Speakers' and Listeners' Processes in a Word-Communication Task

Abstract. *A communication task was developed to investigate the processes by which a speaker selects verbal clues in order to distinguish one word (referent) from another (nonreferent) and the processes by which a listener identifies the speaker's referent word. Data from speakers and listeners in this task were linked to word-association norms by means of a stochastic model.*

The set of objects or events about which a person talks, writes, or gestures, is termed the referent. The referent has a central role in the psychological analysis of communication (*1*). Nevertheless, it is difficult to investigate the relationship between a speaker's referent and his linguistic behavior in ordinary conversation, since the referent must be inferred from the behavior itself. To avoid this circularity, a simplified communication situation was developed in which referents were assigned to a speaker by the experimenter. The accuracy with which a listener identified the referent could thus be determined.

The communication situation was as follows: One subject, the speaker, was shown pairs of words (synonyms), one word-pair at a time; in each word-pair one word had been designated the referent. Another subject, the listener, was shown the same word-pairs with the referents not indicated. The speaker was told to give the listener a one-word clue (the "speaker-response") by which the listener could distinguish the referent from the nonreferent; he was instructed to use "a clue word that has some understandable connection with" the referent but none "that sounds like or is spelled like" either of the stimulus words. The listener then guessed which of the synonyms was the referent.

Our investigation was designed to study the following questions: (i) For a given referent stimulus, what is the linguistic repertoire from which a speaker selects his response? (ii) How is the speaker's selection affected by the nonreferent stimulus from which the referent must be distinguished? (iii) How does the speaker-response affect the probability that a listener will correctly identify the referent?

Results from an exploratory study of the communication task (sample protocols in Table 1) suggested that these questions could be dealt with by linking word-association data to speaker and listener behavior in this task. We speculated that the speaker's referential process consists first of sampling a response from his repertoire of word associations to the referent stimulus alone; in a second stage of the process, the relative "associative strengths" of the sampled response to each of the stimulus words (referent and nonreferent) determine the speaker's decision to utter it or reject it. If he rejects the sampled response, he repeats the entire two-stage process. Ultimately he emits a response, thus terminating the process. We assumed that the listener's choice is also determined by the relative associative strengths between the speaker-response and each stimulus word. Word-association norms appeared to offer a means of estimating these associative strengths.

These intuitive notions were formalized as follows:

A speaker-response results from the concatenation of two stochastic processes, sampling and comparison.

The speaker's sampling process occurs first. In this process the speaker samples, but does not necessarily emit, a response from a linguistic set I_r associated with referent r. The probability of sampling response i, where $i \varepsilon I_r$, is assumed to be equal to $P_r(i)$, the probability that i occurs as a word-associate when r is the stimulus word in a standard word-association test. If we assume homogeneity among the subjects, these probabilities can be estimated from group norms.

The speaker's comparison process follows each sampling. The result of the comparison process is that the speaker either emits the sampled response or rejects it as an inadequate communication. If he rejects it, he samples again from I_r. The sampling-comparison cycle is terminated when the speaker emits a response. The probability that a sampled response, i, will be emitted is expressed by the equation

$$P(\text{speaker emits } i|i \text{ is sampled}) = s_i(r)/[s_i(r) + s_i(n)] \qquad (1)$$

where $s_i(r)$ and $s_i(n)$ are "associative strengths" between i and the referent and nonreferent, respectively. Values of s_i are estimated from word-association norms. If a speaker samples a word that is inadmissable because it sounds like or is spelled like either stimulus word, then $P(\text{speaker emits } i \mid i \text{ is sampled}) = 0$. Equation 1 has been used extensively in paired-comparison problems and is known as the Bradley-Terry Model (*2*). The Bradley-Terry Model is also derived by Luce (*3*) from his choice axiom.

