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The Effects of Context on Multidimensional Spatial Cognitive Models

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CHAPTER 1

INTRODUCTION

1.1 Summary

The cognitive space is introduced as a Euclidean spatial representation of an individual's perception of the dissimilarity of a set of stimulus objects. Since certain experimental evidence suggests that context affects perception, a change in the perceived context is expected to change the cognitive space. Yet investigations of the effect of context on cognitive spaces defined for a group have been inconclusive. Intergroup differences in cognitive spaces have not been explained by context differences. This research argues that the analysis of groups tends to obscure context effects because of interindividual differences, and demonstrates at the individual level, that substantive, statistically significant and replicable changes in cognitive spaces do occur because of context changes. The spaces defined from four experiments differed in dimensionality, dimension identity and configuration of stimulus object points in the spaces.

1.2 Cognitive Models

Expressing preferences for, or assigning values to alternatives can be viewed as the end result of a two-stage cognitive process: comparison and evaluation. While both stages are fundamental to a comprehensive understanding of human decision making, this research focuses on the comparison process part of the complex cognitive operation. Furthermore, this research suggests that explicit recognition of the influence of context on comparisons can substantially enhance the ability to explain and understand evaluative judgments.

It is assumed that the comparison process can be described by a model of an individual's cognitive structure and that affective disposition is associated with elements of that structure. The content of the model consists of mental representations of stimuli (people, concepts, things, etc.) defined in terms of their attributes. The model structure reflects the behavior of the stimuli and their interaction with the individual and his environment in specific situations. The mental representations are related or connected by association or similarity and their interdissimilarity dictates metric relationships in the model.

The theoretical analysis of similarity relationships has been dominated by geometric or spatial models which represent stimuli as points in a coordinate space such that subject-defined stimulus interdissimilarities correspond to metric distances among the respective points. The Euclidean spatial model resulting from a nonmetric multidimensional scaling of the dissimilarity data is used to model an individual's cognitive structure; this model is called a <u>cognitive space</u>.

There is ample evidence from a wide variety of experiments and applications which demonstrates the usefulness of the cognitive space. Examples of various stimuli include human traits (Walters and Jackson

1966), combat situations (Cliff and Young 1968), occupations (Burton 1972), colors (Indow and Uchizono 1960), presidential candidates (Mauser 1972), speech patterns (Matsumoto, Hiki, Sone and Nimura 1973), bakery items (Green, Maheshwari, and Rao 1969), saline solutions (Gregson 1968), natural resource planning objectives (Harris 1977), shapes of U.S. states (Shepard and Chipman 1970), and artistic drawings (Skager, Schultz, and Klein 1966).

1.3 Context and Cognitive Spaces

Attneave (1950) seems to have been the first to recognize that cognitive structures dependent upon dissimilarity or similarity measures can be influenced by context. Similarity needs a referent; when things are similar, they are similar with respect to something. Consequently, the way in which they are similar may also change.

Consider, for example, three stimuli: _table_, _fable_, and _chair_. _Table_ and _fable_ are similar because they sound alike. _Table_ and _chair_ are also closely associated, but as furniture. The pattern of similarity among these three words will differ for an individual depending on whether he is working a crossword puzzle or responding to a word association quiz; on whether he considers the meaning of the words or merely their sounds; on whether other homonyms are included in the stimulus set or merely other pieces of furniture; and whether the individual is a linguist or a furniture salesman. Attneave suggests that a separate cognitive structure might be achievable for each state of attention, or as interpreted here, for each facet of context. Context could thus affect a person's cognitive structure and hence its representation by the cognitive space. It could also affect his evaluation of the objects and his behavior in relation to them. This study will explore the influence of context on cognitive spaces.

Context is believed to have an effect on personal statements of value. This effect has been demonstrated in word ratings (Heise 1969, Halff, Ortony and Anderson 1976), bread and pastry preferences (Green and Rao 1972), and gift selection (Hansen 1972). Sometimes, however, personal statements contradict personal behavior (Bickman 1972). Anecdotal evidence of context influence on behavior is also available. For example, in retail settings, the presence of children (Wells and LoSciuto 1966), friends (Bell 1967), and sales personnel (Albaum 1967) have been observed to alter purchase outcomes.

