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Differential Impacts of Age of Acquisition on Letter and Semantic Fluency in Alzheimer's Disease Patients and Healthy Older Adults

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Abstract

The degree to which the typical age of acquisition (AoA) of words and word frequency have separable influences on verbal production tasks has been strongly debated. To examine the overlap between these factors in verbal fluency tasks, the performance of Alzheimer's disease (AD) patients (N=34) and normal elderly controls (N=36) was compared on semantic (e.g., vegetables) and letter (e.g. words that begin with F) fluency tasks. These comparisons revealed that words generated for the semantic fluency task had an earlier AoA while words generated for the letter fluency task had a higher word frequency.. Differences in AoA between AD patients and controls were larger for semantic than letter fluency. These results suggest that AoA has an effect on verbal production that is independent of word frequency and that AoA has a semantic locus.

Age of acquisition (AoA) refers to differences in the age at which specific words are typically acquired. AoA has been shown to influence performance in a wide variety of tasks including picture naming, word naming, word pronunciation durations, lexical decisions, category fluency and some episodic memory tasks (Juhasz, 2005). The breadth of these effects suggests that AoA is a potentially important variable in an array of language tasks.

A major debate in the literature on AoA effects has been the degree to which these effects are reducible or tightly linked to differences in the frequency of exposure to words learned earlier than later in life and the degree to which AoA has a separable influence on language processing. The first view claims that AoA reflects differences in the frequency of exposure to particular words. According this view, AoA may be a proxy for word frequency; each exposure to a word over an individual's lifetime has a cumulative effect on how words are represented or processed (Lewis, Gerhand, & Ellis, 2004). In contrast, a number of recent proposals have argued that AoA has a semantic locus or basis (Juhasz, 2005). This view states that concepts that are acquired earlier in life influence the acquisition of later concepts (Brysbaert, Van Wijnendaele, and De Deyne 2000; Steyvers and Tenenbaum, 2005). For example, words that are acquired earlier should have a richer set of semantic connections than words that are acquired later (Steyvers & Tenenbaum, 2005). This hypothesis predicts that the magnitude of the AoA effect will increase as the conceptual processing demands of a task increase. For example, Juhasz (2005) found that the magnitude of the effect of AoA

manipulations on RT was greatest on a task with high conceptual demands (picture naming-125msec), intermediate on a test with intermediate conceptual demands (lexical decision making-56 msec) and lowest on a test with the least conceptual demands (word naming-31 msec) in a review of word processing studies.

Disease states may be used to differentiate the cumulative exposure and semantic locus hypotheses. A substantial literature documents semantic memory deficits in patients with Alzheimer's disease (AD) that can be contrasted with relatively minor changes in semantic memory for normal older individuals (see Nebes, 1989, for a review). Recently, Forbes-McKay, Ellis, Shanks, & Venneri (2005) compared the words produced by Alzheimer's disease (AD) patients and controls on a semantic fluency task. They demonstrated that differences in the average AoA better distinguished AD cases and controls than the average typicality or frequency of the words. This result supports the semantic locus hypothesis.

Contrasting performance on tasks that differ in semantic processing requirements provides another test of these alternative hypotheses. Comparing semantic (i.e., category) fluency with letter fluency provides such a contrast. In semantic fluency, participants are asked to produce as many examples of a semantic category (e.g., animals, or fruits) as possible in a limited time period, usually one minute. In a letter fluency task, participants are asked to generate as many instances as possible of words that begin with a specific letter (e.g., F, A, or S). Content analyses of verbal fluency protocols indicate that they tend to be organized around semantic clusters in semantic fluency tasks (e.g., farm animals within the category animals) and phonemic clusters (e.g., words that rhyme such as sand and stand) in letter fluency tasks (Bayles, Trosset, Tomoeda, Montgomery, & Wilson, 1993; Gruenewald & Lockhead, 1980; Raskin & Rearick, 1996; Raskin, Sliwinski, & Borod, 1992). In addition, patient populations with demonstrable semantic memory impairments (Nebes, 1989), including patients with Alzheimer's Disease (AD) or focal damage to the temporal lobes, tend to exhibit greater deficits in semantic fluency tasks than in letter fluency tasks (Barr & Brandt, 1996; Crossley, D'Arcy & Rawson, 1997; Monsch, Bondi, Butters, Paulsen, Salmon, Brugger, & Swenson, 1994; Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998).

