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CURRENT PROBLEMS IN RESEARCH

Psychological Implications of Word Usage

Word usage provides clues about individual differences in learning, perception, and personality.

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If there is a truism in psychology it is that people differ from one another. They differ not only in obvious physical characteristics, and overall levels of ability, but also in many subtle ways, such as in the ways in which they memorize simple facts, react to frustrating events, and perceive objects. Psychology would be a far simpler field in which to work if it were not for individual differences, because such differences among people serve to complicate general principles of human behavior. Without taking account of individual differences, however, it is possible only to talk about the average performance of a group of individuals, which often provides only a very gross estimate of the individual's performance. In order to formulate more precise principles of human behavior it is necessary to measure some of the important sources of individual differences and to employ such measures as parameters in equations relating psychological variables. The purpose of this article is to describe measures of individual differences in the words that people use.

It is easy to see why words may be the mark of a man. To illustrate with some extreme examples, what types of persons would frequently use words from each of the following three lists?

1) Square, pad, cool, crazy-man, real gone, far out, the most, chick.

2) Embolism, lacerated, prevent, determine, antibiotic, rest, superficial.

3) Woocide, milprayermachine, friendsin, brainsound, bumfort.

It is obvious what types of people would be likely to use words from the first two lists, and anyone familiar with the neologisms coined by some mental patients will know what type of person would use words from the third. Individual differences in word usage relate not only to obvious differences such as these but also to subtle differences in the ways people learn, perceive, and interact socially.

Words are of psychological importance because of their close affiliation with thinking processes. In a classic series of studies (*1*) it was demonstrated that a person who is thinking makes detectable small movements of the vocal cords. When the congenitally deaf think (those who use sign language), the movements are in the finger muscles rather than in the vocal cords. Even without such evidence the relation between thought and words should be obvious to anyone who has "listened" to himself think. To at least some extent thinking consists of talking to one's self (*2*). This fact has led many people to speculate about the possible effects of language on thought.

The belief that language and thought processes interact is quite old (*3*), but because it was given its most direct expression by Whorf (*4*) it is frequently referred to as the Whorfian hypothesis. The hypothesis grew out of cross-cultural comparisons of language behavior, in studies by linguists and anthropologists. It was noted, for example, that the Navahos have no words to express simultaneous occurrence of events in two places—for instance, in their village and a remote village—and that they cannot discuss such events without taking into consideration the time necessary to go from "here to there." Eskimos have a variety of words for different kinds of snow: one for wet snow, another for blowing snow, still another for packed snow, and so on. It might be expected that they would spend more time thinking about snow than natives of Atlanta do and that they would be able to make more accurate judgments and finer discriminations about snow conditions.

It is difficult to test the Whorfian hypothesis with cross-cultural comparisons because in such comparisons there are many contaminating variables which it is very difficult if not impossible to control. Differences in cognitive processes between cultures may be due to differences in language behavior, but, equally, they may be due to differences in child-bearing practices, social organization, geographic surroundings, and many other uncontrolled variables.

In the research methods discussed in this article, the methodological difficulties of cross-cultural comparisons are avoided through dealing with individual differences in language behavior *within* cultures, and then relating these differences to other types of behavior. Within cultures it is easy to think of differences in word usage that may mirror current cognitive states and relate to changes in behavior. For example, psychiatrists have an extensive vocabulary concerning manifestations of mental illness; this indicates their preoccupation with such problems and may also help them to make finer discriminations about such phenomena than the average person can make. Women know more color names than men do and in daily life tend to use a wider variety of such names. This

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shows their preoccupation with hues and suggests that women are able to make finer discriminations among colors than men can make.

Two broad hypotheses are illustrated by these examples. (i) Individual differences in word usage indicate differences in what has happened to people previously—to the Eskimo, the psychiatrist, the woman discussing differences in colors. This is the more obvious hypothesis, one which is rooted in common sense. (ii) Individual differences in word usage at one point in time relate to new forms of behavior—in other words, there is a causal relationship between word usage and cognitive behavior. This hypothesis implies, for example, that women should be better able than men to memorize a word pair of which one member is a nonsense syllable and the other is a color name—WUX–fuschia; ZIB–magenta; LAT–chartreuse. It also implies that in a perceptual-recognition experiment, psychiatrists would have lower visual-recognition thresholds for words relating to psychiatric practice than nonpsychiatrists would. The second hypothesis is less firmly rooted in common sense than the first, and considerable research has been done to determine in what ways and to what extent it is confirmable. Still more needs to be done.

