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BRIEF COMMUNICATION

Individual differences in semantic switching flexibility: Effects of handedness

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Abstract

The semantic fluency task is a widely used assessment tool for evaluating memory-related cognitive deficits in neurological and neuropsychiatric disorders. The present study investigates individual differences in performance on this task in a normal population. The aim is to explore handedness differences in switching and clustering tendencies when performing this task. Consistent with our prediction, when asked to produce as many animal names as possible in 1 min, mixed handers demonstrated greater switching between different subcategories of animals than strong handers. These findings are interpreted in terms of the more diffuse spread of activation among conceptual representations in the right hemisphere, and greater access to right hemisphere processes in mixed handers. The findings have implications for the research communities using the semantic fluency task, irrespective of whether or not they are looking at handedness differences per se. (*JINS*, 2009, *15*, 1023–1027.)

Keywords: Verbal fluency, Switching, Clustering, Handedness, Individual differences, Semantic networks

INTRODUCTION

Storing and retrieving mental representations of concepts we encounter is a critical ability without which a normal state of cognition is impossible. Deficits in memory storage and retrieval has been an area of considerable interest to clinicians when dealing with patients. One way to tap into these aspects of memory is by using a simple neuropsychological assessment tool, the Semantic Fluency Task. In this task, individuals are asked to produce as many items as possible belonging to a specific category in a set period of time. Typically, the variable of interest is the number of words produced by the individual; the aim is to draw inferences about patients' knowledge organization and their ease in accessing concepts in memory. It has been observed that several neurological disorders such as Parkinson's disease, Alzheimer's disease, multiple sclerosis, and so on, are associated with declines in performance on this task (Gomez & White, 2006; Henry & Beatty, 2006; Henry & Crawford, 2004).

Although semantic fluency has garnered considerable attention in clinical settings, it has received relatively less attention in studies of normal populations. Troyer, Moscovitch, and Winocur (1997) are among the few researchers to explore this task in nonclinical populations. They not only explored individual differences (based on age) in this task, but have also proposed measures—clustering and switching—that point to the processes underlying this cognitive task. A brief summary of these underlying processes follows.

When individuals are asked to produce words that belong to one particular object category (e.g., animals, fruits, vegetables), they typically do not produce words in a continuous temporal manner (Troyer et al., 1997). Rather, people tend to produce words in temporal clusters, with short time intervals between individual words within a cluster and longer intervals between clusters. The words belonging to a temporal cluster tend to be related to each other semantically. It has been suggested that when searching lexical or semantic fields, longer intervals between clusters represent the time to look for a new subcategory; the shorter interval between the words within a cluster reflects the shorter time required to retrieve words from within that subcategory (e.g., Wixted & Rohrer, 1994).

A study by Kiang and Kutas (2006) suggests that subgroups of the population deviate from this norm when processing semantic information. In their study, the authors explored semantic fluency task in relation with schizotypy.

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In addition to measuring schizotypal personality traits, the authors calculated the typicality index for each participant's response on the semantic fluency task, based on response probability norms. They found that individuals scoring high on schizotypy tended to produce more atypical responses than individuals scoring low on schizotypy. In explaining this observation, Kiang and Kutas state that higher schizotypy is associated with broader spread of activation in semantic networks. That is, in the case of high schizotypy, activation of a concept leads to equal spread of activation to targets that are strongly relevant (for instance, "Robin" leading to activation of another bird "Sparrow") as well as targets that are weakly relevant ("Robin" leading to activation of a mammal "Kangaroo") to the original concept. Atypical responses reflect the activation of weakly relevant concepts. Similar findings were reported by Duchene, Graves, Brugger (1998), who reported that individuals who score high on a measure of magical ideation also produce a greater number of rare words on a semantic fluency task. Finally, subjects with paranormal beliefs also exhibit a wider spread of activation in semantic networks (Pizzagalli, Lehmann, & Brugger, 2001).

In light of these observations, it is interesting to note that both schizotypy and magical ideation are systematically related to one's hand preference, with mixed handers or people with inconsistent hand preference scoring higher on measures of schizotypy (Annett & Moran, 2006) and magical ideation (Barnett & Corballis, 2002) than both consistent right and consistent left handers. Thus, it is hypothesized that mixed handers' knowledge organization may be more diffuse than that of consistent right or left handers. When given a semantic fluency task, mixed handers should exhibit spread of activation among concepts relatively independent of whether they are strongly or weakly relevant, leading them to switch between different subgroups of a category more readily than consistent right and left handers.