Although the Forbes-McKay et al. (2005) study is consistent with the view that AoA has a semantic locus, a much stronger test of this claim would be to compare the role of AoA in semantic fluency to its role in letter fluency. If AoA has a semantic locus, then one would expect to find a stronger relationship between AoA and performance in semantic than in letter fluency. Moreover, this effect should be most pronounced in a group of participants with semantic memory deficits such as AD patients. In contrast, if AoA is reducible to an effect of the cumulative frequency of exposure to a word, then the two variables should be related to performance in the two kinds of verbal fluency tasks in exactly the same way.

To test this hypothesis, the role of AoA and word frequency on performance in verbal fluency tasks was evaluated in a group of AD patients and elderly controls who provided responses to three semantic categories (animals, fruits, and vegetables) and three letter categories (F, A, S). The average AoA and cumulative word frequency of the items produced by each participant in a given protocol was calculated similar to one of the dependent measures calculated by Forbes-McKay et al. (2005). If AoA is a word frequency effect, differences in the average word frequency of responses between semantic and letter fluency tasks should be similar. On the other hand, if AoA is more strongly related to conceptual organization than word frequency, then the influence of AoA ought to be stronger in semantic than letter fluency tasks and this difference should be greater for AD patients.

Method

Participants

Participants in the current study were drawn from the Einstein Aging Study (EAS) at Albert Einstein College of Medicine. As part of this larger study, all participants were administered a comprehensive battery of neuropsychological, neurologic, psychiatric, and medical exams. The neurological examination included the Clinical Dementia Rating [CDR] scale (Morris, 1993) which is a well-validated clinical rating of dementia severity. A diagnosis of probable Alzheimer's disease was made for participants who demonstrated sufficient cognitive and functional decline according to well-established clinical and medical criteria (NINCDS-ADRDA; McKhann et al., 1984 and DSM IIIR; American Psychiatric Association, 1987) at a case conference attended by a study neurologist, a neuropsychologist, and a social worker. Further details are provided in previous publications (Katzman, Aronson, Fuld, et al. 1989; Verghese, Lipton, Hall, et al. 2002).

For the current study, thirty-six participants with a CDR=0 who had fewer than 8 errors on the Blessed Information-Memory-and Concentration test (BIMC: Blessed, Tomlinson, & Roth, 1968) were assigned to the normal elderly control group (NC). Twenty-two of these participants were female. Thirty-four participants with a diagnosis of probable AD and a CDR=1.0 were assigned to the AD group. Twenty-one of these participants were female. All participants in this study were 55 years of age or older. The mean age, educational level, and score on the BIMC for participants from the two samples are presented in Table 1. No difference between the two groups on age, education or BIMC was significant (i.e., all $F < 1$).

Materials

Six different verbal fluency categories were used in this experiment. Three of the categories were semantic categories and three were letter categories. The semantic categories were animals, fruits and vegetables. The letter categories were words that begin with letters F, A and S.

Age of acquisition

Adult ratings of AoA were obtained for each unique word that was produced by any of the participants in any of the six conditions. In many cases, estimates of AoA were based on previously normed materials (Bird, Franklin, & Howard, 2001; Clark, & Paivio, 2004; Coltheart, 1981a; Iyer, Saccuman, Bates, Wulfeck, 2001). These items were scaled to the scale that was established in Bird et al. (2001) by regressing the ratings for overlapping items in each set of norms and the Bird et al. (2001) norms. The slope and intercept from each of these regressions were used to create a scaled rating for items that were unique to each set. The average correlation between the Bird et al. (2001) ratings and each of the other sets of ratings for overlapping items was $r = .80$.

A substantial number of items produced in the fluency tasks were not found in any of these existing norms so native English speaking undergraduates at Lehman College were recruited to provide AoA ratings for the remaining items. Four groups of thirty-one to fifty-six participants were asked to rate the AoA of 200–300 words that included a set of 105 words that had been normed in the Bird et al. (2001) norms. The instructions and rating scale were similar to those used in Gilhooly & Logie (1980) with two changes. First, the items were presented one by one on a computer with the rating scale below each item and participants clicked on a button that indicated the age range (e.g., 0–2, 3–4, etc.). Second, the scale included the addition of an extra category “Unknown” which allowed participants to indicate that an item was unknown to them. The mean rating for each item was multiplied by 100 to give ratings on a scale of 100 to 700, as shown in the MRC database and Bird et al.

(2001). The combined set of norms from all sources included more than 5800 words of which 1786 words began with F, A, or S. The average correlation between the ratings of each group of Lehman participants and the ratings for the same items in Bird et al. (2001) was .84.