In contrast to these studies, Green and Carmone (1972) found that evaluations of magazine ads were generally independent of context. Similar results concerning the negligible effect of context on perception were also reported by Green, Maheshwari and Rao (1969), Ryans (1974), and Heeler (1974). After a series of studies of various stimuli, Cliff concluded that changing the context of a decision making task had only the effect of changing the use of the cognitive space, not the cognitive space itself (Cliff 1966, Cliff and Young 1968). Negative results such as these may have encouraged a neglect of context. Difficulties in explaining behavior by measuring attitudes, for example, have been ascribed to the neglect of context, most explicitly by Rokeach (1968). Further research in this area is clearly needed. Are context effects on individual perception a common occurrence or a rare event? If it is a common event, it raises serious questions about consumer product design or marketing concept evaluation models that assume invariant perception or preference structures under context changes (e.g., Pessemier and Root 1973, Ryans 1974, Shocker and Srinivasan 1974, Rao and Soutar 1975). This research uncovers evidence on the circumstances in which perception of stimulus objects changes, and the cognitive structure which an individual uses to combine his perceptions of the stimuli changes.

It is no doubt due to the inconclusiveness of the evidence that has prompted authors to continue to speculate on whether or not context affects the spatial cognitive model. Day says "there is widespread unsupported (emphasis added) agreement that perceptions (and cognition) and preferences are context bound" (Day 1972, p. 284). And Green and Carmone note, "The question of (cognitive space) invariance over changes in ... scenarios appears wide open for future study. It seems that similarities and preference judgments ought to be context bound . . ." (Green and Carmone 1972, p. 204). They are right, there seem to be no studies in the literature which clearly show that similarity perceptions are context bound. Moinpour, McCullough and MacLachlan (1976) also recognize the need to investigate the nature of changes in individual cognitive spaces in response to context changes in order to apply spatial cognitive models to marketing. Ryans and Deutscher (1978) note that although cognitive models have been studied extensively as an invariant structure, their potential for improving the understanding of the dynamics underlying consumer choice is largely unrealized. To this writer's knowledge, no one has shown that an individual's cognitive space changes under different contexts and that the changes are quantifiable and replicable. This study addresses that void.

The systematic research on the effects of context on cognitive spaces to be reported here has, to the contrary, found substantive, statistically significant and replicable changes in the cognitive spaces due to context. The cognitive spaces differed in dimensionality, dimension identity and configuration of points. It was found, however, that the separate spaces for each context could be embedded in a "master" cognitive space of which they were special cases in which particular dimensions were given more, less, or even zero weight depending on the context. Whereas other studies have treated the cognitive model as an independent variable or invariant structure, the research presented here treats the cognitive space as a dependent variable and investigates the effects of a limited set of other independent variables defining context upon the dynamics of the cognitive model.

1.4 Study Organization

In Chapter 2, context is defined and analyzed and an account is given of how it would be expected to affect judgments of dissimilarity and the spatial cognitive model resulting from such judgments. Chapter 3 provides a critical review of the literature relevant to context changes and their effects on spatial models. Conclusions are drawn and implications are defined for this study. With the review as a background, specific study objectives are presented.

All four experiments in this study used the same procedures and data analyses. These methods are discussed in Chapter 4. The four experiments are detailed in Chapters 5-8. Each of these experiments has been selected to investigate a different type of context change. In each chapter, the nature of the effect of the particular type of context on the cognitive spaces is discussed, quantified, and substantiated by replication and significance tests.

Chapter 9 summarizes the principal results of the study and discusses their implications for practical applications with specific examples.

Three technical Appendices cover areas of particular interest to this study. An extensive review of nonmetric multidimensional scaling (NMDS) is covered in Appendix A, especially the NMDS algorithm (MDSCAL) used to produce cognitive spaces in this research. Basic assumptions and unique features of the algorithm are also discussed. Finally, techniques for determining the proper cognitive space dimensionality and significance of results are also given.

Appendix B discusses the INDSCAL model which is used to develop a cognitive space with differentially weighted dimensions. The use of this technique to produce a master space which spans a set of cognitive spaces is also addressed.

A major objective of this study is to demonstrate that two cognitive spaces formed from different contexts are different. Appendix C provides a metric for comparing two spaces and suggests a measure of congruence. Furthermore, a test of significance is developed for this measure.

CHAPTER 2

EFFECTS OF CONTEXT ON JUDGMENT

2.1 Overview

The term context is defined in this chapter and analyzed into its component aspects. Much of the definition adopted results from a survey of the literature of situation but an important distinction is made between situation and context. A review is then given of the experimental research on the effects of context on human behavior. Finally, an account is made of how context would be expected to affect judgments of dissimilarity and how those effects would be represented by changes in the parameters of the general form of the spatial cognitive model. This is in preparation for presentation in subsequent chapters of experimental work demonstrating such changes.

