SF) fluency tasks reflect different aspects of language and executive function abilities. In the present study, we investigated first response latency as an additional measure of phonemic, semantic and excluded letter fluency of 44 healthy adults (aged 18 to 39 years old) divided in 2 groups, according to their education level. We investigated potential correlations between response times and education level. Preliminary results from a small sample show that when comparing phonemic, semantic and excluded letter tasks the shortest response time was observed in semantic fluency tasks whereas the excluded letter tasks have the longest ($Z = -5.35$, $p < 0.0005$). Education appeared to have a significant negative effect on the mean response times of the participants (for PF $U = 137$, $p = 0.014$; for ELF $U = 141.5$, $p = 0.018$; for SF $t = 2.05$, $p = 0.046$). These results constitute a potential underexamined way to investigate lexical organization and access in verbal fluency. Also, we noted that education contributes not only to overall performance but to response times as well.

## Introduction

Verbal Fluency tests are designed for the assessment of language skills and executive functions in both healthy and clinical populations, and they are often considered sensitive to the detection of early dementia in elderly people (Holtzer et al., 2008). Furthermore, verbal fluency is employed for the investigation of vocabulary knowledge and lexical retrieval in healthy samples (Shao et al., 2014). Verbal fluency is an easily administered language task, which commonly consists of two conditions: 1) phonemic fluency or letter fluency and 2) semantic fluency or category fluency (Shao et al., 2014). For the phonemic fluency test the participant is asked to generate in limited time (usually 60 seconds) as many words as possible starting with a specific letter of the alphabet, while during the semantic fluency test the participant is asked to produce words coming from a specific taxonomic category (e.g., animals, fruits, tools, vehicles etc.) (Henry & Crawford, 2004; Tallberg et al., 2008). A less frequently used task is excluded letter fluency. It is considered a particularly demanding task for the executive functions of the brain and especially for the monitoring system, during which the examinee is asked to produce as many words as possible that do not contain specific letters of the alphabet within one minute (Shores et al., 2006). Increasing age seems to have greater effect on the performance of the examinees, as compared to


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phonemic and semantic fluency (Hughes & Bryan, 2002). Both tasks differ in their demands on the cognitive system and in the underlying cognitive skills recruited to achieve them. Semantic fluency derives from semantic memory and semantic associations, while phonemic fluency requires strategic word search and retrieval based on lexical features, such as recognizing appropriate words by their initial letter (Henry et al., 2004). The traditional scoring of verbal fluency tests is the total number of correct words reported by the examinee within the predetermined time period given by the examiner. The total number of correct words produced is therefore an indicator of the participants' performance. Verbal fluency is considered a multifactorial process, so a single raw score cannot capture all aspects of the examinee's performance and the underlying cognitive functions associated with that performance (Thiele et al., 2016; Troyer et al., 1997; Zhao et al., 2013). The different dimension of the tests becomes evident in clinical populations, whose performance is affected heterogeneously in each task (Shao et al., 2014).

Recent literature has focused on exploring new advanced measures and techniques in order to cover these underexamined aspects and cognitive processes of verbal fluency. These new measures focus on the temporal parameters of the process. Also, advanced studies include the assessment of the rate of word production, as distributed over the one-minute predetermined time constraint (Demetriou & Holtzer, 2017; Raboutet et al., 2010) or the speed of word production (Ayers et al., 2022). Other studies have explored the intervals of silence during the tests, which according to the researchers, featured similar diagnostic value to the traditional measures of test scores (Balogh et al, 2022), as well as, the duration of the pauses between clusters (Gabrić & Vandek, 2022). Following this line, we explored lexical access processes through an underexamined variable, the first response latency in verbal fluency tasks. Martin et al., (1994) reported performance differences in word retrieval between initial letter and semantic criterion tasks. Word retrieval based upon semantic cues involves different neural networks compared to word retrieval according to phonological traits or cues (like in the phonemic fluency tasks). The former depends primarily on processes taking place in the temporal lobes, which are known to be associated with object and symbol perception. The latter engages regions of the left frontal cortex and requires greater mental effort and strategic search. Neuroimaging studies have confirmed these observations (Birn et al., 2010; Li et al., 2017; Libon et al., 2009). We examine if this difference between these two types of word retrieval processes results in different response time measures.

