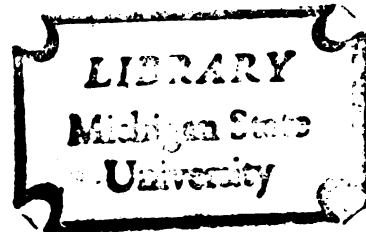


A FEATURE-MATCHING MODEL
FOR SEMANTIC GENERALIZATION,
AS APPLIED TO THE PHONETOGRAPHIC-
SEMANTIC SHIFT

Dissertation for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
ANDREW RALPH GILPIN
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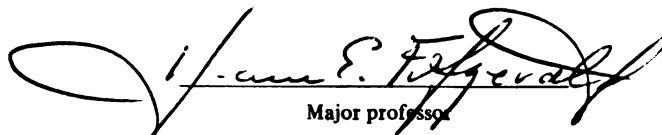
A Feature-Matching Model
for Semantic Generalization,
as Applied to the Phonetographic-
Semantic Shift

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Andrew Ralph Gilpin

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ABSTRACT

A FEATURE-MATCHING MODEL FOR SEMANTIC GENERALIZATION, AS APPLIED TO THE PHONETOGRAPHIC-SEMANTIC SHIFT

By

Andrew Ralph Gilpin

A review of semantic generalization studies was found to be consistent with a model described and tested in the present study. The model postulates that subjects encode words into two sets of distinctive features, phonetographic (perceptual) and semantic, for purposes of response selection in semantic conditioning and generalization tasks. The encoded features are compared with representations of conditioned stimuli. The degree of similarity (number of feature matches) is indexed by the magnitude of the physiological orienting reflex.

Three tasks were administered to third-grade boys and male college students: Task I assessed conceptual tempo; Task II required subjects to sort words into groups on the basis of similarity of meaning. In Task III subjects were instructed to press a button when they saw a particular word (there were two lists of words, and three instruction conditions; words were drawn from five categories including the key (target) word, two sets of control words, a set of words phonetographically similar to the target word, and a set of words semantically similar to the target word). Dependent measures on Task III included the galvanic skin conductance orienting reflex, the cardiac

orienting reflex (in adults), and electromyographic activity in the hand.

Six predictions were derived from the model:

- I. Children less than 10-11 years old should attend more to words which resemble the key word in sound than to words which resemble the key word in meaning; adults should attend more to the latter than to the former.
- II. Instructions defining the key word in terms of meaning (a class of words) should facilitate the amount of semantic generalization in adults more than in children.
- III. Conceptual tempo ought to interact with instructions and/or age in determining amount of semantic generalization.
- IV. Impulsive subjects ought to show more overall electromyographic activity than reflective subjects of the same age.
- V. Scaling solutions for the Task III data ought to resemble those for the Task II data.
- VI. Scaling solutions ought to indicate similarity involving both phonetographic and semantic dimensions.

No support was obtained for Hypothesis I; fairly consistent support was found for Hypotheses II, III, IV (for adults, but not for children), V, and VI.

The model was modified in view of the negative results obtained regarding the phonetographic-semantic shift. Discussion involved implications of psycholinguistic theory for semantic generalization research, and the use of various statistical techniques in psychophysiological research (especially multivariate analysis of variance, multidimensional scaling, and hierarchical clustering techniques).

A FEATURE-MATCHING MODEL FOR SEMANTIC GENERALIZATION,
AS APPLIED TO THE PHONETOGRAPHIC-SEMANTIC SHIFT

By

Andrew Ralph Gilpin

A DISSERTATION

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DEDICATION

For The Babcocks, my friends for twenty years

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Finally, I should like to note my fond memory of the late Dr. William T. Stellwagen, my teacher, colleague, and friend. In response to my question, "What is a semantic marker, anyway?" he replied, "I don't know -- let's find out." I can think of no more appropriate answer, and I am still asking the question.

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INTRODUCTION

Semantic Conditioning and Semantic Generalization

Semantic conditioning refers to "the conditioning of a reflex to a word or sentence irrespective of the particular constituent letters or sounds of the word or the particular constituent words of the sentence: that is, conditioning to meaning" (Rezran, 1961, p. 99). While a rich literature involving verbal learning approaches to semantic generalization has arisen, dating from Cofer and Foley's (1942) review, the present paper is focused on semantic generalization utilizing psychophysiological dependent variables.

Many different dependent variables have been used in this research: salivation (Rezran, 1939); skin conductance or resistance (Diven, 1937); heart rate (Lacey & Smith, 1954); eyeblink (Grant, 1972); vasomotor activity (Acker & Edwards, 1964); muscle activity (Cramer, 1971a); EEG (Voronin & Sokolov, 1960); blood coagulation (Markosian, 1958); and pupillary activity (Hudgins, 1933); however, the most frequently used response measure has been some exosomatic electrodermal activity (resistance or conductance). Most investigators have used only one dependent variable, but a few have employed multiple measures (e.g. Lang, Geer & Hnatiow, 1963; Ludwig, 1972; Raskin, 1969).

One important issue in semantic conditioning concerns the extent to which subject awareness of CS-UCS contingency is necessary for

semantic conditioning to occur. Several studies suggest strongly that awareness enhances semantic conditioning, if it is not actually a sine qua non (see discussions in Feather, 1965; Grings, 1973a; Grant, 1973; Dawson, 1973; Mandel & Bridger, 1973; Rose & Nelson, 1973; Baer & Fuhrer, 1973; Epstein, 1973; Furedy, 1973; Lockhart, 1973). Concern over this question has been prompted by the existence of two essentially incompatible theoretical positions purporting to explain semantic generalization, which Feather (1965) refers to as the "common response" and "common categorization" theories.

Common response theory has a relatively direct precursor in Hullian learning theory. Early advocates of this position postulated that the CS elicited kinesthetic responses which themselves had stimulus properties; when the CS was reinforced by the UCS, the fractional response was also reinforced, and would thereby acquire elicitation properties (here the term "reinforcement" is used in the Russian sense (Pavlov, 1927) rather than in the sense of operant reinforcement as is usually the practice in American psychology). Other stimuli would elicit the same fractional response, thereby enhancing generalization (Cofer & Foley, 1942). This position has been elaborated upon by subsequent investigators, most notably Osgood (1952, 1968, 1970; Osgood, Suci & Tannenbaum, 1957; cf. Fodor, 1965). We can characterize the common response position as assuming that the connection between CS and generalization stimuli is acquired prior to or during the conditioning process itself, without mediation of conscious cognitive activity.

Common categorization theory assumes that the subject compares stimuli along some dimension or dimensions of similarity, classifying some as equivalent to the CS, and others as different (Wallach, 1958);

while equivalent stimuli elicit the same response, the comparison process is distinct from the response itself. [Operationally, the common categorization process resembles one definition of "concept", in which a concept is identified with a class of stimuli to which the same response is made: see Flavell, 1970.]

Currently Maltzman (1968, 1971) is the primary advocate of the common categorization position, although Razran (1952, 1973) also interpreted his seminal research in this manner. It is important to note that while some sort of comparison process is specified by the common categorization position, one need not assume that the comparison is conscious, nor that the response which results is voluntary. However, such a situation would not be inconsistent with the theory.

At present, most of the evidence seems to favor the common categorization position. This is particularly true of research involving components of the physiological orienting reflex (Maltzman, 1968, 1971). In the present paper, I will refer to the common categorization position as the "cognitive" position; most of the subsequent argument presupposes that the cognitive position is essentially more accurate than the common response position. Although the total number of semantic generalization studies is too large to permit detailed discussion in the present paper, a number of earlier reviews are available: Osgood (1952); Razran (1952, 1961); Feather (1965); Hartman (1965); Creelman (1966); Lerner (1970); Maltzman (1968, 1971); and Grings (1973a).

Semantic generalization research has led a rather cloistered life, in that there have been few attempts to integrate results of the studies with contemporary theory in psycholinguistics. There were some early exceptions: Razran (1949, 1952) was clearly interested in semantic

interpretation of sentences, and in pursuing this interest became perhaps the only investigator whose work bears on processing of units longer than words. A number of investigators working within the common response position attempted to correlate generalization with strength of association (Baxter, 1962; Carlin, Grings & Jacobs, 1961; Cole & Williams, 1966; Mednick & Wild, 1962), and Luria and Vinogradova (1959) viewed their procedure, discussed below, as a tool for studying semantic structures. However, none of these attempts has much relevance to contemporary theories in the field that Perfetti (1972) dubbed "psycho-semantic".

With a few exceptions (notably Leach, 1974; Sokol, 1974), current semantic theories characterize meaning as complexes of semantic features. Available psychophysiological techniques are crude in comparison to the relatively sophisticated feature discovery techniques (Miller, 1967, 1969; Fillenbaum & Rapoport, 1971; Osgood, 1970); therefore it is unlikely that semantic conditioning procedures will prove very useful in assessing the structure of semantic systems in the way that Luria and Vinogradova suggest. However, semantic conditioning and generalization studies have some potential in the examination of physiological mechanisms underlying stimulus perception and information processing, and semantic conditioning research is not fundamentally incompatible with semantic feature theory.

The Orienting Reflex and Semantic Generalization

The orienting reflex (OR) is a non-stimulus-specific pattern of responses elicited by changes in stimulation, which is thought to facilitate information detection and processing (Sokolov, 1963; Lynn, 1966). As defined by Sokolov, the OR involves movements of the body,

head, eyes, and ears, and changes in heart rate, blood volume, skin conductance, respiration, and EEG activity. The OR is elicited by novel stimuli, and habituates when such stimuli are repeated.

Maltzman (1968, 1971; Maltzman & Langdon, 1969) have demonstrated that semantic conditioning and generalization may involve production of an OR. Certainly many successful semantic conditioning studies have been reported which measure responses not often considered to be components of the OR (notably salivation; but cf. Stern, 1972). However, Maltzman does not claim that the OR is the only response which can be semantically conditioned; he merely asserts that OR elicitation is necessary if generalization of any response is to occur.

The unconditioned OR is typically conceded to be a response to change in stimulation, although it may occur under other conditions as well (Maltzman & Mandell, 1968). A discrete stimulus which is repeated, but which is not biologically significant (in the sense that it has implications for the survival of the organism) will initially elicit an OR, but the OR will habituate unless the stimulus is given signal value (Sokolov, 1963). One way to give a stimulus signal value is to pair it with a biologically significant stimulus, such as a noxious noise or electric shock in classical conditioning. However, if some motor response is made contingent on presentation of a stimulus, through instructions, or through operant conditioning, this also will give the stimulus signal value, and hence should maintain the OR when the stimulus is repeated. It may not be necessary for the subject ever to perform the motor response to the stimulus, or even for the stimulus to occur, in order for it to acquire signal value through instructions:

semantic generalization of the GSR OR has been demonstrated under those conditions (Maltzman, Langdon & Feeney, 1970).

In the present paper, I shall not attempt to specify whether the OR to signal stimuli is itself a conditioned OR (in which case its gradual waning would represent extinction), or reflects the undifferentiated OR which occurs to all changes in stimuli (in which case its waning would represent habituation). Either process would be compatible with the model presented below; indeed, there is some merit in the Russian practice of using the term "extinction" to refer to both alternatives. However, since most American investigators have followed the practice of referring to waning of the OR as "habituation", that term is used in the remainder of the paper.

Thus far I have suggested that an OR is produced by signal stimuli. How does a subject decide whether a stimulus is a signal stimulus? The cognitive position supposes that new stimuli are compared with the signal stimulus, and if the two are sufficiently similar, an OR will be produced. However, the details of this comparison process have been largely ignored. Maltzman (1971) argued that dominant foci of cortical excitation might provide the physiological basis of the comparison (cf. John, 1962, 1967; Chase, 1967). While this must be considered speculative at present, such an interpretation seems promising. However, it is possible to consider the comparison process from another approach. A point which seems to have escaped most theorists discussing semantic generalization--Maltzman is an exception-- is the seemingly self-evident observation that in order for a comparison process of any sort to occur there must be some internal representation of the signal stimulus (Grant, 1972). One could simply call this a memory trace or a

neuronal model (as Sokolov does) and move on to more empirical matters; but it seems possible further to speculate about the nature of the representation, in light of current theory about encoding and memory for verbal stimuli (Melton & Martin, 1972).

First, however, a point of clarification. Sokolov (1963) postulates a neuronal model of a stimulus, which builds up upon repetition. A new stimulus is compared with the neuronal model (albeit unconsciously), and if a discrepancy occurs, an OR is produced. This would seem to imply the reverse of the cognitive position, which maintains that when a match occurs, an OR is produced. It is not entirely clear whether these predictions are in fact contradictory; in any case, it is sufficient to note that Sokolov's theory, as originally formulated, was concerned specifically with production of unconditioned ORs, and if (as seems likely) the OR in semantic generalization is a conditioned OR, different comparison mechanisms might well be involved. One might also postulate changes in the comparison process which accompany habituation of the OR to the signal stimulus. Another alternative, not considered further in the present paper, would be to suppose that an OR is elicited when the newly-detected stimulus is optimally discrepant from the neuronal model (cf. Kagan, 1967). Grant (1972) has provided an interpretation which might pertain to this issue. He assumes that new stimuli are encoded in a number of dimensions, resulting in an ambiguous encoding and hence an unstable neuronal model; this in turn results in production of an OR. Smith (1968) argued that schema-matching models [of which the neuronal model theory is an example, although Sokolov (1960) has developed some ideas consistent with a feature model] can be reduced in principle to feature-matching models. We

shall return to this point shortly.

A Feature-Matching Model for Semantic Generalization

Few efforts have been made to assimilate information-processing concepts into semantic generalization theories. The most relevant attempt is that of Grant (1968, 1972, 1973) alluded to previously. Grant has combined Bower's (1967) model of short-term memory with Smith's (1968) model of choice reaction time (CRT) information processing, with some modifications, to explain the effects of a number of cognitive variables (instructions, set, individual differences, context) on differential eyelid conditioning. The model described below resembles Grant's in many respects, but differs in that it focuses on the encoding and comparison phases described by Smith (see below), whereas that of Grant is more concerned with response selection.

Since Smith's model serves as the basis for the analysis to follow, I shall describe it further at this point. Smith reviewed a number of studies dealing with CRT tasks, and posited four stages in such tasks: (a) the stimulus is "preprocessed" until a cognitive representation of it is formed (I shall call this the "encoding" stage); (b) the "representation then encounters memorial representations of the possible stimulus alternatives which have been transferred to a rapid-access storage system . . . [and] is categorized as one of the possible alternatives" (pp. 85-86); (c) the appropriate response is selected; and (d) the response is executed. Smith distinguished between two sets of theories describing the comparison process (stage b), viz. template-matching (equivalent to schema-matching) models vs. feature-matching models; he concluded that some form of both is potentially available. I think it is likely that picture recognition involves schema matching

(although there is some evidence that pictures can be recognized by means of verbal labels given to them, which might implicate feature matching: Clark & Chase, 1972); nevertheless, the CRT data seem more consistent with feature-matching models.

As suggested earlier, it might be possible to construct a useful model for semantic generalization using a comparison process in which stimuli once encoded were compared with a schema for the signal stimulus. However, with reference to the perception and storage of verbal stimuli, it seems far more likely that sets of features are involved. In the present paper, no distinction will be drawn between features and markers, nor between paradigmatic and taxonomic arrangements of features. Roughly, a feature is a hypothetical tag which identifies a set of functionally equivalent words. When a word is perceived, it is encoded into one or more features in order to be remembered and otherwise processed.

Two sets of features, viz. phonetic/graphic vs. semantic, are implicit in the distinction between phonetographic similarity and semantic similarity, which has been very important in semantic generalization studies since Razran's early work (Razran, 1939). I shall concern myself only with these two sets of features, but other kinds of features might also be postulated (Gibson, 1971; Kintsch, 1972; Katz & Fodor, 1963; Osgood, 1970). Actually, phonological and graphological features needn't be--probably are not--one set, if for no other reason than the different receptor systems involved (auditory and visual respectively); but neither are they completely independent: thus, pronounceability, a phonological phenomenon, influences recognition of printed words (Gibson, Pick, Osser, & Hammond, 1962; but cf. Gibson, Schurcliff &

Yonas, 1970). I shall treat such features as one group, distinct from semantic features, since the former refer to perceptual properties of word stimuli, as opposed to conceptual properties. I further assume that insofar as syntax (here, form class) provides a basis for features, these features are represented as part of the semantic system.

The model proposed here assumes that verbal stimuli are encoded into sets of features for purposes of storage and comparison (Smith's first two stages). I shall not attempt to deal directly with a rather pervasive controveray in this area, as to whether encoding and subsequent processing occur in serial or parallel mode; if the latter be the case, the comparison process may be exhaustive rather than self-terminating, as Smith notes. The outcome of this issue may influence the final version of the model, but the basic structure seems compatible with either outcome.

The signal stimulus, or rather its representation after encoding, is stored; new stimuli are encoded and compared with the stored representation of the signal stimulus. If some unspecified number of features match, an OR will be produced; and the magnitude of the OR will be positively related to the number of feature matches. The "number of feature matches" should not be confused with the "number of matching features": these will be identical only if the comparison process is exhaustive and if there is a finite set of features, neither of which seems very likely at present.

The comparison process so central to the cognitive position need not be conscious, although its operation could conceivably be influenced by conscious processes (as Maltzman's theory and the present formulation both imply). In any case, the mechanism mediating OR elicitation, which

appears to be located in the lower brain, must be distinct from the neural substrate of the comparison process, which would logically seem to be cortically mediated (Sokolov, 1963). The latency of the comparison process is at most a few hundred milliseconds (Neisser, 1967), while the latency of most components of the OR is greater than one second (this is especially true of the skin responses). It does appear that certain EEG responses, notably evoked potential, have latencies which would be consistent with the position that they occur simultaneously with the hypothesized comparison process (Chapman, 1973; Karlin & Martz, 1973; Shagass, 1972; Vaughan & Ritter, 1973).

It is unlikely that OR elicitation is the only response mechanism involved in semantic generalization. In the present model, the OR is considered a concomitant of the comparison process, as distinct from the response selection process. The comparison process might be performed for its own sake, without any resulting response: reduction of uncertainty is presumably reinforcing per se. This may explain results of some semantic generalization studies, in which the response of interest is involuntarily elicited. However, there are many cases (notably in the verbal learning literature) in which the response being studied is under voluntary control (Deno & Jenkins, 1966; LeNy, 1966; Mink, 1963; Kurcz, 1964; Maltzman & Belloni, 1964). Unfortunately, psychophysiological measures are seldom taken in such studies, so it is impossible to determine whether or not ORs are being produced.

[Maltzman and Mandell (1968) argued that production of the OR is itself reinforcing; Grings (1973a) concurs. However, I find this hard to reconcile with the assumption that the OR to all stimuli eventually habituates as they continue to occur.]

The present model predicts that an OR should occur in a semantic generalization study using a voluntary response. The chief evidence supporting this prediction derives from the motor response paradigm of Luria and Vinogradova (1959), described in more detail below. In their study, subjects were instructed to press a button when they heard a certain word (which thus acquired signal value). An OR was in fact produced not only to the target word, but to stimuli which closely resembled the target word. Unfortunately, Luria and Vinogradova did not examine generalization of the motor response itself, as is the practice in Cramer's (1970a,b,c; 1971a,b; 1972b) EMG technique. It is thus impossible to tell whether generalization of the motor response itself occurred to the stimuli which elicited the OR. Few overt error responses were made to non-signal stimuli in the Luria and Vinogradova study, but Cramer has shown that the EMG record is a more sensitive indicator of generalization than overt responses.

The cognitive position à la Maltzman does not necessarily rule out generalization of the motor response in the task (although such generalization would presumably be positively correlated with OR magnitude), but it could easily explain failure of the motor response to generalize, since the comparison process could ultimately result in accurate discrimination. A number of features might match, yielding a relatively large OR, yet the new stimulus might ultimately be categorized as different from the signal stimulus (this argument does presuppose nearly exhaustive feature comparisons, however; and the new stimulus might be classified as functionally equivalent to the signal stimulus). On the other hand, the common response position would predict that where skin

conductance responses generalized, motor responses would also generalize (at least covertly, as measured by EMG techniques).

One more point, and the basic model will have been described in sufficient detail. There is some evidence that phonetographic features may be encoded more rapidly than semantic features, especially when comparisons with other encoded stimuli must be made. Why this should be true is not clear. Gibson (1971) argued that features of the same class (phonological, graphological, semantic) are encoded together, but the classes are processed sequentially, although overlapping each other (cf. Hyde & Jenkins, 1969). Gibson also concluded that task demands determine the order in which the feature classes are to be encoded. Posner has presented evidence suggesting that the encoding of verbal stimuli along perceptual dimensions is accomplished in intervals under one second, and that subsequent codes can be created involving semantic features (Posner, 1969; Posner & Warren, 1972). However, unlike the initial encoding, the semantic encoding seems to require conscious attention. Posner, Buggie, and Summers (1971) related the semantic coding function to vertex evoked potential. Final clarification of the problem must await solution of the serial vs. parallel processing controversy noted above, as well as the related question of how many features are typically encoded in the first place (Underwood, 1972; Wickens, 1972). At present, though, it seems reasonable to hypothesize that phonetographic similarity can be evaluated faster than semantic similarity, and that the latter may require more conscious cognitive effort on the part of the subject. Interestingly, this bears more than a little resemblance to Pavlov's distinction between first- and second-signal systems.

Summary

Two theories have been advanced to explain semantic generalization. Evidence seems to lend more support to the cognitive (common categorization) position than to the common response position. There is evidence that a physiological OR is produced to stimuli which closely resemble signal stimuli, as well as to the signal stimuli themselves. Research in the areas of pattern recognition and semantic memory suggests that words are encoded into sets of features, including phonetographic features and semantic features. I have presented a model which postulates that test words in semantic generalization tasks are encoded and compared with previously encoded signal words, and that an OR is generated when a number of features are found to match. The model assumes that the OR is generated when the comparison process results in partial "recognition" of the stimulus, though the subject may ultimately discriminate between stimuli which share a number of features with each other and with the signal stimulus. The OR is associated with the comparison stage, rather than with response selection or execution. Finally, I have suggested that the two classes of features involved in the comparison process may not become available at the same time, and that under some circumstances (in which conscious comparison occurs), comparison of phonetographic features may be followed by (or accompanied by) comparison of semantic features.

The model described here draws heavily on a conceptualization of perception as categorization, which was perhaps best articulated by Bruner (1957). It resembles a model of perception proposed by Selfridge (1959) and extended by Lindsay and Norman (1972). Moreover, it draws heavily on work dealing with semantic memory and stimulus encoding

(Melton & Martin, 1972). Most current feature theories, including the present one, can be traced back to a now classic paper by Katz and Fodor (1963). While the present model was formulated before the author became aware of the model proposed by Grant (1972), it has much the same flavor and shares many concepts; Grant has provided a particularly insightful analysis of response selection. In terms of psychophysiological aspects, the present model draws on the work of Maltzman (1968, 1971) and can be regarded as something of a special case of his cognitive theory; however, I think of the late Gregory Razran (1952) as the real intellectual forebear of the cognitive position. Finally (and this will be more apparent in the application of the model which follows) the influence of Eleanor Gibson (e.g. 1970, 1971) must be considered substantial, particularly with respect to the phonetographic-semantic shift, which is discussed below.

Feature Discovery Techniques

Several techniques have been used to investigate semantic features. Lyons (1968) noted a variety of approaches utilizing the intuitive knowledge (i.e. competence) of linguists, and discussions of other approaches are readily available (Miller, 1967; Perfetti, 1972; Fillenbaum & Rapoport, 1971; Anglin, 1970; Wickens, 1970). My concern here lies with methods yielding proximity data (Shepard, 1966); such data are often collected by having subjects sort stimuli into groups on the basis of similarity of meaning. As Miller (1967) noted, this means that one is tapping psychological distance, which will indirectly reflect semantic structure. [An example of the use of proximity data to investigate semantic structure is Henley's (1969) study of the semantics of animal terms.]

One such method involves the use of hierarchical clustering (HC) techniques, in which the number of subjects sorting words into common piles forms the basic dependent variable (Johnson, 1967; Miller, 1969; Anglin, 1970). Another method employs multidimensional scaling (MDS) techniques (Young & Torgerson, 1967; Kruskal, 1964a,b; Shepard, 1962a,b, 1966; Osgood, 1970). Given some assumptions about models underlying the data (and these are minimal) one can use a combination of the two methods rather successfully, although it seems important to consider a priori knowledge about the organization of particular lexical fields (Fillenbaum & Rapoport, 1971).

In the present study, both HC and MDS techniques were applied to data generated by asking subjects to sort words into piles on the basis of similarity of meaning. The stimuli to be used were plant and vehicle terms (see below). There seems little a priori reason to prefer one of the two approaches to the other. Construction of the sets of words by taxonomic category would seem to favor an HC technique. On the other hand, the only directly relevant research with children has found some evidence of organization of animal terms in both a taxonomic arrangement and a multidimensional configuration involving dimensions such as size and ferocity (Michon, 1972; cf. Anglin, 1970); similar results have been reported for adults (Henley, 1969; Rips, Shoben & Smith, 1973).

The model described above implies that since ORs occur to words which share a number of features with signal stimuli, one would expect words which elicit large ORs to be sorted into similar piles with the signal stimulus. Thus, in the present study, scaling and clustering solutions based on sorting data were compared with those based on OR

magnitude.

