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BRIEF REPORTS

Lexical Competition and Phonological Encoding in Young and Older Speakers

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The influence of age on word retrieval was investigated with a speeded picture naming study. Five hundred forty-one pictures were presented to young and older adults, and the influence of name agreement and name frequency was analyzed by multiple regression. The results showed that both name agreement and name frequency are significant predictors of picture naming performance in young and older adults. The results also suggest that older adults are more strongly influenced by name agreement than are young adults. These results indicate that competition during lexical selection may be a particularly age-sensitive stage in language production.

Keywords: picture naming, aging

In a very short period, speakers are able to take an abstract semantic representation that contains the information to be conveyed, select the grammatical structures and words necessary for expressing this information, and coordinate the articulatory movements necessary for actually producing the sounds of the utterance. This process appears to be separated into several levels of processing, with each level influenced by specific properties of the intended utterance. In this article, we examine the influence of aging on two of these levels of processing: lexical selection and phonological encoding. We do this by assessing the impact of factors influencing these two levels in young and older speakers.

Picture Naming in the Standard Production Model

By the standard view of language production (Bock & Levelt, 1994; Garrett, 1975; Levelt, 1989), the process of producing speech is divided into multiple levels of processing that begin with a communicative intent and end with the execution of a motor program. We focus on two levels, those of lexical selection and phonological encoding. Lexical selection involves the selection of representations that best capture the conceptual and semantic properties of the speaker's message. The lexical representations at this level are often referred to as *lemmas,* intermediate representations that satisfy the required semantic properties of the message but that do not contain phonological information. Variations in the difficulty of lemma selection arise partly from how consistently semantic properties converge on one or more possible lemmas. In the context of simple picture naming, pictures that have lower name agreement produce a higher amount of competition for lemma selection than pictures with little competition, and as a result, pictures that have lower name agreement will have longer response times as this competition is resolved (Butterfield & Butterfield, 1977; Johnson & Clark, 1988; Lachman & Lachman, 1980; Lorsbach & Morris, 1991; Mitchell, 1989). Tasks that require a size or category judgment, rather than a naming response, do not show an influence of name agreement, suggesting name agreement is specifically tied to lexical selection and not to simply retrieving information about the object (Kroll & Potter, 1984).

Upon selection of the lemma, phonological processing may proceed in earnest. This involves retrieving the metrical structure of the utterance and selecting phonemic information and is followed by phonetic encoding, through which sounds are specified in more detail, adjusting for contextual variations in articulation (see Levelt, Roelofs, & Meyer, 1999, for a theory of phonological encoding to articulation). The frequency with which a specific word form appears in the language appears to strongly influence the speed of this encoding process (Oldfield & Wingfield, 1965). Phonological segments for frequent words are assembled more quickly and more accurately than phonological segments for less frequent words. Phonological speech errors are more likely to occur with low- than with high-frequency words (Dell, 1990; Stemberger & MacWhinney, 1986). In addition, low-frequency homophones are produced faster than frequency-matched controls, suggesting that low-frequency homophones benefit from sharing the phonological form of high-frequency homophones (Jescheniak & Levelt, 1994). Finally, judgments about objects, such as category or size judgments, do not show frequency effects (Jescheniak & Levelt, 1994; Wingfield, 1967, 1968). We should note that the loci of word frequency effects are a highly controversial topic in

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word production (see Caramazza, Costa, Miozzo, & Bi, 2001; Jescheniak, Meyer, & Levelt, 2003). Here, we do not claim that frequency has no influence on other levels of production but rather that evidence supports the claim that word frequency is largely associated with processes of phonological encoding.