First response latency as a measure in verbal fluency tasks was investigated by Luo et al. (2010) in a bilingual young adult sample and they reported longer response times for bilinguals compared to monolinguals in the letter fluency task. Shao et al. (2014) also investigated response times in adults and found that response times were a predictive factor for performance in semantic, but not in phonemic fluency. They attributed their results to the different retrieval mechanisms involved in the two tasks, suggesting that lexical access ability and vocabulary knowledge are more influential factors in semantic fluency than in phonemic fluency. In addition, they found that these are negatively correlated with response times. The present study is an initial attempt to compare first response latency in a healthy young adult population in 3 different verbal fluency tasks: 1) phonemic fluency, 2) semantic fluency, and 3) excluded letter fluency. We also explored potential correlations between participants' response times and their educational level. In this study, we expect that semantic fluency will have the shortest mean first response latency out of phonemic, semantic and excluded letter fluency tasks and we hypothesize that examinees with higher education will have shorter mean first response times, than those with secondary education.

## Method

### Participants

A group of 44 participants aged 18 to 39 with a mean age of 27,8 years (SD=6.8) were divided into 2 samples, equal in size, according to their education level: 22 participants that have completed secondary education (12

years) and 22 participants that have completed tertiary education (13+ years). All participants met the following inclusion criteria: a) Greek as a native language and b) no history of neurological or psychiatric conditions, that could affect their mental state and cause any cognitive impairment. The participants did not receive any financial or other kind of compensation and they signed a written consent form, informing them of the voluntary nature of their participation and that their answers were being recorded. The study received clearance from the Committee for Research Ethics of the University of Macedonia (Thessaloniki, Greece) (5/15-11-2021). The ethical permission is in accordance with the 1964 Declaration of Helsinki.

The participants were administered three verbal fluency tasks individually and in a quiet environment without distractions. The duration of the examination was approximately 10 minutes for each participant. The answers, along with the verbal instructions, were recorded via a tablet device, in order to be transcribed. The assessment included the calculation of the raw scores for each participant (number of correct responses) and the measurement of the first response time was conducted with the sound recording program Audacity (Price et al, 2009). Response time was defined as the interval between the verbal prompt that was given as a cue by the researcher and the first word mentioned by the examinee. Possible hesitations or other verbal comments besides requested words were measured within the reaction time. Participants were instructed to begin the oral production of the words as soon as the letter/taxonomic category was announced to them (after the verbal cue "Go"). An additional instruction was to avoid repetitions of words, variations, and derivatives of the same word, as well as proper nouns. No guidelines were given regarding their search strategies or other cognitive strategies. The three following tasks were given in one session and in random order for each participant: 1) Phonemic fluency. During this task the participants were asked to produce as many words as possible starting with the particular letters of the alphabet X (Chi), S (Sigma) and A (Alpha) (1 minute for each), which were chosen based on the frequency of words in the Greek language, that begin with these letters (Kosmidis et al., 2004), 2) Semantic fluency. In this task, the participants were asked to produce as many words as possible belonging to the taxonomic categories of animals and fruits (1 minute for each). These two categories were, again, chosen because of their guaranteed validity in the Greek population (Kosmidis et al., 2004), 3) Excluded letter fluency. In this task, participants were asked to name as many words as possible that did not contain the letter A (Alpha) in the first condition and the letter E (Epsilon) in the second condition (1 minute for each). There are no normative data for the Greek population for this specific task. As this is a preliminary data collection attempt and because of the small sample size, non-parametric statistical tests were used.

Statistical analysis was conducted with the program for Social Sciences SPSS Version 26.0. A descriptive analysis was carried out for dependent variables (mean response times), with reference to average performance and response times on three tests. Condition checks were subsequently carried out, with investigation of the normality of the dependent variable data overall, as well as separately at each level of the dichotomous independent variable of the number of years of education. Wilcoxon Signed Ranks tests were performed for the group comparison of verbal fluency response times. Subsequently, two non-parametric Mann-Whitney U tests and one parametric t-test were conducted, with the average response times of the three tests as dependent variables and the number of years of education as the independent variable.