To test the implications of these two hypotheses it is necessary to (i) define some potentially important categories of word usage; (ii) develop reliable measures of individual differences in the tendencies to employ words relating to such categories; and (iii) relate those to measures of learning, perception, and personality. In this article we describe research bearing on these three tasks.

Frequency of Word Usage

Before discussing individual differences in the frequency with which words of different kinds are used, it is desirable to sketch what is known about frequency of word usage for people in general. *Frequency of usage* is employed here to refer to a cluster of interrelated variables. First, a distinction can be made between the words an individual knows—words he can define or use properly in sentences—and the words an individual frequently employs in daily life. Although one would expect a close relationship between an individual's knowledge of words of a particular kind (for example, words relating to baseball) and the frequency with which he employs words of that kind in daily life, the degree of relationships for different categories of words has not been fully explored. Even though it may eventually be demonstrated that the principles that govern knowledge of words in particular categories differ somewhat from the principles that govern the frequency with which such words are used, in this article the two will be grouped under the term *frequency of usage.*

Frequency of usage can be measured in a number of ways. One way is to count the number of times particular words appear in books and magazines; another is to count the frequency with which words occur in personal letters, English themes, and other personal documents; still another is to count the frequency with which words occur in daily conversation. Although not a great deal has been done to determine word frequency in conversation, a good deal of work has been done to determine word frequency in various types of written materials. The best source of such information is the Thorndike-Lorge (T-L) word list (*5*), which shows the frequency with which words are used in (i) textbooks, school readers, the Bible, and English classics; (ii) juvenile books; (iii) recent and popular magazines; and (iv) miscellaneous juvenile and adult publications. The T-L list shows, for example, that *pretty* appears frequently in books and magazines, occurring 100 times in 1 million words. On the other hand, *exquisite* occurs only 16 times in 1 million words.

Closely related to frequency of usage as defined by the T-L list are a number of other variables pertaining to people's past experience with words. One such variable is familiarity (*6*); it can be measured by rating scales showing seven degrees of relative familiarity, from very unfamiliar to very familiar.

Pretty

Very unfamiliar ___ : ___ : ___ : ___ : ___ : ___ : ___ Very familiar

Exquisite

Very unfamiliar ___ : ___ : ___ : ___ : ___ : ___ : ___ Very familiar

A variable related to both the frequency of usage, as shown in the T-L list, and to familiarity, as measured on rating scales, is pronounceability. This also can be measured by rating scales.

Another variable in this cluster of related variables is the number of associations elicited by a word in a set amount of time; this is referred to as the "meaningfulness measure," or *m* (*7*). Each individual in a large sample of subjects is presented with a list of words and, for each word, given 60 seconds to list all of the related words that "come to mind." The average number of associations elicited by a word is called the *m* value for that word.

When a sample of words is indexed by the T-L list and also by the measures of familiarity, pronounceability, and meaningfulness, high correlations are found among the four measures (*8*). Although correlations are far enough from unity to show that the four measures are not exactly the same, the correlations are high enough to suggest that there is a common factor pertaining to the extent to which the words have previously been experienced and employed by the average person.

Theoretically, word frequency (together with related variables) is important because it relates to habit hierarchies. A habit hierarchy is a list of possible responses to a situation, accompanied by the probabilities for the response's being elicited by the situation. Although usually we do not know the exact probability for each response in the hierarchy, we often do have enough experimental evidence to order, by rank, possible responses in terms of such probability. For example, a man enters his automobile to drive to work, looks at the ignition lock, and sees that he has not left his keys in the car overnight. His most probable response would be to feel in his right-hand coat pocket. The keys not being there, the next response in his hierarchy would be elicited, which, say for this person would be to feel in his left-hand coat pocket. The keys not being there either, he feels in his right-hand pants pocket, then in the left-hand pants pocket, and so on. After these high-probability responses in the hierarchy have been made without result, the man begins to make relatively low probability responses: he looks in the glove compartment and on the floor of the car, and he finally goes back to the house to look in miscellaneous places. Everyday life is filled with such habit hierarchies, and investigations of the principles that govern them have produced some of the most interesting facts in psychology (*9*).