According to the common response position, one would expect that words which are associates of the CS in a semantic conditioning experiment would also elicit the CR, in proportion to their strength of association. This has occasionally been demonstrated in studies employing psychophysiological measures (e.g. Mednick & Wild, 1962; but cf. Cole & Williams, 1966; and Carlin, Grings & Jacobs, 1961). Associative strength may reflect feature similarity (Deese, 1962; Clark, 1970; but cf. Anglin, 1970). It is not clear whether association data and sorting data may allow for different predictions in a semantic generalization task, but the possibility seemed to merit empirical investigation, and so association strength data were examined in the present study (see below). Nevertheless, the present study was not specifically directed at the cognitive vs. common response issue, which has been fairly well resolved in favor of the former. Rather, the study was intended to test some implications of the feature-matching model, as applied to a developmental shift in attention.

Application of the Model: The Phonotographic-Semantic Shift

Few semantic generalization studies have been done with children. The two most commonly cited are those of Riess (1946) and Luria and Vinogradova (1959), although others do exist, notably in the Russian literature (Sinkovskaja, 1958; Volkova, 1953; Federov, cited in Krasnorgorskii, 1954). These studies are usually interpreted as indicating that children less than 10-11 years of age generalize more to words which are perceptually similar to the CS than to words which are similar in meaning to the CS. This contrasts with the performance of older children and adults, who generalize more along meaning than sound

similarity. The change in dimensions is referred to as the "phonetographic-semantic shift" (henceforth, the P-S shift). Analogous shifts in attention from perceptual to conceptual dimensions have been found in some other tasks (Olver & Hornsby, 1966; Felzen & Anisfeld, 1970, but cf. Cramer, 1972a; Entwistle, 1966; Palermo & Jenkins, 1964; Rice & DiVesta, 1965; Inhelder & Piaget, 1964). The seeming ubiquity of the shift seems to have prevented careful scrutiny of the evidence from semantic generalization studies.

In point of fact, careful examination of the evidence justifies the assertion that methodologically rigorous demonstration of the P-S shift in semantic generalization has never been reported. Riess' (1946) study is confounded by the absence of controls for sensitization and pseudoconditioning (Feather, 1965). Riess presented words visually in a classical conditioning paradigm, recording skin resistance changes, with a loud buzzer as the UCS. He had four groups, with mean CA ranging from 7-9 to 18-6. The youngest group generalized more to homophones than to synonyms of the CS; a group with mean CA 10-8 generalized equally to the two types of words; older children generalized more to synonyms than to homophones. Thus, sometime around 10 years of age, Riess' subjects shifted from phonetographic generalization to semantic generalization. Salzinger (1967) has argued that the young children might have been responding in terms of phonetographic similarity because the words were unfamiliar. While this is unlikely, since the words were taken from age-appropriate readers, the fact that the words in each age group were different makes comparability difficult to assess. Salzinger's argument is supported by findings that adults give child-like associations to unfamiliar words (Sumby, 1963; Stolz &

Tiffany, 1972). [In the present study, the sorting task ensured that all children were familiar with the words, which were the same across age groups.]

Although the OR normally habituates with repeated presentations of word stimuli, this process can be retarded through imparting signal value to the stimulus. If the subject is told to press a lever or button whenever he hears a particular word, the OR to that word will remain relatively stable (although it will eventually habituate). Luria and Vinogradova (1959) used this motor response technique to give a word signal value. Subjects were children 11-15 years of age. Words bearing various degrees of sound similarity and meaning similarity to the target or key word were presented. The key word led to both a motor response and a vasomotor OR; phonetically related words elicited no response; and semantically related words elicited an OR but no motor response. In younger children of normal intelligence the OR was elicited by both phonetically and semantically related stimuli; and in younger, mentally retarded ("oligophrenic") children, the OR was elicited only by the key word and phonetically related words.

Unfortunately, following the usual Russian practice, Luria and Vinogradova summarized data rather haphazardly. As one reads their account, it is often difficult to decide whether the subjects being referred to were normal or retarded. More importantly, although GSR data were recorded they were not reported: the dependent measure was ostensibly vasomotor activity, but the pressure transducer employed may in fact have monitored blood pressure, which is not typically considered a component of the OR.

Thus, neither of the two direct tests for the P-S shift in

semantic generalization can be considered methodologically convincing. This does not, of course, preclude the veridicality of the P-S shift as such: it simply indicates that the shift remains to be demonstrated under controlled conditions.

More serious questions arise in examination of semantic generalization studies with adults, however. In particular, little real support can be adduced for the conclusion that adults generalize more to synonyms than to homophones or homonyms. Such evidence as is consistent with that position suffers from innumerable methodological flaws. The studies reviewed by Feather (1965) support the observation that relatively few studies have included homophones at all, most merely comparing generalization to synonyms with generalization to "neutral" control words. Several studies which did include homophones found adults generalizing as much or more to them as to synonyms (Wylie, 1940; Eisen, 1954; Korn, 1959; Peastrel, Wishner & Kaplan, 1968). Indeed, Peastrel et al. found they could induce a set for either phonetographic or semantic generalization by instructing subjects to attend to the appropriate dimension, a finding paralleled in Cramer's (1972a) study of false recognition in children.

Furthermore, although there have been numerous attempts to demonstrate generalization gradients along semantic dimensions as defined by associative strength [with little success (Feather, 1965)], almost no investigators have attempted to demonstrate gradients along phonetographic dimensions. Rather, where phonetic similarity has been demonstrated to affect generalization, it consisted solely of homophones. From a linguistic point of view, it is naive to imagine that either meaning similarity or sound similarity is a dichotomy. The

thrust of this is that generalization along phonetographic dimensions, though inadequately tested, seems to be at least as strong as that along semantic dimensions in adults, other things (viz. instructions) equal.

Nevertheless, despite the unimpressive evidence currently available, there is a priori reason to expect that the P-S shift should be demonstrable in semantic generalization. As noted earlier, similar shifts have been observed on other tasks, and shifts of this type can be predicted on theoretical grounds as well (Inhelder & Piaget, 1964). Certainly the P-S shift merits further examination.

In part, the present study is an attempt to replicate Lurie and Vinogradova's motor response technique, using changes in skin resistance as the primary measure of the OR. Maltzman (1971) reported a successful semantic generalization study using the technique with adults, with vasomotor activity as the response measure; but apparently no one has attempted to replicate the study with children. Skin resistance is a convenient measure to record, and in addition to being more reliable than the plethysmographic measures used by Lurie and Vinogradova, skin responses have been far more widely used in semantic generalization research. In the adult subjects, heart rate was also recorded in the present study; equipment limitations prevented its measurement in the children.

The feature-matching model does not equate semantic generalization with production of an OR, instead identifying the latter as a concomitant of the comparison process. Therefore, it is useful to discover whether or not the motor response itself generalizes to those stimuli which produce an OR. Cramer (1970a,b,c; 1971a,b; 1972b)

has found evidence of semantic generalization in a motor task at least similar to that of Luria and Vinogradova. Subjects are instructed to respond to previously presented words in a test of recognition memory; meanwhile EMG activity associated with the response (closing a telegraph key) is monitored. Although in the Luria and Vinogradova task, it seems unlikely that overt motor responses will occur to words other than the target word, implicit motor responses may occur to the generalization stimuli which produce an OR. Therefore, in the present study, EMG activity was also recorded.

Instructional Set and Semantic Generalization

While the feature-matching model does stipulate that comparison processes must involve comparison of features of some sort, it does not imply that these features are necessarily semantic. In fact, the model is quite consistent with the position that the sorts of features being compared are influenced in part by task demands and the assumptions which subjects bring to bear in the experimental situation. As Lerner (1970) has pointed out, most of the results of semantic generalization studies can be shown to be consistent with the notion that subjects form expectancies for the dimensions along which they are "supposed" to generalize. This possibility is of course anathema to common response theories, but it accords well with the assumptions of the cognitive position in general, and the feature-matching model in particular.

That instructions influence subjects' set is suggested by the study noted above, reported by Peastrel, Wishner, and Kaplan (1968), as well as a number of other studies (Maltzman, Langdon & Feeney, 1970; Cook & Harris, 1937; Haggard, 1943; Cornbecker, Welch & Fisichelli,

1949; Chatterjee & Eriksen, 1962; Notterman, Schoenfeld & Bersch, 1952). In addition, the phenomenon of speed-accuracy tradeoff in the CRT paradigm is consistent with the notion that subjects can, as a result of instructions, modify comparison processes (Smith, 1968; Kornblum, 1965).

Definition of the target as a set of words may also enhance semantic generalization. The motor response task of Luria and Vinogradova is in fact a sort of "paced" scanning task, in which the subject sees or hears a series of words and must respond if the word matches the key or target word or words. Gibson (1971), in a discussion of (unpaced) scanning tasks, noted that scanning speed of adults seems to be relatively unaffected by semantic similarity between key and background words (Gibson, Tenney & Zaslowsky, 1971): where single targets are involved, subjects "zero in" on graphological features and (to a lesser extent, at least for printed stimuli) phonological features. However, Neisser and Beller (1965) found that scanning time was far greater when target words were defined in terms of meaning (e.g. "any animal"), even relative to having to scan for a number of specific targets at once. The implication is that when the target word is defined in terms of meaning, scanning occurs on the basis of semantic comparisons, and the process takes longer. [This may in turn implicate feature matching in semantic memory and retrieval therefrom. An interesting model in this regard has been reported by Smith, Shoben and Rips (1974).] Luria and Vinogradova found that instructions to respond to any of several semantically related key words in the motor response task enhanced the degree of semantic generalization of the OR; comparable results in classical conditioning studies using multiple

words as CSs have been reported by Lacey and Smith (1954) and by Brance (1957).

Thus, it seems reasonable to predict that instructions to attend to semantic similarity ought to enhance the degree of semantic generalization on the motor response task. However, the effectiveness of such instructions seems likely to be constrained by at least two factors, viz., the degree to which subjects are set to compare along semantic dimensions in the absence of specific instructions to that effect, and the flexibility of the encoding and comparisons involved. Both these points are relevant to the P-S shift. First, there is reason to suspect that children approach most comparison tasks with a set to compare perceptual features rather than conceptual features, in contrast (perhaps) to adults (Bruner & Olver, 1963). This would suggest that children ought to respond more strongly to instructions to attend to semantic similarity. However, it also appears that children are less able than adults to recode information and to shift strategies (Schonebaum, 1973; Kendler, 1972). Furthermore, Nodine and Simmons (1974) found that third-graders made half as many eye fixations as did kindergarteners in a task requiring comparisons of letterlike symbols; more importantly, the older subjects fixated on more distinctive features. Nodine and Simmons argued that the older subjects called upon (presumably long-term) memory, while the younger children made purely perceptual comparisons. In the next section, I shall consider an individual difference variable, cognitive tempo, which is thought to be associated with ability to recode stimulus information.

To summarize this section, it appears that adults can change the features which they encode and compare, in response to instructions to

attend to particular dimensions of similarity. This hypothesis was tested in the present study. It was also hypothesized that as a group, children would be less sensitive to instructional manipulations, although this effect would interact with cognitive tempo.

Cognitive Tempo and the Phonetographic-Semantic Shift

If the point suggested earlier, that phonetographic features are encoded and compared more readily than semantic features, is correct (and it is by no means integral to the model), comparison in terms of semantic features would require inhibition of encoding, comparison, and/or responding in terms of phonetographic features. One might then expect that subjects who have trouble inhibiting initial responding in other comparison tasks would show relatively less semantic generalization than subjects who are adept at response inhibition. Thus, it seems reasonable that cognitive tempo [alternatively, conceptual tempo, i.e. reflection-impulsivity: Kagan, Moss & Sigel, 1963; Kagan, Rosman, Day, Albert & Phillips, 1964] should be related to amount of semantic generalization. Further, cognitive tempo ought to interact with instructions to attend to semantic features, although it is not clear whether such instructions ought to enhance or to attenuate the difference in semantic generalization between the two response styles; this would depend on whether impulsive subjects were unable to inhibit comparisons based on phonetographic features, or simply failed to do so unless specifically instructed to the contrary. The latter seems more likely in adults, the former in children.

Several other studies provide somewhat more direct evidence that cognitive tempo might be related to feature encoding and comparison. Kagan (1965b) has demonstrated that cognitive tempo differences are

revealed by differential latency and accuracy in a tachistoscopic recognition task, with second- and third-graders as subjects. In a separate study, Kagan (1965a) found that measures of cognitive tempo in first-graders predicted reading difficulty in the second grade. That is, children who responded slowly and accurately on tasks such as matching familiar figures and delayed recall of designs made fewer errors in reading English words a year later, relative to children who responded rapidly and made frequent errors. This is not surprising, since the delayed recall of designs test uses Gibson (1963) figures as designs. However, it is interesting since it implies that children who respond on the basis of initial comparisons may not be comparing semantic features: more errors in reading involved graphemic confusion than semantic confusion.

Samuels (1970) found that fourth grade children responded faster than adults to words flashed tachistoscopically, and argued that this was due to the children being more impulsive than adults. It is known that there is an age trend such that older subjects are more reflective as a group than younger subjects (Kagan, 1966). Odom, McIntyre, and Neale (1971), working with kindergarten children who compared Gibson forms, found that reflective children were attending to perceptual features, while impulsive children did not seem to be comparing stimuli in terms of identifiable features.

These results are particularly intriguing in view of a recent hypothesis proposed by Siegel and his colleagues (Kilburg & Siegel, 1973; Siegel, Babich & Kirasic, 1974). They have suggested that impulsive and reflective children (fifth graders were studied) differ in a visual recognition memory task only in the number of feature

comparisons they make, with the reflective children performing a more exhaustive feature scan. This research, which was reported after the design of the present study, also presumes a feature-matching model.

Thus, there seems to be sufficient a priori evidence to predict the cognitive tempo effects noted above. The present study is additionally enhanced as regards cognitive tempo, in that since the motor response task involves a response under voluntary control, the EMG records might be expected to show differences related to tempo. That is, since a subject must either make a motor response, or inhibit that response (in contrast to the CRT paradigm, where two responses are involved), response inhibition should show up as an increase in EMG activity. While EMG activity certainly seems relevant to cognitive tempo, the technique has not been used widely in conjunction with measures of tempo. In fact, if any previous studies have been reported, they are not cited in the tempo literature. [However, recently Stonner & Geen (1975) reported that impulsive adults take more trials than reflective adults to reach an habituation criterion for the OR to repeated presentation of a visual stimulus; the dependent measures were SP and SR.]

Summary of Hypotheses and Design of Study

It is difficult to summarize all of the hypotheses posed above in any reasonable amount of space. However, most of the predictions made relate to one or more of the following hypotheses. First (I) children less than 10-11 years old should attend more (show greater orienting responses) to words which resemble the key word in sound than to words which resemble the key word in meaning, in the motor response task;

adults should attend more to the latter than to the former. This is the basic P-S shift. Second (II), instructions defining the key word in terms of meaning should facilitate the amount of semantic generalization in adults more than in children. Third (III), cognitive tempo ought to interact with instructions, age, or both instructions and age, in determining amount of semantic generalization. Fourth, (IV) impulsive subjects (regardless of age) ought to show more overall EMG activity than reflective subjects of the same age. Fifth (V), MDS and HC solutions for the motor response task data ought to resemble those for word sorting data. Sixth (VI), scaling solutions ought to indicate similarity involving both phonetographic and semantic dimensions.

The tasks involved in the study are indicated in Table 1. There were two age groups: third-graders and college undergraduates. There were three tasks: Delayed Recall of Designs, a measure of cognitive tempo; word sorting, which served as the source of data for the MDS and HC analyses; and the motor response task, the task on which habituation and generalization of the OR, and EMG activity, were monitored. The first two tasks were administered on one day, in the order indicated; the motor response task was administered in a second session several days later. The order of administration was not varied, since the sorting task served as a test ensuring that all third grade subjects could read the words to be used in the motor response task.

Table 1. Design of Study.

Subjects	Instruction in MRT	Session 1	Session 2	Measures in MRT
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List 1

Third Grade	Target Word (n=8)	DRD; WS	MRT	GSR, EMG
Third Grade	Target Class (n=8)	DRD; WS	MRT	GSR, EMG
Third Grade	Control Word (n=8)	DRD; WS	MRT	GSR, EMG
College	Target Word (n=8)	DRD; WS	MRT	GSR, EMG, HR
College	Target Class (n=8)	DRD; WS	MRT	GSR, EMG, HR
College	Control Word (n=8)	DRD; WS	MRT	GSR, EMG, HR

List 2

College	Target Word (n=4)	DRD; WS	MRT	GSR
College	Control Word (n=4)	DRD; WS	MRT	GSR

-- Note. List 1 and List 2 contained different words. DRD and WS data were not tabulated for List 2 subjects.

DRD = Delayed Recall of Designs
 WS = Word Sorting
 MRT = Motor Response Task

GSR = Galvanic Skin Resistance
 EMG = Electromyogram
 HR = Heart Rate

METHOD

Subjects

The present study was confined to male subjects. While there are no theoretical reasons to restrict the feature-matching model to males, possible changes in skin responsivity associated with the menstrual cycle in adult women made it appear desirable to confine examination to males. Subjects of two age levels were used.

Twenty-nine third-grade boys [mean CA = 8 years 11 months; SD = 6 months] were recruited through two elementary schools in the Holt Public Schools, Holt, Michigan. Teachers were asked to recommend children without diagnosed mental retardation or dyslexia. Letters requesting parental permission to participate were sent [a copy appears in Appendix A], and only children whose parents made affirmative responses were included in the study. The Holt student population is comprised of children whose parents are primarily lower middle-class, residing in the community itself (an unincorporated suburb of Lansing), or on farms in the surrounding area.

Forty-three male undergraduate students enrolled in introductory psychology courses at Michigan State University comprised the adult sample in the present study. Subjects in the study received credit toward an optional experiment participation component in their class requirements.

Subjects were lost from the original samples in several ways. Of the 29 boys, data from two were not included because the subjects were not available for the second testing session due to absence or conflicting school activities. Data from two other boys were discarded due

to their failure to follow instructions on the motor response task [one in the "target class" condition, one in the "control word" condition: see below]; data from one subject were discarded due to equipment malfunction. This left a total of 24 third-graders, assigned randomly to the three instruction conditions subject to the constraint of equal numbers in each.

Of the 43 adult subjects, data from five were lost because they failed to show up for the second session; data from four subjects were discarded due to equipment malfunction. Twenty-six subjects received the List 1 words (see below); to ensure comparable n with the third-graders and to simplify the analyses, two subjects (one each from the target word and target class conditions) were discarded randomly, leaving 24 subjects who were randomly assigned to the three instruction conditions of List 1, with eight per group. An additional eight subjects were run in the two instruction conditions (target word, control word) of List 2, four in each condition, randomly assigned.

Materials and Apparatus

There were three tasks in the study: the Delayed Recall of Designs task (a measure of cognitive tempo); the word sorting task (a measure of semantic structure); and the motor response task (a measure of semantic generalization). These are discussed in the order indicated, which was the order in which they were presented to subjects.

The Delayed Recall of Designs task involved a modified version of the test originally used to assess cognitive tempo by Kagan and his colleagues, the Design Recall Test (Kagan, et al., 1964); the

modifications have been described by Reali and Hall (1970). This test predicts both response latency and errors on the Matching Familiar Figures test (a more widely used measure of cognitive tempo); scores are stable over periods from nine weeks to 17 months (Kagan, 1966). The Delayed Recall of Designs task used in the present study included twelve Gibson figures, with eight transformations of each. [Kagan's term "recall" is a misnomer; the task clearly involves recognition.] Each standard figure appeared alone on one side of a card, and on the reverse side appeared together with the transformations, with location of the standard varied, in a 2 x 4 array.

Data sheets allowed the experimenter to record responses conveniently. Latencies of response (see below) were recorded by having the experimenter depress a footswitch connected to a Lafayette Model 20225A stop clock, monitored by a second experimenter hidden from the subject by a screen (third-graders) or in another room (adults). Subjects were seated at a table for this and the following task, word sorting.

The stimuli in the remaining two tasks, the word sorting task and the motor response task, were a set of words appearing in Tables 2 and 3; composition of the lists is discussed in more detail below. In the word sorting task, these words were typed on separate index cards, one word per card (following Anglin, 1970).

In the motor response task, the subject was seated in an armchair. Stimuli were presented by means of a Kodak Carousel Model 700 slide projector (a rear projection system was used for adults; front projection was used for children). The letters of the words subtended approximately 3° of the visual field. The projector was programmed

with an Ampex model 1100 stereo tape recorder, using a Kodak Carousel sound synchronizer. Slides (4.8 cm x 4.8 cm) were white letters on a blue field, prepared by a professional photographer; words were spelled in block capital letters, and were easily readable.

The motor response task involved monitoring several responses as subjects viewed the slides. Responses recorded from third-graders fell into three groups: skin resistance, EMG, and motor responses as they occurred; for adults, in addition to the previous responses, EKG was recorded (but not scored), and the heart rate was recorded. The polygraphic equipment was as follows: for children, responses were recorded on a portable Beckman Type RS Dynograph, equipped with a type 9892A skin resistance coupler and a type 9852 EMG integrator. For adults, responses were recorded on a Grass Model 7 polygraph, with a model 7P4C tachogram pre-amplifier (EKG and HR), a model 7P1A DC pre-amplifier (GSR), and a model 7P3B AC pre-amplifier/integrator (EMG; a time constant of .2 sec was used). On the Beckman unit two event pens recorded occurrence of a motor response and presentation of a slide; on the Grass unit, the two events were indicated by downward and upward deflection of the event pen, respectively.

Skin resistance and EMG were recorded using Ag-AgCl electrodes made as described by Venables and Martin (1967); electrodes had a surface area of approximately $.78 \text{ cm}^2$. The electrolyte for skin resistance was a unibase preparation (Lykken & Venables, 1971); that for EMG and EKG was Beckman Offner paste. Plate electrodes were used as a ground and to record EKG.

Procedure

The procedure for children was as follows: two experimenters were involved in each session in the study. In the first session (delayed recall of designs and word sorting tasks), the first experimenter accompanied the subject from the classroom while the second experimenter prepared stimuli and equipment. The subjects were run in brightly illuminated rooms supplied by the school (the college students were run in the Developmental Psychobiology Laboratory at Michigan State University).

The experimenter was introduced to the subject by the teacher, and conversed pleasantly with the subject as they returned to the experimental room. The subject was seated at a table across from the experimenter, with a 30 cm high screen dividing the table. The instructions for the first task, delayed recall of designs, were as follows:

"I am going to show you a picture of something, and I want you to look at it very carefully because I will take it away quickly. Then I'll show you a set of pictures. One of the pictures will be the one you just saw, and I want you to point to that picture. Let's try one to see how it works. [A sample was presented, and the subject responded.] Okay, let's begin."

The experimenter presented the standard stimulus for five seconds; the standard was removed and the subject was shown the card containing the standard together with the transformations. The experimenter simultaneously depressed the footswitch, releasing it when the subject pointed to a design; she then recorded whether or not the

response was correct, while the second experimenter recorded response latency and reset the clock. Each response was reinforced with "All right, fine . . . Let's try the next one."

After completion of the twelve trials, a short rest period followed (a minute or so). The instructions for the second task, the word sorting task, were then given. This task was actually independent of the first (although it had to precede the motor response task as it ensured that subjects were familiar with the words used in both tasks), and was administered in the same session as the delayed recall of designs task only because of the additional problems which would have resulted from an additional session.

The cards for the word sorting task were shuffled prior to their being given to the subject. The instructions were as follows:

"Now I'm going to give you a stack of cards. On each one, there's a word printed. [Subject was given the stimuli.] I want you to read each word, and use it in a sentence. [The sentence construction was omitted for adults. After all words had been read correctly, the instructions continued.] Now I want you to put the words that are the same in meaning, that mean the same kind of thing, into the same piles. You can use as many or as few piles as you like."

"Meaning" was not defined further, for any group. A few subjects asked what to do, and were told to do what they thought the task required; their initial responses were then reinforced. This procedure was followed so as to ensure comparability with the earlier study of Anglin (1970). A maximum of 15 minutes were required for sorting the 17 words in the study. The subject was then thanked and asked to

return for the next session, and accompanied back to his classroom (third-graders only). Data sheets were designed so that the experimenter could record sorting results by assigning nominal symbols to each word, representing the pile to which the subject assigned it. Procedure for the college students was the same, except that they were instructed to present themselves at the laboratory at a particular time, and reminded of the second session (part of the original agreement for participation).

The second session, which consisted solely of the motor response task, followed the first session by one to three days. Subjects were run in a dimly illuminated room, to allow slide presentation; light levels in the different rooms used were subjectively equated. The first experimenter ran the polygraph; the second experimenter (who had served as first experimenter in the first session) met the subject, attached electrodes, and administered instructions.

The task was presented to the third-graders as an "astronaut game" to alleviate possible discomfort caused by the electrodes. This ruse was supported by having third-graders wear a Radio Shack Corporation space-helmet, which was adjusted so as not to impair vision, and an armband with an emblem reading "Space Patrol", in reality the result of an attempt to disguise the rather ominous looking (to the adults) ground electrode. These props were omitted for the adults. In addition, adults were run in a soundproof chamber; an additional reason for the use of the helmet was to attempt to minimize interference from external sound sources in the school. [Nevertheless, the helmet may well have been unnecessary; the third-graders seemed fully capable of performing the task without it.]

Any subject who seemed reluctant to participate in the motor response task would have been allowed to decline participation without coercion, although none did. As the electrodes were attached, the following instructions were given:

"Today I want to show you some words on this screen. I want you to read each word, and while you do that, we're going to be making measurements from your arm. We'll put these sensors on your arms and hands. It's just like putting on a band-aid except it doesn't hurt when you take them off--see?" [Demonstration of micro-pore tape followed. After attachment of electrodes ("sensors"), college students were informed that no shocks would be delivered during the experiment. This was necessary since a colleague was conducting shock-threat research in the same laboratory; no mention of shock was made to third-graders.]