Word frequency

Log transformed word frequency values were obtained online from the English Language Lexicon Project (Balota, Yap, Cortese, Hutchison, Kessler, Loftis, Neely, Nelson, Simpson, & Treiman, 2007). These values are taken from the Hal frequency norms (Lund & Burgess, 1996) which consists of approximately 131 million words gathered across 3,000 Usenet newsgroups during February 1995.

Procedure

Participants were administered the verbal fluency tasks as part of the EAS. Although the EAS is a longitudinal study, only the initial assessment for each participant on each category was used in the current study to avoid practice effects. At the beginning of each assessment, participants were told by the experimenters that they had to generate as many different exemplars of the given category as they could in a one-minute interval. They were instructed that proper nouns and words with the same stem but different endings (e.g., send, sending, sender) would not be counted. All responses generated by the participant were written down in order by the experimenter.

Results

Only tokens that were valid exemplars of the target category were accepted as correct responses. Plural forms were counted as identical to singular forms (e.g., mice vs. mouse); for the category of animals, several shortened forms of a longer form (e.g., rhino for rhinoceros) were changed to the longer form. In addition to items that were judged to be non-exemplars of the category, repetitions of an item and illegible instances were dropped from the analyses. Finally, word frequency values were not found for a small percentage of responses. Some of these responses were quite rare (e.g., synod, sylph) but others involved a compound name (e.g., sea lion, green bean). These responses constituted approximately 3.6% of all responses and they were omitted from analyses of word frequency.

As reported in previous studies (Carew et al., 1997; Ober, Dronkers, Koss, Delis, & Friedland, 1986; Weingartner et al., 1993), AD patients produced fewer items than the normal elderly controls for both fluency tasks. A separate summary score was calculated for the number of responses to the letter (i.e., F + A + S) and semantic (i.e., animals + vegetables + fruit) fluency tasks for each participant and the averages of these values are presented in Table 2. These data were transformed by taking the square root of the total output for each category and then submitted to a mixed analysis of variance (ANOVA) in which group (NC or AD) was a between-subjects factor and task (semantic vs. letter) was a within-subjects factor. Normal elderly controls recalled more items ($M=32.6$) than AD patients ($M=22.1$), $F(1,68)=52.8$, $p<.001$. Although the main effect of task was not significant, $F(1,68)=2.17$, $p>.05$, the reduced fluency of AD patients was more pronounced for semantic than for letter fluency, $F(1,68)=15.4$, $p<.01$. This interaction replicates previous findings and overall the performance of the two groups is similar to the patterns observed in the literature (Barr & Brandt, 1996; Crossley, D'Arcy, & Rawson, 1997; Monsch et al., 1994).

To compare the relative influence of AoA on letter and semantic fluency, the mean of the tokens produced by a participant in the three letter categories and in the three semantic categories was computed. These data are presented in Table 3. They were submitted to an

ANOVA in which group (NC or AD) was a between-subjects factor and type of task was a within-subjects factor. The mean AoA for items produced in the semantic categories ($M=316$) was lower than it was for letter categories ($M=362.7$), $F(1,68)=65.5$, $p<.001$. This difference was greater for AD patients than it was for normal controls as indicated by a significant interaction, $F(1,68)=4.63$, $p<.05$. In addition, the AoA of items produced by AD patients was younger than the AoA of items produced by normal controls, $F(1,68)=9.3$, $p<.01$.

To determine whether these results would be replicated if differences in word frequency were controlled, AoA was regressed on cumulative word frequency for all responses. The residuals were then averaged and analyzed in a manner that was identical to the rated AoA of each response. When cumulative word frequency was controlled in this manner, AoA was still lower for semantic than letter categories $F(1,68)=334.5$, $p<.001$. The interaction between group and type of category was also significant, $F(1,68)=5.7$, $p<.05$. However, the AoA of responses produced by AD patients did not reliably differ from that of normal controls, $F(1,68)=1.5$, $p=.23$.

A parallel analysis was conducted to compare the cumulative word frequency of the two groups for the two conditions. The average cumulative frequency was calculated by adding the log of the word frequency of the item and the log of the difference between the current age of the participant and the estimated AoA of the word (Lewis et al., 2004). These values were averaged for all the words in the participant's letter fluency protocols or semantic fluency protocols. The average cumulative frequency was greater for the letter fluency than semantic fluency, $F(1,68)=315.6$, $p<.001$. The average cumulative frequency of AD patients was greater than it was for normal controls $F(1,68)=22.5$, $p<.01$. However, the group by task interaction was not significant ($F<1$) indicating that the difference in average cumulative frequency between NC and AD participants did not differ by task.