2.2 Context

2.2.1 Context vs. Situation

The terms context and situation are used almost interchangeably by human behavior researchers with much of the psychological literature on this subject using the term situation. The term context, however, is preferred in this report because of a significant distinction. The dictionary (Webster's Third New International 1968) defines situation as the sum total of internal and external stimuli (physical, social and psychocultural factors) that act upon an individual in orienting and conditioning his behavior in a given interval. Context is defined as the interrelated conditions in which something exists or occurs so as to characterize or indicate its meaning. The difference lies in the use of the phrase "indicate its meaning." Where situation is objective, potentially measurable, and is described in terms of physical, psychological and social stimulus features, context is subjective and represents a person's response to those stimulus features. It is described in terms of aspects of the psychological significance of the situation, of how it is perceived and reacted to. Confusion has existed in the literature because of a failure to recognize this difference. Magnusson (1971), Ekehammar (1974) and Pervin (1975) noticed, however, a difference in usage of situation and context depending on whether the terms are used to mean objective description or personal perception. Their views support a definition in which context results from the perception of a situation, and attaches meaning to it.

Since context depends on situation, a discussion of how situation is treated in the literature is given next. Bieri et al. (1966, page 209) and Belk (1975) suggested that a situation may be viewed as comprising all those factors peculiar to a time and place of observation which do not follow from a knowledge of individual or external stimulus attributes, and which have a demonstrable and systematic effect on current behavior. Several attempts to inventory "all those factors" have met with limited success. Sells (1963), for example, classified situations in terms of their objectively measured characteristics which are external to the individual. However, he listed 5 major categories, 16 subcategories, and over 50 further subdivisions which appeared to vary in the ease with which they could be measured (e.g., terrain, natural resources, language, social organization, novelty). Classification attempts by Bellows (1963), Wolf (1966) and Moos (1973), are less complex, but also are impractical from the standpoint of measurement. A limited taxonomy by Allen (1965) of the situational factors found to affect conformity, highlighted several important *social* dimensions (e.g., public/private, interdependence of participants) and *task* dimensions (e.g., difficulty, importance) of the situation. Magnusson (1971) factor analyzed similarity judgments of typical student activities or situations in an academic domain to investigate the cognitive aspects of situations. *Social*, *task* and *personal involvement* dimensions were included in his list of factors.

Barker (1963) described a situation in terms of the entities and actions of which it is composed; that is, the physical objects, the people present and the processes going on. Finally, Bieri et al. (1966, pages 14-15, 209-210) considered three types of situational influences on judgment: social, interpersonal, and contingency. Social influences refer to the relatively stable characteristics of the social structure within which the subject makes his judgment. Interpersonal characteristics address the nature of the relationship between the judge and the stimuli, subdivided into role, purpose, inferences, and personal involvement. Situational contingencies consist primarily of situational events that are antecedent to or precede a judgment. By such terminology, it is obvious that Bieri addressed the perception of situation; i.e., context.

In contrast to objectively defined properties of situation, Endler and Magnusson (Endler and Magnusson 1974, Magnusson 1974) and Ekehammar (1974) emphasized how the individual represents and constructs the situation. Hansen (1972, page 47) believes that the individual's perception of the situation depends upon the actual elements in the situation. Since perception is unique to the individual, the same situation can yield different contexts for different persons (Magnusson, Gerzen, and Nyman 1968). Restle (1961), however, blurs the distinction between situation and context by defining identical situations as those with exactly the same perceived characteristics. This has led toward a definition of situation in terms of perceived properties (Berlyn 1967, Palmer 1975), essentially the definition of context to be adopted for this study.

Bobrow and Norman (1975) show that context determines how information contained in memory is interpreted and used; it delineates some restricted set of elements or connections within the memory that are relevant to the situation and used to understand it. Reitman (1965, Chapters 3-4) relates context to an individual's cognitive structure by describing context as a link from the abstract or general to the specific; a connection between the meaning of an element in the cognitive structure and its relation to other elements. Others emphasize that context serves to limit the range of possible meanings of information or bound the internal representations of a concept (Kaplan 1972, Halff, Ortony, and Anderson 1976). For Neisser (1976), context is embodied in what he (after Bartlett) calls schemata, preexisting structures that direct perceptual activity by determining what stimulus features will be perceived, and that are modified as perception takes place. Dreyfus and Dreyfus (1976) suggest that the context aids the individual to perceive which stimulus attributes are relevant to the task, the importance of these attributes relative to each other, and the extent to which each attribute is present in the stimuli. In support of this, Haber's (1966) study suggests that the selection of stimulus attributes thought relevant to the task follows a "tuning" hypothesis whereby attending to a certain context results in a clearer and more vivid perception of certain properties--they stand out more. By the same token, the incidental attributes are not as clear and do not stand out.

