Approximating the Semantic Structures behind Category Fluency Sequences

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Category (or semantic) fluency is a test in which subjects are asked to produce orally as many words as possible that pertain to a single semantic category in a designated time period—usually sixty seconds. As the number of correct words produced by an individual has been reported to be a predictor of variation in cognitive abilities (Maseda et al. 2014; McDowd et al. 2011; Tombaugh, Kozak, and Rees 1999), category fluency is commonly practiced as a part of various neuropsychological assessment batteries (Mioshi et al. 2006; Weintraub et al. 2009). In addition to the unique word count, the tendency of the subjects to organize lexical items into semantically coherent *clusters* and their ability to effectively *switch* between those clusters enable finer qualitative analysis of cognitive decline and brain dysfunction (Abwender et al. 2001; Lezak 2004; Troyer et al. 1998). Troyer and colleagues (Troyer 2000; Troyer, Moscovitch, and Winocur 1997) have proposed a manual assessment protocol to analyze category fluency test results in terms of clustering and switching, exploiting the hierarchical structure, or the taxonomic organization of the lexical items that are semantically related. An interesting aspect of this seminal method is that although it is based on real-world taxonomy, the cluster definitions are manually selected and therefore carry some degree of arbitrariness. Nevertheless, empirical evidence shows that these scores show good correlation with various cognitive conditions related to executive processes and semantic memory (Raoux et al. 2008; Tröster et al. 1998), which suggests that the manually constructed clusters are good approximations of the semantic structures underlying the production of category fluency sequences. Another note is that although these manual scores are known to be useful indicators of certain neuropsychological conditions, the scoring process according to the established protocol is 1) time- and resource-consuming and 2) not adaptable to linguistic, cultural and categorical variations.

With respect to these points of discussion, we propose a novel scoring method named Backlink-VSM, that resolves both time/resource issues and adaptability problems. In the design process, we explore effective ways to approximate the semantic structures that may give rise to the category fluency sequences in order to compute scores that correlate well with the established findings in the literature. As a result, our method achieves automation of the traditional scoring protocol by estimating the semantic organization of lexical items using information extracted from large amounts of linguistic data. We extract two types of information—relational and distributional—from Wikipedia, with a goal of reproducing the results obtainable from applying the standard protocol. Relational knowledge is represented by links between Wikipedia entries (*backlink model*), and distributional information is represented by a semantic proximity metric derived from vector representations of the linguistic contexts of each word (i.e., its distribution; Harris 1954; Mikolov et al. 2013) (*vector space model*). We illustrate our approach with data collected from two languages/cultural backgrounds (English and Korean), and with two categories of items (Korean fruits and Korean animals) and show that the measures generated can reproduce previously reported age-related distinctions via clustral analyses (Troyer 2000). Our results show

significant correlation with the manual clustering and switching analyses, implying that our automated model is also a reasonable approximation of the underlying semantic structures. Furthermore, we find that the combination of relational and distributional models yields better prediction performance in comparison to standalone uses of either model, which suggests that non-hierarchical, non-taxonomic cluster and switch definitions drawn from distributional similarity could augment the original estimation based on relational structures.

References

Abwender, David A. et al. (2001). "Qualitative analysis of verbal fluency output: Review and comparison of several scoring methods." In: *Assessment* 8.3, pp. 323–338.

Harris, Zellig S. (1954). "Distributional structure." In: *Word* 10.2-3, pp. 146–162.

Lezak, Muriel Deutsch (2004). *Neuropsychological assessment*. Oxford University Press, USA.

Maseda, Ana et al. (2014). "Verbal fluency, naming and verbal comprehension: three aspects of language as predictors of cognitive impairment." In: *Aging & mental health* 18.8, pp. 1037–1045. ISSN: 1364-6915. DOI: 10.1080/13607863.2014.908457. URL: http://dx.doi.org/10.1080/13607863.2014.908457.

McDowd, Joan et al. (2011). "Understanding verbal fluency in healthy aging, Alzheimer's disease, and Parkinson's disease." In: *Neuropsychology* 25.2, pp. 210–25. ISSN: 1931-1559. DOI: 10.1037/a0021531. URL: http://www.ncbi.nlm.nih.gov/pubmed/21381827.

Mikolov, Tomas et al. (2013). "Distributed representations of words and phrases and their compositionality." In: *Advances in neural information processing systems*, pp. 3111–3119.

Mioshi, Eneida et al. (2006). "The Addenbrooke's Cognitive Examination Revised (ACE-R): a brief cognitive test battery for dementia screening." In: *Int J Geriatr Psychiatry* 21.11, pp. 1078–1085. ISSN: 0885-6230 (Print); 0885-6230 (Linking). DOI: 10.1002/gps.1610.

Raoux, Nadine et al. (2008). "Clustering and switching processes in semantic verbal fluency in the course of Alzheimer's disease subjects: results from the PAQUID longitudinal study." In: *Cortex* 44.9, pp. 1188–96. ISSN: 0010-9452. DOI: 10.1016/j.cortex.2007.08.019. URL: http://www.ncbi.nlm.nih.gov/pubmed/18761132.

Tombaugh, Tom N., Kozak, Jean, and Rees, Laura (1999). "Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming." In: *Archives of Clinical Neuropsychology* 14.2, pp. 167–177.

Tröster, Alexander I. et al. (1998). "Cortical and subcortical influences on clustering and switching in the performance of verbal fluency tasks." In: *Neuropsychologia* 36.4, pp. 295–304.

Troyer, Angela K. (2000). "Normative data for clustering and switching on verbal fluency tasks." In: *Journal of clinical and experimental neuropsychology* 22.3, pp. 370–378.

Troyer, Angela K., Moscovitch, Morris, and Winocur, Gordon (1997). "Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults." In: *Neuropsychology* 11.1, p. 138.

Troyer, Angela K. et al. (1998). "Clustering and switching on verbal fluency tests in Alzheimer's and Parkinson's disease." In: *Journal of the International Neuropsychological Society* 4.02, pp. 137–143.

Weintraub, Sandra et al. (2009). "The Alzheimers disease centers uniform data set (UDS): The neuropsychological test battery." In: *Alzheimer disease and associated disorders* 23.2, p. 91.