In the comparison process, the speaker essentially takes the role of the listener, and the speaker's comparison process is formally identical to the process by which a listener guesses the referent. An equation similar to Eq. 1 is assumed to give the probability that the listener chooses the referent using i as his clue-word. To distinguish the listener's comparison process from that of the speaker, however, we shall introduce new notation. The probability that a listener chooses the referent r correctly when given i as his clue word is expressed by the equation

$$P_i\{r,n\} = l_i(r)/[l_i(r) + l_i(n)] \qquad (2)$$

where $l_i(r)$ and $l_i(n)$ are associative strengths between i and the referent and the nonreferent, respectively. It should be noted that $P_i\{r,n\}$ can be estimated directly from listeners' data, whereas $P(\text{speaker emits } i \mid i \text{ is sampled})$ is only indirectly related to speaker's data. The listener-model is completed by relating l_i to observables independent of the listeners' data. The associative strengths $l_i(r)$ and $l_i(n)$ in Eq. 2 were linked to word-association data by letting $l_i(x) = a[P_x(i)+c]^b$, where x is a given r or n and a, b, and

Table 1. Speaker-response frequencies and listener-errors in sample protocols from an exploratory study with 18 speaker-listener pairs.

Referent: Alike			
Nonreferent: Equal			
similar	10	likeness	1
look	2	match*	1
twins	2	not	1
exactly	1		
Referent: Gay			
Nonreferent: Cheerful			
queer	5	joyful	1
Ben	1	light	1
exhilarated	1	liquor	1
fairy	1	lively*	1
happy	1	Paris	1
homo	1	party	1
homosexual	1	wild	1
Referent: Disappear			
Nonreferent: Vanish			
lost	2	frequently	1
absent	1	gone*	1
act*	1	hide	1
can't find	1	leave	1
cease	1	leave*	1
dishes	1	magician*	1
dissolve*	1	soapsuds	1
expire*	1	symptom	1
fade*	1		

* Resulted in incorrect identification by the listener.

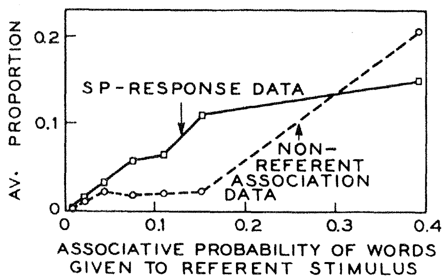

Fig. 1. The relation between the proportion of times that a response word occurred in the word-association norms of the referent and the average proportion of times that the same response occurred (i) as a speaker-response (solid line) and (ii) in the word-association norms of the nonreferent (dashed line).

c are constants. It should be noted that while $s_i(x)$ may also be related to word-association data by a power law, the parameter values may be different for the speaker.

Two experiments were designed to evaluate portions of the general theory; one pertaining primarily to speaker's sampling and the other to listener's comparison. A total of 218 male undergraduates served as subjects, 108 in the speaker study and 110 in the listener study. In addition, word-association data were collected from 544 male undergraduates not used in either the speaker or listener study; half these subjects were given one word from each of 153 synonym-pairs as stimulus words, the other half were given the remaining 153 words. Subjects in the word-association study were instructed to give "the first word that comes to mind" in response to each stimulus word.

In the speaker study, each speaker was given 50 synonym-pairs in one of two orders and was told that his speaker-responses along with the synonym-pairs would be given to listeners at a later data. The synonym-pairs were projected on a screen, one pair at a time, and the speaker was given 20 seconds to write his one-word clue for the assigned referent.

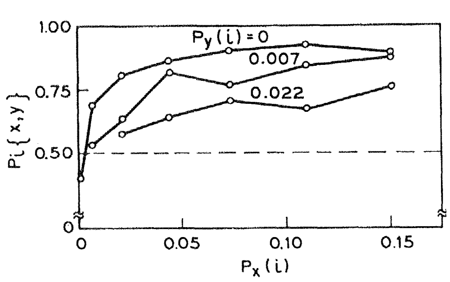

Fig. 2. The relation between word-association data and listeners'-choice data. $P_x(i)$ and $P_y(i)$ are estimated by the proportions of times a clue word occurred as a word-associate to words x and y, respectively. $P_i\{x,y\}$ is estimated by the proportion of listeners who chose x in x,y synonym-pair. Each point in the graph is based on the average of eight different word-triples.

The solid line in Fig. 1 summarizes the empirical relation between speaker-responses and word-associates to the referent, after deletion of word-associates which are inadmissable as speaker-responses. According to one of the fundamental assumptions of speaker-sampling, the associative probability of a word should be monotonically related to the proportion of times that the word occurs as a speaker-response. The results in Fig. 1 (solid line) support this prediction.

