BRAIN AND LANGUAGE 30, 106–115 (1987)

Aphasic Performance on a Lexical Decision Task: Multiple Meanings and Word Frequency

BRUCE R. GERRATT

V.A. Medical Center, West Los Angeles, and UCLA School of Medicine, University of California at Los Angeles

AND

DEBORAH JONES

Glendale Adventist Medical Center, California

The lexical access of words varying in the number of meanings and frequency of occurrence was examined in fluent and nonfluent aphasic individuals and a control group of non-brain-damaged adults, using a lexical decision task. Fluent aphasic subjects performed similarly to nonfluent aphasic and normal subjects, showing that words with a high number of meanings and with a high frequency of occurrence were recognized as real words faster than words with few meanings or a low frequency of occurrence. While previous research has demonstrated that the number of meanings associated with a word exerts a powerful influence on the internal lexicon of normals, the results of this study suggest that brain damage resulting in aphasia does not disrupt this semantic organization. © 1987 Academic Press, Inc.

A relatively recent area of interest in semantic research is the lexical access of words with multiple meanings. Looking through an unabridged dictionary, one may be struck by how few English words have only one meaning. It would follow, then, that in the normal individual, the internal lexicon would have properties reflecting the fact that a written word can be associated with many, occasionally unrelated, meanings. In fact, Rubenstein, Garfield, and Millikan (1970) and Rubenstein, Lewis, and Rubenstein (1971) found that homographs (words spelled alike but having different meanings) are recognized as English words faster than non-

Send correspondence, including reprint requests, to Bruce R. Gerratt, V.A. Medical Center, Audiology and Speech Pathology (126), Wilshire and Sawtelle Boulevards, Los Angeles, CA 90073.

0093-934X/87 $3.00

homographs in lexical decision tasks, in which subjects were required to decide as quickly as possible if a string of letters is an English word. This relative ease of lexical access for homographs has been called the "number-of-meanings effect." These studies were criticized by Jastrzembski (1981) for an inadequate difference in number of meanings between words chosen for homographs and nonhomographs. Consequently, Jastrzembski, who compared lexical decision latencies on words with a high number of multiple meanings with latencies on words with few meanings, found that the number-of-meanings effect was considerably larger than that of frequency of occurrence in the language, another variable investigated in his study. This finding was surprising considering the fact that investigators often pay much attention to frequency of occurrence but seldom control for number of word meanings. Apparently, the number of word meanings is an important property in the organization of the internal lexicon in the normal individual.

Rubenstein et al. (1971) proposed a model to explain the number-of-meanings effect in word recognition which utilizes four processes: (1) division of the stimulus into letters; (2) the use of the letters to distinguish a subset of possible lexical entries for consideration; (3) the comparison of the identified letters with the entries under consideration; and (4) the selection of one of the entries. The frequency of occurrence effect is thought to occur at the second process since candidate lexical entries are considered according to their frequency of occurrence. The number-of-meanings effect is thought to occur within the third process. Rubenstein et al. (1971) explain that among words of similar frequency, the larger the number of meanings of a word, the larger the number of lexical entries and the greater the probability of encountering one of them. Consequently, a word with many meanings will be recognized faster than one having only a few meanings.

A word with multiple meanings can have many related senses derived from the same etymological source (polysemy), or the senses can be from several unrelated derivations (homonymy). Both Rubenstein et al. (1970, 1971) and Jastrzembski (1981) do not address this issue in their investigations, but use words which are both polysemous and homonymous as stimuli. In many cases, because of errant semantic history, the distinction is unclear. In fact, since there really is no empirical, clear-cut method for making the distinction, and Jastrzembski (1981) found that the number of derivations of word meaning did not affect lexical access in word recognition, the procedure of using an unrestricted dictionary count seems to be a reasonable approach in choosing word stimuli.

Deloche and Seron (1981) and Pierce (1984) found that aphasic subjects experienced more difficulty than normal subjects in comprehending the multiple meanings of homographs, especially those meanings which are less frequently encountered, or were judged less typical. In view of the controversy surrounding the level of breakdown in semantic tasks as exhibited by fluent aphasic subjects, the findings of Deloche and Seron (1981) and Pierce (1984) may be explained by either a disruption in the underlying semantic organization, or by a more peripheral impairment in the lexical access to the word meanings in such comprehension tasks.