The need for contextual representation of a situation for intelligent behavior has been extensively analyzed by Minsky (1975) who proposes the notion of "frames," information processing structures that act as schemata, for implementing context in artificial intelligence. Some attempts have been made to implement frames in machine vision (Kuipers 1975).

2.2.2 Characteristics of Context

For purposes of the present research, situation is defined as the sum total of external and internal stimuli that act upon an individual in orienting and conditioning his behavior in a given time interval.

Context is then defined as an individual's interpretation of the perceived characteristics of a situation which gives it meaning for him.

By selectively combining features suggested in the various studies and taxonomies cited earlier, a notion of the factors that comprise a context may be offered. The reviewed experimental research suggests that context depends on the meaning attached to who is involved, including the possibility that the individual is alone, why he is involved, where the action is taking place, what the nature of the action occurring is, and when it occurs. The context is defined by the perceptual organization of these various components so that it takes on a gestalt quality and if one of the components changes sufficiently, the context is considered to have changed. These components suggest five aspects of context that may have an influence on spatial cognitive models:

1. Physical environment factors are generally related to the site or facility where the action takes place but may also reflect the physical state of the subject. Some of the more readily apparent features of physical environment include geographical and institutional location, decor, sounds, aromas, lighting, weather, and visible material configurations surrounding the stimulus objects. The environment also includes intangibles such as scenic beauty and physical facts like gravity and limitations (e.g., deafness) of the subject.

2. Social environment describes the presence or absence of other individuals (participants and non-participants) in the task action. The

social environment considers the number of such individuals, their personal characteristics and backgrounds, and the extent and nature of their previous interactions with the subject. The actual or assumed attitudes and beliefs of these individuals concerning the subject, the stimuli and the task are also of importance, especially the manner in which such information is exchanged between the individuals and the subject.

3. Task definition specifies the desired conditions as to how the task will be performed, as well as criteria and constraints of performance. The definition always reflects a stated or implied objective or purpose of the task. This purpose is instrumental in the subject's selection of a set of stimulus attributes which are appropriate to the specified use of the stimuli or the purpose of the task.

4. Individual perspective represents the relationship of the person judging the stimulus objects to the task, to the objects, or to the purposes which the task or the objects serve. It is essentially the role the person plays in relation to the other aspects of context and his view of that role. Some factors which may influence perspective are familiarity with the stimulus objects or the task, fatigue, commitment to task purpose and ownership of the stimulus objects.

5. Temporal setting characterizes the context along the time dimension and relates the subject to actual or assumed past or future events. This allows considerations such as time of day, season of year, time since payday, and time constraints imposed by prior commitment or external limitations.

2.3 Context Characteristics Experimentally Investigated

There are two relevant kinds of situations and hence contexts which relate specifically to spatial cognitive models. The first context is identified with the stimulus comparison task itself (i.e., the dissimilarity judgments), while the second is identified with the real or imagined application, use or consequences of the stimuli. For example, if the stimuli are political candidates, the first context may deal with a subject's choosing among the candidates at the polls while the second context may be associated with the candidates being in office. Situational characteristics that affect context apply to either. Of the two kinds of context specifically related to spatial cognitive models, this research held the stimulus comparison context fixed by intention and did not consider it further. Rather this research was concerned with the context of stimulus application.

Five context characteristics were identified above: physical environment; social environment; task definition; individual perspective; and temporal setting. The physical environment was not analyzed because its features were too numerous and difficult to identify, quantify or control, and it is not at all clear which features can be manipulated to affect context. Similarly, temporal setting was not analyzed because of the difficulty in controlling experimental conditions over any appreciable interval of time. This research investigated the remaining three characteristics of context: <u>social environment</u>; <u>task definition</u>; and <u>individual perspective</u>. Task definition, however, was subdivided for further study.

One of the more interesting features of task definition is the individual's interpretation of how the stimulus objects are to be applied or used in the task. Many tasks differ on whether or not the use is made specific. Accordingly, these two features of task definition called specific use and nonspecific use (of the stimulus objects) were investigated in this report.