To determine whether these results would be replicated if differences in AoA were controlled, cumulative word frequency was regressed on AoA for all responses. The residuals were then averaged and analyzed in a manner that was identical to the cumulative word frequency of each response. Controlling for AoA did not change the pattern of results. Average cumulative frequency was greater for letter than semantic fluency, $F(1,68)=961.6$, $p<.001$. AD participants tended to produce higher frequency words, $F(1,68)=16.4$, $p<.001$. Finally, the interaction between type of fluency task and diagnosis was not reliable, $F<1$.

The main effects of type of fluency task on AoA and cumulative frequency are interesting because word frequency is generally correlated with AoA (Juhász, 2005 but see Brysbaert & Ghyselinck, 2006 for an analysis of departures from this pattern). Thus, the fact that responses in the semantic fluency task were learned earlier than words produced in the letter fluency task but were also lower in cumulative frequency is a departure from this general pattern. One possibility is that these differences reflect general differences in the AoA or cumulative frequency of specific populations of words in the lexicon. For example, differences may exist in the age at which concrete nouns as opposed to verbs or various other parts of speech are learned. If this is true then the main effect of task on word frequency and AoA may occur because of differences in the population of words that are available for retrieval in each task rather than in the relative ease with which specific words within a particular population of words can be retrieved. On the other hand, AoA and cumulative frequency may affect the relative ease with which a specific word within a population of words can be retrieved and this effect on the relative accessibility of words may differ across semantic and letter fluency tasks.

To control for possible differences in the AoA and frequency of words that belong to one of the three semantic or three letter categories, a z score was computed for all tokens based on the distribution of values found within each of these two populations of words. In the case of responses to the semantic fluency tasks, this was accomplished by identifying all words that were fruits, animals, or vegetables in the word norms and calculating the z score for each of these instances. In the case of responses to the letter fluency task, the z score for any word that began with the letters F, A, or S in the word norms was calculated and used to estimate the AoA or the log frequency of words relative to this population of words.

The z scores for the responses in each set of protocols were averaged to give a semantic and a letter fluency score for each participant. This standardizing of values makes it possible to compare the role of AoA or word frequency in determining access to items from semantic and letter categories. For example, if AoA has a stronger influence on determining which items are retrieved for the animals category than for the category of words that begin with F then the standardized values should be more negative in the animals category. Similarly, if the ease with which a word can be retrieved is more strongly influenced by word frequency in letter fluency tasks then the average z score should be larger in letter fluency than semantic fluency.

These averages are presented in Table 4 and were analyzed using a mixed ANOVA in which group (NC or AD) was a between-subjects factor and type of task was a within-subjects factor. For AoA, this analysis revealed that early acquired words more strongly represented in the protocols of AD patients than NC participants $F(1,68)=8.9, p<.01$. In addition, responses to the semantic tasks were learned at a relatively earlier age than responses to the letter tasks, $F(1,68)=9.16, p<.01$, and this difference was larger for AD than NC participants, $F(1,68)=5.29, p<.05$.

The previous analysis of cumulative frequency revealed that AD patients were relatively more likely to produce high frequency instances than NC participants. As in the analysis of cumulative frequency, AD patients produced relatively more high frequency words than NC participants, $F(1,68)=29.3, p<.001$. In contrast, to the analysis of cumulative frequency, the average standardized word frequency was slightly lower for letter categories than for semantic categories but the difference was not reliable in the standardized data, $F(1,68)=1.86, p=.18$. Finally, the interaction between type of task and group was not reliable but trended in the direction of larger differences in the standardized frequency of the two types of tasks for AD participants, $F(1,68)=3.52, p=.06$.

General Discussion

In this study, older adults with AD and normal cognitive abilities performed semantic and letter fluency tests. Although average AoA was lower for semantic fluency than for letter fluency, the cumulative word frequency of responses was higher for letter fluency than it was for semantic fluency for both participant groups. In general, AD participants produced words that were acquired earlier with a higher word frequency than did aged controls. Finally, the lower AoA of AD participants' protocols was greater for semantic than letter fluency.