A number of recent studies have focused on the question of lexical organization and retrieval in aphasia, especially in subjects having fluent aphasia. Howes (1967) reported that these patients demonstrated abnormal patterns of word association and response latencies, deviations which were interpreted as evidence of abnormal semantic organization. Zurif, Caramazza, Meyerson, and Galvin (1974) similarly interpreted the results of Wernicke's patients' abnormal categorization of words as an indication of alteration in their internal lexicon. Other studies came to similar conclusions. Goodglass and Baker (1976) reported that aphasic subjects were impaired in the ability to judge semantic associations. Grober, Perecman, Kellar, and Brown (1980), using a semantic categorization task, showed that posterior aphasic subjects exhibited difficulty in classifying atypical category members and semantically related nonmembers. In addition, Whitehouse, Caramazza, and Zurif (1978) found that aphasic subjects demonstrated difficulty in categorizing and utilizing perceptual or functional properties of pictures of objects. In contrast, Milberg and Blumstein (1981) and Blumstein, Milberg, and Shrier (1982) reported that aphasic subjects demonstrated semantic facilitation effects in both visual and auditory lexical decision tasks. These results were interpreted as evidence that the semantic deficit in these subjects is related to impairment in access to the semantic information rather than to a disturbance in the underlying organization.

The present study was designed to investigate whether the number-of-meanings effect observed in normal individuals is preserved in the semantic organization in aphasic subjects. Frequency of occurrence in the language was also considered, since this variable has been shown to have a pervasive influence on semantic organization in normal individuals (Morton, 1969; Solomon & Postman, 1952), and is known to be negatively related to reaction time (RT) to word stimuli. Furthermore, a number of studies concluded that aphasic subjects show more difficulty with words which occur less frequently than with those occurring more frequently (Wepman, Bock, Jones, & Van Pelt, 1956; Bricker, Schuell, & Jenkins, 1964; Schuell, Jenkins, & Landis, 1961; Howes, 1964; Goldfarb & Halpern, 1981).

If that aspect of semantic organization underlying the multiple meanings of words is impaired, the aphasic subjects should demonstrate a reduced or absent number-of-meanings effect. However, if this effect does occur, it can be assumed that the problem that aphasic subjects show in the comprehension of multiple meanings occurs more peripherally at the level of word retrieval.

METHOD

Stimuli

Stimuli consisted of a total of 320 letter strings, half of which were real words and half of which were nonwords. Forty real words were selected for each of the four conditions formed by a factorial arrangement of high and low frequency in the language, and high and low number of dictionary meanings. Number of meanings was determined by a count in the *Unabridged Random House Dictionary* (Stein & Urdang, 1967), while frequency of occurrence was selected from the Kucera and Francis (1967) word counts. The mean number of meanings and word frequency, respectively, for each of the four conditions were the following: high number of meanings, high frequency—36.5, 104.38; low number of meanings, high frequency—5.95, 105.47; high number of meanings, low frequency—36.15, 13.85; low number of meanings, low frequency—5.07, 12.8. Word length was also controlled. There were 15 four-letter, 15 five-letter, and 10 six-letter words in each set of 40 words. Nonwords were created by changing a single letter of each of the 160 English words, with the restriction that the resulting nonwords should be pronounceable by English speakers. Forty similarly chosen English words and 40 similarly constructed nonwords served as practice items.

Subjects

Experimental subjects were 12 aphasic, male patients from the V.A. Medical Center, West Los Angeles, and the V.A. Outpatient Clinic, Los Angeles, and 6 male patients without brain damage from nonneurological wards served as normal control subjects. The aphasic subjects were separated into fluent and nonfluent groups on the basis of results from the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972), the Porch Index of Communicative Ability (1981), and clinical examination. Fluent can be considered to be equivalent to Wernicke's and nonfluent to Broca's aphasia. All subjects were native English speakers. All but one of the subjects was right-handed.