Experiments, presented in four subsequent chapters, were designed to produce changes in these context characteristics and to test the effects of these changes on individual cognitive spaces. Each experiment assumed that context characteristics of physical environment and temporal setting were held constant.

For context to be a useful concept, it must not only be defined, but shown to have a systematic effect on behavior. The following section reviews some empirical research on the effect of context on judgments other than those used to derive spatial cognitive models (i.e., dissimilarity judgments) and examines the extent to which contextual knowledge can be expected to add to one's ability to explain human behavior.

2.4 Context in Judgment Tasks

In the past decade, an increasing number of empirical studies of contextual influence on human behavior have been conducted using various consumer-oriented contexts and stimulus objects. Typically, subjects are asked to rate the likelihood that they would choose each of several alternate products or services under each of different contexts. The trends indicate a general influence of context on preference judgments but the results are far from conclusive. For example, in a series of studies of preferences for beverages (Sandell 1968), meat products (Belk 1974a), snack products (Belk 1974b), and fast foods (Belk 1975), it was shown that systematic context differences explained a sizable proportion of variance in individual preferences; for the first two cases, context explained more variance than did individual differences. When leisure activities (Bishop and Witt 1970) were analyzed, the effects of context were lightly overshadowed by individual differences. In the case of preferences for motion pictures (Belk 1974b) and TV programs (Friedman and Fireworker 1977), however, the results indicated that subject preferences did not depend on context. Individual differences explained the largest variance in preferences.

Regarding contextual influence on consumer behavior, Lavidge (1966) maintains that for many products, consumption is closely related to specific contexts, and he cites evidence from media and other studies. Longman (1968) makes the same point in relation to attitude measurements and consumer purchase studies.

In the general areas of psychology and sociology, the question of contextual influence upon behavior has been raised most directly by Endler and Hunt (1969). Based on a study of variations in human anxiety responses from different situations, their findings consistently showed that more variation is explained by contextual factors than by individual differences, and that interaction between these two sources of variation accounts for more variation than either of the other two sources taken separately.

In summary, evidence strongly supports the proposition that contextual factors, separately and in interaction with personal variables, influence behavior. In particular, this influence applies to consumer behavior. However, it is worth noting that all of the above experimental research deals with the effects of context on behavior assessed by aggregating individuals' responses. Such studies rely on the questionable assumption that interpersonal comparison of context is meaningful, a topic to be addressed further in Chapter 3.

2.5 Spatial Cognitive Model and Context

2.5.1 Origins of Spatial Cognitive Models

One's actions are based on an understanding of the world, and this understanding can be thought of as being embodied in cognitive structures built up through successive interactions with the world. The cognitive structure is linked to the world by perception and is modified by context. The concept of spatial cognitive structures has been used variously in psychological theories, including Sarbin's (1960) "modules," Osgood's (1957) "representations," and Kelly's (1955) "constructs." Although there are a variety of conceptions of cognitive structure, there are at least four common areas of agreement among cognitive theorists:

1. The individual is assumed to possess a finite number of (usually) bipolar dimensions represented by an adjective and its opposite.

2. The individual perceives and discriminates stimulus objects in terms of these dimensions.

3. The individual is assumed to use a hyperspace formed from these dimensions to assess his perception of a set of stimulus objects.

4. The hyperspace, the stimulus objects, and their interrelationships as represented in the hyperspace comprise the individual's cognitive structure.

Cognitive structures are impossible to observe directly. If one is willing, however, to assume that such a structure would imply specifiable behavioral consequences, it may be possible to construct a descriptive model of the structure from observable behavior. The notion of an n-dimensional hyperspace is central to the concepts of "space" employed by Sarbin, Osgood, and Kelly. All three of these theorists suggest that nonmetric multidimensional scaling (NMDS) procedures are appropriate for describing an efficient representation of an individual's cognitive space. A NMDS-derived spatial model is proposed to be a descriptive model of a cognitive structure. Whether the model represents what actually is going on inside an individual, whether one thinks spatially as it were, is a separate question and will not be addressed here.

Many researchers have developed NMDS numerical techniques (e.g., Torgerson 1958, Shepard 1962a, 1962b, Kruskal 1964a, 1964b) for construction of spatial cognitive models. Each procedure represents stimulus objects as points in a Euclidean space. The position of each object is determined in relation to the cognitive dimensions used by the individual when he discriminates among objects. Psychological content of the objects is represented by their projections on these dimensions, which can be related to perceived stimulus attributes. Observed dissimilarities between objects correspond to metric distances between the respective points in the cognitive space. The more psychologically dissimilar two objects are, the more separated they are assumed to be in the space.