The electrodes were then attached. During the task itself, the subject held the response button (a hospital call button) in his right hand, in such a way that he could press it with his thumb. Thus, the two EMG electrodes were placed on the surface of the thenar muscle at the base of the right thumb, secured with commercial electrode collars and micropore tape if necessary. The two skin resistance electrodes were placed on the left palm, secured with collars. Collars were dabbed with cotton to prevent adhesion to the button or the chair. A common ground site on the left forearm was provided by a plate electrode (as noted above, for the children this was disguised as an armband). For adults, in addition to the previously mentioned electrodes, EKG electrodes were secured over the wrists of the left and

right hands. The surface of electrode sites was cleaned with 70 percent ethanol prior to electrode placement.

The subject was then seated in an armchair and given the following instructions:

"Now, it's important that you stay as still as possible so that we can take our measurements. Put your thumb on this button; try pressing it a few times. I want you to press the button as soon as you see

[target word condition] the word flower.

[target class condition] a word that means something like a flower.

[control word condition] the word boy.

Do you understand? [Experimenter satisfied herself that the subject understood.] You'll see the first word in a minute or two. I'll tell you when we've finished."

After a few minutes to adjust equipment, twelve words [Battig & Montague (1969) responses to "an article of furniture," "a natural earth formation," and "a toy," all Thorndike & Lorge (1944) A or AA frequency] were presented as an initial habituation list (see Table 4). These words did not appear in the word sorting task, and responses to them in the motor response task were not scored.

If the subject did not seem to be following instructions during the first few habituation stimuli, he was presented with his instructions again. If there was no problem, at the end of the habituation list, the test list was begun immediately.

Stimuli were drawn from five categories of words (see Table 2).

The following definitions of categories were involved: (a) the key word

Table 2. Stimuli in List 1.

Category	Words
(a)	FLOWER
(b)	BOY
(c)	HOUR, SHOWER ^a , POWER, TOWER, FOUR
(d)	PLANT, TREE, STEM ^b , ROSE, DAISY ^c
(e)	CAR, SHIP, BOAT, TRAIN, PLANE

-- Note. All Thorndike & Lorge A or AA except where noted.

^aThorndike & Lorge 41 (J200).

^bThorndike & Lorge 39 (J235).

^cThorndike & Lorge 28 (J220).

Table 3. Stimuli in List 2.

Category	Words
(a)	CAR
(b)	FLOWER
(c)	STAR, FAR, BAR, JAR, CARD
(d)	SHIP, TRAIN, BOAT, PLANE, WAGON
(e)	GLASS, PAN, POT, CUP, DISH

-- Note. All Thorndike & Lorge A or AA.

Table 4. Stimuli in Habituation List, Motor Response Task.

BALL, BLOCK, GAME, WAGON (List 1 only), ROPE, CHAIR (List 2 only), TABLE, BED, DESK, LAMP, HILL, LAKE, VALLEY
--

-- Note. All Thorndike & Lorge A or AA.

(flower); (b) the control word (boy); (c) phonetographically related words [mostly words which rhyme with the key word, drawn from Stillman (1964)]; (d) words which were semantically related to the key word [occurring with varied frequency in the Battig & Montague (1969) category, "a flower"]; and (e) neutral words [Battig & Montague category, "a type of vehicle."] Entwistle (1966) has reported the frequencies with which third-graders produce these words as associates to the stimulus flower. All words used in the present study are rated at least "A" in the Thorndike and Lorge (1944) count, with three exceptions, all common in children's readers, noted in Table 2: words of this frequency are presumed readable by third-graders.

Stimuli were presented in a random blocks order constructed as follows: the habituation list, followed by five blocks of five trials (words), with one word from each of the above categories in each block, in random order within blocks. All subjects received the same order, within each list condition. The ISI was randomly varied among 15, 20, and 25 seconds (mean of 20); each word was displayed for 2.0 seconds, with a solid gray slide projected between words. After the test list, one slide containing a picture of a flower was presented in order to test for dishabituation of the OR (List 1 only).

The electrodes were then removed, and the (third-grade) subjects were returned to the classroom after the polygraph record was explained to them. All subjects were told that they did well, thanked for their cooperation, and invited to ask questions; they were cautioned not to discuss the study with other potential subjects.

The procedure for subjects receiving List 2 was comparable to that above, except that the list was constructed as follows: Category (a)

was the word car; category (b) was the word flower; category (c) words were drawn from Stillman (1964) and rhymed with car; category (d) words were drawn from Battig and Montague category "a type of vehicle;" and category (e) words were drawn from the category "a kitchen utensil." Subjects who were given List 2 (Table 3) on the motor response task also had these words on the earlier word sorting task. There were only two instruction conditions on the motor response task for List 2, the target word condition (car) and the control word condition (flower) respectively.

RESULTS AND DISCUSSION

Cognitive Tempo (The Delayed Recall of Designs Task)

As Kagan and his colleagues (Kagan, et al., 1964) originally conceived the concept of cognitive tempo, the operational definition involved latency of response in a task requiring a choice from among several alternatives. However, most subsequent work has combined the latency measure with a measure of response accuracy [implicitly adding the requirement that the task must have exactly one correct answer, a requirement for which no specific theoretical rationale seems ever to have been presented], typically defining impulsive children as those with below median latency and above median errors, and reflective children as those with above median latency and below median errors. Tasks such as Matching Familiar Figures and the delayed recall of designs test in the present study are supposed to show strong negative correlations between latency and errors (which is consistent with speed-accuracy tradeoff).

Recently that supposition has come under strong attack, notably by Block, Block, and Harrington (1974; see also O'Donnell & McGann, 1974), who reviewed evidence suggesting that a strong negative correlation is the exception rather than the rule, and (more important) that accuracy, but not latency, was correlated with a number of personality dimensions.

Moreover, a cursory review of the cognitive tempo literature reveals that latencies are almost invariably recorded using a stopwatch or (as in the present study) a clock; i.e., recording of latency is not automated. Since it is rare to report the number of experimenters

involved in a study (there were six individuals, all females, involved in administering the delayed recall of designs task in the present study), it is difficult to estimate the contributions of experimenters' "personal equations" to between-subject variance; but despite careful training, the differences are likely to be substantial. When one then pools all subjects' data, and performs a median split, one may in fact be distinguishing among subjects who were merely run by different experimenters. Unfortunately, the present author became aware of this only after the data had been collected in the present study; it was not feasible to separate subjects by the experimenters, because of the low and variable n associated with each experimenter. Experimenter differences are less likely to bias error scores, suggesting the greater reliability of the latter.

At any rate, in the present study experimenter effects were probably confounded with subject latency scores. Thus, latency scores must be viewed somewhat skeptically. The analyses were performed on the assumption that similar confounds permeate previous cognitive tempo studies. Since there is nothing inherent in the original definitions of cognitive tempo that would require median splits (since that clearly makes the definition dependent on the sample), in most of the following analyses the original measurements (errors and latency) were used.

The following analyses compared errors on the delayed recall of designs task (12 possible); latency in seconds, summed over 12 trials; the number of piles each subject produced in the word sorting task; and the total amount of EMG activity on the motor response task, as

described later. Means and variances on each of these variables, as a function of age, appear in Table 5. Independent groups t-tests were performed comparing means for children and adults on each of the four measures, with the results also listed in Table 5 [all t-tests in the present study are two-tailed except where otherwise noted; also, "significant" means "significant at the five percent level" unless otherwise indicated.]. As can be seen, children made significantly more errors than adults, but the latencies were not significantly different from each other. There was no significant difference in total EMG activity. Interestingly enough, there was a significant difference in number of word sorting piles, in the predicted direction: that is, children used more piles than adults. Thus, of necessity, the mean number of items per pile was smaller for children than for adults. Exactly what this means is hard to say, since grouping in a

Table 5. Age Differences in Cognitive Tempo and Related Measures.

Age	Measure			
	DRD Errors	DRD Latency (secs)	WS Piles	Total EMG
Children	3.88(7.94)	47.11(229.69)	7.12(9.68)	267.33(42,117.28)
Adults	1.25(1.94)	43.54(485.25)	5.83(4.14)	226.46(11,801.22)
$\pm$	4.10**	0.65 (n.s.)	1.71 ^a	0.86 (n.s.)

-- Note. $N = 24$ per age group.

** $p < .01$

^a $p < .05$, 1-tailed test

DRD = Delayed Recall of Designs

WS = Word Sorting

common pile can result either from perception of an abstract feature (but differentiation of concrete features), or from failure to differentiate any features at all. Nevertheless, the same finding was reported by Anglin (1970).

Product-moment correlation coefficients between all six pairs of variables were calculated, for adults (Table 6), children (Table 7), and adults and children pooled (Table 8). The positive correlation between number of delayed recall of designs errors and number of word sorting piles supports the assumption that using large numbers of piles (i.e. few words per pile) is due to failure to discriminate between features rather than attention to concrete features.

In view of Siegel's argument (described above) that reflective children attend to more features than impulsive children, we should expect to find delayed recall of design latency negatively correlated with number of word sorting piles, and number of delayed recall of design errors positively correlated with number of piles. In point of fact, both DRD measures were positively correlated with number of

Table 6. Correlations with Cognitive Tempo in Adults.

	DRD Errors	DRD Latency	WS Piles	Total EMG
DRD Errors	1.00			
DRD Latency	.25	1.00		
WS Piles	-.05	.54**	1.00	
Total EMG	.45*	.62**	.09	1.00

-- Note. N = 24; DRD = Delayed Recall of Designs; WS = Word Sorting.

* $p < .05$

** $p < .01$

Table 7. Correlations with Cognitive Tempo in Children.

	DRD Errors	DRD Latency	WS Piles	Total EMG
DRD Errors	1.00			
DRD Latency	-.02	1.00		
WS Piles	.22	.49*	1.00	
Total EMG	-.07	.19	.16	1.00

-- Note. N = 24; DRD = Delayed Recall of Designs; WS = Word Sorting.

*p < .05

Table 8. Correlations with Cognitive Tempo (Pooled Over Age).

	DRD Errors	DRD Latency	WS Piles	Total EMG
DRD Errors	1.00			
DRD Latency	.12	1.00		
WS Piles	.26 ^a	.48**	1.00	
Total EMG	.10	.34*	.17	1.00

-- Note. N = 48; DRD = Delayed Recall of Designs; WS = Word Sorting.

*p < .05

**p < .01

^ap < .05, 1-tailed test

piles. That is, the evidence supports Siegel's hypothesis if cognitive tempo is defined in terms of number of errors, but not if it is defined in terms of latency [Siegel's studies (Siegel, et al., 1974; Kilburg & Siegel, 1973) report consistent differences in both correct choices and latency, although the task was somewhat different

from the delayed recall of designs task]. Both latency and number of errors are positively correlated with total EMG activity for adults, but not for children, results bearing on Hypothesis IV.

Note that (contrary to Kagan's position) in no case was the correlation between delayed recall of designs latency and errors significantly different from $r = 0$. Suppose the two measures are combined, or at least taken into account: is it possible to predict either EMG activity or number of word sorting piles? To answer this question, the multiple correlation coefficient for predicting each of the "dependent" variables from a combination of the delayed recall of designs variables (based on the pooled data) was computed. The R value for EMG was $R = +0.35$; following Ferguson (1966, p. 401) this yields an $F(2, 45) = 3.08$, not significant. The corresponding value for number of piles is $R = +0.52$, yielding an $F(2, 45) = 8.49$ ($p < .01$). Thus, while number of piles can be predicted using the combination of delayed recall of designs scores, it is not possible to predict EMG activity better than before considering the variables. Note, however, that the multiple correlation is not much larger than the original correlation with latency (0.52 vs. 0.48 respectively).

Suppose one partials out variance associated with each of the two delayed recall of designs scores: what happens to the correlation between the remaining score and each of the two criterion variables? Let the subscripts 1, 2, 3, and 4 represent delayed recall of designs errors and latency, word sorting piles, and EMG activity respectively. Then $r_{23.1} = 0.47$ [$t(45 \text{ d.f.}) = 3.59$, $p < .001$]; $r_{13.2} = 0.23$ [$t(45) = 1.59$, n.s.]; $r_{24.1} = 0.34$ [$t(45) = 2.38$, $p < .05$]; and $r_{14.2} = 0.06$ [$t(45) = 0.40$, n.s.]. Thus, partialling out (co)variance associated

with latency destroys the (borderline) significant correlation between delayed recall of design errors and word sorting piles, but doesn't change the correlation between delayed recall of design errors and EMG activity; whereas partialling out variance associated with delayed recall of design errors does not affect either corresponding correlation involving delayed recall of designs latency.

To summarize the results of the delayed recall of designs task, most of the evidence above suggests that delayed recall of designs errors are a better measure than either delayed recall of designs latency or a linear combination of errors and latency, in the sense that delayed recall of designs errors are related to other variables in ways that reflect the theoretical implications of cognitive tempo. For that reason, in addition to the methodological observations at the beginning of this section, in further analyses the distinction between impulsive and reflective subjects was drawn on the basis of a median split on delayed recall of design errors (above median for age group = impulsive), with latency used only as a tie-breaker (lower latency = impulsive). [As an aside, an F-test for homogeneity of variance over age groups on delayed recall of design errors was significant: $F(23, 23) = 4.09, p < .01$. While the statistical tests employed in the present study are relatively robust against violation of homogeneity with equal n , this could be a potential problem in other studies. It is related to the earlier observation that median splits make definition of cognitive tempo dependent on characteristics of the sample.]

The findings above are not easy to interpret. However, as a group they cast some doubt on the utility of cognitive tempo as Kagan has

tended to define it. If one assumes that cognitive tempo is measured by accuracy on the delayed recall of designs task, then the results support the following conclusions:

1. Adults are more reflective than third-graders.
2. The more impulsive a subject was, the more piles he tended to use in sorting words.
3. While cognitive tempo appears to have little relation to EMG activity for children, for adults, the more impulsive an adult, the more EMG activity he showed on the motor response task.

The last finding is important, since the less sensitive analysis of variance for EMG reported below, based on a median split for cognitive tempo, found neither main effects nor any interactions with cognitive tempo: this suggests that other studies in which median splits are employed are discarding potential information.

While these conclusions are interesting, it seems something of a misnomer to call delayed recall of designs errors cognitive tempo. Decision latency had little to do with accuracy. Obviously firm conclusions must await investigation of latencies under better methodological control, but at the moment it is tempting to re-label "cognitive tempo" on the delayed recall of designs task as "accuracy in letter recognition." Small wonder, then, that Kagan (1965a) found "cognitive tempo" to be related to reading ability.

Generalization of the OR: The Motor Response Task, List 1

This section deals specifically with measures taken during the motor response task. The variables recorded were skin resistance, EMG activity, motor responses when they occurred, and (for adults) heart rate (HR) via cardiotelemetry (EKG, though recorded, was not scored).

Original plans had called for calculation of post-stimulus change scores, corrected for pre-stimulus changes, for all three psychophysiological measures (GSR, EMG, HR). The long recovery time of the phasic GSR OR precluded this: complete recovery time was often slightly longer than 15 seconds, the minimum ISI. Correction for a subsequent trial would thus reflect response recovery from the previous trial. Thus, correction was unfeasible for GSR; HR was not corrected in order to maintain rough comparability of treatment. Because the EMG measure in the present study would not be expected to reflect the OR, and since it had relatively fast recovery time, EMG responses were corrected for pre-stimulus change.

The scoring procedure for GSR was as follows: the maximum and minimum pen deflections during the ten seconds following stimulus onset were determined for each of the stimuli in the test list. These values were then keyed into a computer program (together with sensitivity and balance values) which converted the corresponding resistance change scores into conductance change scores, in units of root $[100 \times |\Delta C \text{ in micromhos}|]$. The multiplicative factor was introduced for convenience in later programming; the root transform was intended to reduce skewness.

Heart rate was scored as the minimum value in beats per minute subtracted from the maximum value in beats per minute (both of these values being read from the tachogram tracing), for the ten beats which followed stimulus onset.

The EMG activity was scored as follows. [It is difficult to assign unit values to EMG responses, which were integrated over a .2 sec. time interval.] For each subject, sensitivity and balance controls

were adjusted so that a motor response (button press) produced an upward pen deflection of approximately 4 cm. prior to onset of the first habituation stimulus. Thereafter, the baseline was adjusted when necessary to maintain a constant baseline, although records were surprisingly clean and very few subjects required this correction. The minimum (downward, i.e. positive) pen deflection in mm. from centerline was subtracted from the maximum (upward) pen deflection for the ten seconds prior to stimulus onset, and the ten seconds following stimulus onset; the difference for the pre-stimulus interval was subtracted from that for the post-stimulus interval. Thus, where post-stimulus change was less than pre-stimulus change, a negative score resulted. The resulting units are mm. of pen deflection. [This procedure was actually carried out by a computer, as was determination of the HR scores.]

Motor responses per se were remarkably consistent. Subjects who had been instructed to press when they heard the word "boy" did so then and only then, regardless of age; this was also true for subjects instructed to press for the word "flower". Subjects in the target class condition pressed the button for words in categories a (key word) and d (semantically related words) only, regardless of age. This was somewhat surprising in the case of the children, but is consistent with the results of the word sorting task reported below. As noted above, two children were lost from the sample because they persisted in pressing the button to every word.

The operation of the event pens was not sufficiently precise to allow determination of the latency of response: latencies appeared to vary from about .2 secs. to 3.0 secs., but much of this variation was

probably due to the experimenter, who manually operated the event pen as the projector advanced.

Among adults, equipment failure prevented obtaining accurate HR data from one to three subjects (out of eight) in each instruction condition. To obtain equal n , subjects were randomly discarded (for the following analysis only) so that each instruction category contained five subjects. The skin conductance and HR scores were summed across words within each category, and a 5 (Categories) $\times$ 3 (Instructions) Multivariate Analysis of Variance performed. The data are presented in Tables 9 and 10; the MANOVA summary appears in Table 11. The procedure followed was described by Tatsuo (1971, chapter 7). The resulting statistics, a generalization of Wilks' Λ -ratio, can be tested for significance with an exact F-test [no approximation is necessary since there are two dependent variables (Tatsuo, 1971, p. 205)], also indicated in Table 11. Both main effects, and the interaction, were significant at the five percent level.

Normally, following the recommendations of Hummel and Sligo (1971), the next step would be to perform separate univariate analyses on the two dependent measures. Because skin conductance (GSC) data were treated in a more extensive analysis reported below, only the HR values were examined in a univariate analysis of variance. [The design, like all ANOVA designs in the present study, was generated using a set of algorithms reported by Bogartz (1968), modified and extended by Professor R. W. Frankmann and by the present author. While this particular analysis did not necessitate pooling effects into error, some of the subsequent analyses did require that, and because of the complexity of the analyses, standard textbooks did not present the

Table 9. Conductance Totals, Summed over Subjects (adults) and Words,
for MANOVA.

Category	Instruction		
	Target Word	Target Class	Control Word
(a) key word	222.4	214.8	220.7
(b) control word	102.1	139.4	357.9
(c) phonetographic	122.1	135.7	213.6
(d) semantic	124.4	216.9	192.4
(e) neutral	90.9	126.6	233.0

-- Note. N = 5 per cell.

Table 10. Heart Rate Totals, Summed over Subjects (adults) and Words,
for MANOVA.

Category	Instruction		
	Target Word	Target Class	Control Word
(a) key word	852.0	826.0	236.0
(b) control word	327.0	247.0	821.0
(c) phonetographic	405.0	223.0	241.0
(d) semantic	352.0	649.0	244.0
(e) neutral	311.0	247.0	294.0

-- Note. N = 5 per cell.

Table 11. Multivariate Analysis of Variance Summary.

Source	SSCP Matrix	d.f.	$ S_h + S_e $	Λ_h	d.f. (F)	F	
Categories	2010.092533	9908.213333	4	6,510,852,318.3940	.7511	8, 118	2.27*
(5)	9908.213333	51,025.733334					
Instructions	6477.658400	-4994.672000	2	6,513,656,871.6053	.7508	4, 118	4.55**
(3)	-4994.672000	3982.426667					
Categories x	5246.116267	22,383.758667	8	8,566,286,301.9918	.5709	16, 118	2.39**
Instructions	22,383.758667	105,282.906667					
Within Cells	19,981.204000	-5134.200000	60	4,890,526,753.3824	---	---	---
	-5134.200000	246,075.600000					

-- Note. Variable A = GSC; Variable B = HR.

*p < .05

**p < .01

Table 12. Analysis of Variance Summary for Heart Rate.

Source	d.f.	MS	F
<u>Between Subjects</u>			
Instruction	2	1991.2133	0.19
Error	12	10,252.6200	--
<u>Within Subjects</u>			
Category	4	12,756.4333	4.98**
Instruction x			
Category	8	13,160.3633	5.13**
Error	48	2563.4200	--

**p < .01

appropriate formulae.] The results appear in Table 12. It can be seen that the simple effect for category was significant, as was the interaction between category and instruction. The interaction requires further examination.

It is of course inappropriate to apply a posteriori comparison techniques such as the Newman-Keuls or Duncan's methods to an interaction: although this is often done, one defeats the purpose of such procedures, by in effect accepting a spurious alpha level. However, it is possible to apply conservative a posteriori tests such as the Scheffe F-test or the Tukey Test (Snedecor, 1956; Winer, 1962, calls this the Tukey "a" procedure), if one confines examination only to non-confounded comparisons (Cicchetti, 1972). There are 45 such comparisons in the present analysis (out of 105 total). Using totals,

Table 13. Tukey Test for Heart Rate, Instructions x Category.

Target Word					Target Class					Control Word					Category	Instruction
a	b	d	e	c	a	b	d	e	c	a	b	d	e	c		
---	525	500	<u>541</u>	447	26					<u>616</u>					a	Target Word
	---	25	16	78	80					494					b	
	---	---	41	53	297					108					d	
	---	---	---	94	64					17					e	
				---	182					164					c	
					---	<u>579</u>	177	<u>579</u>	<u>603</u>	<u>590</u>					a	Target Class
					---	---	402	0	24	<u>574</u>					b	
					---	---	---	402	426	405					d	
					---	---	---	---	24	47					e	
					---	---	---	---	---	18					c	
						---	<u>585</u>	8	58	5					a	Control Word
						---	---	<u>577</u>	<u>527</u>	<u>580</u>					b	
						---	---	---	50	3					d	
						---	---	---	---	53					e	

--- Note. Underlined numbers are significant ($p < .05$); contains unconfounded comparisons only.

the appropriate critical value for the Tukey Test ($p < .05$) would be $(T_1 - T_2) \geq 526.4$. The totals are presented in Table 13; underlined values are significant.

In the target word instruction group, responses to the key word (flower) were greater than those to the neutral words, but there were no other significant differences. In the target class instruction group, responses to the key word were greater than those to all other categories except the semantically related words; in the control word group, responses were greater to the control word (boy) than all other words. These results may suggest either that HR was a relatively insensitive measure of generalization, or that little generalization occurred. However, such evidence of generalization as did appear suggests the presence of semantic generalization in the target word and target class groups, and phonetographic generalization in the target word (but not the target class) group. This can be interpreted as supporting Hypothesis II, although absence of data from children makes this conclusion only tentative. In the analysis below, roughly comparable conclusions are drawn with respect to GSC, suggesting that both measures of the OR allow similar conclusions with regard to the instruction manipulation.

The adult GSC data, along with those from the children, were analyzed in a 2 (age) x 3 (instruction) x 5 (category) x 2 (cognitive tempo) ANOVA, with words and subjects treated as random effects. This analysis did require extensive pooling into error. The totals appear in Table 14; the analysis is summarized in Table 15. While a number of effects (14 of the 25 total) were significant at the five percent level, the presence of high order interactions suggests examination only of the

Table 14. Conductance Totals, Summed over Subjects and Words, for ANOVA.

Category	Instruction		
	Target Word	Target Class	Control Word
Impulsive Adults			
(a) key word	204.30	151.30	218.20
(b) control word	93.80	111.80	345.50
(c) phonetographic	104.90	120.60	185.10
(d) semantic	118.40	145.70	181.70
(e) neutral	82.70	105.20	222.20
Reflective Adults			
(a)	196.10	161.40	140.50
(b)	106.70	86.40	266.10
(c)	140.90	79.50	140.40
(d)	104.90	145.80	119.30
(e)	79.30	82.20	171.90
Impulsive Children			
(a)	125.10	110.60	93.80
(b)	88.80	101.40	234.90
(c)	89.40	96.70	116.40
(d)	95.80	137.10	116.40
(e)	90.40	104.40	104.40
Reflective Children			
(a)	183.40	136.38	122.70
(b)	135.10	119.00	265.80
(c)	136.20	123.90	122.20
(d)	130.00	141.50	137.80
(e)	117.60	115.70	118.00

— Note. N = 4 per cell.

Table 15. Analysis of Variance Summary, Conductance Data.

Source	d.f.	MS	Error MS	Error d.f.	F
A (Instructions)	2	873.7616	23.1295	796	37.78**
B (Age)	1	302.0033	23.4875	776	12.86**
C (Category)	4	249.3731	9.7880	884	25.48**
D (Word)	20	15.9175	8.1522	720	1.95**
E (Cognitive Tempo)	1	0.7301	23.5737	776	0.03
S (Subjects)	36	338.0181	8.1522	720	41.46**
A x B	2	240.9348	23.2503	796	10.36**
A x C	8	384.9796	9.6317	904	39.97**
A x D	40	9.3201	8.1522	720	1.14
A x E	2	126.8604	23.1666	796	5.48**
B x C	4	42.8580	9.6406	884	4.45**
B x D	20	9.4013	8.1522	720	1.15
B x E	1	493.5701	23.5034	776	21.00**
C x E	4	3.0879	9.7162	884	0.32
C x S	144	17.1154	8.1522	720	2.10**
D x E	20	12.7454	8.1522	720	1.56
D x S	720	8.1522	—	—	—
A x B x C	8	20.8123	9.7381	904	2.14*
A x B x D	40	11.7244	8.1522	720	1.44*
A x B x E	2	47.4890	23.2981	796	2.04
A x C x E	8	5.4513	9.6643	904	0.56
A x D x E	40	10.0575	8.1522	720	1.23
B x C x E	4	3.9948	9.6546	884	0.41
B x D x E	20	10.0191	8.1522	720	1.23
A x B x C x E	8	8.8152	9.7802	904	0.90
A x B x D x E	40	12.6758	8.1522	720	1.55*

*p < .05

**p < .01

instruction x tempo effect, the age x tempo effect, and the instruction x age x category effect. As for the heart rate analysis, only unconfounded comparisons were tested, again via the Tukey procedure.