The normal control group had a mean age of 55.0 years (range 36–78), the fluent aphasic group had a mean age of 63.5 years (range 58–72), and the nonfluent aphasic group had a mean age of 56.7 years (range 43–71). Table 1 summarizes the age, months postonset, z scores for the Auditory Discrimination subtest of the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972), and the overall percentile for the Porch Index of Communicative Ability (Porch, 1981).

Apparatus

The stimuli were presented in uppercase letters on a high-contrast video screen and subtended about 1.4 degrees of visual angle. The subjects responded by pressing one of two touch-sensitive keys mounted on a response box. The word "YES" was positioned above one key, and the word "NO" above the other key. All subjects were asked to use their left hand for key selection. Randomization and presentation of the stimuli and collection of responses were controlled by a DEC 11/23 computer.

Procedure

Subjects were given the verbal instructions to press the key marked "YES" if a letter string was a word, and the key marked "NO" if it was not a word. They were told to respond as quickly as possible, but emphasis was placed on responding accurately.

A trial consisted of a brief tone as a ready signal and the presentation of a fixation point in the center of the screen for 1.5 sec, followed by a letter string. The string remained on

TABLE 1
SUBJECT CHARACTERISTICS AND TEST SCORES OF APHASIC SUBJECTS

Subject	Age	Postonset (in months)	PICA (%ile)	Boston Aud. Discrim. (z score)	Aphasia type
1	65	17	62	−0.26	Fluent
2	64	44	82	0.54	Fluent
3	68	144	73	−0.37	Fluent
4	52	3	32	−2.45	Fluent
5	72	4	64	−0.55	Fluent
6	60	7	64	0.31	Fluent
7	58	120	48	0.71	Nonfluent
8	54	10	33	−0.43	Nonfluent
9	71	18	67	0.37	Nonfluent
10	67	120	71	0.94	Nonfluent
11	43	132	88	0.89	Nonfluent
12	47	6	33	0.71	Nonfluent

the screen until the subject responded. Reaction time was measured from the onset of the stimulus. Following a response, there was a blank interval of 1.5 sec until the next trial began. The trials were divided into three experimental sessions with short rest periods between each session. A random order of letter strings was selected for each session.

Prior to the experimental sessions, the subjects participated in practice sessions. The experimenter demonstrated the lexical decision task by presenting samples of words and nonword letter strings on the video screen and showing the appropriate procedure for responding using the response box. After a few trials performed with the aid of the experimenter, the subject was presented the practice list. If the subject did not respond with at least 75% accuracy, the above procedure was repeated. In all, each subject was given up to three presentations of the practice series. Two fluent and two nonfluent aphasic subjects could not peform in this way and were not included in the experimental sessions.

RESULTS

Reaction Time Analysis

Two analyses of variance were performed on the reaction time data, one for the real word stimuli and the other for the nonword stimuli. The analyses of variance used one between-subjects factor of subject group, and two within-subject factors of number of meanings and frequency of occurrence. Figure 1 shows the mean reaction time latencies in milliseconds for real word stimuli as a function of subject group, number of meanings, and frequency of occurrence. An ANOVA for the real word data indicated no significant differences among the three groups, $F(2, 15) = 0.81$, $P > .46$, a significant difference between high and low levels of meaning, $F(1, 15) = 25.87$, $P < .0001$, and a significant difference between high and low levels of frequency, $F(1, 15) = 17.41$, $P < .0001$. None of the interactions were significant.

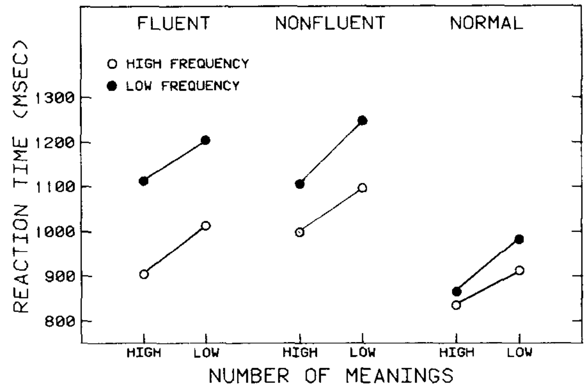

FIG. 1. Reaction time in milliseconds for real words as a function of the three subject groups, high and low number of meanings, and high and low frequency of occurrence.