The habit hierarchy described is a rather specific one, relevant only to a search for car keys. An entirely different hierarchy would be important in a search for a can opener in the kitchen. Overall word frequency (as indicated by the T-L list and related indices) may be viewed as a manifestation of a rather general habit hierarchy, which, though not highly predictable for specific situations, does, in an actuarial sense, provide a rank-ordering of words with respect to the probability of their being elicited from people in general in situations in general. For example, for people in general and for situations in general, in any segment of oral or written discourse, the probability that the word *pretty* will be used is higher than the probability that the word *exquisite* will be used.

General habit hierarchies (such as that exhibited in frequency of word usage) are important determiners of behavior when, in specific situations, the cues for correct or appropriate behavior are not clear. In other words, general hierarchies tend to take over when situational cues are either absent or unclear to the point where habit hierarchies specific to the situation are not elicited. This effect is illustrated in investigations of the perceptual thresholds of tachistoscopically presented words.

In a typical experiment, members of a list of words are presented one at a time in a random order to the subjects. In the first presentation the exposure time is so short that none of the subjects is likely to recognize any of the words. In subsequent presentations of the list the length of the exposure is gradually increased until all the subjects recognize all the words. The length of exposure required for a subject to recognize a given word is called the duration threshold for that subject for that word. Uniformly it is found that word frequency (as given in the T-L list) has a marked influence on the duration threshold: the less frequently used the word, the higher the duration threshold. A typical set of results is shown in Fig. 1. Numerous variants (*10*) of this type of perceptual experiment point to the same fact: word frequency is highly related to perceptual detection.

Overall word frequency has a marked effect on verbal learning. For example, in a rote-memory experiment, subjects would learn the pair ZIB-PRETTY more quickly than ZIB-EXQUISITE because *exquisite* is a less frequently occurring word than *pretty*. A considerable amount of research has been done (*6, 11, 12*) to demonstrate relations between rote verbal learning and word frequency (as given in the T-L list and by rating scales for related variables). The results from these studies show that high-frequency words are learned more rapidly than low-frequency words. A typical set of results is shown in Fig. 2.

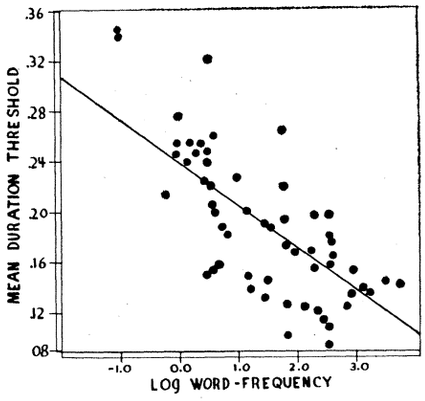

Fig. 1. Visual duration threshold (in seconds) as a function of Thorndike-Lorge word frequency. [From R. L. Solomon and D. H. Howes, *Psychol. Rev.* **58**, 256 (1951), reproduced with permission]

Frequency of usage has been shown to have numerous other marked effects on perception and learning: on (i) the effects of contexual words on the learning of words buried in verbal contexts (*13*); (ii) the rate at which associations are produced (*14*) (high-frequency stimulus words elicit more rapid responses than low-frequency words); and (iii) the extent to which previous auditory exposure facilitates visual recognition of words (*15*).