The dashed line in Fig. 1 illustrates the probability that a word-associate of the referent will also occur as an associate to the nonreferent is *proportionately* greater for high- than for low-probability associates of the referent. The large overlap between high-probability word-associates of referent and nonreferent is likely to be a property of synonyms. The presence of a speaker's process in addition to sampling, presumably comparison, would be particularly noticeable for these high-probability word-associates, since the speaker would tend to reject them as speaker-responses; the solid line in Fig. 1 does, in fact, depart most radically from linearity for the high-probability word-associates. The net effect is that the low-probability word-associates of the referent are favored as speaker-responses.

From the sampling process assumed for the speaker, it would also be expected that, except for sampling error, all speaker-responses to a referent are contained in the word-association norms to that referent. To evaluate this prediction, it was first necessary to estimate the reliability of the norms themselves. For this purpose, the 272 responses obtained for each stimulus word in the word-association study were first partitioned randomly into two subgroups of 108 (equal in size to the speaker group) and 164. Results based on the norms from 25 stimulus words revealed that 56 percent (on the average) of the responses of the smaller subgroup were found at least once among the responses given by the larger subgroup. This value was obtained after deleting those re-

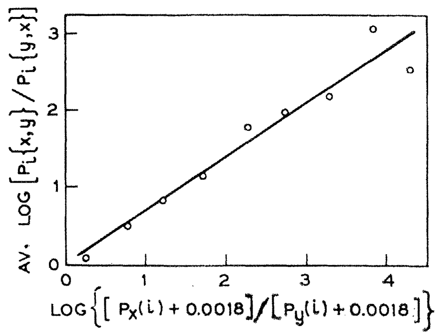

Fig. 3. The use of a single-valued function of $P_x(i)$ and $P_y(i)$ derived from the comparison model to relate word-association data and listeners'-choice data. See Eq. 3 in the text.

sponses which would have been inadmissible as speaker-responses, for example, the nonreferent word. The average percentage of speaker-responses to a referent that were found at least once among word-associates (to that referent) of the 164 subjects used to assess norm reliability was 53 percent—satisfactorily close to the estimated reliability figure of 56 percent. A perusal of the speaker-responses not found in the word-association norms suggests that most of them may be low-probability word-associates and hence may not occur in norms based on a small sample. As already noted, overlap between high-probability word-associates of synonyms results in proportionately greater preference for the more remote associates by the speaker.

In the listener study, each listener was given 256 word-triples in one of four orders. Each triple consisted of a synonym-pair and a speaker-response. Subjects were told that speaker-responses had been obtained in a previous semester and that their task as listeners was to guess which of the two synonyms in each word-pair had been the speaker's assigned referent. Speaker-responses had actually been selected from word-association norms in order to control their associative strengths systematically. Word-triples were projected on a screen, one triple at a time, and a listener was given 8 seconds to guess the referent in each case.

Figure 2 illustrates the relation between listeners' choices and the proportions of times the clue word occurred as a word-associate (among all 272 word-associates) to x and to y, the two synonyms in a pair (*4*). Figure 2 is analogous to a set of psychometric functions with $P_x(i)$ and $P_y(i)$

as measures of stimulus magnitude $[P_x(i) > P_y(i)]$.

If we substitute $a(P_x(i)+c)^b$, that is, the listener's power function for $l_i(x)$ in Eq. 2, we obtain the following linear equation with zero intercept

$$\log [P_l\{x,y\}/P_l\{y,x\}] = b \log [(P_x(i)+c)/(P_y(i)+c)], \quad (3)$$

where $P_l\{x,y\}$ is the probability that a listener chooses x as the referent in an x-y pair and $P_l\{y,x\} = 1-P_l\{x,y\}$. Figure 3 is a plot of the empirical relation between listeners' choice data and word-association data $(P_x(i) \geqq P_y(i))$ in which the log transformations in Eq. 3 are used and $c = .0018$ (obtained from a modified least-squares procedure). The fitted straight-line has a slope of .700, that is, the value of b also obtained from the least-squares procedure. The linear fit is particulaly good; there is no indication of any systematic curvilinearity in the observed relationship.

In conclusion, the results of the empirical studies indicate that the stochastic theory described in this paper can provide a satisfactory account of speaker and listener behavior in the communication task. The theory can be generalized, without difficulty, to studies in which a speaker and a listener are given more than one nonreferent and, possibly, to studies in which nonverbal stimuli are assigned as referent and nonreferent(s). The listener theory can also be generalized to studies in which speaker-responses given to a listener consist of phrases and sentences rather than single words.