## Results

The average response time was measured for the total sample (N = 44) in each of the three tests. We found the fastest average response times in the semantic fluency task, significantly slower response times in phonemic fluency, and the slowest response times in the excluded letter fluency. The average response times (in seconds) for the three verbal fluency tasks were: a) Phonemic Fluency 2.62 s (SD= .976), b) Semantic Fluency 1,97 s (SD=.596), and c) Excluded Letter Fluency 3.70 s (SD=1.64). Data for phonemic fluency ($p$ = .001) and excluded letter fluency ($p$ = .004) did not follow a normal distribution. The boxplots for these two variables showed four outliers on phonemic fluency and two on excluded letter fluency. As presented in Table 1 we found that 32

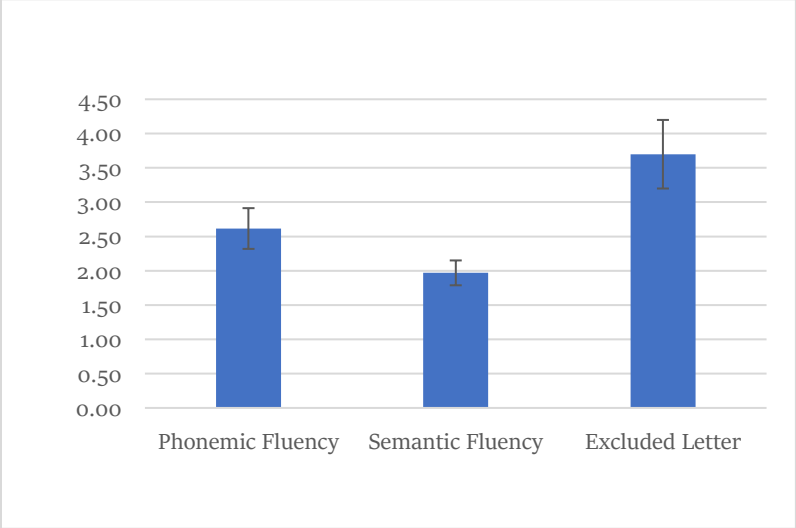
participants responded faster on semantic compared to phonemic fluency (Z = -3.91, *p*= .000046, *p* < .0005), and 37 participants responded faster on phonemic fluency compared to the excluded letter task (Z = -4.13, *p*= .000018, *p* < .0005). 39 participants responded faster on semantic compared to the excluded letter task (Z= -5.345, *p*=00001, *p*< .0005). The observed differences were statistically significant for all three verbal fluency tests. The task with the shortest response times was the semantic fluency followed by the phonemic fluency test. Excluded letter fluency had the longest response times. For the second part of our investigation the Shapiro-Wilk test of normality indicated that only the data for semantic fluency followed a normal distribution across the two levels of education ("13+ years" *p* = .595, "12 years" *p* = .638) thus we applied a parametric independent samples t-test. Two non-parametric Mann-Whitney U tests were conducted for phonemic and excluded letter fluency. Table 2 presents the results of the two non-parametric Mann-Whitney tests and Table 3 the results of the t-test. The education level significantly affected the average response times in the phonemic fluency tests (U = 137, *p* = .014) and excluded letter fluency (U = 141.5, *p* =.018). The independent samples t-test showed that the difference of the two samples in semantic fluency was also statistically significant (*t*(42) = 2.05, *p* = .046). In conclusion, subjects with higher education had statistically significant shorter response times, than subjects with secondary education in all three tests.

**Table 1.** *Wilcoxon Signed Ranks Test*

| | | **N** | **Mean Rank** | **Sum of Ranks** | **Z** | **Asymp. Sig. (2-tailed)** |
|---|---|---|---|---|---|---|
| **Semantic-Phonemic** | Negative Ranks | 32 | 25.94 | 830.00 | -3.910* | .000 |
| | Positive Ranks | 12 | 13.33 | 160.00 | | |
| | Ties | 0 | | | | |
| | Total | 44 | | | | |
| **Excluded Letter-Phonemic** | Negative Ranks | 7 | 20.21 | 141.50 | -4.126** | .000 |
| | Positive Ranks | 37 | 22.93 | 848.00 | | |
| | Ties | 0 | | | | |
| | Total | 44 | | | | |
| **Excluded Letter-Semantic** | Negative Ranks | 5 | 7.40 | 37.00 | -5.345** | .000 |
| | Positive Ranks | 39 | 24.44 | 953.00 | | |
| | Ties | 0 | | | | |
| | Total | 44 | | | | |