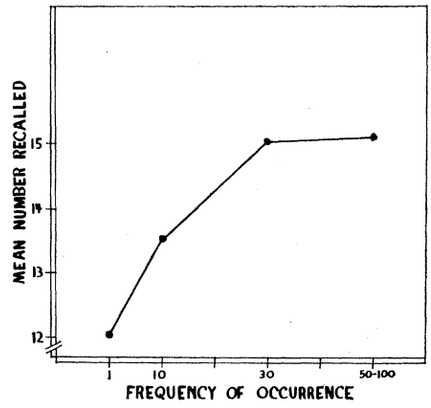

Fig. 2. The mean number of words recalled (out of 20 possible) at four levels of frequency of usage. [Data from J. F. Hall (*11*)]

Measurement of Individual Differences

The many correlations between overall frequency of word usage and other psychological variables show why it is important to measure individual differences in the frequency with which words of different kinds are used. Such individual differences may relate to individual differences in learning, perception, and personality.

There are three general approaches to collecting and measuring frequency of usage for individuals. (i) Either with people's consent or without their knowledge, recordings can be made of conversations in daily life. Content analyses can then be made to determine the frequency with which different types of words are employed. (ii) Analyses can be made of written documents such as personal letters and English themes. (iii) In a laboratory-type approach, subjects can be presented with a list of stimuli (either words or objects) and requested to give specified kinds or numbers of verbal responses. Analyses of free conversation and written material have not been used extensively so far because such studies are very difficult and time-consuming, and because they fail to provide controls for stimulus objects and response categories. Consequently, most of what we know in this field has come from rather restricted situations in which the stimulus objects have all been supplied to the subjects and the numbers or kinds of verbal responses the subjects have been permitted to make have been strictly limited. Perhaps after we learn more about individual differences arising in such restricted situations, investigations can be extended to more life-like spheres of verbal behavior.

Some people know and use many more words than other people do. This is an obvious source of individual differences in word usage. Investigation of other sources of individual differences must rest upon the definition of potentially important categories of words. Investigations can be made, for example, of the tendencies to use (i) various parts of speech; (ii) the first person rather than other pronouns; (iii) different types of words; (iv) the past tense rather than the present or future tense; (v) superordinate rather than subordinate relations; and so on. Woodworth (*16*) presents an extensive list of classification schemes that have been employed. Some classifications lead to very interesting relationships and others lead to complete dead ends.

Among the word classes that have produced some of the most interesting results are words that connote evaluations; words of a high rather than a low level of abstraction; words that relate to stimulus properties of objects (for example, color names); words that infrequently are given in response to particular stimuli; and words that relate to personal attitudes.

Most investigations of individual differences in word usage conform to a single plan of research. First, measures are made of individual differences in the frequency with which particular kinds of words are used. Second, such measures are then correlated with measures of individual differences in other important forms of behavior, principally with measures of (i) verbal learning, of paired-associate rote memorization in particular; (ii) perceptual thresholds for different types of words; and (iii) "personality" traits, including attitudes, interests, and values.

For measuring individual differences in word usage, by far the most frequently used technique is that of counting the numbers of words of different kinds given as responses by each subject in the classical method of association. The subject is presented with a list of words and for each stimulus word is asked to give as a response the first word that comes to mind—for example, the response *chair* to the stimulus word *table*. Other methods and measures of word usage that have been employed are (i) variants of the classical method of association, with restriction to certain types of responses; (ii) vocabulary tests, either of words in general or of particular kinds of words; (iii) experimental induction of differences in familiarity with different words through pretraining; and (iv) free responses in oral and written expression.

Wide individual differences typically are found in laboratory investigations of learning and perception, and these differences can be measured by classical experimental methods. In contrast, the measurement of personality (including attitudes, interests, and values) presents very difficult problems. Most frequently, efforts to measure personality have been made by using questionnaires which require the subject to rate or report on his own behavior. Although there are some exceptions (for example, the measurement of interests), such questionnaires usually provide only highly approximate measures of personality characteristics (*17*). To offset the lack of proved measures of personality, in some studies word usage for groups of people who presumably differ in personality characteristics has been investigated—people in different professions, men and women, mental patients and normal people, and others. Because of the many uncontrolled variables, such contrasted-group investigations leave many questions unanswered. They do, however, provide important leads for more controlled investigations.

Experimental Results

Let us summarize some of the major investigations that have linked individual differences in word usage with other forms of behavior. These experiments have been chosen because they represent a variety of independent and dependent variables, and because they have produced promising results.