Aging and Lemma Selection

Generally, in both normative studies (Borod, Goodglass, & Kaplan, 1980; Kaplan, Goodglass, & Weintraub, 1983; Nicholas, Brookshire, MacLennan, Schumacher, & Porrazzo, 1989; Van Gorp, Satz, Kiersch, & Henry, 1986) and experimental studies (Bowles, Obler, & Albert, 1987), older adults show a decrease in picture naming accuracy. Across studies, this decrease in accuracy appears most often in participants over the age of 70 years old, although such a decrease appears less pronounced for younger old adults (Feyereisen, 1997; Goulet, Ska, & Kahn, 1994). The term *error* should be interpreted carefully. In many cases, "errors" are defined as nonnormative responses that in some circumstances may still be acceptable responses. Most of these errors, in both young and older adults, consist of the production of semantically related names rather than of errors related to visual confusions, and these semantically related picture names, indicative of some problem in the process of lemma selection, appear to become more common with age (Feyereisen, 1997).

Aging and Phonological Encoding

One line of evidence for age-related difficulties in phonological encoding comes from the so-called tip-of-the-tongue (TOT) phenomenon (see A. S. Brown, 1991; R. Brown & McNeill, 1966). When speakers are in a TOT state, they often report a strong subjective sense of knowing the word but are unable to access all of its sounds. This has been taken as indicating successful lemma selection in the absence of phonological encoding because speakers are able to identify grammatical characteristics represented at the lemma level, such as English count–mass noun distinctions (Vigliocco, Martin, & Garrett, 1999) and Italian grammatical gender (Badecker, Miozzo, & Zanuttini, 1995; Miozzo & Caramazza, 1997; Vigliocco, Garrett, & Antonini, 1997).

Older adults show an increased tendency to enter a TOT state (Burke, MacKay, Worthley, & Wade, 1991; Maylor, 1990; Rastle & Burke, 1996). The increased susceptibility of older adults to TOT states suggests a weakening of the connections between the lemma level and the phonological forms in language production (see Burke, MacKay, & James, 2000). The weakened connections also serve to reduce the partial activation of phonological information, explaining the reduced ability of older adults to report partial information about the target word. The consistency of the age differences in TOT studies supports the notion that aging may influence the speed and accuracy of the phonological encoding process.

The Present Study

To investigate age differences in the processes of lemma selection and phonological encoding, researchers might use a traditional design in cognitive aging involving the selection of a set of pictures that vary orthogonally along the critical dimensions. For example, to examine the effect of name frequency on the performance of young and older adults, one might select a small set of pictures that elicit consistent picture names of high and low frequencies. To examine the effect of name agreement, one would select a similar set of items that vary along this dimension (e.g., high vs. medium or low name agreement). We take an alternative approach in this study by examining the influence of aging on lexical selection and phonological encoding in the context of a speeded picture naming study of a large number of items.

Here, we collected naming responses and naming times for a set of 541 simple object photographs. Each individual's response for a given picture can be described in terms of the response's frequency and the consistency in naming across all individuals within an age group. After these values were entered into a regression analysis, we could ask about the relative influence of frequency and name agreement on the time necessary to produce a given object name. Rather than asking how mean naming latencies might differ across dichotomized groups of items selected a priori for certain properties, we asked about the amount of variance accounted for by each of these two factors and whether these factors differentially influence the performance of young and older adults.

Method

Participants

Thirty young adults (mean age = 20.3 years, *SD* = 1.53) from the undergraduate participant pool at the Georgia Institute of Technology and 30 community dwelling older adults (mean age = 71.6 years, *SD* = 4.2) completed this study. The young adults scored an average of 90.6 (*SD* = 12.6) on the Wechsler Adult Intelligence Scale (WAIS–III) Digit–Symbol subscale and an average of 50.0 (*SD* = 6.3) on the WAIS Vocabulary subscale (Wechsler, 1997). Older adults in the study averaged 59.9 (*SD* = 17.0) on the WAIS Digit–Symbol subscale and 46.33 (*SD* = 9.3) on the WAIS Vocabulary subscale. There were reliable age differences in scores on the Digit–Symbol subscale, $t(58) = 7.97$, $p < .01$, with young adults outperforming older adults, but not for scores on the Vocabulary subscale, $t(58) = 1.78$, $p > .05$. All participants were native English speakers.