The ANOVA for nonwords revealed no significant main effects nor any significant interactions. Thus, the subjects' responses for nonwords followed no consistent pattern.

Error Analysis

Analysis of errors yielded results similar to the analysis of reaction time. The mean percentage of errors committed by the subjects on real words (NO responses) are presented as a function of subject group, number of meanings, and frequency of occurrence in Fig. 2. The pattern of these results appears to be close to that presented in Fig. 1, which portrays reaction time latencies to real word stimuli. Subjects responded more slowly and made more errors identifying words which occur in-

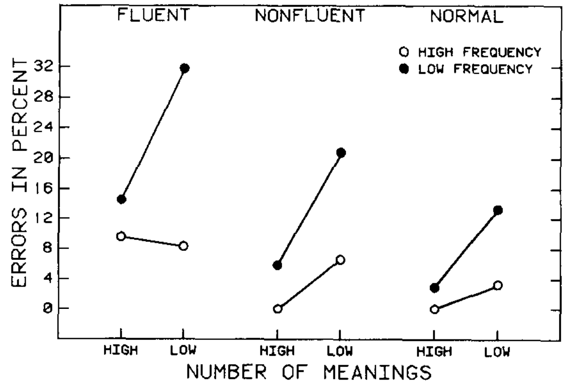

FIG. 2. Errors in percentage on real words as a function of the three subject groups, high and low number of meanings, and high and low frequency of occurrence.

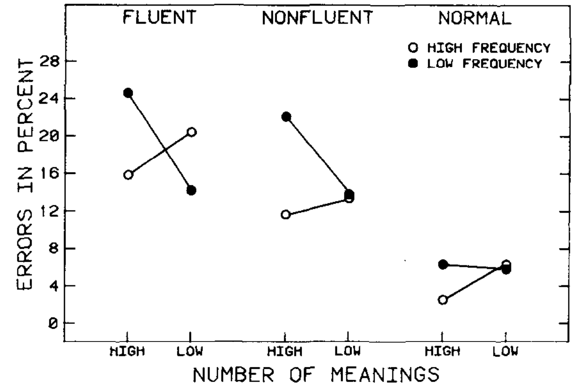

FIG. 3. Errors in percentage on nonwords as a function of the three subject groups, high and low number of meanings and low and high frequency of occurrence.

frequently and have a low number of dictionary meanings. Overall, the results indicate that speed and accuracy were related. The slower the response, the more likely an incorrect decision was made. Since there were a number of instances in which subjects made no errors, a nonparametric test was chosen for statistical analysis. Consequently, G^2, a log-linear approximation to Pearson X^2 was used (Bishop, Feinberg, & Holland, 1975). There was a significant effect for group, $G^2(2) = 60.07$, $P < .001$, number of meanings, $G^2(1) = 52.33$, $P < .001$, and frequency of occurrence, $G^2(1) = 76.52$, $P < .001$, with a significant group $\times$ meaning association, $G^2(2) = 12.16$, $P < .002$. The fluent group responded with relatively more errors than the normal and nonfluent groups.

The mean percentage of errors for the nonword stimuli (YES responses) is presented in Fig. 3. Analysis of errors revealed a significant effect for group, $G^2(2) = 82.99$, $P < .001$, and no other significant effects or associations. While the two aphasic groups showed a higher percentage of errors than the control group, there is no clear pattern of errors across frequency of occurrence and number of meanings.

DISCUSSION

The most important finding of this study is that regardless of subject group, words having a high number of meanings result in faster lexical decisions than words having only a few meanings. The results show that the number of meanings associated with a word does exert a powerful influence on its recognition, and suggest that fluent aphasic patients are relatively unimpaired in at least this aspect of their semantic organization. The fact that the number-of-meanings effect is an important factor in lexical decisions suggests that multiple word meaning should be controlled in lexical research in aphasia. Frequency of occurrence is often controlled in the study of semantic organization. Failure to control for number of meanings could cause difficulty in the interpretation of results.

Frequency of occurrence was shown also to exert a strong influence on the recognition of words in this study. This finding was expected considering much previous research in both naming and comprehension tasks. However, these results did not agree with those of Filby, Edwards, and Seacat (1963), who reported that aphasic subjects did not show impairment on infrequent words in a matching-to-sample task.