An extensive series of investigations was undertaken, by Jenkins (*18*) and his colleagues, of individual differences in commonality of association as evidenced in the classical method of association. *Commonality* refers to the tendency to give the most frequently occurring (or "popular") response to the stimulus word rather than less frequently occurring responses. For most stimulus words there is one response word that is given much more frequently than any other—for example, *chair* to *table, food* to *eating, hard* to *soft*. An individual's commonality of association is measured by counting the number of stimulus words to which he gives the most popular response word. Commonality has long been thought of as manifesting a tendency to be like the average rather than to be different. The studies by Jenkins and others show results as follows.

1) People high in commonality tend to be more consistent in the responses they give to the same words on different occasions; people low in commonality tend to switch from one set of uncommon responses on one occasion to another set of uncommon responses on another occasion.

2) On the average, women have higher commonality scores than men; this might be expected because women usually are considered to be more socially conscious and conforming than men.

3) Commonality has small negative correlations with some personality inventories pertaining to various types of maladjustment; people low in commonality tend to rate themselves less well adjusted.

4) High-commonality subjects memorize word pairs more quickly than low-commonality subjects do when the words are words that occur frequently, according to the T-L list, but low-commonality subjects do better with infrequently occurring words.

5) High-commonality subjects learn better in situations where elements in associative chains are high-frequency associates of one another; low-commonality subjects have the advantage when elements of the chain are unrelated words.

Numerous pieces of evidence indicate that individual differences in frequency of use of, or familiarity with, particular words correlate positively with individual differences in the rate at which those words are learned in paired-associate memorization. Johnson and Watson (*19*) found that the number of associates that subjects gave to particular words correlated positively with the rate at which those words were learned as pairs. Other studies (*20*) show that subjects who are given prior familiarization with nonsense syllables learn those nonsense syllables more readily than subjects who are given no prior familiarization. In other words, when familiarization (usage) is experimentally induced rather than "natural," it also facilitates rote learning.

Several lines of evidence converge to show that individual differences in word usage have effects on perception. Postman and Schneider (*21*) found positive correlations between individual differences in "values" and individual differences in perceptual thresholds for words relating to values—for example, *church* for the person who has strong religious values. Although some workers have taken this and related findings as suggesting a motivational interpretation of the phenomena, the phenomena might equally well be explained in terms of individual differences in frequency of word usage. Two studies suggest that there are individual differences in the use of words relating to values that correspond to individual differences in values. Foley and MacMillan (*22*) found that people in particular professions had a tendency to interpret homophones as words related to their professional interests; for example, with the stimulus word *administer*, medical students tended to associate such words as *dosage*, *sick*, and *attend*,

while students of law associated *estate, govern*, and *justice*. Havron and Cofer (*23*) found that subjects with strong religious values were better able to learn paired associates when the response words pertained to religion than when the response words pertained to politico-economic values; the reverse was true for subjects with strong politico-economic values. Because of the correlation that has been found between rate of learning paired associates and frequency of use of the response words employed, this finding suggests that, just as there are individual differences in values, there are differences in the use of words relating to those values.

A study by Daston (*24*) provides more evidence of a relation between differences in word usage and differences in perception. He found that individual patients had lower perceptual thresholds for words which they used frequently in therapeutic interviews than for control words of the same frequency of usage as the idiosyncratic words, according to the T-L list.

A recent experiment by Spielberger and Denny (*25*) has provided a more direct link between word usage and perception than any other experiments have to date. They compared the visual-duration thresholds of subjects who ranked high in overall verbal ability (as evidenced on a vocabulary test and related measures) with thresholds of subjects who ranked low in verbal ability. Threshold comparisons were made for words of high, medium, and low frequency of usage (according to the T-L list). Spielberger and Denny hypothesized that subjects of high verbal ability employ infrequently used words more than subjects of low verbal ability do but that the two groups differ little if at all in their use of frequently occurring words. On this basis it was expected that subjects with high verbal ability would have lower thresholds for infrequently occurring words than subjects of low verbal ability would have. Striking confirmation was found. The results are shown in Fig. 3.