These differences in the effect of AoA and word frequency on fluency tasks are consistent with the view that AoA effects are not simply a reflection of differences in the frequency with which words are encountered. First, the dissociation between AoA and word frequency in letter categories and semantic categories should not have occurred if AoA is determined by frequency of exposure alone. Thus, the fact that fruits, animals, and vegetables have lower AoA and lower word frequencies than words that begin with F, A, or S indicates that

the age at which the former were acquired is not entirely dependent on their frequency of occurrence in the language. Second, if the effect of AoA is really a consequence of cumulative exposure then changes in the AoA of responses with AD should have paralleled the changes in the cumulative frequency of responses with AD. Instead, the reliable interaction between diagnosis and type of fluency task in AoA was not observed for cumulative frequency. In fact, if raw word frequency had been used instead of log transformed frequencies then the difference in word frequency between the groups would have been numerically larger for letter than semantic fluency.

One difficulty in interpreting AoA effects is that AoA is a behavioral variable based on the performance of participants rather than an exogenous factor that can be more directly measured such as the frequency of words in a text (Zevin & Seidenberg, 2004). In a recent review of several tasks, Brysbaert & Ghyselinck (2006) proposed that AoA effects may be partially related to frequency of exposure and partly independent of frequency of exposure. These authors argued that an effect of AoA is generally observed in tasks that require the selection of a single response on the basis of semantic criteria and that this effect cannot be attributed to word frequency as the size of this effect is unrelated to the size of word frequency effects in these tasks. The current results are quite consistent with this view. If AoA and word frequency had a single common locus then the typical negative correlation between AoA and word frequency should have been observed across the semantic and letter fluency tasks. Instead, responses in the semantic fluency task tended to be acquired earlier than words produced in the letter fluency task even though they were also less frequent.

This dissociation does not appear to have a simple explanation in the distribution of word frequency and AoA across letter and semantic categories. One can easily imagine that learning the members of certain categories such as fruits, animals, and vegetables at an early age is important and that even exemplars whose names do not occur frequently in the language may be learned at an earlier age than other words. At the same time, if AoA ratings are generally correlated with word frequency then ease of access within a category might be purely attributable to word frequency even if differences across categories were not. This possibility was examined by standardizing AoA and word frequency with respect to each population of words. The more negative values for standardized AoA in semantic than letter fluency tasks indicates that AoA was a stronger factor in determining which members of these categories were sampled or retrieved than it was in the retrieval of words that began with F, A, or S. Although standardized word frequency may have been somewhat greater in semantic than letter fluency for AD participants, the main effect of task was not reliable. Collectively, these results indicate that AoA influences the ease with which words can be retrieved in fluency tasks and that differences between semantic and letter fluency tasks cannot be entirely attributed to the influence of word frequency.

In summary, the current results extend previous findings that the verbal protocols of AD participants contain more early acquired words than do the protocols of elderly controls (Forbes-McKay et al., 2005). It extends this research by demonstrating that this effect is larger in semantic than letter fluency tasks and by adding to a growing body of findings that support the view that AoA effects are most distinguishable from frequency effects in tasks that require access to semantic or conceptual knowledge.

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Table 1

Participants' demographic and diagnostic information.

Groups	Age (yrs)	BIMC	Education (yrs)
Normal Elderly	78.9	2.1	11.6
AD Patients	77.9	10.9	10.9

Abbreviations: yrs- years; BIMC-Blessed Information-Memory-Concentration test

Table 2

Mean Fluency (With Standard Deviations) as a Function of Task and Group

Groups	Letter fluency	Semantic Fluency
Normal Elderly	29.0 (6.6)	36.3 (5.9)
AD Patients	23.9 (11.2)	20.3 (6.3)

Table 3

Mean age of acquisition and word frequency (With Standard Deviations) as a Function of Task and Group.

Task	<i>Groups</i>	
	Normal Elderly	AD Patients
Age of Acquisition ^I		
Letter	366.9 (44.7)	358.6 (54.1)
Semantic	332.6 (18.7)	299.5 (17.8)
Cumulative Word Frequency		
Letter	13.4 (.63)	13.8 (.73)
Semantic	11.9 (.83)	12.5(.43)

^I Age of acquisition units are age on a 7 point scale (1=0–2 years...7=age 13 years and over) multiplied by 100. Thus, a score of 300 nominally corresponds to 5.5 years of age

Table 4

Mean standardized age of acquisition and word frequency (With Standard Deviations) as a Function of Task and Group.

Task	<i>Groups</i>	
	Normal Elderly	AD Patients
Age of Acquisition		
Letter	-.66 (.38)	-.72 (.44)
Semantic	-.70 (.16)	-.98 (.14)
Word Frequency		
Letter	.46 (.29)	.64 (.33)
Semantic	.44 (.15)	.77 (.22)