The logogen model proposed by Morton (1979) and elaborated by Jastrzembski (1981) can help explain the obtained results. A logogen is a mental device that accumulates evidence that a certain word is present as a stimulus. The evidence is gained from information provided by the stimulus, and contextual information. The contextual evidence, such as semantic knowledge, is provided by the subject. The more contextual evidence, the less stimulus-related evidence (such as characteristics of a particular letter string) required to recognize the word. The total amount of evidence necessary to recognize the word must exceed a certain threshold. When a word is encountered frequently, the threshold for its recognition is reduced. Consequently, a high-frequency word needs less visual evidence to exceed the threshold, leading to the word's faster recognition. The number-of-meanings effect is explained differently. Words which have multiple meanings are represented by one logogen or lexical entry for each meaning. As soon as one logogen accumulates enough evidence to reach threshold, the word can be recognized. Thus, a word having many meanings, and therefore many logogens, will be more likely to have one of its logogens reach threshold sooner than a word with only a few.

Alternate theories propose a less fixed representation of each possible meaning of a word in the internal lexicon. Caramazza and Grober (1976) theorized that a set of specific instructions applied to a core meaning of a word is necessary to generate specific meanings. Miller (1978) described a similar theory in which there is a general lexical entry associated with a word and a process which uses sentence context and pragmatic information to specify the appropriate information.

These process models propose a more parsimonious use of memory storage than multiple entry theories, since information conveyed in the sentence is used to generate surface meaning from a deeper conceptual representation. Thus, each sense associated with a word does not require separate storage in memory. However, the application of these models to our results is difficult, since the lexical decision task used in this study provides only the individual words as stimuli, not the sentences. Without the sentence to provide a context for determination of the particular sense, a subject would not have been able to transform a core meaning into a specific, intended meaning.

Whatever way in which multiple meanings of words are actually stored in the internal lexicon, the fact that the fluent aphasic subjects responded similarly to the normal subjects suggests that the organization of multiple word meaning is preserved in fluent aphasia. These findings are consistent with those reported by Milberg and Blumstein (1981) and Blumstein, Milberg, and Shrier (1982), who found that Wernicke's aphasic subjects were similar to normal subjects in demonstrating faster recognition of words which had been immediately preceded by semantically related words. In contrast, the Wernicke's aphasic subjects demonstrated a greater degree of difficulty on a semantic judgment task than did the normal group. Thus, in these two studies, no significant correlation was found between the performance on a semantic priming task and a semantic judgment task. The authors attributed this low correlation to differences in the language tasks, concluding that semantic organization in Wernicke's aphasia appears intact, as long as no overt, semantic manipulation is required by the aphasic subject.

The results of the present study lend support to this interpretation. Again, fluent aphasic subjects responded like normal control subjects in a lexical decision task. In this type of task, the subject is merely required to recognize whether a group of letters is a word, rather than gain access to part or all of the semantic information associated with a lexical entry. Apparently, when a more complex task is required, whereby the patient must tap into this semantic information or relate that information to other words, the fluent aphasic individual demonstrates a significant impairment. However, when the complexity of the semantic decision-making process is sufficiently low, as in the lexical decision task, aphasic subjects do not demonstrate such a disturbance. This interpretation, then, supports the conclusion that it is the retrieval of semantic information rather than the underlying semantic structure that is impaired in fluent aphasic individuals.

REFERENCES

Bishop, Y. M., Feinberg, S. E., & Holland, P. W. 1975. *Multivariate analysis: Theory and practice*. Cambridge, Mass.: MIT Press.

Blumstein, S. E., Milberg, W., & Shrier, R. 1982. Semantic processing in aphasia: Evidence from an auditory lexical decision task. *Brain and Language*, **17**, 301–315.

Bricker, A., Schuell, H., & Jenkins, J. 1964. Effect of word frequency and word length on aphasic spelling errors. *Journal of Speech and Hearing Research*, **7**, 183–192.

Caramazza, A., & Grober, E. 1976. Polysemy and the structure of the subjective lexicon. In C. Rameh (Ed.), *Semantics: Theory and application*. Washington, D.C.: Georgetown Univ. Press.