Although the evidence is neither strong nor highly consistent, numerous studies show the potential importance of word usage in relation to personality characteristics. Pioneering work in association by Jung (*26*) was undertaken primarily to detect psychological "complexes," and much of the work in association since that time has been done to develop tests of personality. Numerous such tests have been composed, but for most of them, evidence of validity is incomplete. Some studies provide sufficient evidence to encourage further research. The many differences in word usage between males and females (for example, the difference in degree of commonality of association) provide circumstantial evidence, because, if there is anything of which we are sure, it is that women differ from men in interests, values, and other aspects of personality. Some evidence of a link with personality traits was found by Osgood and Walker (*27*) in a comparison of word usage in suicide notes with word usage in personal letters. Because of the intense emotion that attends suicide, one would expect suicide notes to be much more stereotypical and repetitious and to contain more words relating to emotions than ordinary letters. The predictions were strikingly borne out. Bousfield and Barry (*28*) found a positive correlation between subjects' rating of their own moods and the relative numbers of positive and negative words produced, respectively, in each of two 3-minute periods. Other studies (*29*) have shown relations between word usage and masculinity, leadership ability, mental illness, and many other aspects of personality.

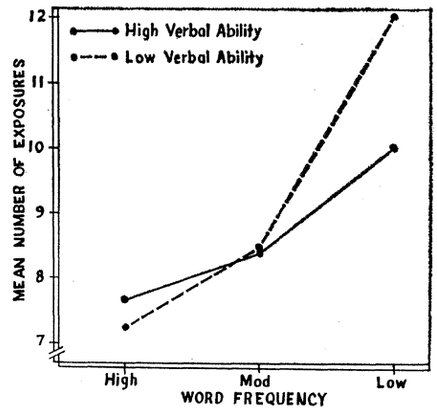

Fig. 3. The mean number of exposures required for the recognition of high-, moderate-, and low-frequency words by subjects of high and low verbal ability. [From C. D. Spielberger and J. P. Denny (*25*), reproduced with permission]

Recent Trends and Developments

Two interrelated problems stand in the way of more fruitful investigation of individual differences in verbal behavior: (i) finding new methods of measurement, and (ii) specifying more of the classes of words for which investigation may be fruitful. What is being done about these two problems is illustrated by recent work (*30*) by my associates and me. In order to develop new measures of word usage, modifications of the classical method of association have been made. Such modifications were thought necessary in order to produce reliable measures of individual differences for some types of words that occur very infrequently with this method. With the classical method subjects are encouraged by the task itself to give syntactic (word-word) associations. Most frequently the responses are *relational* associates—that is, they concern objects and ideas that frequently are related spatially or temporally (for example, *chair* and *table*, *bread* and *butter*). The prevalence of syntactic associations (particularly relational associations) makes it difficult to measure individual differences in other important types of associations.

We have developed associational methods that control the extent to which relational associates dominate responses, and that thus make it possible to measure individual differences in other types of responses. In particular, efforts have been made to measure individual differences in the use of various types of semantic, as opposed to syntactic, responses. Semantic responses serve to define, describe, categorize, or portray personal reactions to stimulus objects, either to actual objects or to words symbolizing objects. An illustration may help to show the difference. In the classical method of association, by far the most frequent response to *girl* is *boy*; this is purely a syntactic (word-word) rather than a semantic (word-object) response. The odds against the word *boy* being used to describe an actual girl, or girls in general, are great indeed. Semantic responses to *girl* are *pretty, short, coed*, and so on.

In our measurement methods, individual differences in the tendency to employ particular types of associations are brought out either by having the response word or words complete a sentence ("A girl is _____") or by limiting the subjects to one among a number of supplied alternative responses.

In our early work we designated four types of semantic habits. The first is the tendency to make positive evalua-

tions such as "good" and "sweet," which we call the E-plus tendency. The second is the tendency to make negative evaluations such as "bad" and "sour," which we call the E-minus tendency. The third is the tendency to respond in terms of denotative attributes such as "green," "long," and "sharp," which we call the D tendency. The D tendency concerns palpable, observable features of "things." The fourth is the tendency to categorize things, the C tendency. In giving a C response the subject does not directly evaluate the object, nor does he respond in terms of observable features of the object; rather he places the object in a broad class—Republican, fruit, institution, and so on.