For the instruction x tempo effect, there are 15 paired comparisons, of which nine are unconfounded. The critical value for the difference in totals is 262.76. Four of the nine unconfounded comparisons are significant (see Table 16). In both cognitive tempo groups, there was significantly more responding in the control word instruction than in the other two instruction groups, which did not differ among themselves. This indicates that the instruction x tempo effect arose in the confounded comparisons, which although of potential interest in view of Hypothesis III, are not readily interpretable in the present study.

For the age x tempo effect, there are six possible comparisons, of which four are unconfounded. The critical value for totals is 277.9. Of the four unconfounded comparisons, three were significant (see Table 17). For adults, impulsive subjects made larger responses than reflective subjects; for children, reflective subjects made larger responses than impulsive subjects. This result is interesting and unexpected, but probably irrelevant to the theoretical model, which predicts high order interactions. Those high order interactions did not materialize; but this could have been due in part to the significant age x tempo effect per se, which could be considered (from the point of view of the model) as sampling error. It is clear, however, that age and tempo are both related to GSC responsivity.

There are 435 paired comparisons in the instruction x age x category effect, of which 105 are unconfounded. The critical value for

Table 16. Tukey Test for Instructions x Tempo, Conductance Data.

Impulsive			Reflective			Instruction	Tempo
Target Word	Target Class	Control Word	Target Word	Target Class	Control Word		
--	91.2	<u>725.0</u>	236.6			Target Word	Impulsive
	--	<u>633.8</u>		6.9		Target Class	
		--			213.9	Control Word	
			--	138.5	<u>274.5</u>	Target Word	Reflective
				--	<u>413.0</u>	Target Class	
					--	Control Word	

Table 17. Tukey Test for Age x Tempo, Conductance Data.

Adults		Children		Age
Impulsive	Reflective	Impulsive	Reflective	
--	<u>370.0</u>	<u>685.8</u>		Impulsive Adults
	--		83.8	Reflective
		--	<u>399.6</u>	Impulsive Children
			--	Reflective

totals is 94.73. Of the 105 unconfounded comparisons, 27 were significant (see Tables 18, 19, and 20). If we assume that in order to contend that phonetographic or semantic generalization occurred, the difference between the relevant category and the neutral category must have been significant, then the only cell in which generalization was observed was the adults in the target class instruction condition, where semantic generalization (but not phonetographic generalization) was

Table 18. Tukey Test for Instruction x Age x Category, Conductance Data (Target Word Condition).

Children					Adults					Category	Age	Instruction
(a)	(b)	(d)	(e)	(c)	(a)	(b)	(d)	(e)	(c)			
---	84.6	82.7	100.5	82.9	91.9	23.4	2.5	46.0	20.2	(a) (b) (d) (e) (c)	Children	
	---	1.9	15.9	1.7								
		---	17.8	0.2								
			---	17.6								

					---	199.2	177.1	238.4	154.6	(a) (b) (d) (e) (c)	Adults	Target Word
						---	22.8	38.5	45.3			
							---	61.3	22.5			
								---	83.8			

										(a) (b) (d) (e) (c)	Children	
										(a) (b) (d) (e) (c)	Adults	Target Class
										(a) (b) (d) (e) (c)	Children	
										(a) (b) (d) (e) (c)	Adults	Control Word

Table 19. Tukey Test for Instruction x Age x Category, Conductance Data (Target Class Condition).

Children					Adults			Category	Age	Instruction
(a)	(b)	(d)	(e)	(c)	(a)	(b)	(d)	(e)		
61.6	3.5	52.8	12.1	5.0					Children	Target Word
					87.7	2.3	68.2	25.4	Adults	
								45.7		
---	26.5	31.7	26.8	26.3	65.8	22.2	12.9	32.7	Children	
	---	58.2	0.3	0.2						
		---	58.5	58.0						Target Class
			---	0.5					Adults	

					---	114.5	21.2	125.3	20.5	
						---	93.3	10.8	112.6	
							---	1.9		Control Word
							---	104.1	91.4	
							---	---	12.7	
							---	---	---	
									Children	Control Word
										Control Word

observed. This is consistent with the earlier conclusion drawn with regard to heart rate.

However, one ought perhaps also to insist that responses to the key word be greater than those to the repeated word control. That is, in order for generalization to be possible, there must have been a conditioned response to the key word. Only a few cells revealed this: adults in all three instruction conditions, and third graders only in the control word instruction group. That is, the failure to find semantic generalization or phonetographic generalization can be attributed either to the relatively weak strength of the conditioned response itself, or to a uniform generalization gradient. In the control word instruction group, where the response to the control word was different from that to the key word (and from the other three categories), no other differences were significant. This is consistent with either position, but may lend support to the notion of uniform gradients.

There is some evidence for both semantic and phonetographic generalization in the children in the target word condition (but not the target class condition), for which responses to the key word were greater than those to the neutral words. This must be considered as rather weak evidence, however, since responses to semantic and phonetographic words were not themselves significantly greater than those to the neutral words. One must also recognize that out of 105 comparisons, with an alpha of five percent, approximately five comparisons can be expected to arise from error alone.

The results of this analysis, then, do not provide any substantial support for Hypothesis I, although they are consistent with Hypothesis

II. As noted earlier, the results provided weak support for Hypothesis III.

A potentially more sensitive analysis was performed on the GSC data. Define $\lambda = [(\sum_{i=1}^5 X_i \text{ category d}) \div (\sum_{i=1}^5 X_i \text{ all categories})] \times 100$, where X refers to the GSC change score for a particular subject and word, and i refers to words. This is roughly interpreted as the percentage of total responding reflecting semantic generalization. The resulting totals appear in Table 21. A 3 (instruction) $\times$ 2 (age) $\times$ 2 (tempo) ANOVA was performed on the λ values, with the results summarized in Table 22. As can be seen, the only effect reaching statistical significance was the main effect for instructions. Examination by means of the Newman-Keuls procedure (Winer, 1962, p. 80) revealed that the λ value for the target class group was significantly ($p < .05$) greater than that for either the target word group, or the control word group; the latter two did not differ significantly from each other. That is, the instruction effect noted earlier was verified in both age groups when the λ -ratio was used. Further, the instruction variable did not seem to interact with age or tempo.

What happens if λ' is defined in terms of phonetographic generalization? The resulting totals appear in Table 24; the corresponding ANOVA is summarized in Table 25. As can be seen, in addition to a significant instruction $\times$ tempo interaction, the instruction $\times$ age $\times$ tempo interaction was statistically significant. The Tukey critical value ($p < .05$) for totals is 26.31; there are a total of 66 paired comparisons, of which 24 are unconfounded. The Tukey analysis is presented in Table 26. Of the 24 unconfounded comparisons, only two were statistically significant. Both of these refer to adults: in the

Table 21. Cell Totals for λ -Analysis, Conductance Data.

Age	Cognitive Tempo	Instruction		
		Target Word	Target Class	Control Word
Children	Impulsive	78.6	92.8	72.6
Children	Reflective	74.6	89.6	70.4
Adults	Impulsive	78.3	89.6	63.5
Adults	Reflective	67.8	100.7	59.7

-- Note. N = 4 per cell.

Table 22. Analysis of Variance Summary, λ -Analysis, Conductance Data.

Source	d.f.	MS	F
Instructions	2	185.6815	27.97**
Age	1	7.5200	1.13
Tempo	1	3.3075	0.50
Instructions x Age	2	12.0165	1.81
Instructions x Tempo	2	7.9919	1.20
Age x Tempo	1	0.8008	0.12
Instructions x Age x Tempo	2	7.3902	1.11
Error	36	6.6392	--

**p < .01

Table 23. Newman-Keuls for Instructions, λ -Analysis, Conductance Data.

Control Word	Target Word	Target Class	Instruction
---	33.1	106.5*	Control Word
	---	73.4*	Target Word

*p < .05

Table 24. Cell Totals for λ' -Analysis, Conductance Data.

Age	Cognitive Tempo	Target Word	Instruction	
			Target Class	Control Word
Children	Impulsive	73.1	74.8	70.1
Children	Reflective	77.4	76.9	65.2
Adults	Impulsive	66.7	82.0	65.2
Adults	Reflective	86.8	51.9	67.1

-- Note. N = 4 per cell.

Table 25. Analysis of Variance Summary, λ' -Analysis, Conductance Data.

Source	d.f.	MS	F
Instructions	2	20.7033	2.32
Age	1	6.6008	0.74
Tempo	1	0.9075	0.10
Instructions x Age	2	7.1633	0.80
Instructions x Tempo	2	42.9325	4.80*
Age x Tempo	1	1.9200	0.21
Instructions x Age x Tempo	2	40.6875	4.55*
Error	36	8.9415	--

* $p < .05$

Table 26. Tukey Test for Instructions x Age x Tempo Effect, λ' -Analysis, Conductance Data.

Children				Adults			Age	
Impulsive		Reflective		Impulsive		Reflective	Instruction	Tempo
Target Word	Control Word	Target Word	Control Word	Target Word	Control Word	Target Word		
---	1.7	3.0	4.3	6.4			Target Word	Impulsive
---	---	4.7	2.1	7.2			Target Class	
	---	---	4.9	4.9			Control Word	
		---	0.5	12.2		9.4	Target Word	Children
		---	---	11.7		25.0	Target Class	
		---	---	---		1.9	Control Word	
				---	15.3	1.5	Target Word	Impulsive
				---	---	16.8	Target Class	
				---	---	---	Control Word	
						---	Target Word	Adults
						34.2	Target Class	
						---	Control Word	
						---	Target Word	Reflective
						15.2	Target Class	
						---	Control Word	

target class instruction, impulsive subjects had higher λ' ratios than reflective subjects (i.e. the former showed more phonetographic generalization). Among reflective adults (but not impulsive adults), λ' ratios were higher in the target word instruction than the target class instruction.

These results suggest that instructions also affected the degree of phonetographic generalization, but only among adults and even then only by interacting with tempo. Neither λ analysis necessarily pertains directly to the P-S shift, since the analyses do not allow comparisons of the absolute amount of generalization. However, although the results are irrelevant to the P-S shift (Hypothesis I), they do support Hypothesis III.

Generalization of the OR: The Motor Response Task, List 2

So as further to examine replicability of the results across words, a second test list was administered to a second sample of adults, as noted above. Only GSC responses in that list will be reported here; also, no attempt was made to assign subjects to cognitive tempo groups, because of the small n available; and only the target word (car) and control word (flower) instruction conditions were used. The cell totals are presented in Table 27; the results of a 2 (instruction) x 5 (category) x 5 (word) ANOVA appear in Table 28. As can be seen, all effects and interactions were statistically significant. The only effect of direct theoretical interest, however, was the instruction x category interaction. This was examined by means of the Tukey procedure. Of the 45 paired comparisons, 25 were unconfounded. The critical value ($p < .05$) for totals was 48.00; comparisons appear in Table 29. Of the 25 unconfounded comparisons, 13 were significant.

Table 27. Cell Totals, List 2, Conductance Data.

Instruction		
Category	Target Word	Control Word
(a) Key Word	211.91	70.43
(b) Control Word	71.51	155.83
(c) Phonotographic	96.90	70.77
(d) Semantic	137.71	65.21
(e) Neutral	85.78	66.98

-- Note: N = 4 per cell.

Table 28. Analysis of Variance Summary, Conductance Data, List 2.

Source	d.f.	MS	d.f. error	MS error	F
Instructions	1	152.4083	126	15.5135	9.82**
Category	4	66.2158	164	6.5618	10.09**
Words	20	10.7312	120	4.4247	2.43**
Subjects	6	237.2895	120	4.4247	53.63**
Instructions x Category	4	170.7662	164	6.2219	27.45**
Instructions x Words	20	7.9444	120	4.4247	1.80*
Category x Subjects	24	13.7723	120	4.4247	3.11**
Words x Subjects	120	4.4247	--	--	--

*p < .05

**p < .01

Examination of Table 29 indicates that in both instruction groups there was more responding to the word in the instructions than to words in all other categories. In the control word group, all other categories did not differ among themselves. For the target word group, however, responses to the semantic category were significantly greater than those to either the control word category, or the neutral category; they were also significantly greater than the corresponding value for the control word group. Thus, results from List 2 were consistent with those from List 1, in that semantic generalization was evident.

Habituation and Dishabituation of the GSC OR (List 1)

Recall that Luria and Vinogradova (1959) argued that giving words signal value via instructions to perform a motor response served to delay habituation of the OR. It seems reasonable to ask if any evidence for this were obtained in the present study. It is important to note that the present analysis is chiefly concerned with habituation of phasic responses: habituation involving changes in tonic level of conductance may have occurred, but is not of theoretical significance in the present study. That such habituation may have occurred is suggested by the presence of significant main and interaction effects involving words in the GSC analysis above. Words within a category were treated as a random effect (after Clark, 1973); but each category contained one word from each of the five randomized blocks in the test list.

Habituation effects were examined only for GSC data from adults, on List 1, on the five repeated presentations of the key word (flower). For each occurrence of the word, the mean GSC score over the eight subjects in an instruction condition was obtained. A trend analysis using the method of orthogonal polynomials (Crow, Davis & Maxfield, 1960, p. 186f.)

was performed for each instruction condition, and the regression equation $Y = f(x)$ determined. A somewhat unorthodox procedure followed.

To determine the minimum responsivity which an instruction produced, the first derivative of the regression equation was obtained [i.e. $Y' = f'(x)$], and set equal to zero to obtain local inflection points; naturally, a positive second derivative at a particular point implies that the point is a local minimum. No claim is made here that this procedure is original, but it is certainly not a standard technique. It has the virtue that it allows parameterization of the curves; however, it does not allow for subsequent statistical analysis.

Further, consider Figure 1. The amount of habituation, H , over the test list can be seen to be proportional to $\int_1^5 g(x) dx - \int_1^5 f(x) dx$; but the antiderivative for both functions, $G(x)$ and $F(x)$ respectively, can be determined. By the Fundamental Theorem, $H = [G(5) - G(1)] - [F(5) - F(1)]$. Thus, one can calculate H to determine the relative amount of habituation occurring over the test list. This value can of course be negative, implying that the "habituation" curve really reflects response increase.

The resulting regression equations are as follows: for the target word group, $Y = 4.54x^2 - 32.47x + 127.55$; target class group, $Y = 0.34x^3 - 1.46x^2 - 24.41x + 121.81$; control word group, $Y = 6.77x^2 - 40.62x + 119.13$. One does expect habituation curves to be exponential functions, although the prediction would be quadratic equations (Thompson & Spencer, 1966). The most important conclusion in this section, then, is that imparting signal value by defining the target as a set of words does not simply "move over" the habituation curve, but appears to alter its shape. This suggests that Luria and Vinogradova's (and Sokolov's, 1963)

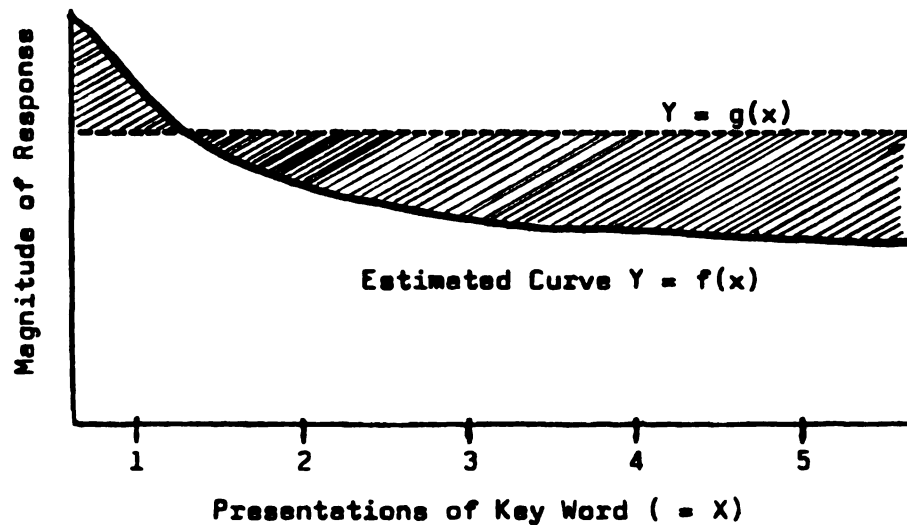


Figure 1. Amount of Habituation as Area Between Curves

description of the effects of signal value on habituation of the OR was too simplistic.

The three instruction conditions (target word, target class, and control word) produce minima at $X = 3.58$, 6.15 , and 3.12 presentations respectively. That is, minimal responding occurred earliest in the control word group, followed by the target word group, and last in the target class group. This is consistent with the assumption that habituation would be retarded in the target class group.

The value of H , defined above, can be calculated from the regression equations. For the target word condition, $H = [510.2] - [308.64] = 201.56$; for comparison across instructions, this value can be expressed as a percentage of the area under $g(x)$, thus: $H_1 = \frac{201.56}{510.20} \times 100 = 39.5\%$. Similarly, for the target class condition, $H = [487.24] - [183.60] = 303.64$ and $H_1 = 62.3\%$; and for the control word condition, $H = [476.52] - [269.32] = 207.20$, and $H_1 = 43.5\%$. Thus, the greatest relative amount of habituation occurred in the target class condition, followed by the control word condition, and the target word condition.

The analyses in this section have been included because it is rare for investigators dealing with habituation of the OR to report the effects of experimental manipulations on parameters of the habituation curve. However, an optimal test of the habituation process would have involved examination of the responses to the habituation list: the first test stimulus was presented late in the list of words that subjects received. This procedure was presumably necessary in order to demonstrate semantic generalization; however, if one were to examine habituation over all words, one would probably observe that the rate of habituation was greater early in the habituation list. Thus, the conclusions above can probably best be interpreted as characterizing the course of habituation fairly late in the process.

After the last test stimulus, subjects were shown a picture of a flower, which was presented as though it were the next word in the list. It is interesting to ask whether the response to the picture was a function of age or instruction condition. However, earlier analyses indicated that the variables affected responsivity on the test list; and dishabituation might be expected to reflect in part the effects of habituation. To examine dishabituation effects, the response to the last neutral (category a) stimulus was treated as a covariate. A preliminary 3 (instruction) $\times$ 2 (age) ANOVA was performed on responses to the neutral word, to ensure that neither variable affected the covariate: none of the effects reached statistical significance (see Tables 30 and 31). An analogous analysis of covariance (Bruning & Kintz, 1968, p. 177f.) was performed on the responses to the picture: see Table 32. Neither the instruction effect nor the interaction were significant, but the age effect was significant ($p < .01$): adults responded more than children.

Table 30. GSC Responses to Last Neutral Stimulus and Picture as a Function of Age and Instruction (Cell totals).

Age	Instruction	Stimulus	
		Neutral Stimulus	Picture
Children	Target Word	43.60	65.30
Children	Target Class	42.10	57.60
Children	Control Word	45.60	82.30
Adults	Target Word	28.05	103.43
Adults	Target Class	39.10	74.00
Adults	Control Word	57.22	113.80

-- Note: N = 8 per cell.

Table 31. Analysis of Variance Summary on Response to Last Neutral Stimulus.

Source	d.f.	MS	F
Instructions	2	15.9395	<1.00
Age	1	1.0005	<1.00
Instructions x Age	2	11.5568	<1.00
Error	42	16.0244	--

Table 32. Analysis of Covariance Summary for Response to Picture.

Source	d.f.	Adjusted MS	F
Instructions	2	41.7129	1.93
Age	1	180.7673	8.36**
Instructions x Age	2	24.6869	1.14
Error	41	21.6239	--

**p < .01

Generalization of the Motor Response: EMG Data

There are muscle potential components of the OR, involving gross orientation of the receptor apparatus; however, it is less clear whether EMG activity recorded over the thenar muscle ought to be considered part of the physiological OR. There can be little doubt that EMG activity at this site should reflect tonic changes in muscle tension, but the extent to which the muscle participates in the phasic OR is not clear. Certainly it is conceivable that phasic EMG changes recorded in the present study reflected the OR; but it is also conceivable that such changes reflected simple generalization of the motor response. That is, EMG changes might not reflect attentional activity in the same way as the phasic changes in HR and GSC are presumed to index such activity. Nevertheless, EMG data are of interest if only in that they represent a relatively sensitive measure of the motor response itself, particularly in view of the predictions involving cognitive tempo (especially Hypothesis IV above).

The EMG data are summarized in Table 33. A 3 (instruction) x 2 (age) x 2 (tempo) x 5 (category) ANOVA, with subjects and words treated as random effects, was performed, and appears in Table 34. As can be seen, the only effects reaching statistical significance were the main effect for category and the instruction x category interaction. The latter was examined by means of the Tukey procedure. There were 105 total paired comparisons, of which 45 were unconfounded. The critical value ($p < .05$) for totals is 1294.6. The comparisons appear in Table 35. Of the 45 unconfounded comparisons, 15 were significant. Regardless of instruction, the word mentioned in the instructions (flower or boy) led to more responding than all other categories, which were not different

Table 33. Cell Totals for EMG Data, Summed over Subjects and Words.

Category	Instruction		
	Target Word	Target Class	Control Word
Impulsive Adults			
(a) Key Word	+664	+547	+ 77
(b) Control Word	+ 55	+ 99	+608
(c) Phonotographic	+ 99	+166	+ 73
(d) Semantic	+ 88	+502	+ 10
(e) Neutral	- 23	+200	+130
Reflective Adults			
(a)	+688	+335	- 20
(b)	+111	+ 68	+567
(c)	+114	+102	+ 23
(d)	- 94	+ 67	+ 39
(e)	- 89	+ 48	+173
Impulsive Children			
(a)	+377	+209	+111
(b)	+ 82	+183	+682
(c)	+171	+112	+ 50
(d)	+205	+228	+ 40
(e)	+ 94	+157	+ 11
Reflective Children			
(a)	+769	+746	+135
(b)	+ 78	+183	+483
(c)	+ 77	+112	+ 88
(d)	+133	+662	+127
(e)	+ 40	+105	- 34

-- Note. N = 4 per cell.

Table 34. Analysis of Variance Summary, EMG Data.

Source	d.f.	MS	Error MS	d.f.	F
A (Instructions)	2	1495.8033	1163.6758	796	1.29
B (Age)	1	801.9675	1191.8885	776	0.67
C (Category)	4	10,191.6071	1068.5240	884	9.54**
D (Word)	20	240.7629	1223.0922	720	0.20
E (Cognitive Tempo)	1	26.7008	1193.4079	776	0.02
S (Subjects)	36	1044.3697	1223.0922	720	0.85
A x B	2	208.4700	1164.9217	796	0.18
A x C	8	9134.4221	1048.4759	904	8.71**
A x D	40	201.5567	1223.0922	720	0.16
A x E	2	47.6633	1163.8667	796	0.04
B x C	4	468.9821	1070.6354	884	0.44
B x D	20	334.0896	1223.0922	720	0.27
B x E	1	3898.8075	1188.0897	776	3.28
C x E	4	666.3404	1071.9692	884	0.62
C x S	144	410.6496	1223.0922	720	0.34
D x E	20	393.0396	1223.0922	720	0.32
D x S	720	1223.0922	--	--	--
A x B x C	8	439.1033	1049.5729	904	0.42
A x B x D	40	226.3496	1223.0922	720	0.19
A x B x E	2	2289.1600	1167.8210	796	1.96
A x C x E	8	414.0092	1048.6439	904	0.39
A x D x E	40	205.3546	1223.0922	720	0.17
B x C x E	4	1798.2804	1067.3008	884	1.68
B x D x E	20	186.6962	1223.0922	720	0.15
A x B x C x E	8	469.0579	1052.1258	904	0.45
A x B x D x E	40	284.0450	1223.0922	720	0.23

**p < .01

Table 35. Tukey Test for Instruction x Category Effect, EMG Data.

Target Word					Target Class					Control Word					Instruction	
(a)	(b)	(d)	(e)	(c)	(a)	(b)	(d)	(e)	(c)	(a)	(b)	(d)	(e)	(c)	Category	
----	2172	2166	2476	2037	661					<u>2195</u>					(a)	
	----	6	304	135	207					<u>2014</u>					(b)	
		----	310	129	1127					108					(d)	Target
			----	439	488					258					(e)	Word
				----	31									227	(c)	
										<u>1534</u>					(a)	
					----	1304	378	<u>1327</u>	<u>1345</u>	<u>1807</u>					(b)	
						----	926	23	41	1235					(d)	Target
							----	949	967						(e)	Class
								----	18	230					(e)	
									----					258	(c)	
															(a)	
										<u>2037</u>	79	23	69		(b)	Control
										----	<u>2116</u>	<u>2060</u>	<u>2106</u>		(d)	Word
										----	56	10			(e)	
										----	46				(c)	

among themselves. That is, interpretation of EMG activity does not differ materially from the previous description of overt motor responses.

While it is possible that confounded comparisons were involved in the interaction, it is clear that the EMG data did not reveal the clear tempo differences which were predicted in Hypothesis IV. It is important to keep in mind, however, that the earlier analysis examining correlations between overall EMG activity and cognitive tempo did find some support for Hypothesis IV, at least among adults. Here, cognitive tempo was determined only by a median split.