**Note.* *Based on positive ranks, ** *Based on negative ranks*

**Graph 1.** *Error Bar Chart for the distribution of the response times*




**Note.* Y Axis refers to seconds

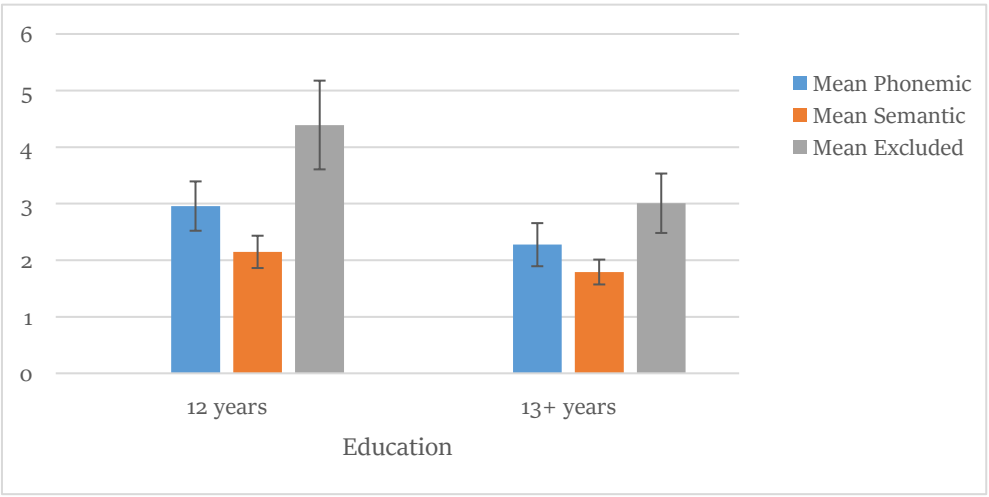
**Table 2.** *Comparison of two levels of education on phonemic and excluded letter response times*

| | **Phonemic fluency** | **Excluded letter fluency** |
|---|---|---|
| **Mann-Whitney U** | 137.000 | 141.500 |
| ***p*** | .014 | .018 |

**Table 3.** *Comparison of two levels of education on semantic fluency response times*

| **t-test** | *t* | df | *p* |
|---|---|---|---|
| **Semantic Fluency** | 2.052 | 42 | .046 |

**Graph 2.** *Error Bar Chart for the distribution of the response times*




**Note.* Y Axis refers to seconds

## Discussion

The purpose of the present investigation is to explore first response latency as a new measure in verbal fluency tasks, following the line of the recent research literature in investigating the temporal parameters of the procedure. As verbal fluency is a valuable assessment tool, any aspect and variable of the procedure can be useful for the evaluation of healthy and clinical populations. First response latency, in particular, is an underexamined variable that could be identified as an important measure, assuming that further investigations will be conducted.

First response latency measurements were administered separately for each participant and for each of the 3 verbal fluency tasks. The task with the shortest response times was the semantic fluency test, followed by phonemic fluency, and the one with the longest was the excluded letter fluency test. Our preliminary results are in agreement with Luo et al. (2010) and Shao et al. (2014) in that the semantic fluency task presented the shortest response times as compared to the phonemic fluency task. Several researchers have suggested that in the semantic fluency tasks the linguistic factor prevails so they are primarily linguistic tools and to a much lesser extent executive functions assessment tools (Kraan et al., 2013; Whiteside et al., 2016). During the initial stage of category fluency there is automatic activation of the most easily accessible words from long-term memory, while a more extensive search is conducted through executive functions during the subsequent time intervals of the task (Crowe et al., 1998; Demetriou & Holtzer, 2017; Raboutet et al., 2010). Besides, during semantic fluency tasks there are "bursts" that are semantically related or form clusters (Crowe, 1998; Unsworth et al., 2011) which have been identified as two distinct stages in word production. Automatic retrieval and strategic search are alternated during performance and, therefore, the final performance is the result of the dynamic interaction of these factors (Rosen & Engle, 1997; Unsworth et al., 2011). It is possible that semantic fluency, especially in the first few seconds of the task, does not require the strategic search that is required in initial letter fluency (and even more in excluded letter fluency) and this is reflected in significantly shorter response times. Further investigation is needed.