The hypothesis that mixed handers will display greater flexibility in switching between different semantic subcategories is supported by recent evidence that mixed handedness is also associated with (i) greater flexibility in processing ambiguous figures (Christman, Sontam, & Jasper, 2009) and (ii) a broader spread of activation among semantic representations (Sontam & Christman, 2007). The aim of the present study is to explore individual differences as a function of strength of handedness in switching in the semantic fluency task.

METHOD

Participants

A total of 113 Introductory Psychology students, from the participant pool at the University of Toledo, took part in the study. They were given course credit for participation. There were 48 females and 61 males, and 62 mixed handers and 50 strong handers in the sample. Gender information for four students and handedness for one student was missing.

Design and Procedure

The current experiment was carried out as part of a larger study assessing things such as phonemic fluency and ambiguous sentence completion. The participants received these tasks in a random order. Also, at the beginning of each experimental session, informed consent was obtained from participants in compliance with the research protocols of Institutional Review Board at the University of Toledo.

Participants were given a semantic fluency task in which they were asked to come up with as many animal names as possible in a 1-min period. Although this task can be done using a few different semantic categories (e.g. animals, fruits, vegetables, furniture), the category "animals" was chosen for the present study, as it is the most frequently used category and is considered to be relatively consistent across different languages, cultures, generations, and educational systems (Ardila, Ostrosky-Solis, Bernal, 2006). Also, unlike the traditional way of recording oral responses, participants in the present study were asked to write down their responses. This allowed for the flexibility of administering the task to multiple students at once. This format also helped the task to fit into a bigger battery of tasks of which the present study was a part. Although the semantic fluency task is typically administered in an oral format, research indicates that written and oral formats yield comparable data (Garcia-Albea Ristol, 1977; Muñiz, Garcia-Cueto, Garcia-Alcañiz, & Yela, 1985).

Participants wrote down the names of animals on a sheet of paper. A stop watch was used to time the participants; they were instructed as to when to start and stop the task. The following specific instructions were given to participants: "In this task I am going to name an object category and ask you to come up with as many names as possible that you think belong to that category. You will be given one minute to do so. I will tell you when to start and when to stop. Do you have any questions?" When the participants indicated that they understood the instructions, they were told: "The category is Animals…So, please write down as many animal names as possible on the sheet of paper in front of you… Your time starts now." The task was administered to groups of 1–4 participants.

A modified version of Edinburgh Handedness Inventory (EHI; Oldfield, 1971) was used to measure strength of handedness. Participants completed the EHI at the end of the entire study. The questionnaire requires individuals to rate hand preference for 10 activities (e.g., writing, teeth brushing, throwing, etc.) on a five-point scale—always left, usually left, no preference, usually right, always right. A score of −100 indicates strong left-handedness and a score of +100 indicates strong right-handedness. The median of absolute value of handedness scores is typically taken as the cutoff point to separate mixed and strong handers. In the present sample, the median was 75. Thus, people whose absolute scores were 75 and below were classified as "mixed handers," and those who scored 80 and above were classified as "strong handers."

Design

The experiment used a between subjects design with handedness (strong *vs.* mixed) and gender as independent variables. Although switching was the main variable of interest, analyses of mean cluster size and total number of words produced were also conducted.

Scoring

Scoring was based on guidelines provided by Troyer et al. (1997). The lists were scored for switching tendency by counting the number of transitions from one category to the other. Categories were based on attributes like sharing a common habitat (e.g., North American, African, water dwelling), species (e.g., insects, amphibians), type of usage by humans (farm animals, pets) and so on. Cluster size was assessed by counting the number of animal names within a cluster, starting from the second animal in the cluster. For example, in a sequence of animals such as cow-chicken-goose-cat-dog, there are two categories. Cow, chicken and goose belong to the category "Farm animals," and cat and dog belong to the category "Pets." A switch is counted at the junction of goose and cat. The category size for the first category (Farm Animals) is 3−1 = 2, and the category size for the second category (Pets) is 2−1 = 1. Cluster sizes were added together and then divided by the total number of clusters, yielding a measure of mean cluster size.

Because the number of switches depends, to some extent, on the total number of words produced, it was considered important to use a weighted measure of switches, the "switch rate" (number of switches/total number of words; see Epker, Lacritz, & Cullum, 1999), for assessing participants' switching flexibility.

All participant responses were coded by the experimenter. Half of the data was separately coded by an independent rater for cluster size and switches. Inter-rater reliability was calculated using Pearson correlation. There was strong agreement between raters for the "number of switches" participants exhibited, $r\,(48) = .94$; $p < .01$, as well as mean cluster sizes, $r\,(48) = .95$; $p < .01$. Before subjecting data to final analyses, points of disagreement were resolved by discussion.