2.5.2 The Spatial Cognitive Model Used in the Present Research

The present research uses the NMDS approach to derive individual spatial models, but modifies it under the assumption that some salient attributes will be more important than others in discriminating among stimuli, or more desirable or essential for the stimulus to possess in a given context. The result is a model called a master space which spans the several spaces for an individual obtained under several contexts.

If d_{ijk} is the distance between points representing stimuli i and j in the cognitive space derived under context k (context space k), and if

y_{ir} = projection of stimulus i on master cognitive space dimension r

w_{kr} = subjective relevance of master space dimension r under context k then the spatial cognitive model is specified by

$$d_{ijk} \doteq \sqrt{\sum_{r=1}^{M} w_{kr}\left(y_{ir} - y_{jr}\right)^2}$$

where symbol $\doteq$ means approximation in a least sum of squares sense.

The model parameters of dimension projections (y), dimensions weights (w) and proper choice of dimensionality (M) are obtained in a two-part process. The first part employs an ordinary NMDS analysis that incorporates the weights implicitly in the definition of the stimulus projections. It requires a matrix of dissimilarity judgments (δ) taken under one context and produces one spatial model for that context (context space k) by finding the dimension projections (x) and dimensionality (m) such that

$$d_{ijk} \simeq \delta_{ijk}$$

and

$$d_{ijk} = \sqrt{\sum_{r=1}^{m}\left(x_{ir} - x_{jr}\right)^2}$$

where δ_{ijk} = dissimilarity judgment between stimulus i and j under context k, and

$x_{ir} = w_{kr}y_{ir}$

The symbol $\simeq$ means a monotonic transformation which requires $d_{ijk} \geq d_{pqk}$ whenever $\delta_{ijk} > \delta_{pqk}$.

Procedures for finding the x's, d's, and m are discussed in Appendix A. Note that the derived projections (x) are implicitly dependent upon the context k. These projections are collected for each of several contexts and serve as input to the second part.

The second part analyzes the several spatial configurations obtained under the various contexts and produces a master configuration, such that when dimensions are weighted, it approximates (in a least squares sense) each input configuration from each separate context. Inputs to this part are each of the configurations (x) derived by an NMDS analysis of the dissimilarity judgments made under various contexts and output consists of the dimension weights (w) and a master space dimensionality (M), such that

$$d_{ijk} = \sqrt{\sum_{r=1}^{m}\left(x_{ir} - x_{jr}\right)^2} \doteq \sqrt{\sum_{r=1}^{M} w_{kr}\left(y_{ir} - y_{jr}\right)^2}$$

The solution for the parameters is based on an algorithm adapted from a procedure of individual difference scaling (INDSCAL) developed by Carroll and Chang (1970). The procedure was modified to work with spatial configurations rather than dissimilarity judgments and a detailed discussion is given in Appendix B.

2.5.3 The Relation of Context to the Spatial Cognitive Model

The spatial cognitive model is based on experimental observations that people act as if the following processes were carried out:

1. Context development: The individual subjectively develops the judgment context by: noticing the physical and social environment and temporal setting, perceiving the task definition, and establishing an individual perspective. The outputs from this process are the set of attributes or dimensions the individual considers relevant to stimulus discrimination and a set of dimensional weights which reflect the relative importance of the dimensions. (See Bobrow and Collins 1975, p. 133, Osgood, Suci, and Tannenbaum 1957.)

2. Stimulus analysis: Each stimulus is analyzed to discern particular values of relevant attributes. This information is used to prepare a stimulus description or concept. The perceived attributes may be augmented with information from observation, retrieved from memory (Baker and Santa 1977) or inferred through the use of personal heuristics (Gregory 1970).

3. Cognitive organization: Weighted information is organized by representing the stimuli as points in the cognitive space. The dimensions reflect relevant attributes with relative importances implied by dimensional weights.

4. Stimulus classification: The stimuli are classified in the spatial model such that the perceived dissimilarity of two stimuli is a monotonic nondecreasing function of the distance between the two points representing these stimuli.