Stimuli and Apparatus

The 541 stimuli used for this study were a subset taken from the Photo-Objects 50,000 Volumes I and II collections distributed by Hemera Technologies.[1] Items chosen for this study contained a variety of common and uncommon objects, but each item contained a single, unique object that could be accurately named in a word or two without requiring additional modifiers. Stimuli were presented in 30 different orders, with 1 young adult and 1 older adult seeing each order. The full-color pictures were displayed on a light-gray background in the center of the 15-in. computer screen. All pictures were contained within a box measuring 6.7° × 6.7° (200 pixels × 200 pixels) of visual angle.

Stimulus display and recording were accomplished via personal computers running Red Hat 7.2 with low latency and preemptive kernel patches to ensure submillisecond timing accuracy. Speech was recorded at a 22.1 kHz sampling rate by the computer via a Sennheiser m@m40 microphone (Sennheiser Electronic Corporation, Old Lyme, CT).

Procedure

Testing sessions took approximately 30–45 min. The first and second blocks had 180 trials and the third had 181 trials, with breaks between each

Table 1
Means and Standard Deviations of Variables for Young and Older Adults

Variable	Young adults *M*	Young adults *SD*	Older adults *M*	Older adults *SD*	*t*(58)	*SD* Within-individual: Young adults	*SD* Within-individual: Older adults	*t*(58)
Name agreement	0.69	0.02	0.62	0.04	7.93**	0.32	0.32	0.49
Log frequency	0.95	0.05	1.05	0.06	7.53**	0.75	0.74	3.39*
Response time (ms)	976	300	1,261	276	3.83**	484	781	4.07**

* $p < .01$. ** $p < .001$.

block. Each trial began with a fixation point (+) presented in the center of the screen for 500 ms, which was followed by the onset of the picture, and then by the onset of recording. Participants were instructed to produce a name for the object pictured on the computer screen and to avoid detailed or overly descriptive responses, including most adjectives. They were asked to avoid making any noises (such as "umm" or "uhh") before their chosen response. After participants provided their response, the experimenter advanced the computer to the next trial.

Analyses

Each naming response was measured in three ways: the frequency of the name, the degree of agreement across individuals within an age group, and the time of the onset of the picture name. The recording was hand transcribed by one of four trained transcribers. Transcribers entered all sounds produced in the sound file, including disfluencies such as filled pauses, in addition to the word response. Sound files with initial sounds that were not part of the object name were not included in the analyses of response time. Speech onsets were measured with a relative energy criterion to detect speech onsets (Bansal, Griffin, & Spieler, 2001). Onsets that measured less than 200 ms were not included in the analysis, as this time is too short to expect the onset of an intentional response.

Frequency measures were obtained with the combined spoken and written English word form frequencies per million from the Centre for Lexical Information (CELEX) database (CELEX English database, 1993). If multiple entries existed for a word (e.g., *ball*, which has multiple meanings), the frequencies for each entry were summed to give a total for each spoken response. If the picture name contained multiple words that were not found together in the CELEX database (e.g., *manual typewriter*), then we used the frequency of the first content word of the picture name (e.g., *manual*). Although our use of the CELEX database, which is based on British English, may affect specific point estimates and thus could lower our beta estimates, it should not differentially bias our target comparison of older versus young adults.

Name agreement for each response was calculated as a ratio of the number of individuals with the given response divided by the number of acceptable responses produced across individuals within an age group. We calculated these separately for each group because of the possibility of cohort differences in name preferences. If the response included a modifier such as "red car" then this would be counted as a different response from "car."

