Neighborhood effects in aging and aphasia

Most speakers have encountered occasional difficulty in retrieving an intended word. This difficulty becomes even more frequent as speakers get older, especially after seventy years of age (e.g. Connor et al., 2004). Furthermore, virtually all individuals with aphasia show significant word-finding problems. Also contributing to retrieval success are characteristics of the intended word. For example, both word length and how frequently a word occurs have been shown to affect the ease with which the word is retrieved (e.g. Meyer et al., 2003; Luce & Pisoni, 1998). Another lexical characteristic of particular interest for the current study is the number of words similar in sound to the target. Phonological neighborhood density is typically defined as the number of words which differ from the target by the addition, substitution, or deletion of one phoneme (Luce & Pisoni, 1998). In studies of word recognition, words with many neighbors, i.e. those from dense neighborhoods, are found to be more difficult to distinguish from their competitors (e.g. Luce & Pisoni, 1998). However, some word production studies have found a facilitative effect of neighborhood density (Gordon, 2002; Vitevitch, 2002; Vitevitch et al., 2004), a result which has been explained by the interaction of lexical and sublexical information during speech production (Dell & Gordon, 2003).

Although competitive phonological neighborhood effects have been shown in word recognition studies, and facilitative effects in word production studies, no studies have examined neighborhood effects in both expressive and receptive tasks in the same participants. Furthermore, we included a larger and more varied set of stimuli than has previously been examined. In the current study, we assessed word production and word recognition in younger and older adult non-brain-damaged participants, as well as participants with aphasia, in order to investigate the effects of phonological neighborhood density and its related variables, and how these influences might change with age and aphasia.

Methods

Ninety-two native English-speaking participants between the ages of 22 and 90 were tested: 73 non-brain-damaged (NBD) participants (31 Young NBD, 22-49 years old; 42 Older NBD, 50-90 years old), and 19 individuals with aphasia (APH).

Each participant carried out word production and word recognition tasks. Word production was assessed with a picture naming task using 200 line drawings with single-syllable names, gathered from several sources (*Boston Naming Test*, Goodglass et al., 2001; *Object and Action Naming Battery*, Druks & Masterson, 2000; *Philadelphia Naming Test*, Roach et al., 1996; *Snodgrass and Vanderwart-like Object Set*, Rossion & Pourtois, 2004). Word recognition was assessed with a lexical decision task including the same 200 words, and 200 pronounceable non-words developed by reassigning the onsets of the real-word stimuli. All participants completed the naming task first. Stimuli were presented in random order in both tasks. Accuracy and response time (RT) were measured for both tasks. Naming RTs were measured using a voice-activated response box and *E-Prime* software (Schneider et al., 2002). Lexical decision accuracy and RT were both measured by *E-Prime*. In RT analyses, only correct responses were counted.

Mean RTs and mean accuracy rates across participants in each group were correlated with nine item variables, including length (number of phonemes), three measures of phonotactic probability, phonological neighborhood density and neighborhood frequency, and three measures of lexical frequency. On the basis of these correlations and the inter-correlations among the item variables, the number of predictors was narrowed down to five: length; probability of the initial phoneme; mean probability of the word's biphones; neighborhood density; and log-transformed frequency of the noun lemma. These were included in separate multiple regression analyses conducted for each group, task, and outcome measure (log-transformed accuracies and RTs).

Results & Discussion

Raw correlations between mean naming latencies and accuracy rates are shown in Table 1 for the five retained item variables. These findings suggest that an item's length and frequency influence word retrieval for all groups, but that phonotactic frequency appears to play little role. Density shows significant effects only on naming by participants with aphasia, but these are in the predicted direction: naming is more accurate and faster for items with more neighbors. However, because the item predictors are confounded with each other, we conducted a series of multiple regressions to assess the independent contributions of each variable.

Significance values for each of the predictors in each multiple regression are shown in Table 2, along with the total variance accounted for by each model (R^2).

Naming. The multiple regressions confirm that the strongest predictor is lemma frequency: the more frequent the word, the more accurate naming responses were for each group, and the faster responses were for ONBD participants. Shorter words were named more quickly by each group, and more accurately by individuals with aphasia. Greater phonotactic probability of the initial phoneme also speeded reaction times for the two non-brain-damaged groups. Neighborhood density affected naming RTs only for the ONBD group, and in the opposite direction than was predicted: items with more neighbors were responded to more slowly than items with fewer neighbors. The correlations show that naming was more accurate (as expected) but unexpectedly slower for items with larger neighborhoods. This finding seems to reflect a speed-accuracy trade-off. The activation of multiple neighbors may increase the likelihood of target production for older speakers, but also the time taken to differentiate the target from its neighbors in order to prepare it for production.