Context is expected to affect the pattern of stimulus values and weights that an individual uses in a particular judgment task. The value of stimulus information is defined to be the quantitive representation of that information on a particular relevant judgment dimension. Weight refers to the functional importance of that dimension for the required judgment, and is always in reference to a particular context. A change in context, then is expected to change the stimulus coordinates (i.e., attribute values) because a different dimensional weight in the spatial cognitive model becomes relevant. Changes in weights could then account for differences in dissimilarity judgments made under different contexts. The next chapter reviews the pertinent literature that deals with the effect of context on spatial cognitive models.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

In Chapter 1 it was noted that the usefulness of a cognitive space has been demonstrated in a wide variety of experiments and applications. A review of those applications will not be attempted here. Most of the studies, however, treat the cognitive space as a well-defined invariable structure. Yet a few authors have conjectured that the space could change with a change in context. The idea that a variety of cognitive spaces could exist for the same stimulus set, depending upon the context under which they are perceived, is not original to this research. But this research is the first to demonstrate that changing the context while maintaining the same set of stimuli and requiring the same set of judgments can change the cognitive space for a given individual. Some studies have shown that a cognitive space defined for a group of subjects can change because of variations in experimental treatment but none have addressed variations in context or the effect of these variations on an individual's cognitive space. (The use of the term group does not refer to "an assemblage of persons belonging together with established reciprocities" as social psychologists would define the term, but rather to a process whereby the responses from a number of subjects are pooled or aggregated in some way under the assumption that

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the individual differences can be treated as noise.) Nevertheless, these studies are reviewed to demonstrate the nature of cognitive space changes and to indicate theories of change and methods of analysis which proved untenable.

A literature review of the relevant experimental treatment of groups of cognitive spaces suggests that the treatments can be broadly categorized into five types:

1. Variations in skill or experience level
2. Changes in stimulus attributes
3. Context confounded with stimuli
4. Variations in the cognitive space over time
5. Specification of stimulus attributes considered

The review will be divided into sections corresponding to those types.

There is one study that addresses context directly and it will be discussed separately. Cliff (1966a) had three respondent groups judge the similarity of photographs according to different instructions. These instructions determined the context. The cognitive spaces derived from the three groups as well as from a fourth control group were found to differ only slightly and the differences could be directly attributed to differences among groups. This apparent insensitivity of cognitive space to context changes was essentially replicated in a later study (Cliff and Young 1968) involving human trait adjectives and simulated combat conditions as stimuli, and prompted Cliff to conclude that changing the context of the decision making task had only the effect of changing the use of the cognitive space, not the space itself. The present research, however, contradicts this finding. Here, the cognitive space did change with a change in context in a replicable and statistically significant way. Cliff's studies may have obscured contextual effects by only investigating groups or by not analyzing stability of the cognitive spaces.

3.2 Review of Specific Studies

Although none of the studies reviewed addresses context directly, all demonstrate the potential dynamics of the cognitive space with appropriate manipulation of experimental treatments. The studies differ in the variable treated, but all derive cognitive spaces at the group level.

3.2.1 Variations in Skill Level

Shepard (1963) reanalyzed four separate previously published studies of subjects judging whether two successive Morse code signals were the same or different. The studies differed in the number of subjects, data collection techniques, signal similarity measures, signal content, and signal generation procedures. In spite of this, Shepard found that there was a common underlying two-dimensional structure that could be recovered from independent groups. In two studies (Keller and Taubman 1943, Rothkopf 1957), however, the nature or identity of the dimensions differed depending on whether the group consisted of subjects who were skilled or unskilled in understanding Morse code. But a reanalysis of these two studies indicates that there was a context change which may have caused the difference in group cognitive spaces. The task purpose differed between two experiments: one required judgments of discriminability while another required stimulus identification and therefore constituted a learning task. Consequently skill may have been confounded with context obscuring its effect on cognitive spaces. Furthermore, all of the studies reviewed by Shepard were perception tasks rather than cognitive tasks and the transfer of findings between the two domains is not at all clear.

In a similar study, Neidell (1974) had three groups (ordinary drivers, traffic engineering students, and traffic engineering experts) view wide angle movies of road segments and evaluate each segment for driving safety. A spatial cognitive model was formed for each group based on similarity data derived by averaging individual road evaluations along specific attributes over the group. Neidell found very little difference among group cognitive spaces. In contrast to Shepard's findings, the differences could not be related to differences in road safety training among the groups.

3.2.2 Changes in Stimulus Attributes

In their report of attempts to modify cognitive spaces, Moinpour, McCullough and MacLachlan (1976) describe two types of modification: 1) structural -- a change in the number or character of dimensions, and 2) spatial -- a change in the importance of dimensions or position of stimuli on dimensions. Their study dealt with the impact of persuasive communications on group cognitive spaces. Half of the groups received instructions designed to cause spatial changes for actual toothpaste brands, while the other half received instructions designed to cause structural changes.