Deloche, G., & Seron, X. 1981. Part of speech and phonological forms implied in written word comprehension: Evidence from homographic disambiguation by normal and aphasic subjects. *Brain and Language*, **13**, 250–258.

Filby, Y., Edwards, A., & Seacat, G. 1963. Word length, frequency and similarity in the discrimination behavior of aphasics. *Journal of Speech and Hearing Research*, **6**, 255–261.

Goldfarb, R., & Halpern, H. 1981. Word association of time-altered auditory and visual stimuli in aphasia. *Journal of Speech and Hearing Research*, **24**, 233–243.

Goodglass, H., & Baker, E. 1976. Semantic field, naming, and auditory comprehension in aphasia. *Brain and Language*, **3**, 359–374.

Goodglass, H., & Kaplan, E. 1972. *The assessment of aphasia and related disorders*. Philadelphia: Lea & Febiger.

Grober, E., Perecman, E., Kellar, L., & Brown, J. 1980. Lexical knowledge in anterior and posterior aphasics. *Brain and Language*, **10**, 318–330.

Howes, D. 1964. Application of the word frequency concept in aphasia. In A. V. S. de Rueck & M. O'Connor (Eds.), *Disorders of language*. Boston: Ciba Foundation.

Howes, D. 1967. Some experimental investigations of language in aphasia. In K. Salinger & S. Salinger (Eds.), *Research in verbal behavior and some neuropsychological implications*. New York: Academic Press.

Jastrzembski, J. E. 1981. Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology*, **13**, 178–305.

Jastrzembski, J. E., & Stanners, R. F. 1975. Multiple word meanings and lexical search speed. *Journal of Verbal Learning and Verbal Behavior*, **14**, 634–637.

Kucera, H., & Francis, W. N. 1967. *Computational analysis of present-day American English*. Providence, R.I.: Brown Univ. Press.

Milberg, W., & Blumstein, S. E. 1981. Lexical decision and aphasia: Evidence for semantic processing. *Brain and Language*, **14**, 371–385.

Miller, G. 1978. Lexical meaning. In J. F. Kavanaugh & W. Strange (Eds.), *Speech and language in the laboratory, school, and clinic*. Cambridge, Mass.: MIT Press.

Morton, J. 1969. Interaction of information in word recognition. *Psychological Review*, **76**, 165–178.

Morton, J. 1979. Word Recognition. In J. Morton & J. C. Marshall (Eds.), *Psycholinguistics 2: Structure and processes*. Cambridge, Mass.: MIT Press.

Pierce, R. S. 1984. Comprehending homographs in aphasia. *Brain and Language*, **22**, 339–349.

Porch, B. E. 1981. *Porch index of communicative ability*. Palo Alto, Calif.: Consulting Psychologists Press.

Rubenstein, H., Garfield, L., & Millikan, J. A. 1970. Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, **9**, 487–494.

Rubenstein, H., Lewis, S., & Rubenstein, M. 1971. Homographic entries in the internal lexicon: Effects of systematicity and relative frequency of meanings. *Journal of Verbal Learning and Verbal Behavior*, **10**, 57–62.

Schuell, H., Jenkins, J., & Landis, L. 1961. Relationships between auditory comprehension and word frequency in aphasia. *Journal of Speech and Hearing Research*, **9**, 30–36.

Solomon, R., & Postman, L. 1952. Frequency of usage as a determinant of recognition thresholds for words. *Journal of Experimental Psychology*, **43**, 195–201.

Stein, J., & Urdang, L. Eds. 1967 *The Random House dictionary of the English language*, unabridged. New York: Random House.

Wepman, J., Bock, R., Jones, L., & Van Pelt, D. 1956. Psycholinguistic study of aphasia: A revision of the concept of anomia. *Journal of Speech and Hearing Disorders*, **21**, 468–477.

Whitehouse, P., Caramazza, A., & Zurif, E. B. 1978. Naming in aphasia: Interacting effects of form and function. *Brain and Language*, **6**, 63–74.

Zurif, E. B., Caramazza, A., Meyerson, R., & Galvin, J. 1974. Semantic feature representations for normal and aphasic language. *Brain and Language*, **1**, 167–187.