RESULTS

The data for 13 participants were excluded from the analysis for various reasons. Some participants reported animal names in a tabular form under superordinate category headings such as mammals, birds, fish, and so on; some reported the animal names in alphabetical order; and some had experience with similar stimuli in previous experiments.

Effect of Gender

A 2 × 2 Analysis of variance indicated a main effect of gender for the total number of animal names produced, such that females ($M = 16.99$) generated more words than males ($M = 15.41$), $F(1,94) = 4.48$; $p = .037$. Similar effects were not present for switch rate or mean cluster size. There was no handedness × gender interaction for any of dependent variables. Therefore, further analyses excluded gender from consideration.

Effect of Handedness

Mixed handers ($M = 15.41$) and strong handers ($M = 16.44$) did not differ in the total number of animal names generated, $t(97) = -1.33$; $p = .19$.

Shifting focus to the main hypothesis, the aim of this study was to examine handedness differences with regard to switching. Table 1 displays the means and standard deviations. An analysis of switch rate indicated a handedness difference such that mixed handers ($M = .51$) switched between different animal subcategories more frequently than strong handers ($M = .45$), $t(97) = 2.63$; $p = .01$ [$d = .54$]. Mixed handers ($M = .85$) also produced significantly smaller clusters when compared with strong handers ($M = 1.11$), $t(97) = -2.72$; $p < .01$ [$d = .55$].

DISCUSSION

Although there was no handedness difference in the total number of animal names produced, mixed and strong handers did appear to carry out different strategies in terms of switching and clustering. Mixed handers exhibited greater switching between different animal subcategories and produced smaller clusters when compared with strong handers. Thus, as predicted, mixed handers showed a greater readiness in crossing the categorical barriers and exhibited greater semantic switching flexibility.

This means that, when asked to produce animal names, mixed handers have almost equal access to exemplars inside a category versus outside the category (i.e., in a different category), which is reflected in their higher switching score. In contrast, the within and between category links for strong handers may be relatively disparate, causing them to dwell longer in the same category before switching their attention to a different category. Also, the fact that such an organizational difference does not necessarily point to any differences in the size of the network itself explains the lack of handedness difference in the total number of animal names generated.

Table 1. Mean scores of mixed and strong handers on the semantic fluency task

Variable	Mixed	Strong	Overall
n	54	45	99
Words generated	15.41 (3.87)	16.44 (3.92)	15.87 (3.91)
Switch-rate	0.51 (0.13)*	0.45 (0.11)*	0.48 (0.13)
Mean cluster size	0.85 (0.44)**	1.11 (0.52)**	0.97 (0.49)

Note. Standard deviations are indicated in parentheses.
*$p < .05$.
**$p < .01$.

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The idea of differential semantic organization is consistent with research that indicates hemispheric asymmetry in semantic processing. Specifically, research shows that right hemisphere semantics operate more diffusely than that of the left hemisphere (Chiarello, Burgess, Richards, & Pollock, 1990). This is further supported by a priming experiment by Beeman, Friedman, Grafman, Perez, Diamond, and Lindsay (1994), where participants were presented with visual stimuli either to their left visual field–right hemisphere or to their right visual field–left hemisphere. The stimuli were either three words weakly relevant to the target (summation priming) or one word strongly related to the target (direct priming). It was found that the left hemisphere showed better performance with direct priming whereas the right hemisphere showed equally good recognition with both direct and summation priming. Beeman et al. argued that the left hemisphere carries out finer, focused coding and, therefore, can activate only closely related information, whereas the right hemisphere handles relatively coarser coding and, therefore, activates closely related as well as distantly related information equally well. Pizzagalli et al. (2001) also reported indirect priming in the right hemisphere.

These observations, combined with the fact that mixed handers have greater access to right hemisphere processes (Christman, Propper, Dion, 2004; Niebauer, Aselage, & Schutte, 2002; Propper, Christman, & Phaneuf, 2005), explain why their behavior is consistent with the right hemisphere mode of semantic processing. The greater access to right hemisphere processes in mixed handers presumably reflects the fact that mixed handedness is associated with larger corpus callosum size (e.g., Witelson & Goldsmith, 1991), thus enhancing interhemispheric interaction.

In conclusion, we think the present study makes a useful addition to the currently small body of literature related to the semantic fluency task in the normal population. It introduces handedness as an individual difference factor and further supports the usefulness of looking beyond the total number of words produced when dealing with the Semantic Fluency task.

From a more practical perspective, even researchers who are not interested in handedness *per se* should consider assessing handedness in their experiments using the semantic fluency task. The current finding of systematic differences in semantic fluency performance as a function of degree of handedness suggests that taking handedness into account would move variability out of the error term of statistical analyses and into an effect term, thereby allowing greater power to observe other effects.

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