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References and Notes

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2. W. S. Torgerson, *Theory and Methods of Scaling* (Wiley, New York, 1958), pp. 201–203.
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4. Figure 2 is based on 144 word-triples rather than all 256 since, for fixed values of $P_y(i)$ larger than those shown in Fig. 2, the number of $P_x(i)$ values available in word-association data was insufficient for plotting detailed curves over an adequate range of $P_x(i)$. However, since any combination of $P_x(i)$ and $P_y(i)$ values can be substituted into Eq. 3, the data in Fig. 3 are based on all word-triples. The 112 word-triples not usable in Fig. 2 were selected so as to obtain a wide range of values of $P_x(i)$ and $P_y(i)$.
5. Supported in part by a grant from the Rutgers University Research Council and NSF grant GS-179 to one of us (B.D.C.). This is a preliminary report of this research. We thank Claire Hammond, Meyer Rothberg, and Pathe Vivekananthan for assistance in collecting and processing the data.

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Creative Scientists of Today

Abstract. *To investigate traits differentiating highly creative research scientists from less creative ones, a questionnaire was sent to 740 male scientists (400 chemists and 340 psychologists). Half of each group had achieved eminence as research scientists; the other half had not achieved research eminence, but were matched on relevant variables. Results indicated that creative scientists are more dominant than less creative ones, that they have more initiative, and are more strongly motivated toward intellectual success.*

In this report we are mainly concerned with the differences in personality and biographical factors between mature scientists who are highly creative in research work and those who are much less creative. Previous studies most pertinent to this investigation are those conducted by Roe (*1*) and Cattell and Drevdahl (*2*), in which highly creative scientists were chosen as the subjects for study. Whereas Roe selected a small number of men (64) and used personal interviews and projective techniques, Cattell and Drevdahl chose to use a larger number of subjects and to depend on an objective pencil-and-paper test of personality. Roe's major finding was that the men were very strongly motivated—that is, they were willing to work hard and for long hours. Cattell found his scientists to be cool and aloof, dominant, and introspective. A general summary of studies in this area may be found by consulting Taylor and Barron (*3*).

In this current study attempts were made to improve on the previous studies of creativity by using larger samples of subjects, by using control groups matched on the variables of sex, age, education, discipline, and opportunity to do research, and by using measuring instruments which have had the variables they purport to measure anchored by validity studies to ultimate criteria (real-life situations).

The subjects used were U.S. male scientists, 400 chemists and 340 psychologists. Within each profession, half were chosen on the basis of having achieved eminence as research scientists, as recognized by membership in the National Academy of Sciences or the American Philosophical Society, being starred in *American Men of Science*, or similar evidence of national recognition of research contributions; the other half were chosen from the membership lists of professional societies of the discipline, and each individual in the lower half was chosen to match an individual in the upper half on the bases of age, sex, discipline, amount of education, and opportunity to do research. None of the members of the lower half of either group had achieved eminence or had been noted for having produced research work of any great value. The productivity of the scientists (number of publications), however, did *not* serve as one of the criteria for admission to either the highly creative or control groups.

For the major study (*4*) an 81-item biographical inventory (*5*) was used to obtain information concerning personal data; job-related behavior and attitudes; undergraduate, secondary, and primary schooling; and home life in childhood and youth. Also used for the study were factors E (dominance), F (enthusiasm), H (adventurousness), and Q_2 (self-sufficiency), from Cattell and Stice's 16 Personality Factor Questionnaire (*6*); items 51 to 75 from Maslow's Security-Insecurity Inventory (*7*); and the Initiative Scale from Ghiselli's Self-Description Inventory (*8*). The items were reproduced in the form of a printed questionnaire and mailed to each subject. A total of 438 forms, or approximately 60 percent, was returned usable. The characteristics of the various groups and of the total sample in relation to number of doctorates, age, and type of employment are shown in Table 1.

Two major findings in the personality tests (Table 2) were: (i) creative scientists are more dominant than control scientists (higher mean E score); and (ii) they have more initiative (higher mean score on the Ghiselli scale). Neither the 16 Personality Factor for measuring creativity nor any other scale differentiated between creative and control scientists.

Significant differences were found for 16 biographical items. Specifically, the creative scientists more often had fathers who were professional men. They