For our principal measuring instrument we employ binary-choice associations. For example, "Orange: ___ sweet ___ round" pairs an E-plus and a D response. The subject marks the word that he considers the most appropriate in association with *orange*. "Orange: ___ sweet ___ fruit" pairs an E-plus and a C response. "Orange: ___ fruit ___ round" pairs a C and a D response.

In no case do we pair E-minus and E-plus responses with the same stimulus word. Rather, different stimulus words are used to contrast E-minus with C and D. For example, "Snake: ___ dangerous ___ long" compares E-minus and D responses, and "Snake: ___ dangerous ___ reptile" compares E-minus and C responses. "Snake: ___ long ___ reptile" compares D and C responses.

Our present practice is to work with three experimentally independent scales. E-plus versus D and E-plus versus C are combined into one overall E-plus scale, and E-minus versus D and E-minus versus C, into an E-minus scale. A separate set of words directly contrasts C and D responses. This we refer to as the C-D balance scale.

Some of the major findings from our research on semantic habits are as follows.

1) The three major scales have high internal consistency, and scores are surprisingly stable over periods of 6 months and 1 year. This shows that we have been able to measure some sources of individual differences in word usage (for example, the E-plus tendency) that could not have been measured from responses obtained by the classical method of association.

2) Scales for the binary-choice measure correlate highly with corresponding scales for two alternative methods of measurement: a multiple-choice method and a sentence-completion method.

3) Small but consistent correlations are found between the three major scales and numerous personality inventories. For example, as might be expected, people who rate high on the E-plus scale rate themselves as being happy, extroverted, and nonanxious.

4) Marked differences are found among different types of people. Women give more E responses. Schizophrenic mental patients give far fewer E-plus and E-minus responses and more C responses than normal subjects do. Congenitally deaf adolescents give considerably fewer E-plus responses and somewhat fewer E-minus responses than "hearing" adolescents do.

5) Preliminary evidence (*31*) strongly suggests that there are correlations between our three scales and various aspects of learning and perception.

Forced-choice association methods can be used to measure many other sources of individual differences in word usage. For example, in our studies of the deaf it was hypothesized that, because the congenitally deaf have never heard words, they cannot possibly think with word sounds, and that consequently, if they think with words at all, they must think with word pictures. If this is the case, one would expect that, in the deaf, associations among words would to some extent be determined by morphological similarities. A binary-choice measure was composed in which one alternative response for each item was a meaningfully related word and the other response was a morphologically similar word; for example, "deal: ___ cards ___ dear." Normal subjects almost never give morphological associates; we find that the deaf give many such responses.

There are two ways of determining what categories of words elicit responses that reveal the sources of important differences in individuals. The first way is to decide which categories are likely to elicit such responses and then to demonstrate experimentally that they do so. This was the approach illustrated in the examples given. A second approach is to arrive at hypotheses through a statistical "mapping" of individual differences in the use of words. For this approach we need to measure the frequencies of use of many types of words by many individuals, to intercorrelate the measures, and to subject the correlations to factor analysis. Such investigations have not yet been reported in the research literature, but at Vanderbilt we are at present completing a large-scale study. We administered, to a large number of college students, binary-choice measures of the semantic-habits scales described, plus measures of various types of relational associations and others. These results help clarify the nature of individual differences in word usage, point to hitherto uninvestigated categories of words, and suggest many hypotheses for investigation.

Conclusion

We do not mean to imply that research on individual differences in word usage is easy or that investigations typically meet with success. Many studies have failed, either because no reliable categories of words were found or, if such categories were found, because no significant correlations were obtained with other forms of behavior. Only the naïve would expect to find more than rather small correlations between individual differences in learning, perception, and social behavior and differences in word usage. Human behavior is so complexly determined that it is illogical to expect various kinds of individual differences to correlate highly. In order to document such small correlations it is necessary to work with relatively large samples of subjects. Usually 300 subjects or more are required for a study.