Lexical Decision. Like naming, lexical decisions were faster and more accurate to more frequent words for each group. The only other significant predictors involved two other unexpected findings: for YNBD participants, longer words, and words with more neighbors, were more likely to be accurately recognized. Longer words are typically less frequent than shorter words; however, after partialling out this effect, it appears that words with more phonemes are actually easier to recognize for YNBD participants. Longer words (here, single-syllable words with more clusters) are also more distinctive, which might explain this result, except that words with more neighbors (so, by definition, less distinctive) were also easier to recognize by these participants, after partialling out length and frequency effects. Apparently, words with consonant clusters seem more word-like than simple CVCs, but among these more complex words, those with more neighbors are easier to recognize. Considered in the context of other lexical and sublexical variables, the effects of neighborhood density are subtle and complex.

Some processing differences are suggested by comparing the results across measures, tasks, and groups. For NBD speakers, only word frequency, a lexical variable, affects retrieval of the correct name, whereas lexical and sublexical variables (length and initial phoneme probability) affect the time taken to formulate these responses. For individuals with aphasia, sublexical variables play a stronger role in naming—accuracy is affected by length, and RT is only affected by length, suggesting that it is the post-lexical stages of retrieval that are most affected by aphasia. In lexical decision, younger participants appeared to be able to take advantage of sublexical features of the stimuli to recognize them as words, whereas responses were affected only by frequency for older participants and those with aphasia, suggesting a more cautious, lexically based approach to the task. Comparing across these groups helps differentiate processing changes which occur with normal aging from those brought on by aphasia.

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Table 1. Mean outcome values for each group, and correlations of outcome variables with item variables. Highlighting indicates significance (p<0.05) for 200 items.

Group	Measure	Mean Value	Correlations with Item Variables: # Phon	Initial PP	Ave BP	Den B	Log Freq
Naming Task							
YNBD	Accuracy	0.976	0.0371	0.0510	-0.0056	-0.1027	0.1482
YNBD	RT	879	0.2116	-0.0879	0.0868	-0.1363	-0.0980
ONBD	Accuracy	0.952	-0.0905	0.0186	-0.0534	-0.0091	0.2111
ONBD	RT	965	0.0933	-0.0907	0.0412	0.0408	-0.1922
APH	Accuracy	0.829	-0.2353	0.0197	-0.0441	0.1646	0.3074
APH	RT	1568	0.2458	-0.0361	0.0881	-0.1615	-0.1356
Lexical Decision Task							
YNBD	Accuracy	0.986	0.1615	0.0037	0.0855	0.0055	0.1306
YNBD	RT	973	0.0914	0.1289	-0.0020	-0.0999	-0.2813
ONBD	Accuracy	0.979	0.0386	-0.1185	0.0297	0.0055	0.1744
ONBD	RT	1046	0.1482	0.1153	0.0088	-0.1246	-0.4109
APH	Accuracy	0.951	0.0643	0.0288	0.0595	-0.0709	0.1574
APH	RT	1522	0.0425	0.1183	-0.0378	-0.0024	-0.3069

Table 2. Results of multiple regressions. Significant predictors are highlighted (p<0.05).

Group	Measure	Significance Value in Multiple Regression: # Phon	Initial PP	Ave BP	Den B	Log Freq	R^2
Naming Task							
YNBD	Accuracy	0.737	0.291	0.956	0.138	0.022	0.042
YNBD	RT	0.017	0.023	0.847	0.736	0.386	0.073
ONBD	Accuracy	0.198	0.274	0.865	0.211	0.005	0.059
ONBD	RT	0.032	0.018	0.836	0.041	0.009	0.082
APH	Accuracy	0.040	0.116	0.684	0.980	<0.001	0.136
APH	RT	0.017	0.136	0.978	0.850	0.229	0.078
Lexical Decision Task							
YNBD	Accuracy	0.001	0.412	0.843	0.024	0.012	0.082
YNBD	RT	0.540	0.144	0.892	0.259	<0.001	0.094
ONBD	Accuracy	0.090	0.064	0.953	0.322	0.011	0.056
ONBD	RT	0.974	0.378	0.787	0.377	<0.001	0.178
APH	Accuracy	0.702	0.641	0.568	0.522	0.014	0.039
APH	RT	0.852	0.219	0.480	0.820	<0.001	0.105

Note: # Phon = phonemes; PP = phonotactic probability; Den B = phonological neighborhood density, as defined in the text; Log Freq = log value of noun lemma frequency.