Shao et al. (2014) showed that accessing words of a specific category is easier because it is supported by the semantic links among the words belonging to that category as opposed to letter fluency, for which there are no such links. In addition, longer pauses have been associated with more cognitively demanding tasks (Bortfeld et al., 2001; Wolters et al., 2016). Excluded letter fluency is referred to in the literature as a fairly demanding monitoring task (Crawford et al., 1995; Shores et al., 2006), which relies on distinct search strategies, since there cannot exist stored words based on the absence of a letter in them (Hughes & Bryan, 2002). Consistent with that statement, we detected unique search and retrieval strategies during excluded letter fluency. More specifically, most of our subjects tended to retrieve words by naming objects of the surrounding environment (according to the given instructions) and not by their long-term memory. As a consequence, it is rather reasonable to expect the longest response times in excluded letter fluency.

On top of that, we can presume that longer response times in phonemic fluency compared to semantic fluency and even longer times in excluded letter fluency, are indicative of greater difficulty for participants in these tasks. Kosmidis et al. (2004) also reported that the superior raw scores (number of correct responses) in semantic fluency compared to phonemic fluency could be attributed to the fact that participants find the phonemic task more difficult, as there is less structure when searching for words starting with the same initial letter. Moreover, searching based on semantic categories restricts the search field and reduces the cognitive demands of the task. In addition, many researchers who have analyzed the frequency of occurrence of semantic patterns indicate the occurrence of very common and familiar words in the first seconds of semantic fluency (Crowe, 1998; Raboutet et al., 2010; Wolters et al., 2016). The present research is in complete agreement with these observations, as the majority of participants, regardless of their level of education, generated the strong semantic pair "dog-cat" as the first words in the category "animals", which is indicative of the automatic retrieval of familiar and ordinary words during the initial time interval.

In conclusion, different response times reflect different lexical retrieval processes, as well as different underlying cognitive skills that are required for completing verbal fluency tasks. According to the prevailing models of lexical retrieval, words are selected firstly based upon their semantic features and secondly upon their phonological properties, so semantic activation precedes phonological activation (Levelt et al., 1999). This observation may explain this small advantage of semantic fluency tasks in terms of speed as an overlearned process during word production. Generating words based upon their initial letter or retrieving words that do not contain a specific letter of the alphabet is not an individual's common strategy or routine, hence it requires more effort and possibly, the engagement of executive functions to accomplish it.

Furthermore, we compared the response times of two samples with different levels of education. Participants with an education level of 13+ years had faster mean response times than participants with an education level of 12 years in all 3 verbal fluency tasks. Most studies have demonstrated a constantly positive effect of education on verbal fluency (Acevedo et al., 2000; Da Silva et al., 2004; Kosmidis et al., 2004). It has been demonstrated that higher education increases the individual's exposure to a wider vocabulary (Nogueira et al., 2016), which can result in both better performance and faster response times in verbal fluency tasks, as vocabulary has been associated with faster responses in various language processing tools, including naming tasks, word recognition tests, tests of lexical retrieval and word processing speed (DeAnda et al., 2018; Mainz et al., 2017). In broad terms, it has been illustrated that formal education is associated with a greater ability to acquire general and wider knowledge and with a greater ability to process this knowledge, as well (Ardila et al., 2000). As mentioned above, this is a preliminary study, therefore further investigation is required in order to arrive at safe conclusions about the nature of the correlation between education and response times. This study has some limitations. A relatively small sample was initially used and may not allow the generalization of the findings but we are continuing the data collection. The sample was selected based on availability (convenience sample) due to the coronavirus pandemic. However, the strength of this particular sample was its homogeneity across the two groups which was appropriate for the investigation of the education effect on response times. While we limited our sample to healthy individuals, with no history of cognitive or neurological deficits that could potentially affect their performance, the accuracy of this criterion was based only on self-reports. One last limitation concerning the response times investigation was the absence of adequate reference studies, as the measurement of first response latency has been employed previously only a few times. In the future, response times can be employed for further comparisons both in other types of verbal fluency tests and in the different categories given for semantic and phonemic fluency. For example, comparing the category "animals" with other kinds of semantic categories often recruited in research, such as "objects", "kinds of trees", "things we buy at the supermarket", and "fruits", can provide additional information about semantic/lexical access and organization. At the same time, the measurement of response times can be extended to other population groups, such as children and the elderly, and to various clinical populations. Particularly, as regards to clinical application of the tasks, the construction of relative normative data might be helpful in utilizing response times as a screening tool. The utilization of temporal parameters in the different subcategories of semantic fluency can provide us with useful information about their effect on verbal fluency and the appropriateness of their use in the research and clinical process.