For two reasons, investigations of individual differences in word usage should, and will, continue. First, common sense tells us that a person's tendency to use certain types of words reflects his past experiences and to some extent conditions his handling of new experiences. Second, even though many studies have met with failure, enough positive results have been obtained to leave little doubt that there actually are correlations between individual differences in word usage and differences in learning, perception, and personality.

References and Notes

1. These studies are summarized → E. Jacobson, *Am. J. Psychol.* **44**, 677 (1932); L. W. Max, *J. Comp. Psychol.* **24**, 301 (1937).
2. Although a theoretical controversy exists between the "central" theorists and the "peripheral" (motor) theorists, it is generally agreed that the responses involved in thinking may be of any sort but are predominantly verbal. See, for example, G. A. Kimble, *Conditioning and Learning* (Appleton-Century-Crofts, New York, 1961), p. 461.
3. Many allusions to this belief can be found in classic literature: "As the man is, so is his talk" [Seneca (A.D. 64)]; "Language most

shews a man: speak that I may judge thee" [Ben Johnson (1636)]; "Speech is the picture of the mind" [J. Ray, *English Proverbs* (1670)].
4. J. B. Carroll, Ed., *Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf* (Wiley, New York, 1956).
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High-Temperature Research

By means of "liquid containers," liquid metals can be studied at much higher temperatures than heretofore.

Aristid V. Grosse

The field of high-temperature research is a great frontier of science. But it is by no means a new frontier. Since prehistoric times the attainment of higher and still higher temperatures has characterized successively more advanced civilizations. Thus, the stone age gave way to the bronze age, and the bronze age, to the iron age. In the last 20 years men have learned how to produce temperatures equivalent to those of the sun and stars, if only for an instant, and we have the atomic age and the space age. But space technology requires the production of exceedingly high temperatures for long periods, not just instants, for powering rockets and producing the components of spacecraft. This we must accomplish if we are to continue our scientific advance and lead the way into space.

High-temperature research is a field of very broad scope, involving as it does the sciences of chemistry, physics, metallurgy, and ceramics. An important problem is that of producing high temperatures by chemical reactions, which necessarily must have thermally stable reaction products. This can be achieved in several ways—through combustion of metals in oxygen; through combustion of gaseous mixtures; or through plasma jets. In every case, there is a corollary problem—that of confining or containing chemical substances at temperatures which conventional containers cannot withstand. In this article I discuss the high-temperature research conducted by the Research Institute of Temple University, since it illustrates several important aspects of the subject. The Research Institute has devoted its main efforts to this field for the last 16 years. I will attempt to give a more or less historical outline of our studies and to show how our investigations led to new possibilities—to the attainment of high flame temperatures, the development of a "liquid crucible," and the establishment of some relationships for liquid metals.

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The first problem we considered was, How high a temperature can be reached for extended periods through chemical reactions? Combustion of wood, charcoal, and coal has been for ages the standard method of producing heat. In contrast, the combustion of metals in oxygen had hardly been studied at all, and our first efforts were devoted to this subject.

The chemical production of high temperatures requires not only the evolution of great heat in particular chemical reactions but also thermal stability of the reaction products. As the temperature increases, the dissociation of the reaction products into atoms, radicals, or intermediate unstable molecules increases until a balance between the evolution of heat and the energy of dissociation is reached at a particular temperature, usually defined as the flame temperature.

At the temperature of the sun's disk —that is, about 5000° to 5500°K— only about a dozen compounds can exist, as one may easily deduce from spectroscopic analysis (*1*). This group of compounds can be divided into metallic and nonmetallic compounds. The metallic compounds include four oxides (AlO, MgO, ZrO, TiO), two fluorides (MgF and SrF), and two hydrides (MgH and CaH). The five nonmetallic compounds are N_2, CO, C_2, CN, and OH. The heats of combustion of various metals in oxygen are given in Table 1 and compared with the heats of combustion of hydrogen, carbon, methane, and carbon monoxide. As Table 1 shows, hydrogen and hydrocarbons generate, on an equal weight basis, more heat than the metals generate; this is due to their high heats of combustion and their low atomic