Results

Because response onset time was our dependent measure, we excluded all responses without valid naming responses or with beginning sounds other than the onset of the speaker's picture name. These criteria left 96.6% and 87.0% of the responses for young and older speakers, respectively. Because the effect of word frequency on behavioral measures is highly nonlinear, log frequency is more commonly used in these types of analyses. Because name agreement ranges from 0 to 1, we applied an arcsine transform (Winer, Brown, & Michels, 1991) before entering name agreement into the regression analysis. Summary statistics for the predictors are shown in Table 1.

To more accurately assess how the influence of these predictors might differ across age group, we used the frequency and name agreement for each individual's response to conduct individual regression analyses for each participant, to predict the timing of the naming response (see also Lorch & Myers, 1990; Spieler & Balota, 2000). Because the interaction terms of the two predictors were not significant, we do not include these terms in the analyses. From each individual's regression analysis, we obtained standardized regression coefficients for each predictor (see Table 2). These coefficients were then treated as dependent measures in their own right and analyzed in a mixed-factor analysis of variance with the predictor as the within-participant factor and the age as the between-participants factor.

Older adults exhibited larger coefficients than young adults, $F(1, 58) = 12.25$, $MSE = .0060$, $p < .001$; name agreement exerted a greater influence than frequency, $F(1, 58) = 183.37$, $MSE = .0092$, $p < .001$. This analysis also suggested that the age differences were not equivalent across the two predictors, $F(1, 58) = 6.78$, $MSE = .0092$, $p < .05$. Comparisons showed that young and old did not differ in the influence of frequency, $t(58) < 1$, but the two groups did differ in the effect of name agreement, $t(58) = 3.56$, $p < .01$.[2]

As shown in Table 1, the two groups differ slightly in mean name agreement, although the within-individual variability in name agreement on which the regression analyses are based did not differ across the two groups. However, in a between-groups comparison of regression coefficients, it may be more appropriate to test for differences with the nonstandardized coefficients. Doing so revealed the same pattern of age differences in name agreement, $t(58) = 4.10$, $p < .001$. The influence of frequency was nonsignificant, although marginal, $t(58) = 1.73$, $p = .09$.

We also repeated these analyses, limiting the responses to single-word utterances (.81 and .80 proportion of the responses for young and older adults, respectively) and, again, found the same pattern of results, age differences in name agreement, $t(58) = 3.02$, $p < .01$, and marginal difference for frequency, $t(58) = 1.88$, $p = .07$. These analyses suggest that we cannot rule out the possibility that there are age differences in the influence of frequency, al-

[2] We used arcsine transformed name agreement percentages for these analyses; however, the results hold for untransformed name agreement percentages as well, $t(58) = 7.93$, $p < .01$.

Table 2
Mean Standardized Regression Coefficients for Each Predictor Averaged Across Participants for Each Group

	Name agreement		Frequency	
Group	*M*	*SD*	*M*	*SD*
Young adults	−0.27	0.13	−0.066	0.08
Older adults	−0.36	0.08	−0.068	0.06

though it is clear that this difference is much smaller than that found for name agreement.

Note that in our computation of name agreement, we do not take into account how responses are distributed among the varying number of response alternatives. For example, if a response is given by 20% of respondents, we do not explicitly take into account whether the other 80% of the responses are just one other dominant response or many equally likely responses. Although we could not control the distribution of responses, we could select items that ensure that variations in the distribution of responses do not drive the pattern of age differences. We selected a subset of pictures for each group that equated young and older adults on the number of response alternatives. Repeating the analysis again demonstrated age differences in name agreement, $t(58) = 4.00$, $p < .01$, but not in frequency, $t(58) < 1$.

We can also take into account how the responses are distributed among the set of names produced by computing the *H* statistic used by Snodgrass and Vanderwart (1980).

$$H = \sum_{i=1}^{k} \mathrm{p}_i \log_2 (1/\mathrm{p}_i)$$

where k is the number of different response types, and p_i is the proportion of responses given for each *i*th response. Note that if all participants gave the same response, *H* would be 0; more broadly distributed responses would result in larger *H* values. Because this measure is computed across all participants within a group, this predictor is more a property of the picture than of an individual's response. In other words, this predictor is different across items but equivalent across participants within a group. This is different from the above analyses in which name agreement was based on the specific response produced and thus was variable across both items and participants. Analyses in which the *H* statistic is the measure of name agreement again demonstrated age differences in name agreement, $t(58) = 2.70$, $p < .01$, but not in frequency, $t(58) < 1$.