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**ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER**

# Η σημασία των χρόνων απόκρισης σε τρεις δοκιμασίες λεκτικής ευχέρειας

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Λεκτική ευχέρεια
Χρόνοι απόκρισης
Λεξιλογική πρόσβαση
Εκπαίδευση

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ΠΕΡΙΛΗΨΗ

Οι δοκιμασίες λεκτικής ευχέρειας αποτελούν συχνά χρησιμοποιούμενα εργαλεία νευροψυχολογικής αξιολόγησης, τόσο σε κλινικούς πληθυσμούς, όσο και στην έρευνα. Ως λεκτική ευχέρεια ορίζεται η δυνατότητα ενός ατόμου να παράγει λέξεις μιας ζητούμενης κατηγορίας σε προκαθορισμένο χρόνο. Στις δοκιμασίες, συνήθως, συμπεριλαμβάνονται 2 τύποι λεκτικής ευχέρειας, η φωνημική και η σημασιολογική, οι οποίες εξετάζουν διαφορετικές λεκτικές ικανότητες και εκτελεστικές λειτουργίες. Στην παρούσα έρευνα εξετάσαμε τους χρόνους απόκρισης της πρώτης λέξης 3 δοκιμασιών λεκτικής ευχέρειας (φωνημική, σημασιολογική και ευχέρεια αποκλειόμενου γράμματος) ως ένα επιπρόσθετο μέτρο αξιολόγησης, σε δείγμα 44 υγιών ενηλίκων ηλικίας 18 έως 39 ετών, οι οποίοι χωρίστηκαν σε 2 ισάριθμες ομάδες βάσει της εκπαίδευσης τους. Επιπλέον, διερευνήσαμε την πιθανή επίδραση του εκπαιδευτικού επιπέδου στους μέσους χρόνους απόκρισης σε αυτές τις δοκιμασίες. Η σύγκριση των χρόνων απόκρισης των 3 δοκιμασιών, υπέδειξε ότι η σημασιολογική ευχέρεια διαθέτει τους μικρότερους χρόνους απόκρισης, ενώ η ευχέρεια αποκλειόμενου γράμματος τους μεγαλύτερους ($Z = -5.35$, $p < 0.0005$). Τα αποτελέσματα του δεύτερου σκέλους της ανάλυσης υπέδειξαν την στατιστικά σημαντική επιρροή της εκπαίδευσης στους μέσους χρόνους απόκρισης των συμμετεχόντων ( $U = 137$, $p = 0.014$; $U = 141.5$, $p = 0.018$; $t = 2.05$, $p = 0.046$). Τα αποτελέσματα αυτά συνιστούν έναν καινούργιο τρόπο διερεύνησης της λεξιλογικής πρόσβασης στην λεκτική ευχέρεια και υποδεικνύουν πως οι χρόνοι απόκρισης στις δοκιμασίες ανάκλησης λέξεων βάσει του αρχικού τους γράμματος διαφέρουν σημαντικά από τους χρόνους απόκρισης κατά την ανάκληση λέξεων βάσει σημασιολογικών κριτηρίων. Παράλληλα, επισημαίνεται η σημαντική επιρροή της εκπαίδευσης, όχι μόνο στην συνολική επίδοση των συμμετεχόντων, αλλά και σε αυτό το επιπρόσθετο μέτρο αξιολόγησης.


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