All the analyses reported thus far have relied on the a priori categories of words from which the test lists were constructed. However, to assume that those categories were reflected in psychological similarity judgments may not be a valid assumption. In order to examine the degree to which generalization of the OR reflected judgments of similarity, MDS and HC techniques were employed.

Generation of Dissimilarity Data: A Methodological Summary

The word sorting task yielded similarity data based on the number of subjects sorting two words into the same pile (alternatively, dissimilarity data based on number of subjects sorting two words into different piles); such data can be analyzed by either MDS or HC techniques to obtain a representation of the implicit semantic relations underlying the sorting data (Fillenbaum & Rapoport, 1971). This procedure, introduced by Miller and his colleagues, is now well demonstrated and widely used.

The application of scaling techniques in psychophysiological research is, however, largely unprecedented. The present author is not aware of

any previous research of this type, nor is any indicated, for example, in Harris' (1972) bibliography (though that is now somewhat out of date). This is probably due in large part to lack of familiarity with the techniques, as well as the rather depressing lack of substantial contact between researchers dealing with semantics -- where the techniques are widely used -- and those dealing with semantic generalization. The latter have been handicapped by the lack of a convenient method for generating dissimilarity data, as well (the method used in the present study is somewhat tenuous, technically speaking, although the focus here lies largely in comparing solutions from different age and instruction conditions, in which the method used is of course constant). It is assumed that differences in magnitude of the GSC OR reflect perceived dissimilarity, such that the greater the difference in OR, the greater the perceived dissimilarity in the two words. This is of course consistent with the feature-matching model, but it does require assumptions about the processes whereby the OR is generated. One can produce dissimilarity data by summing these differences over subjects. The author has written a Fortran IV program, DISRDAT [an acronym for "Dissimilarity from Ordinal Data"], which will generate dissimilarity data from either the Word Sorting task or the motor response task, and which incorporates several output options making the program useful in many other situations as well; this program appears in Appendix B. The dissimilarity matrices which result formed the "raw" data for analysis by means of the scaling procedures. The basic questions examined below refer to whether the solutions for the motor response task data resemble those for the word sorting data, and whether the degree of resemblance is related to the variables age and instruction (original plans to examine effects of

cognitive tempo proved impractical both because this would effectively have multiplied the already cumbersome numbers of analyses by far more than a factor of two, and because such analyses would have been based on ns of four per group.

Hierarchical Clustering Analyses

Hierarchical clustering solutions were obtained for both "Min" and "Max" (connectedness and diameter) methods (Johnson, 1967), for the following groups, with separate solutions for children and adults: word sorting data; motor response task data, with separate solutions for each of the three instruction groups; and response strength to the stimulus flower. Response strength data for third graders were based on the norms collected by Entwistle (1966). The data for adults were collected for the study, from a sample of 107 college students enrolled in a child psychology course at Michigan State University (response strength data appear in Table 36). Response values for the words flower and boy in the motor response task were the mean value for each subject over the five presentations of each word. The resulting solutions appear as Figures 2 through 11. The alpha values have been transformed as ratios based on a scale where the largest alpha is assigned a value of 1.0, to facilitate comparison across solutions. However, no rigorous attempt to obtain uniform orders of stimuli was made. In both HC and MDS solutions, the key and control words (flower and boy) appear only once.

One can compare the solutions crudely by scanning the figures from the "top" down, taking (arbitrarily, based on the a priori categories) the first five clusters which emerged. One can then construct an incidence matrix, where an entry consists of "1" if the

Table 36. Strength of Response of each Word in List 1 as Associate to the Stimulus "Flower".

Category	Word	Associative Strength	
		Children	Adults
(a)	FLOWER ^a	100	100
(b)	BOY	0	0
(c)	TOWER	0	0
(c)	HOUR	1	0
(c)	SHOWER	1	0
(c)	FOUR	0	0
(c)	POWER	1	1
(d)	STEM	2	19
(d)	DAISY	6	20
(d)	TREE	2	1
(d)	PLANT	25	7
(d)	ROSE	36	64
(e)	PLANE	0	0
(e)	BOAT	0	0
(e)	CAR	0	0
(e)	SHIP	0	0
(e)	TRAIN	0	0

-- Note. Data for children based on Entwistle (1966).

^aValue for "flower" set at sample size.

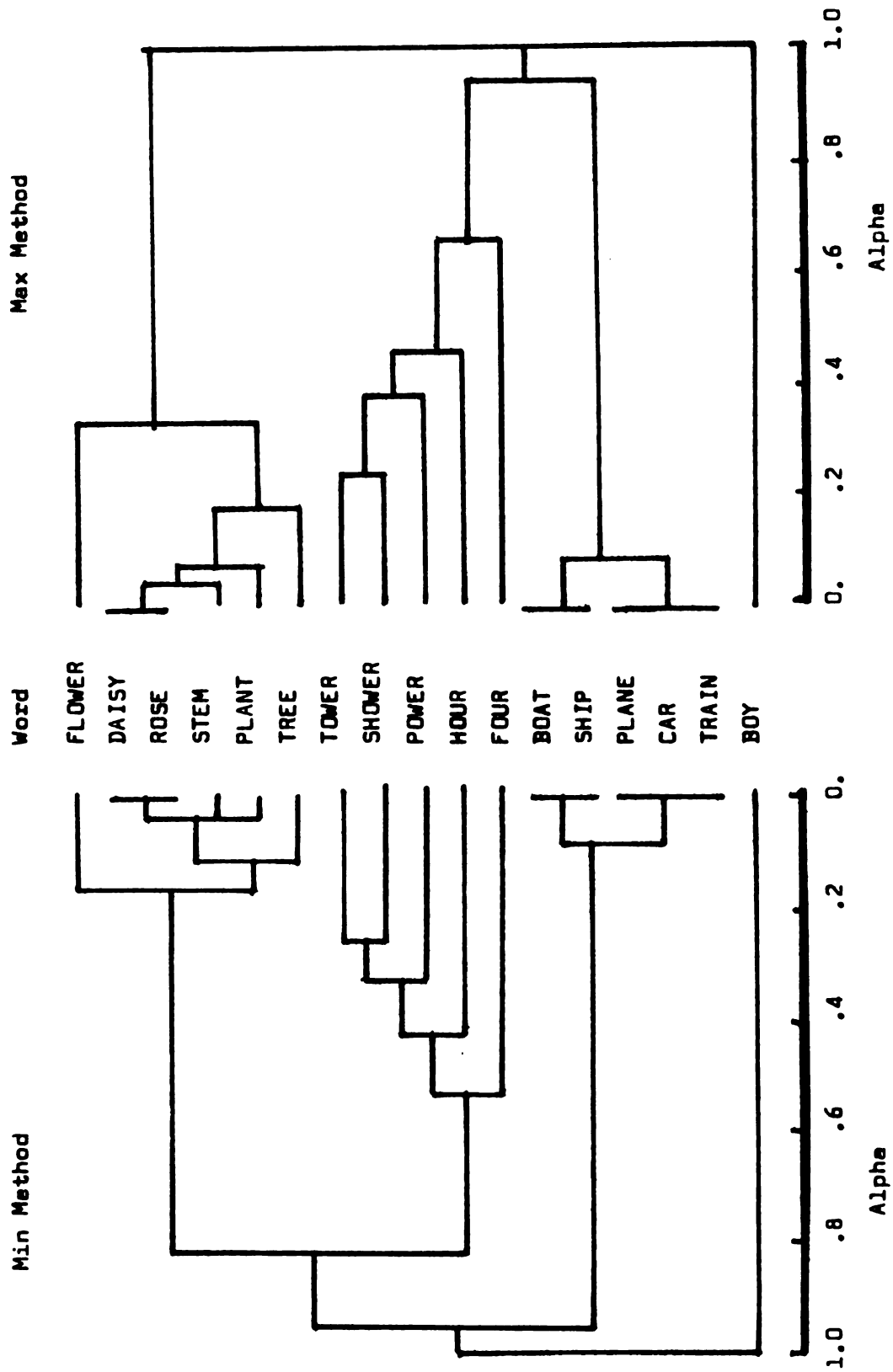


Figure 2. Dendograms for Word Sorting Task, Adults.

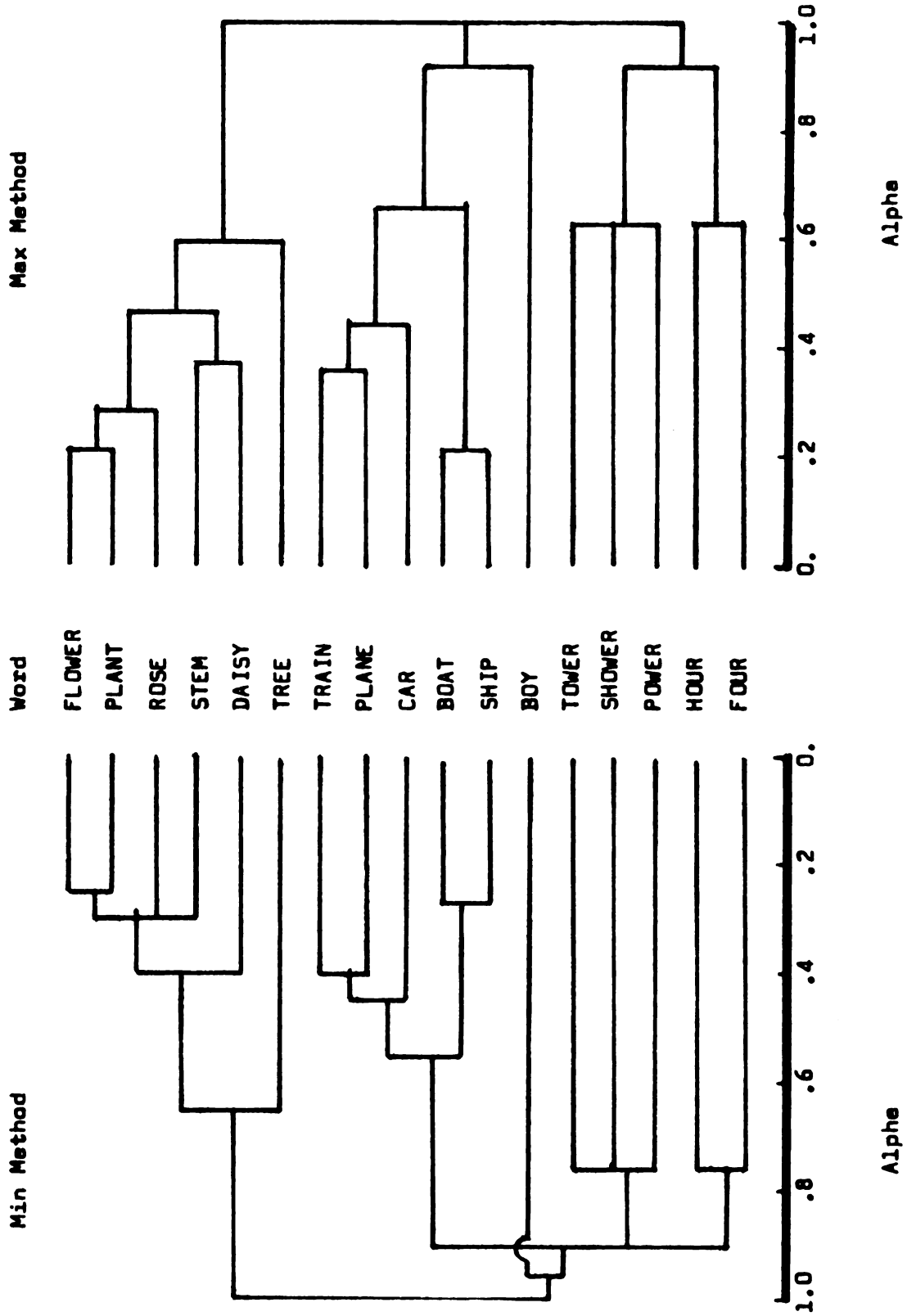


Figure 3. Dendograms for Word Sorting Task, Children.

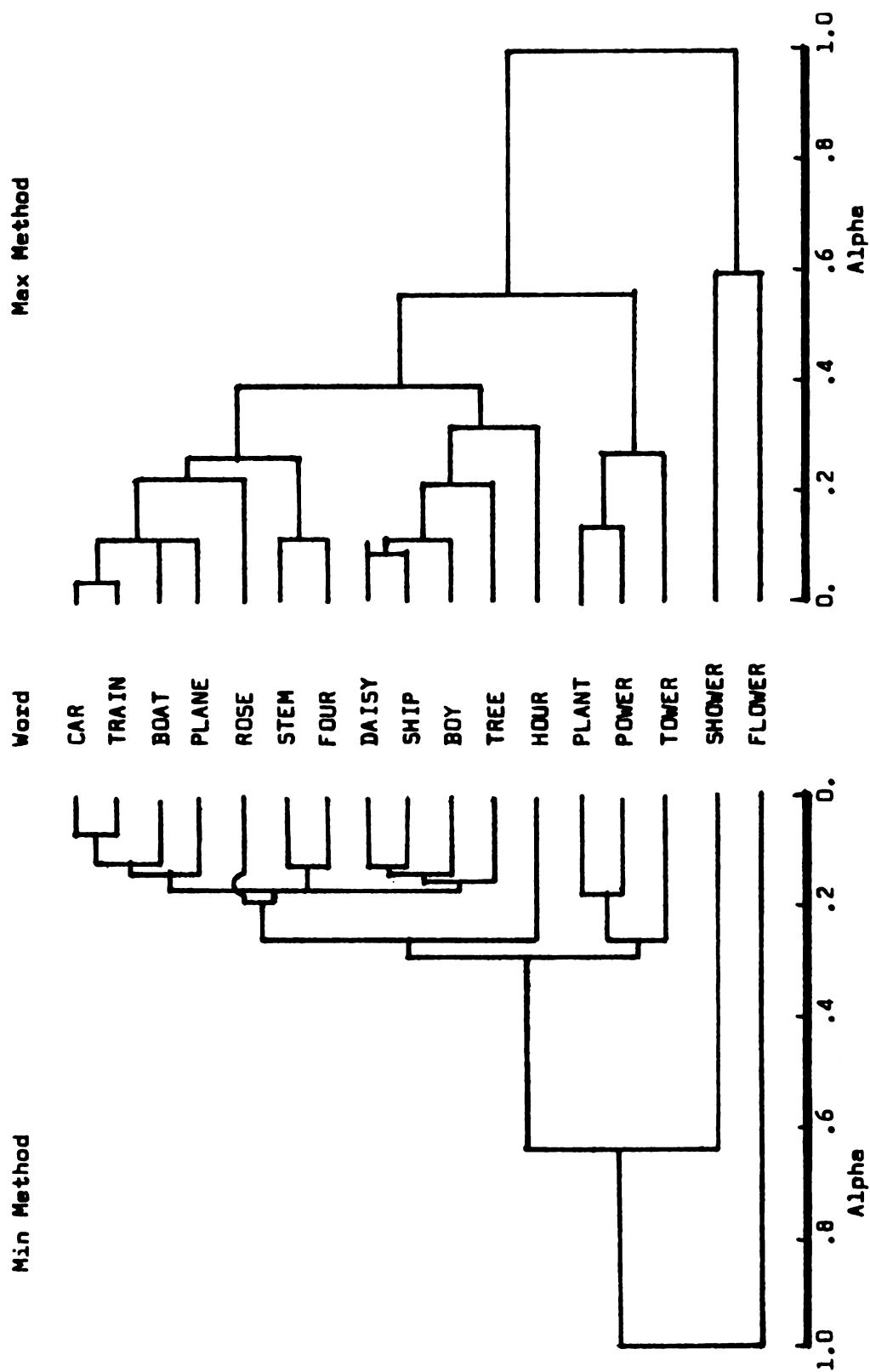


Figure 4. Dendrograms for Motor Response Task, Target Word Condition, Adults.

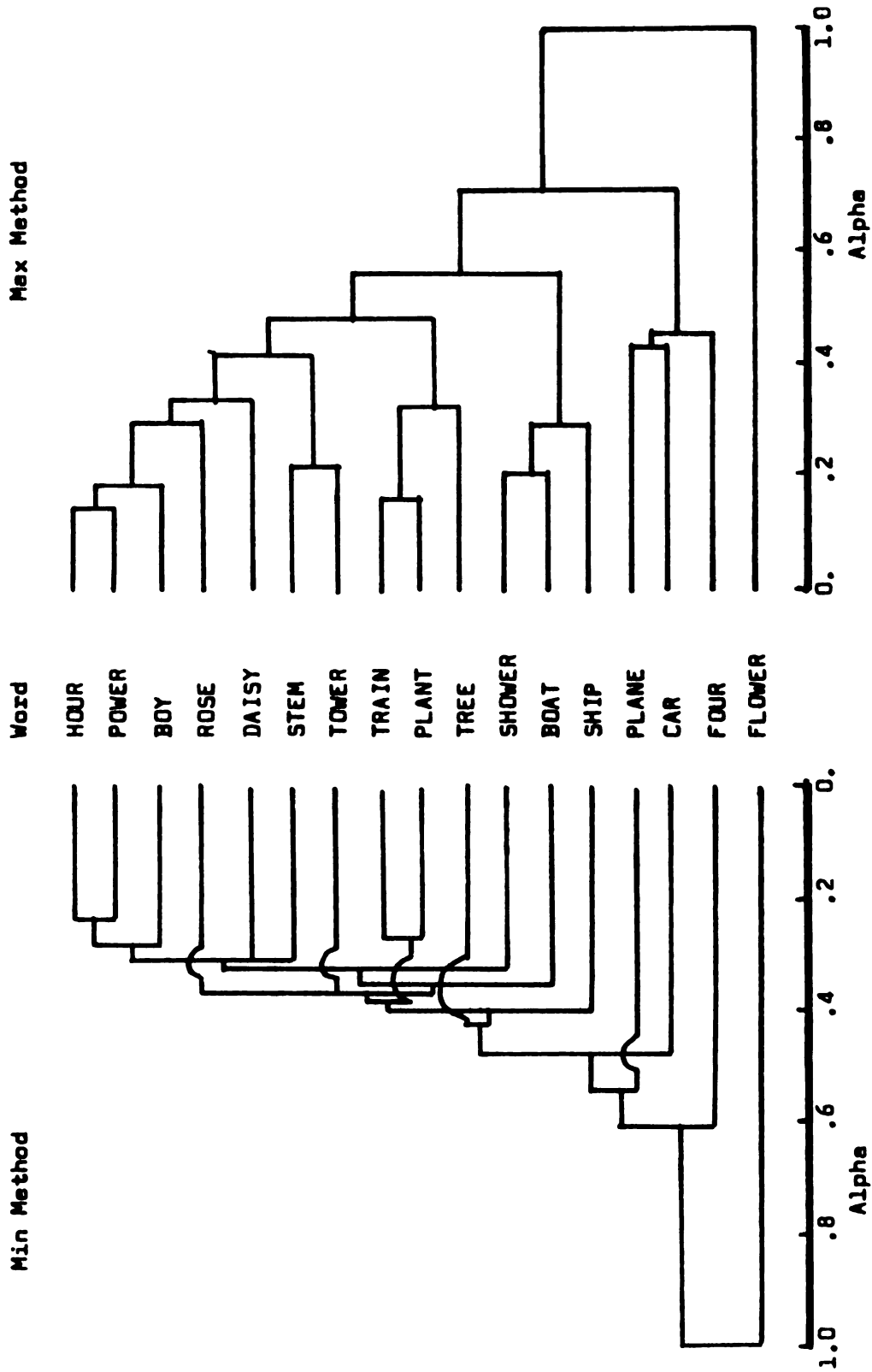


Figure 5. Dendograms for Motor Response Task, Target Word Condition, Children.

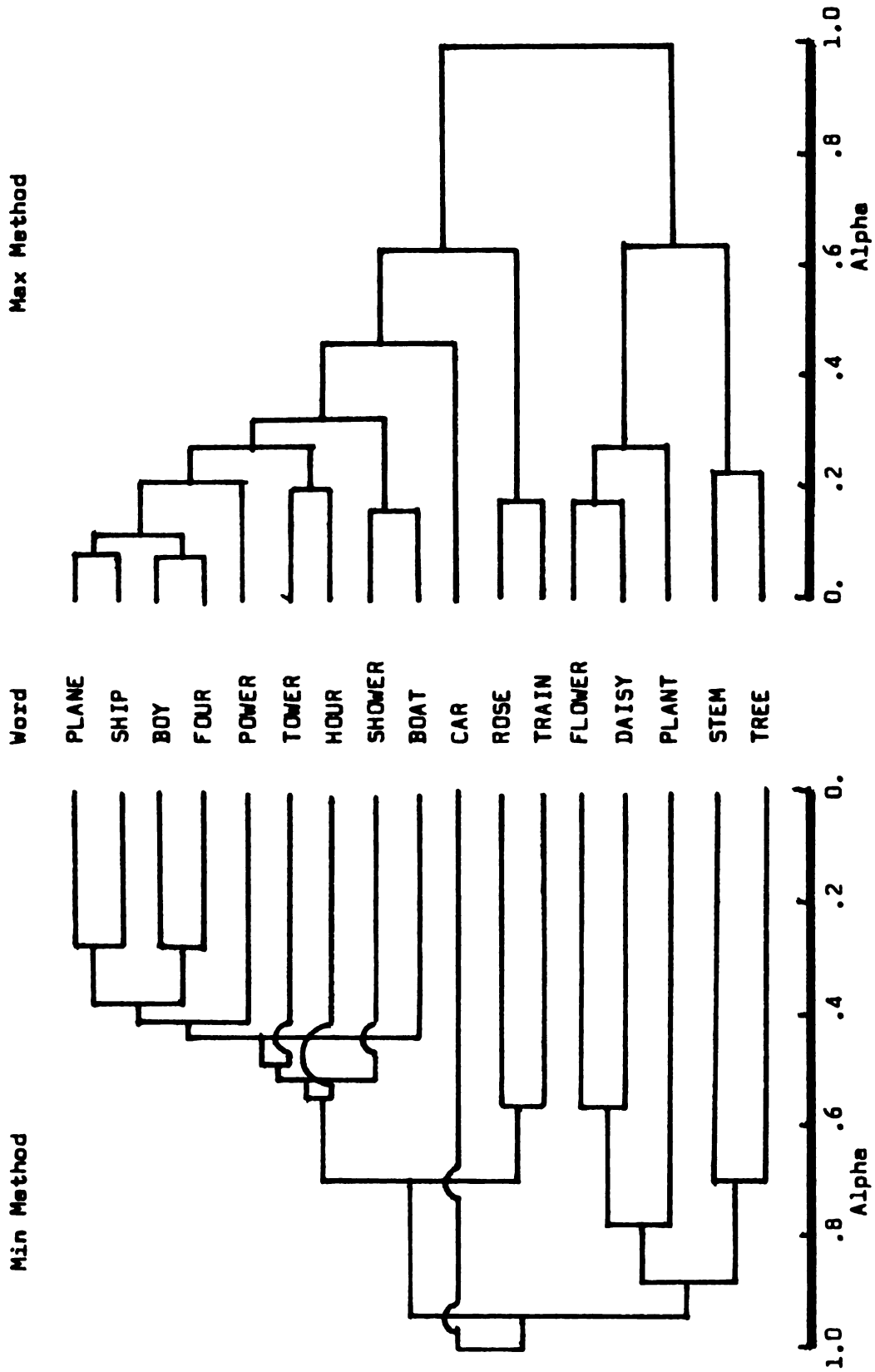


Figure 6. Dendrograms for Motor Response Task, Target Class Condition, Adults.

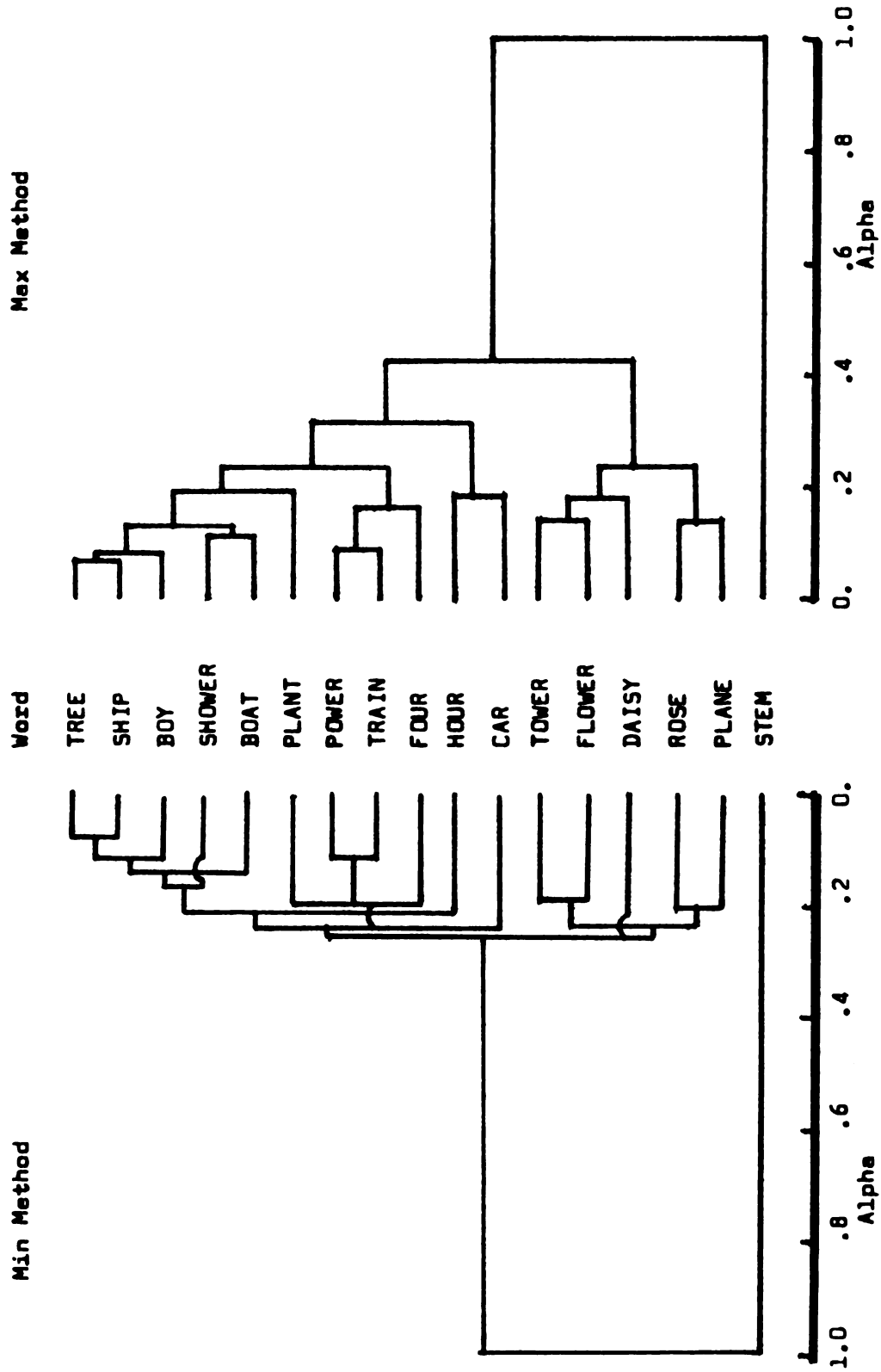


Figure 7. Dendrograms for Motor Response Task, Target Class Condition, Children.