Discussion

The main results of this study are straightforward. Both young and older adults show significant relationships between name agreement, name frequency, and naming time. Older adults are particularly more sensitive to variations in name agreement. Word frequency appears to influence the performance in young and older adults similarly, although there is some hint from some analyses that even word frequency might be slightly stronger in older adults than in young adults. Several mechanisms could be responsible for the increased difficulty in lexical selection in older adults compared with young adults. In models of language production (e.g., Levelt, Roelofs, & Meyer, 1999), lexical selection is often accomplished via comparisons of individual lemma activations relative to the activity of other competing lemmas (e.g., via Luce's choice rule; Luce, 1963). The simple injection of noise into the activations of lemmas at this level can have the effect of reducing the difference between the target lemma and the competitors, and thus, additional time would be required before any individual lemma exceeds the criterion and is selected. Some models resolve competition partly via lateral inhibitory connections between competing lemmas (e.g., Harley, 1993; for discussion see Schade & Berg, 1992). Age-related changes in the efficiency of inhibitory connections at this level could reduce the ability of slightly more activated lemmas to suppress the activation of competing entries. The continued activation of these competitors will have the effect of reducing the relative differences in activation between possible lemmas, again requiring more processing time prior to lexical selection.

The finding that lexical competition is a powerful factor in word retrieval is consistent with studies of continuous speech that show an increase in the probability of speech disfluencies at choice points in an utterance. For example, Goldman-Eisler (1968) showed that the predictability of words just after a disfluency is low relative to the predictability of words not following disfluencies. The lack of predictability reflects relatively low levels of contextual constraint and a larger set of possible words competing for selection. There is some increase in disfluencies during natural speech with age (Kemper, 1992a; Kemper, Herman, & Lian, 2003; see Kemper, 1992b, for a review). However, the influence of any increased susceptibility to competition may be attenuated by the ability of older speakers in natural discourse contexts to trade additional planning (Griffin & Spieler, 2000), slower speech rates (Cooper, 1990), or shorter and simpler utterances (Kemper & Rash, 1988; Kynette & Kemper, 1986), all of which are associated with fewer overt speech disfluencies (see Griffin & Spieler, in press, for a review).

The two age groups in the current study did not differ significantly in the influence of name frequency. However, in several of the analyses, there was a marginal age difference. Moreover, evidence from age differences in TOT states detailed by Burke and colleagues (Burke et al., 2000, 1991) makes us hesitant to conclude that the groups are equivalently influenced by word frequency.

In the present study, we examined the specific factors selected because of how each maps onto levels of processing in standard models of language production. In doing so, we did not seek out other predictors that may also have an influence on processing, albeit at levels that were of less theoretical relevance. For example, the input to the production system during picture naming is the output of the visual object recognition system. Clearly, visual properties of the stimuli will have an effect (Snodgrass & Feenan, 1990) on picture naming. However, the few studies that have used measures of visual complexity to predict picture naming have found that the overall contribution of these factors is small or nonsignificant (Szekeley et al., 2005), and these measures exhibit little correlation with other factors (Cuetos, Monsalve, Pinto, & Rodriguez-Ferreiro, 2004). The results of the present study confirm both that competition during lexical selection is a strong influence in word retrieval for all speakers and that the process of resolving this competition is particularly age sensitive. These results suggest that older adults should experience difficulties in speaking during periods of low contextual constraint when competition for lexical selection is relatively high and that this susceptibility to competition may be a critical factor in determining how aging influences the process of producing language.

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