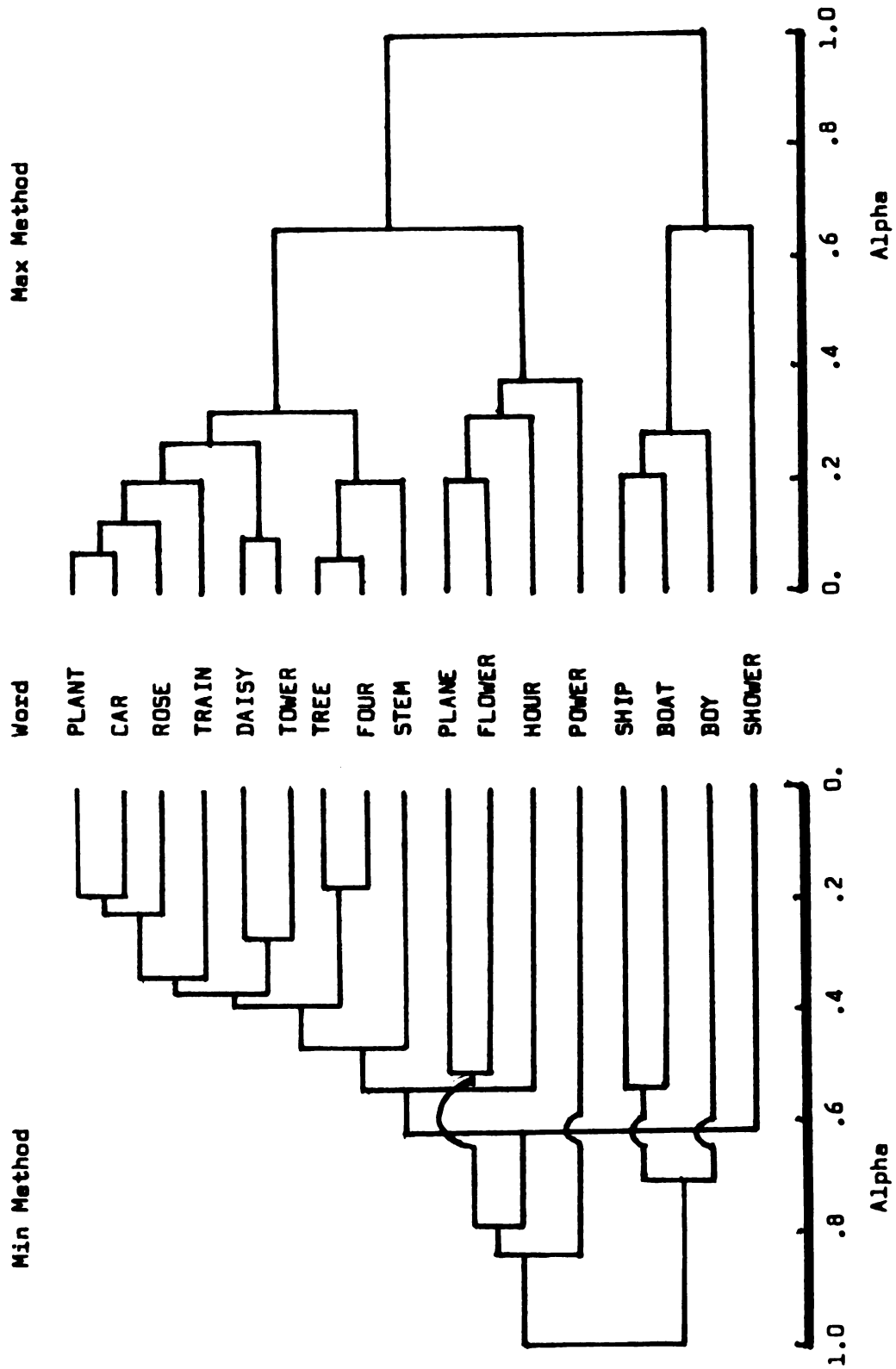


Figure 8. Dendrograms for Motor Response Task, Control Word Condition, Adults.

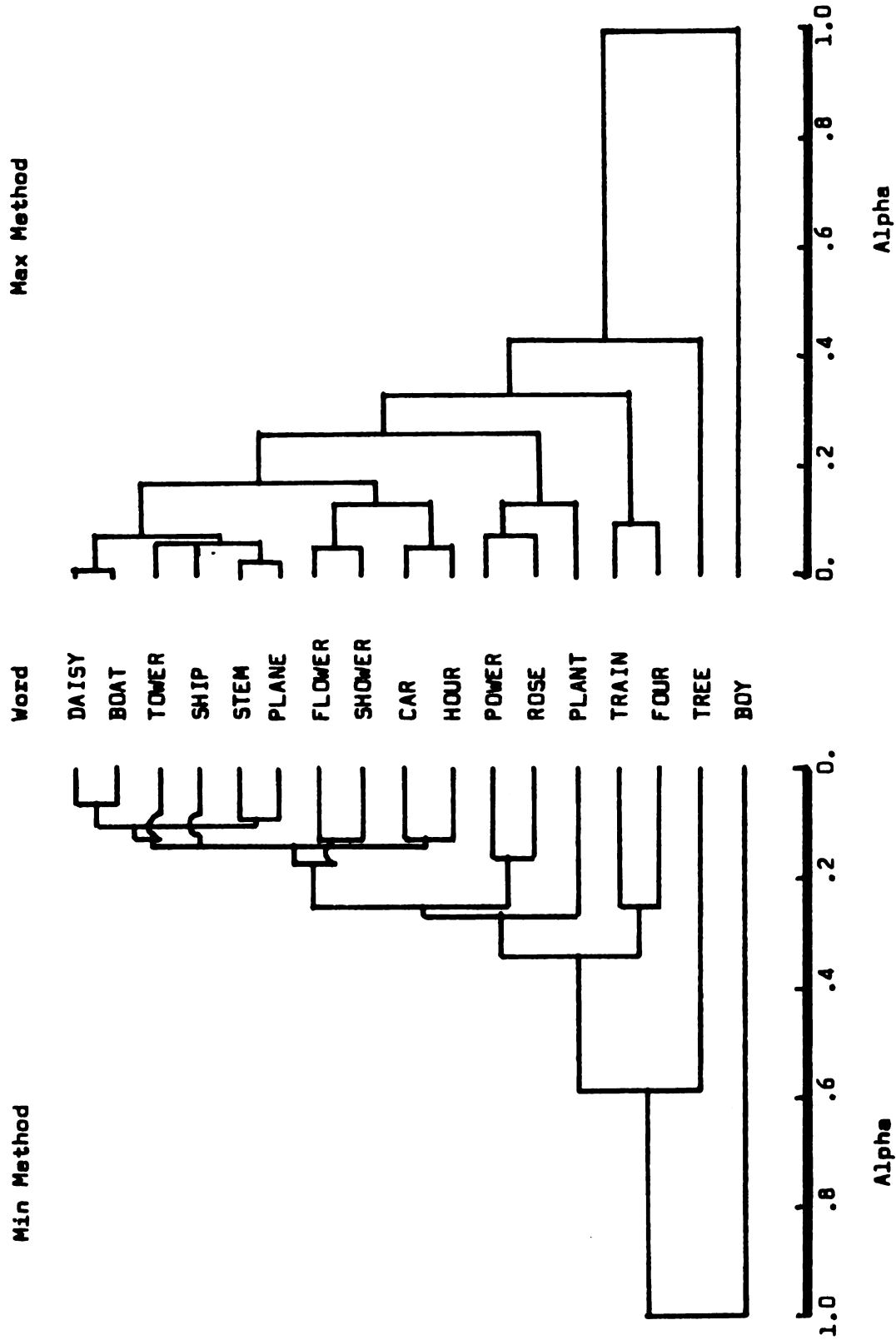


Figure 9. Dendrograms for Motor Response Task, Control Word Condition, Children.

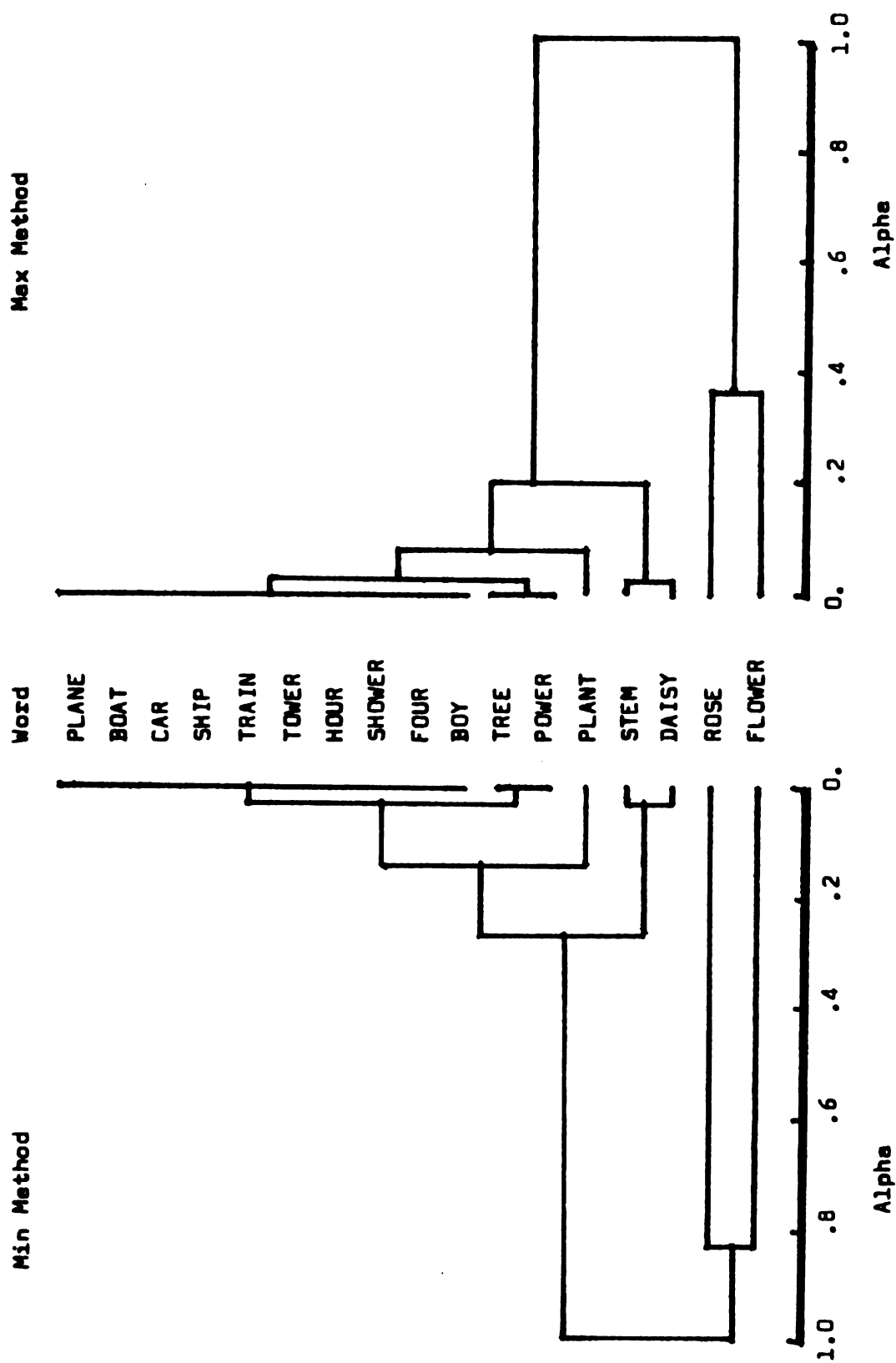


Figure 10. Dendograms for Response Strength Data, Adults.

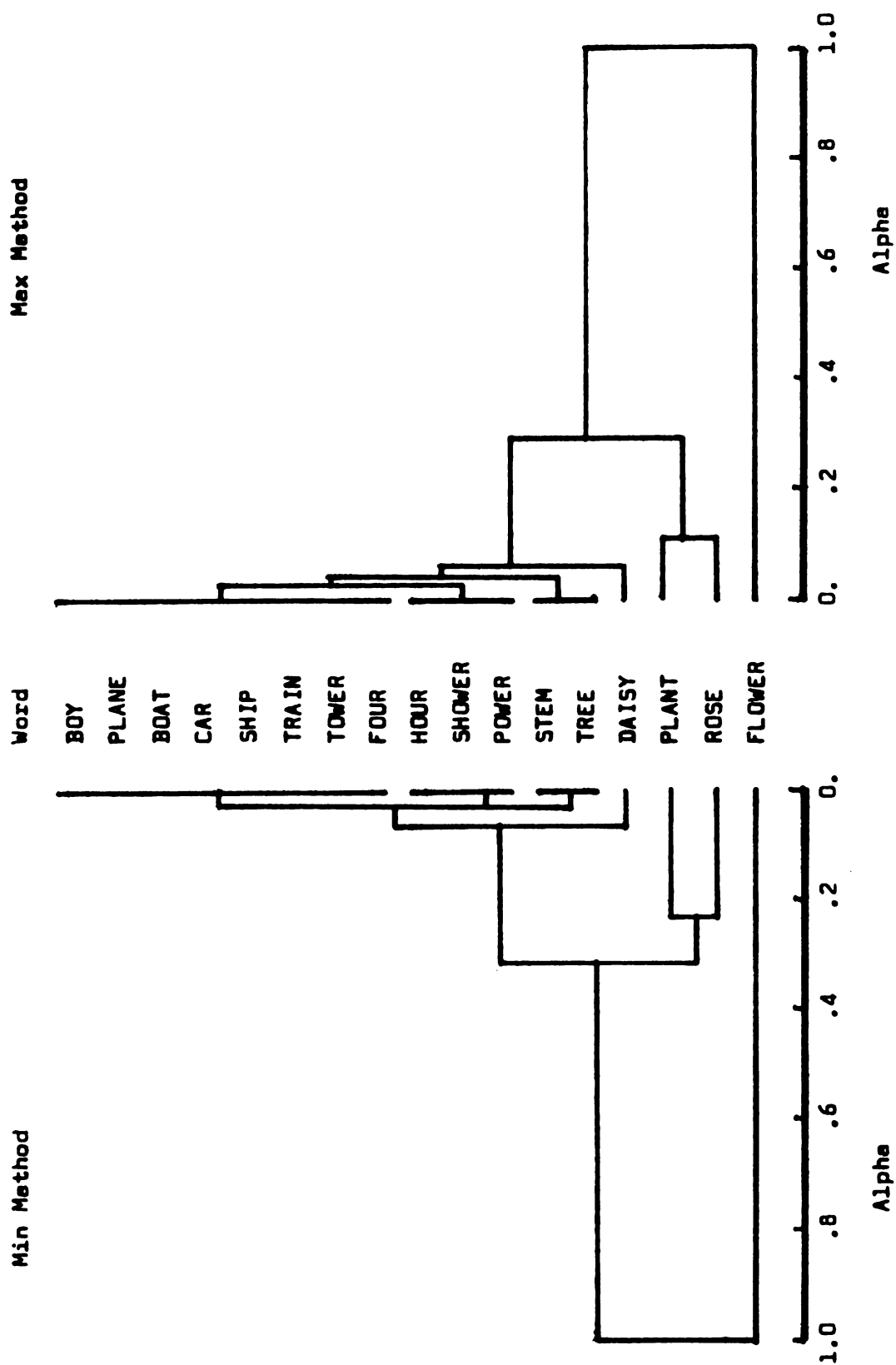


Figure 11. Dendrograms for Response Strength Data, Children.

stimuli are in the same cluster and "0" if they are in different clusters, allowing definition of a measure of dissimilarity,

$$D(C_1 C_2) = \frac{\text{number of entries where number is different}}{N(N-1)}$$

where N = number of stimulus objects (Johnson, cited in Fillenbaum & Rapoport, 1971). Although the sampling distribution of D is not known, one can examine the relative similarity between pairs of clusterings without actually testing the significance of the differences. The results, based on the max method clusterings only, appear in Table 37; conclusions based on the min method were roughly comparable, but are not reported here.

In addition to hypotheses V and VI, it is reasonable to predict (a) that motor response task solutions should resemble word sorting solutions more closely for adults than for children, if for no other reason than the anticipated differences in between-subject variability (Anglin, 1970). It is also possible to predict (b) that, for both age groups, $D(\text{word sorting, motor response task target class}) \leq D(\text{word sorting, motor response task target word}) < D(\text{word sorting, motor response task control word})$. Finally, (c) $D(\text{word sorting, motor response task target word}) < D(\text{word sorting, response strength data})$ for both age groups. Examination of Table 37 reveals that hypothesis (a) was confirmed in the target class and control word conditions, but the direction was opposite that predicted in the target word condition. Hypothesis (b) received partial support in children but not among adults. Finally, hypothesis (c) was supported for both adults and children; this is the only point in the present study in which predictions based on the cognitive theory are pitted directly against those based on the common

Table 37. Values of D for Hierarchical Clustering Solutions.

Adults					Children					Age
WS	MRT Target Word	MRT Target Class	MRT Control Word	MRT Response Strength	WS	MRT Target Word	MRT Target Class	MRT Control Word	MRT Response Strength	
--	.324	.309	.272	.368	.088	.324	.419	.390	.434	WS
--	--	.353	.338	.397	.294	.353	.434	.449	.456	MRT Target Word
	--	--	.294	.294	.250	.309	.390	.434	.279	MRT Target Class
		--	--	.404	.206	.324	.390	.419	.471	MRT Control Word
				--	.382	.426	.390	.375	.088	Response Strength
					--	.250	.375	.375	.456	WS
					--	--	.404	.419	.456	MRT Target Word
						--	--	.529	.390	MRT Target Class
								--	.449	MRT Control Word
									--	Response Strength

-- Note. WS = Word Sorting; MRT = Motor Response Task.

response theory: the results support the former, as expected.

Figures 2 through 11 provide general support for both hypotheses V and VI. In addition to the general similarity of word sorting and motor response task solutions, the a priori categories tended to emerge fairly clearly. The degree of correspondence is generally better for adults than for children. Thus, while the structure underlying the sorting and motor response tasks is not exactly identical, there is ample evidence that many of the same clusters can be found on both tasks.

Multidimensional Scaling Analyses

The method whereby the test list was constructed provides a priori reason to expect hierarchical clustering solutions adequately to reflect underlying structure. However, Sokal (1974) notes that ordination (as revealed by nonmetric MDS) is often useful in describing taxonomic structure in many stimulus domains. The dissimilarity data were therefore analyzed by means of Kruskal's MDSCAL program (Kruskal, 1964), with the Minkowsky exponent set at 2. Solutions were obtained for 1, 2, 3, and 4 dimensions; three different starting configurations were used at each value to ensure against the local minimum problem. Separate MDS solutions were found for each instruction x age cell, on both word sorting and motor response tasks (GSC data). Thus, a total of 144 separate MDS solutions were obtained. Clearly it is not practical to include them all in the present report, even in appendix form.

The resulting stress values appear in Table 38 (stress is a measure of "badness of fit"). Deciding whether solutions are non-random is often difficult. Kruskal (1964b) recommended three criteria:

1. The number of dimensions, m , must make S (stress) small and be such

Table 38. Stress Values of Multidimensional Scaling Solutions.

Age	Task	MRT Instruction	m=1	m=2	m=3	m=4
Adults	WS	Target Word	.008;.009;.009	.006;.006;.009	.004;.006;.010	.009;.010;.002
Adults	WS	Target Class	.017;.131;.010	.009;.008;.008	.007;.009;.006	.008;.007;.008
Adults	WS	Control Word	.010;.172;.010	.009;.009;.007	.004;.009;.008	.009;.008;.007
Adults	MRT	Target Word	.102;.104;.102	.077;.075;.075	.051;.040;.040	.034;.035;.032
Adults	MRT	Target Class	.296;.417;.296	.158;.158;.160	.108;1.00;.125	1.00;1.00;.075
Adults	MRT	Control Word	.559;.541;.618	.156;.162;.340	.109;.111;.106	.101;.981;.090
Children	WS	Target Word	.402;.402;.402	.120;.120;.120	.009;.010;.014	.010;.015;.021
Children	WS	Target Class	.174;.155;.181	.012;.016;.009	.004;.009;.008	.007;.010;.008
Children	WS	Control Word	.627;.616;.564	.381;.484;.351	.187;.253;.175	.044;.152;.039
Children	MRT	Target Word	.352;.353;.398	.251;.263;.249	.198;.177;.197	.117;.115;.115
Children	MRT	Target Class	.008;.007;.006	.010;.009;.005	.010;.010;.007	.010;.011;.008
Children	MRT	Control Word	.255;.254;.171	.067;.067;.139	.044;.044;.043	.033;.035;.033

--- Note. WS = Word Sorting; MRT = Motor Response Task.

that increases in m don't reduce S materially (the "elbow" criterion);

2. the solutions must be interpretable;

3. the more accurate the data, the greater the potentially acceptable m .

Stenson and Knoll (1969), in a Monte Carlo investigation, suggested that the hypothesis of randomness be accepted (sic) when $N = 20$, if the stress is closer than .04 ($m = 1, 2$, or 3) or .02 ($m=4$) to the values in Table 39. This is a fairly conservative test.

In evaluating MDS solutions in the present study the following criteria were applied:

1. A solution must be non-random according to criteria in Table 39;

2. Word sorting data are presumed more reliable than motor response task data and therefore, m for word sorting data is assumed to be greater than or equal to the corresponding value for motor response task data [this criterion was the least important of the group, since it was partly a posteriori];

3. Adult data are presumed more reliable than children's data; therefore dimensionality of children's data is presumed to be at most equal to the corresponding value for adults;

4. The elbow criterion is used only to resolve ties by other criteria;

5. Other things equal, low m is to be preferred to high m ;

6. A solution which places a priori category stimuli in simple and convex patterns is to be preferred to one which does not do this;

7. Solutions must resemble those generated by at least one other starting configuration, with comparable stress;

8. The Shepard diagram must indicate a continuous curve.

The most acceptable solutions, according to the above criteria, appear

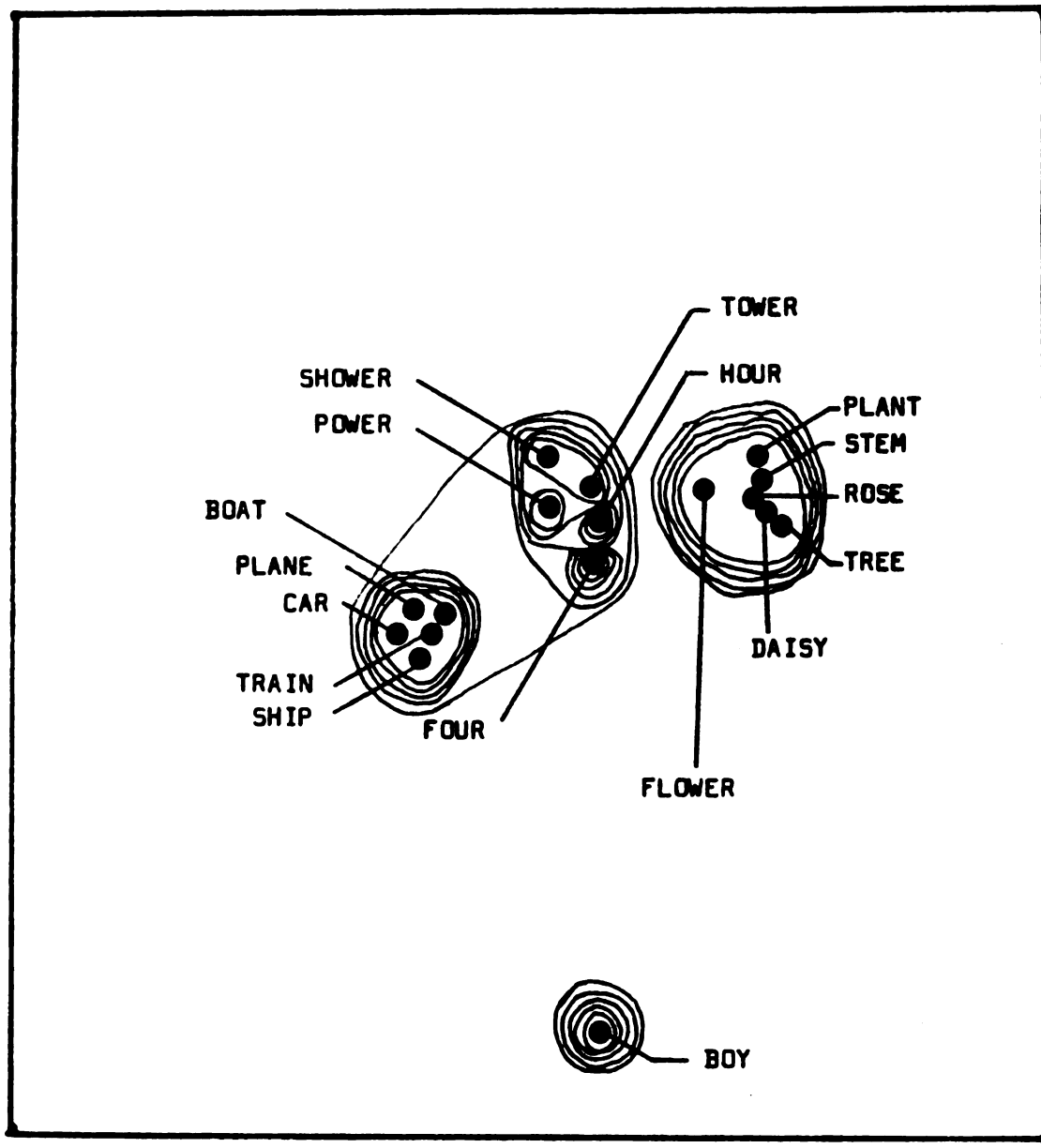


Figure 12. Multidimensional Scaling Solution, Adults, Word Sorting Task.

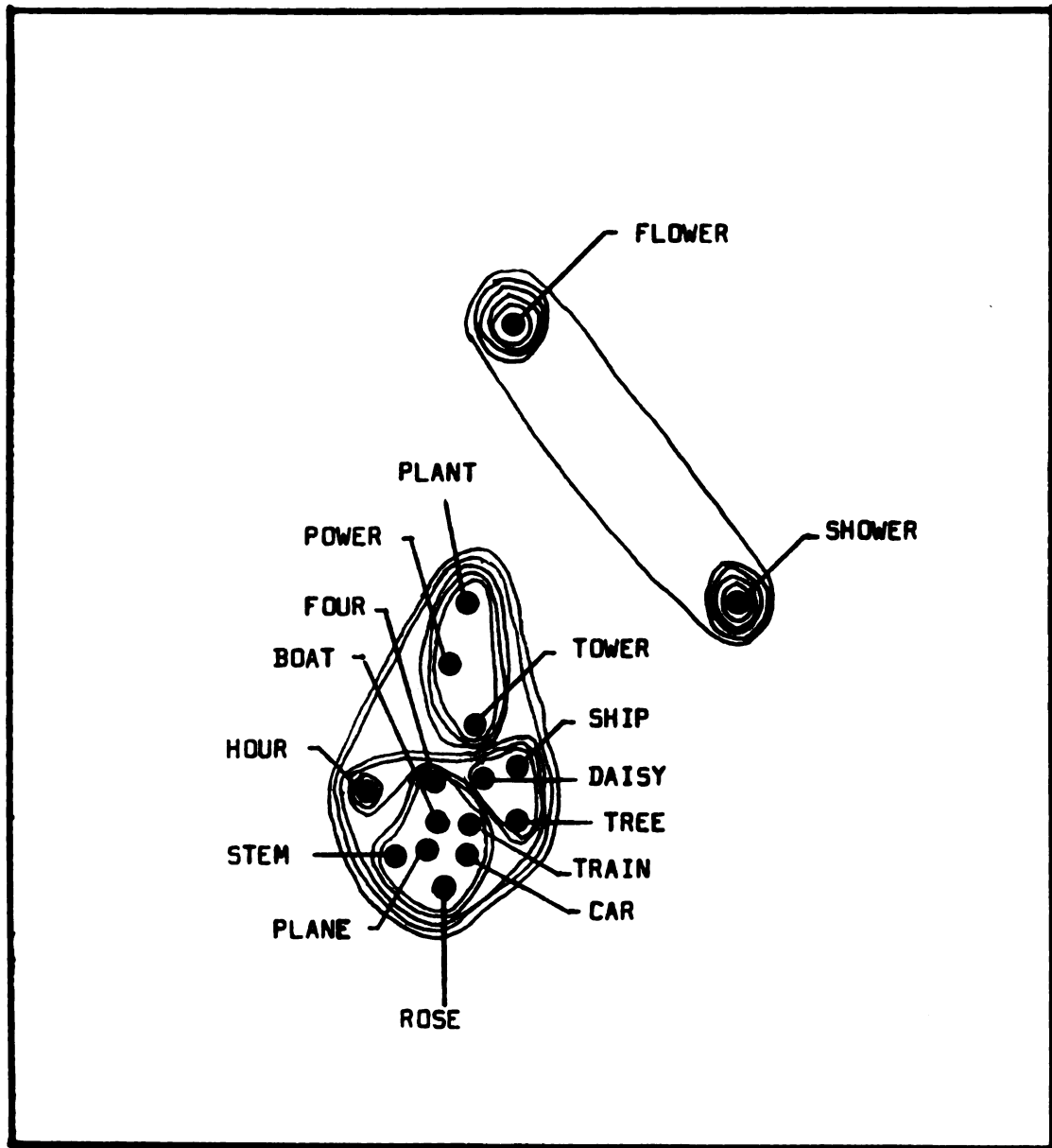


Figure 13. Multidimensional Scaling Solution, Adults, Target Word Condition, Motor Response Task.

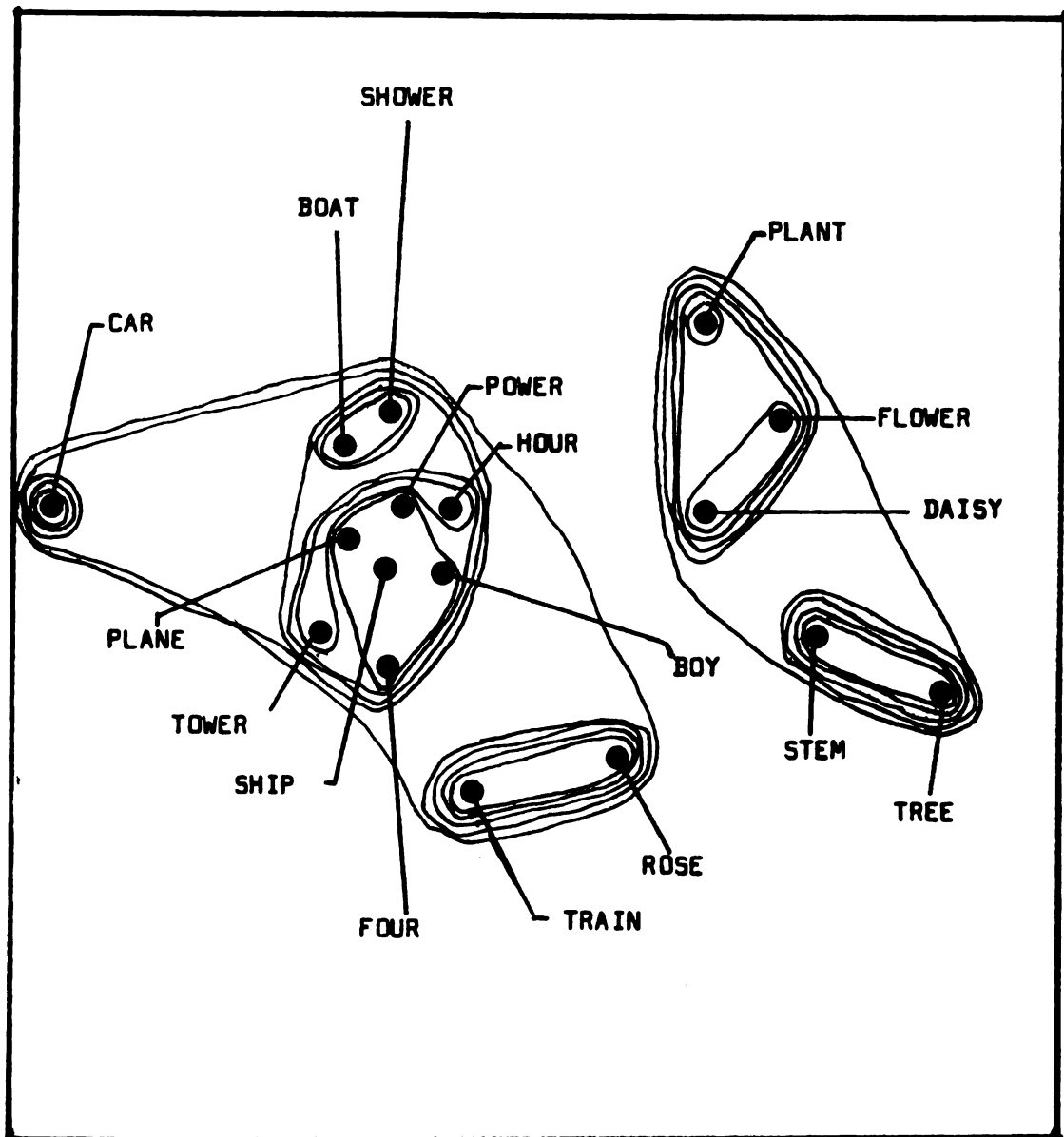


Figure 14. Multidimensional Scaling Solution, Adults, Target Class Condition, Motor Response Task.

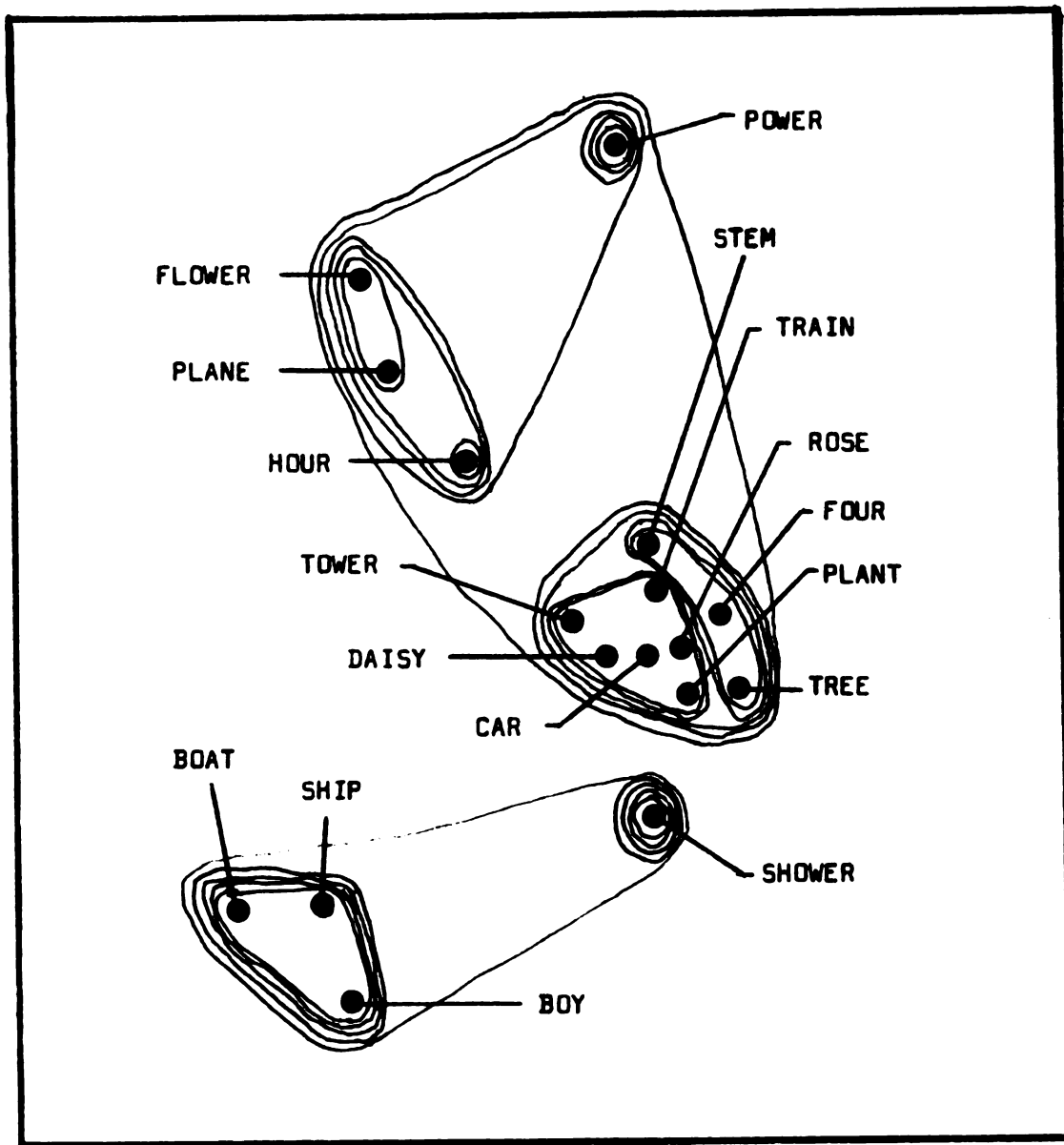


Figure 15. Multidimensional Scaling Solution, Adults, Control Word Condition, Motor Response Task.

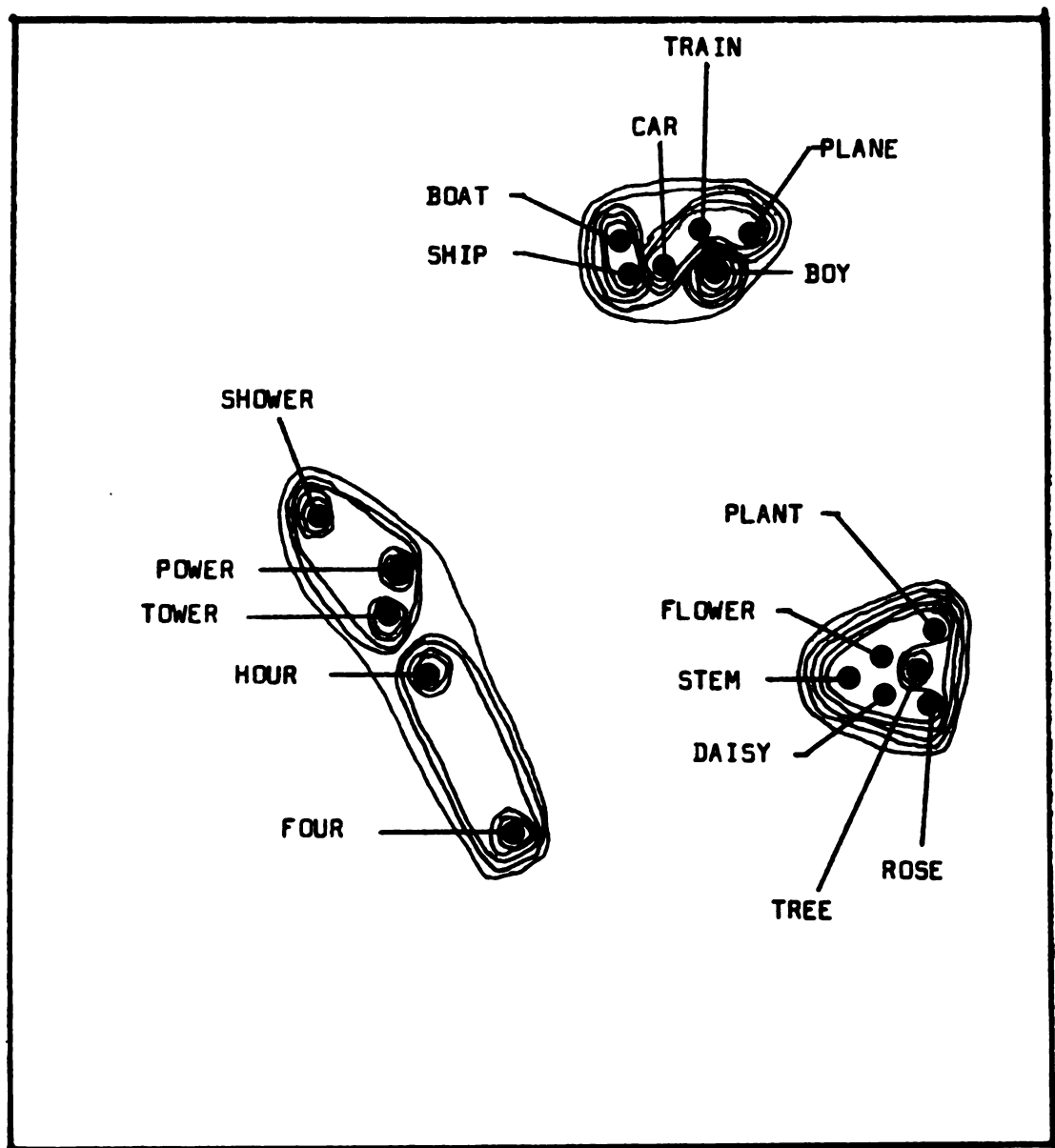


Figure 16. Multidimensional Scaling Solution, Children, Word Sorting Task.

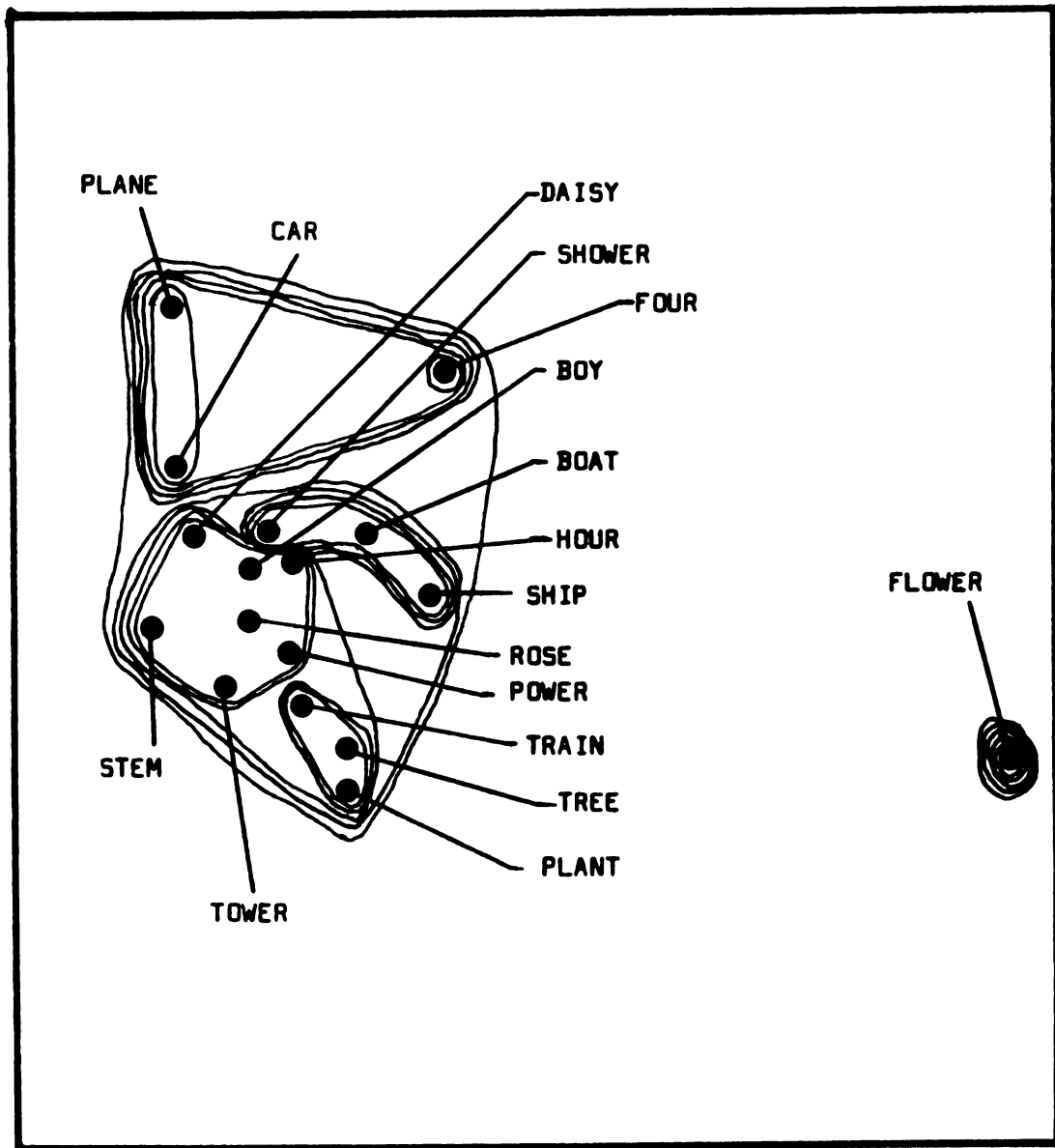


Figure 17. Multidimensional Scaling Solution, Children, Target Word Condition, Motor Response Task.

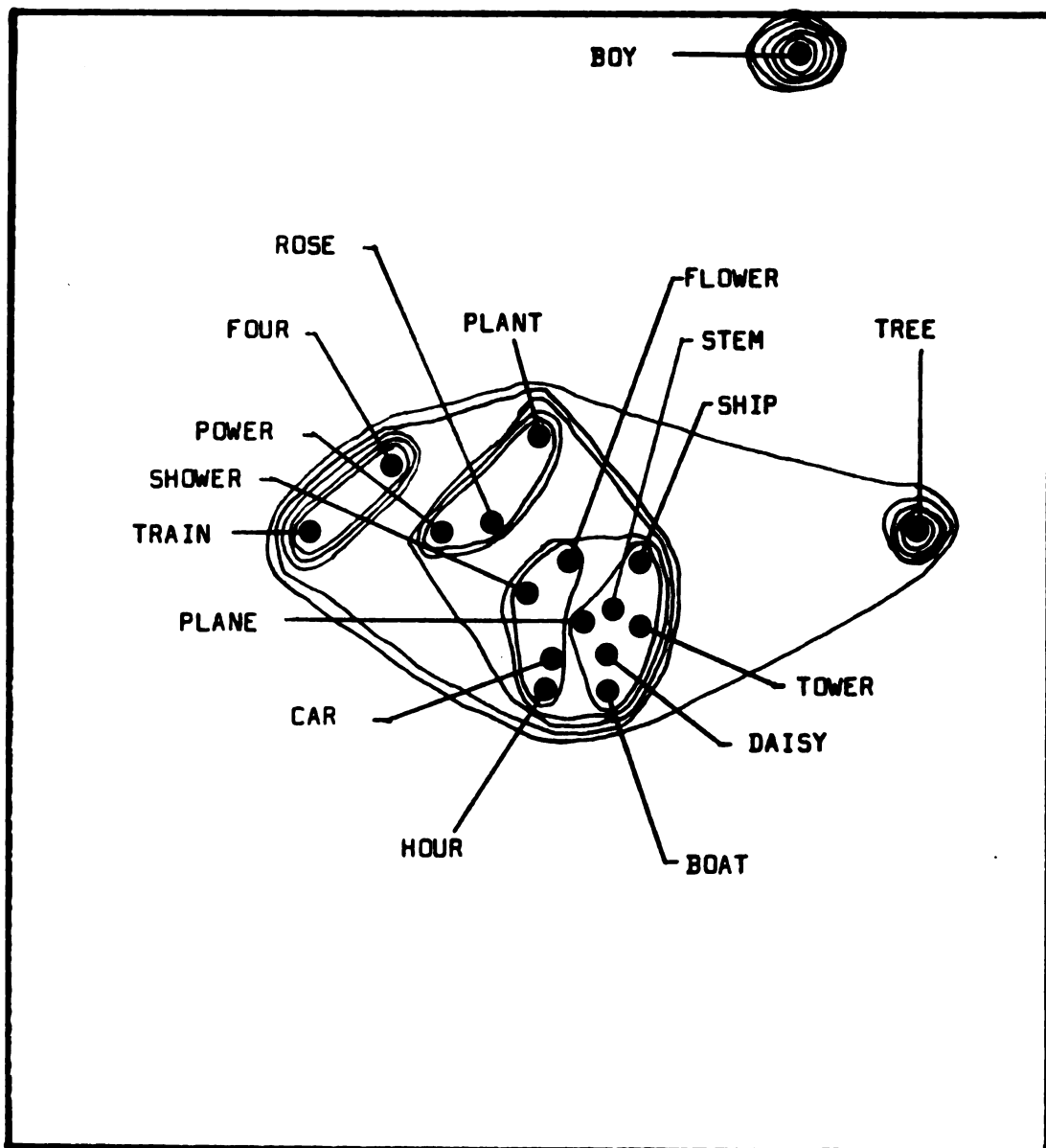


Figure 18. Multidimensional Scaling Solution, Children, Control Word Condition, Motor Response Task.

Table 39. Critical Values of Stress as a Function of Number of Dimensions.

Dimensions	Critical Value
1	.50
2	.31
3	.21
4	.16

-- Note. Values estimated from data in Stenson & Knoll, 1969, Fig. 1; assumes Euclidean metric.

as Figures 12 through 18. No "rigid motion" or other treatment has been applied; that is, there is no assumption that the axes in the figures represent the most appropriate dimensions. Distances are, of course, determined by the Euclidean metric. In all cases except the target class group of children on the motor response task, two-dimensional solutions seemed satisfactory. All solutions for that particular group mapped all stimuli into one point, violating criteria 6 and 8. That is, it did not appear possible to represent the data in the children's target class condition in a space of from one to four dimensions, using a Euclidean distance metric. It is of course possible that a city-blocks metric, or some other metric might have been more appropriate (cf. Arnold, 1971). This finding has important implications for the study, since it suggests that children may have used different comparison processes under different instruction conditions (despite the earlier speculation about their inability to shift strategy).

Original plans had called for comparison of the m values of the

different solutions as a global check on whether similar structures were involved in the different groups. Since dimensionality was involved in selection of solutions, this approach was not feasible. Nevertheless, it is possible to draw a few conclusions. First, the a priori categories emerged as closely spaced points in both adults' and children's word sorting data; criterion 6 was satisfied reasonably well. This was not so true of motor response task solutions, where there were numerous violations of the simplicity and convexity criteria. Nonetheless, solutions for motor response task groups which produced the best evidence of generalization also resemble the word sorting solutions reasonably well.

It is important to keep in mind that the a priori categories were generated from category norms, in a task measuring strength of association. Failure of the multidimensional scaling solutions to reflect a priori categories, where such failure occurred, may be due in part to the failure of the latter to reflect underlying feature structure. Perhaps a more meaningful comparison can be made by embedding HC clusters in the corresponding MDS solutions. The convex lines in Figures 12 through 18 reflect the five highest-order HC clusters in each group. The clusters by no means match perfectly, but do appear to fit better than the a priori categories.

Interpretation of these results probably resembles interpretation of ambiguous stimuli in projective tests, in that it is difficult parametrically to describe the degree of similarity of the solutions. It does seem reasonable to draw the following conclusions:

1. Qualified support for both hypotheses V and VI was obtained.
2. Dimensionality of the word sorting task solutions, and most of the

motor response task solutions, was comparable for adults and children.

3. In the motor response task and the word sorting task, the HC solutions are better represented than the a priori categories.

4. It is clear that both semantic and phonetographic similarity were reflected in MDS solutions (hypothesis VI); however, it is not clear that these were the two dimensions revealed in all motor response task instruction groups. In particular, they did not emerge in the children in the target class group (although they are clearly present in the corresponding group of adults).

DISCUSSION

Evaluation of Hypotheses

The purpose of the present study was to test a variety of hypotheses following from the feature-matching model described earlier.

Six major predictions were generated:

- I. Children less than 10-11 years old should attend more to words which resemble the key word in sound than to words which resemble the key word in meaning; adults should attend more to the latter than to the former.
- II. Instructions defining the key word in terms of meaning (target class) should facilitate the amount of semantic generalization in adults more than in children.
- III. Cognitive tempo ought to interact with instructions and/or age in determining amount of semantic generalization.
- IV. Impulsive subjects ought to show more overall EMG activity than reflective subjects of the same age.
- V. Scaling solutions (MDS and HC) for the motor response task data ought to resemble those for the word sorting task data.
- VI. Scaling solutions ought to indicate similarity involving both phonetographic and semantic dimensions.

Each of these hypotheses has been presented earlier, and so it should be sufficient to note that essentially no support was found for hypothesis I; and fairly consistent support was found for hypotheses II, III, IV (for adults, but not for children), V, and VI. The theoretical ramifications of these findings can be addressed by considering four topics, followed by some broader issues.

Status of the Phonetographic-Semantic Shift

It is often observed that children younger than 10-11 years of age attend more to perceptual dimensions than to conceptual dimensions; it seems reasonable to expect that the relative degree of phonetographic generalization vs. semantic generalization in generalization studies such as the present one ought to reflect this developmental shift. The two most important studies previously reported (Riess, 1946; Luria & Vinogradova, 1959) are usually interpreted as supporting such a shift.

However, as noted earlier, both these studies contained major methodological imperfections which mitigate against drawing firm conclusions. Moreover, although phonetographic generalization has been inadequately studied even with adults, the available evidence suggests that among adults, the relative amounts of phonetographic and semantic generalization are a function of instructions or tacit assumptions which subjects make about the task. Thus, although it is eminently reasonable to have predicted the P-S shift in the present study, the fact that little evidence implicating it was obtained is not fundamentally inconsistent with earlier research. It does, however, suggest that the traditional interpretation of available research as supporting existence of the P-S shift is quite tenuous.

That is not to say that there are no developmental shifts in generalization of the OR; in the present study, there were age differences in the effects of instructions, and cognitive tempo. But it is clear that the developmental changes observed in the present study were more complex than the basic P-S shift would indicate.

Three additional issues are relevant here. First, it is possible

that a P-S shift occurs in somewhat younger children. A variety of evidence suggests that the effects of instructions might be different among children less than about 5-7 years old than among older children (Luria, 1959; White, 1965). If there are technical difficulties in psychophysiological research with third-graders, those with younger children are even worse. Also, printed stimuli could not be used with such subjects, although one of the reasons why children younger than 5-7 experience difficulty learning to read may well be that they attend solely to perceptual features. It also seems likely that the effects of cognitive tempo would be enhanced in younger children.

A second issue arises from consideration of the stimuli used in the present study. Compared with earlier studies, the words in the test list were systematically selected to constitute specific lexical fields, in addition to selection for frequency of occurrence. This procedure is more appropriate than earlier approaches in most respects, since it recognizes the difficulty in defining the concepts of synonymy and homophony. However, it is possible that haphazard sets of words might have served better. It may well be that in choosing only two areas along a dimension of similarity (neutral category and relevant generalization category) we have restricted the sensitivity of the test. The parameters of habituation of the OR preclude using more than about 20 words in any one session.

It is probably not possible to rule out the interpretation that the particular stimuli chosen were inappropriate for demonstration of the P-S shift. No theoretical rationale for this position seems

available, but it is consistent with the rather surprising degree to which word sorting solutions of children resembled those of adults. However, the effects of the instructional variable on the motor response task seem somewhat at variance with this argument (after all, the problem was not failure to show generalization where it was expected, but rather existence of generalization where it was not predicted), as do the facts that words were treated as a random effect in the analyses, and that results on List 2 were comparable to those on List 1 with respect to category and instruction effects, for adults.

The rough similarity of results obtained with GSC and HR measures of the OR suggest that the choice of GSC as the primary response measure was probably not a major factor in failure to find the P-S shift.

A third issue is raised by the fact that the analyses indicated that the GSC response to the key word for children was very weak. This may simply imply that one ought not to expect identical generalization gradients when a CR is strong as compared with the situation where it is weak. However, differences in magnitude of OR have been implicated in studies of several individual difference variables, including presence of schizophrenia (Peastrel, 1964) and mental retardation (Luria & Vinogradova, 1959): schizophrenic and retarded subjects are reputed to show unusually large amounts of phonetographic generalization. Maltzman and his colleagues (Maltzman & Reskin, 1965; Maltzman & Mandell, 1968) have argued that individual differences in magnitude of OR are important determinants of attention and learning, and in their studies typically dichotomize subjects by magnitude of the OR

before performing further analyses (in the same way that cognitive tempo was treated in the present study).

This procedure was not feasible in the present study, due to the small N and the already cumbersome numbers of factors involved in the analyses. However, Maltzman and his associates rarely pursue any interactions of other variables with OR magnitude except to attribute them to attentional differences, nor do they note that this procedure makes the OR magnitude variable difficult to compare across studies. Moreover, the results are self-contradictory in at least two respects: first, the OR magnitude for one measure (e.g. GSC) is not consistently found to be related to OR magnitude on other measures (e.g. HR) [Raskin, 1969; Maltzman & Mandell, 1968; Allen, 1971], nor have multivariate analyses of variance been applied to the data, though they are clearly appropriate. Second, while OR magnitude has sometimes been found to interact with other variables in semantic generalization (e.g. Raskin, 1969), these interactions are not always replicable (cf. Allen, 1971).

Further, in the present study there was a negative correlation between overall GSC OR magnitude (summed over all words) and λ scores ($r = -0.20$, n.s.). Maltzman (1971) argued that subjects showing large ORs should show relatively more semantic generalization than those with low ORs: i.e., he would predict a positive correlation here. Thus, the theoretical significance (if indeed any exists) of the weak OR to the key words for children in the present study is unclear. The point deserves further empirical examination, but for the moment it seems unlikely that this played an important role in failure to observe the P-S shift.

The OR as a Measure of Psychological Similarity

Most previous investigators of semantic generalization have endorsed the common response position, the chief exceptions being Razran, and Maltzman and his colleagues. Only Razran's research with salivary conditioning reflects a body of data compatible with contemporary feature-matching theories of semantics, and Razran dealt with a response not usually considered a component of the OR.

Thus, the present study was motivated in part by the clear need to integrate psycholinguistic theory with semantic generalization. It is appropriate to ask whether the results justify the endeavor: the answer is a tentative affirmative. Several assumptions were involved in generating the present study. In particular, it was assumed that scaling solutions of word sorting data reflect psychological similarity, which in turn reflects the number of feature matches resulting from a comparison process. It was further assumed that the OR, a unidimensional response, implicitly contains multidimensional information. To the extent that the results are consistent with these assumptions, one can conclude that the assumptions remain tenable.

First, it is clear that there is multidimensional structure implicit in the OR: both MDS and HC solutions were non-random. While it would be risky to conclude that the same relationships were revealed by the word sorting and motor response tasks, they did reveal a substantial degree of correspondence to each other, and to the a priori categories. This was particularly true for HC solutions: it seems reasonable to conclude that the structures underlying both tasks seem to be hierarchical. Furthermore, the effects of the instructions argue strongly that GSC OR reflects attention to dimensions of psychological

similarity.

Tenability of the Feature-Matching Model

Certainly the results were uniformly more consistent with cognitive (common categorization) theories than with common response theories. There is virtually no result which a common response position could explain, which the feature-matching model cannot also explain; and there were numerous examples (most clearly associated with the instruction manipulation) where the latter generates successful predictions incompatible with the common response position.

Of course, the feature-matching model is not the only possible version of the cognitive position. With the exception of the findings vis a vis OR magnitude, Maltzman's theoretical description received general support from the present study. This is hardly surprising, since the feature-matching model is in many respects a special case (albeit a more detailed one, restricted to word stimuli) of Maltzman's theory. The real value of research of the sort presented here is not that it confirms a model's accuracy -- which it can never do to the exclusion of alternatives which make the same predictions -- but rather that it suggests revisions of the model.

A case in point is the P-S shift. The feature-matching model described above distinguished between phonetographic and semantic features. The model per se need not have posited that processing of the former occur more readily than the latter, but that prediction seemed consistent with available evidence, and was easily incorporated into the model. Although the evidence from the present study is probably too inconclusive to justify rejecting this prediction, it is certainly true that there was little to support it. Most of the results

are consistent with the position that comparison of phonetographic features proceeds relatively unaffected by instructional variables, while semantic features are compared only under certain instructional conditions. That is, although phonetographic features may be compared whether or not there are specific instructions to do so, semantic features are compared only when instructions require such comparison. This does not require any assumptions about the temporal availability of the two sorts of features, but does maintain the distinction between the two classes.

An alternative position would be to argue that the distinction between the two classes of features is really rather meaningless. One could still posit comparison of features, but the features would not fall into two separate classes. This possibility is more attractive than the assumption regarding the temporal availability of the classes. However, the emergence of clusters of words reflecting the two types of features, particularly in the word sorting task, suggests that both types of features were being compared.

Resolution of this issue must await manipulation of the instructions in such a way that a target class defined as "words which look or sound like the key word" is employed. If phonetographic features are of equal status with semantic features, such an instruction ought to facilitate phonetographic generalization, perhaps with only negligible effects on semantic generalization.

In fine, the feature-matching model as clarified here seems capable of explaining results of the present study, and previous semantic generalization studies, better than available alternative theories. Obviously further tests of the model ought to be performed,

particularly with reference to additional instructional manipulations, measurement of multiple components of the OR, and further examination of the effects of cognitive tempo (like the P-S shift, not really central to the model). However, the model does organize available results, and generates further predictions (perhaps the chief criterion of a useful model); it also has the advantage of drawing together semantic generalization research with psycholinguistics and pattern perception.

Cognitive Tempo and Semantic Generalization

As noted above, cognitive tempo has proved to be a less clearly understood concept than it appeared to be several years ago. It is very difficult to deal with questions about the relation of cognitive tempo to various tasks in the absence of adequate definition of cognitive tempo itself. Nevertheless, the present study does suggest that variables related to tempo are of potential relevance to semantic generalization research. Tempo interacted with both age and instructions in the GSC analysis of the motor response task. Specification of the theoretical significance of these interactions must await further research, but it is clear that substantial individual differences related to cognitive tempo do exist, and will be essential to an adequate description of the processes involved in semantic generalization.

The use of EMG measures has been rare in semantic generalization research, confined largely to the work of Phoebe Cramer. Although cognitive tempo as described by Kagan has clear implications for EMG activity, EMG measures have not been widely employed in studies investigating cognitive tempo. The EMG measures of the motor response

task were not very useful in terms of helping to examine semantic generalization. However, the finding that cognitive tempo was related to total EMG activity in adults, but not in children, is extremely interesting.

In view of the recent suggestion of Siegel and his colleagues (Siegel, Kirasic & Kilburg, 1973; Kilburg & Siegel, 1973; Siegel, Babich & Kirasic, 1974) that cognitive tempo indexes the number of features encoded and compared by children, which is quite consistent with the revised feature-matching model, there seems ample reason further to investigate the role of cognitive tempo in generalization tasks; EMG activity is a promising measure in this investigation. Moreover, it provides a link between cognitive tempo and ability to inhibit voluntary motor activity, itself an area in which much interest has been shown (Luria, 1961).

Implications for Psychophysiological Research

The present study can be regarded as a demonstration of the utility of applying several statistical techniques not often used in psychophysiological research. Most important of these is multivariate analysis of variance. One of the characteristics of much psychophysiological research is that multiple measures are recorded. Yet, despite the fact that there is often no reason to prefer one particular variable to others, univariate analyses are the rule rather than the exception. As McCall (1970) has noted, MANOVA techniques offer a means of testing effects of multiple independent variables and their interactions, where the question being asked is whether some optimal (linear) combination of the dependent variables might indicate such effects. The OR, a complex response which involves components from a number of

response systems, is obviously a candidate for analysis of that sort.

Two other techniques relatively new to psychophysiology are MDS and HC procedures. As discussed above, there are probably several reasons why these procedures have not been used. Suffice it to say that the present study indicates their value in extracting information from the unidimensional data with which psychophysicists often find themselves. These techniques are likely to prove particularly useful in studies of semantic generalization. Feather's (1965) observation that gradients of semantic generalization within the individual remain to be demonstrated is accurate even at the present writing. However, in large part this failure may well have been prompted by the relatively restrictive assumptions made about the dimensions along which objects resemble each other. Stimulus generalization is at once one of the most important and least understood phenomena of interest to psychologists.

Finally, the results of the present study are consistent with one of the clearest trends in psychology over the last ten or fifteen years, *viz.*, the tendency to view the subject in an experiment as an active participant in his environment, rather than simply as a response-producing black box. A consistent theme of the study has been that instructions and individual difference variables play an important part in determining the sort of generalization that is observed. This paradigm shift has come to psychophysiology relatively late, as evidenced by the controversy -- still continuing -- over awareness of CS-UCS contingency and the rather similar controversy -- now resolved, one hopes -- over ability to control respondent behavior (Kimmel, 1967; Katkin & Murray, 1968). Nevertheless, the

evidence now available is convincing. Psychophysiolologists can ignore cognition only at their own risk. Thus, some fifty years later, we have finally begun to see some of the implications of Pavlov's observation:

"So infinitely complex, so continuously in flux, are the conditions in the world around, that that complex animal system which is itself in living flux, and that system only, has a chance to establish dynamic equilibrium with the environment. Thus we see that the fundamental and the most general function of the [cerebral] hemispheres is that of reacting to signals presented by innumerable stimuli of interchangeable signification." (Pavlov, 1927, p. 15)

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APPENDICES

APPENDIX A

**Sample copy of letter sent to parents of potential subjects
(children only) appears on following page.**

MICHIGAN STATE UNIVERSITY, East Lansing 48824

Department of Psychology - Olds Hall

Dear Parent:

As you know, one of the most important things that a child must learn in school is how to read. Yet despite the important nature of the reading process, we lack complete understanding of the mechanisms involved. What kind of mistakes do children make in reading? Are their mistakes simply more numerous than those of adults, or do they differ in more complex ways? Do children who are quick to respond on other tasks do better at reading than most children?

We are trying to answer these questions by examining the dimensions of words to which children pay most attention. We would like very much for you to allow your child to participate in this study along with many of the other children in his class.

Each child devotes about an hour, in two sessions of 30 minutes each. In the first session, we will examine his speed of responding on non-reading tasks; in the second, we will ask him to read some words while we record some simple physiological responses from sensors attached to his arm (these measurements are recorded automatically, and cannot be felt by the child, but our measurements will tell us the sorts of things to which he is paying attention.). The study will not detract from his work in the classroom. This does not involve any sort of personality or intelligence test. Our previous work has shown that children enjoy participation in the study, and ultimately the information we learn will aid in the development of more effective methods of reading instruction.

The Holt School District Superintendent and the School Principal have already given their approval to the project. Please use the form below to indicate whether or not you consent to your child's being included in the study (your child cannot be included unless the form is returned to the teacher). If you need more information please contact Mr. Gilpin (353-3933), or the school principal.

We appreciate your prompt consideration for cooperation in this study. On request, an interpretive summary of the results will be sent to you at completion of the project.

Sincerely,

Dr. Hiram E. Fitzgerald
Mr. Andrew R. Gilpin (M.A.)

Please check one of the following alternatives:

_____ I wish my child to be included in the study described.

_____ I do not wish my child to be included in the study.

Parent _____

Date _____

Child's Name _____

(PLEASE RETURN THIS COMPLETED FORM AS SOON AS POSSIBLE)

APPENDIX B

The following computer program was written to facilitate generation of dissimilarity data in the present study. It was written in Fortran IV for use on the Control Data Corporation 6500 computer at Michigan State University.

```

      PROGRAM DISRDAT(INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT)
C     J=NO OF VARIABLES -- MAXIMUM 20
C     N=NO OF SUBJECTS -- MAXIMUM 40
C     LOPT=OUTPUT CONTROL -- SET TO 1 FOR ABSOLUTE VALUE
C                               SET TO 2 FOR BINARY VALUE
C
C     LOPT1=OUTPUT CONTROL -- SET TO 1 FOR MATRIX EACH SUBJECT
C                               SET TO 2 FOR ONLY MATRIX OF SUM
C
C     PROGRAM DISRDAT YIELDS N X N MATRICES OF DISSIMILARITIES
C     (WHICH MAY OR MAY NOT BE PRINTED DEPENDING ON LOPT1), FOLLOWED
C     BY SUM OVER N SUBJECTS. THE DISSIMILARITY MEASURE USED IS
C     SPECIFIED BY LOPT, AND CAN BE EITHER (0 OR 1) OR ABSOLUTE VALUE
C     OF AN ORDINAL MEASURE -- ACTUALLY PROGRAM WILL HANDLE INTERVAL
C     DATA, OR NOMINAL DATA, AS WELL.
C
C     DISRDAT IS ACRONYM FOR DISSIMILARITY FROM ORDINAL DATA.
C     WRITTEN BY A. GILPIN. THIS RESEARCH SUPPORTED IN PART BY
C     SIPP GRANT 74-0100. DATE THIS VERSION 2 JULY 1974.
      DIMENSION SUBMAT(20,20),SUMMAT(20,20),VARNAME(20),VARVALU(20)
      INTEGER TITLE,VARNAME
      READ(60,400)TITLE
400  FORMAT(A10)
      PRINT401,TITLE
401  FORMAT(*1*,A10)
C     THIS IS IDENTIFIER FOR THIS RUN
      READ(60,1)J,N,LOPT,LOPT1
1  FORMAT(I2,X,I2,X,I1,X,I1)
      DO 300 INCT=1,20,1
      DO 301 INCT1=1,20,1
      SUMMAT(INCT,INCT1)=0.0
301  CONTINUE
300  CONTINUE
C     INITIALIZES SUM MATRIX AT 0

```

```

      DØ 20 N1=1,N,1
      DØ 10 INTCNT=1,J,1
      READ(60,2)VARNAME(INTCNT),VARVALU(INTCNT)
      2 FØRMAT(3X,A10,2X,F5.0)
10 CØNTINUE
      J1=1+J
      DØ 11 J2=J1,20,1
      VARNAME(J2)=0
      VARVALU(J2)=0.
11 CØNTINUE
C     READS IN 10 CHARACTER NAMES, LABELS VARNAME(1-J)
C     READS IN 5 DIGIT NUMBERS FØR EACH WØRD, LABELS VARVALU(1-J)
C     SETS REST ØF VALUES AT 0
      DØ 30 INTCNT2=1,20,1
      DØ 40 INTCNT3=1,20,1
      VARVAL1=ABS(VARVALU(INTCNT2)-VARVALU(INTCNT3))
      IF(LØPT-1)31,31,32
31 GØ TØ 36
C     IF LØPT IS LESS THAN ØR EQUAL TØ 1, WANT ABSØLUTE VALUE
32 IF(VARVAL1-0.0)34,35,34
34 VARVAL1=1.
C     ABS VALUE NØT 0 SØ WØRDS ARE IN DIFFERENT FILES.
      GØ TØ 36
35 VARVAL1=0.
C     ABS VALUE 0, SØ WØRDS IN SAME FILE.
36 CØNTINUE
C     NØW HAVE APPRØPRIATE VALUE IN VARVAL1
      SUBMAT(INTCNT2,INTCNT3)=VARVAL1
C     NØW HAVE CELL IN SUBJECT MATRIX.
      SUMMAT(INTCNT2,INTCNT3)=SUMMAT(INTCNT2,INTCNT3)
      1+ SUBMAT(INTCNT2,INTCNT3)
C     NØW HAVE SUMMED MATRIX
40 CØNTINUE
30 CØNTINUE
C     NØW HAVE BØTH MATRICES STØRED
      IF(LØPT1-1)305,306,307
305 GØ TØ 307
306 PRINT121
121 FØRMAT(*ØDISSIMILARITY MATRIX FØR SUBJECT AS FØLLØWS*)
      CALL BARFØ(J,N1,VARNAME,VARVALU,SUBMAT)
C     BARFØ PRINTS ØUT SUBJECT MATRIX
      GØ TØ 307
307 CØNTINUE
20 CØNTINUE
C     NØW HAVE MATRIX FØR EACH SUBJECT, IF DESIRED
      DØ 200 INTCNT5=1,20,1
      DØ 201 INTCNT6=1,20,1

```

```

SUBMAT(INTCNT5,INTCNT6)=SUMMAT(INTCNT5,INTCNT6)
201 CONTINUE
200 CONTINUE
N1=0
C   0 IS CODE INDICATING SUMMATRIX FOLLOWS
PRINT202,N
202 FORMAT(*-FOLLOWING MATRIX CONTAINS VALUES SUMMED OVER *,
1I2,X,*SUBJECTS.*)
CALL BARFØ(J,N1,VARNAME,VARVALU,SUBMAT)
C   BARFØ PRINTS OUT SUMMED MATRIX. IGNORE MARGINAL VALUES...
END
SUBROUTINE BARFØ(J,N1,VARNAME,VARVALU,SUBMAT)
DIMENSION VARNAME(20),VARVALU(20),SUBMAT(20,20)
INTEGER BARF1,VARNAME
PRINT101,N1
101 FORMAT(*1SUBJECT NO. *,I2)
C   PRINTS SUBJECT NUMBER ON TOP OF PAGE
PRINT140,J
140 FORMAT(*- IGNORE RIGHT SECTION MATRIX FOR WD NO OVER *,I2)
PRINT102
102 FORMAT(*0*,60X,* WORD NOS.*)
PRINT103
103 FORMAT(*OVALUE LABEL NO 1 2 3 4
1 5 6 7 8 9 10*)
C   PRINTS HEAD FOR TOP HALF MATRIX
DO 130 BARF1=1,J,1
PRINT120,VARVALU(BARF1),VARNAME(BARF1),BARF1,SUBMAT(BARF1,1),
2SUBMAT(BARF1,2),SUBMAT(BARF1,3),SUBMAT(BARF1,4),SUBMAT(BARF1,5),
3SUBMAT(BARF1,6),SUBMAT(BARF1,7),SUBMAT(BARF1,8),SUBMAT(BARF1,9),
4SUBMAT(BARF1,10)
120 FORMAT(*0*,F5.0,3X,A10,X,I2,X,F9.0,X,F9.0,X,F9.0,X,F9.0,X,F9.0,X,
1F9.0,X,F9.0,X,F9.0,X,F9.0,X,F9.0)
130 CONTINUE
C   TOP HALF OUT
PRINT105,N1
105 FORMAT(*1 LOWER HALFMATRIX FOR SUBJECT NO. *,I2)
PRINT141,J
141 FORMAT(*- IGNORE RIGHT SECTION MATRIX FOR WD NO OVER *, I2)
PRINT106
106 FORMAT(*0*,60X,* WORD NOS.*)
PRINT107
107 FORMAT(*OVALUE LABEL NO 11 12 13 1
14 15 16 17 18 19 20*)
C   PRINTS HEAD FOR LOWER HALFMATRIX
DO 142 BARF1=1,J,1

```

```
      PRINT143,VARVALU(BARF1),VARNAME(BARF1),BARF1,SUBMAT(BARF1,11),  
      2SUBMAT(BARF1,12),SUBMAT(BARF1,13),SUBMAT(BARF1,14),  
      3SUBMAT(BARF1,15),SUBMAT(BARF1,16),SUBMAT(BARF1,17),  
      4SUBMAT(BARF1,18),SUBMAT(BARF1,19),SUBMAT(BARF1,20)  
143  FØRMAT(*Ø*,F5.Ø,3X,A1Ø,X,I2,X,F9.Ø,X,F9.Ø,X,F9.Ø,X,F9.Ø,X,F9.Ø,X,  
      1F9.Ø,X,F9.Ø,X,F9.Ø,X,F9.Ø,X,F9.Ø)  
142  CØNTINUE  
      RETURN  
      END
```

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