Spatial changes attempted by linking a particular brand with a favorable message were unsuccessful. A second procedure informed subjects of the abrasion levels of all brands which seemingly caused a significant repositioning of brands along the abrasiveness dimension and an increase in the importance of that dimension. Since the information about abrasion could be consulted by the subjects while they made their judgments, the observed change in the group's spatial model does not necessarily reflect an internal change in group perception of that information. The observed change might be appropriately considered the result of judging a new set of stimuli.

Attempts at changing the structure of the groups' spaces by instructing the subjects to use only one of two attributes were totally unsuccessful. This result has been previously demonstrated by Peak (1960), Axelrod (1963), and Lutz (1975) using Fishbein's (1963) linear-sum-of-weighted-beliefs model to predict behavior. Also Briar (1963) has shown that physical environment effects persist even when subjects are instructed to ignore their actual environment when making judgments under experimental conditions. It seems that subjects have difficulty ignoring attributes which they know to exist, and which, it seems, they consider important in a specific judgment context.

Based on their findings, Moinpour et al. (1976) stated that spatial changes are easier to accomplish than structural ones. They also observed that attempts to cause cognitive change will be quite difficult when the stimuli are unfamiliar and cognitively complex (e.g., more than two important attributes). The present research did not find either of these observations to be the case.

Ryan (1975) demonstrated that information causing cognitive dissonance can reshape one's perception of reality and cause distortions in a cognitive space. He had undergraduates rank distances between a number of campus landmarks before and after detouring around an imaginary barrier, and substituting new landmarks for some original ones. He found that while landmark substitutions caused little perturbation to the group cognitive space, the introduction of the barrier generated significant distortions.

It is important to note that both Ryan and Moinpour et al. manipulated stimulus attributes in trying to affect the cognitive space. The stimuli with the changed attributes technically amount to a different stimulus set and it is reasonable to expect different (but related) cognitive spaces to result from judgments concerning different (but related) stimulus sets.

3.2.3 Context Confounded With Stimuli

Wish (1976) had college students rate communication episodes on bipolar scales. The episodes consisted of interpersonal relations (e.g., between business associates) in a specific situation (e.g., having a brief exchange about a minor technical problem). Wish, Deutsch and Kaplan (1976) essentially repeated this experiment with a larger set of relations. In both studies dissimilarity measures between the episodes were derived by averaging individual ratings over the group.

In these studies the context is that of the "actors" being judged and not that of the judges themselves relating to the actors. Thus context, as used in these experiments, is confounded with the stimuli. Furthermore, the two studies reach conflicting conclusions. The earlier study indicated that the way groups perceived how people in different kinds of relationships communicate with each other is influenced by the communication context; the later study did not support this finding.

Wish's work dealing with the effect of context changes on spatial models was contemporary with this author's preliminary research (Dupnick 1975). In Wish's studies, however, the context is part of the stimulus and the question addressed in the present study is the effect of the subject's context on his cognitive organization of the stimuli. Context, in the sense used in the present study, is in the person perceiving the stimulus, and not in the stimulus itself.

Some of the episodes (stimuli) in Wish's experiments specified the subject as a participant in the stimulus event (e.g., communication between you and your mother vs. between a child and his mother) and thus the social environment characteristic of context was addressed. These cases, however, were not sorted out or even separately identified in Wish's experimental analyses.

3.2.4 Variations Over Time

Osgood and Luria (1954) performed an analysis of semantic differential ratings of abstract concepts (e.g., truth) obtained from a subject exhibiting multiple personalities and presumably undergoing psychological therapy. Osgood and Luria knew nothing about the person. The ratings were obtained while the subject was "in" each of three personalities, with a 2-month period between two testings of each personality. The spatial representation of the goodness, activeness and strength dimensions (the usual dimensions in semantic differential analyses) of the concepts showed that there was little similarity in relationships of the concepts across the personalities. For all practical purposes, three separate persons existed. Each person's perception remained stable over the 2-month interval since none of the personalities showed significant repositioning of the concepts. Differences in spatial models stemming from phenomena of this kind (e.g., multiple personalities, hypnosis, drugs, etc.) are due to changes in the subject and are not the result of a context change.

In a study of a group's perception of presidential candidates in the 1973 election, Moinpour and MacLachlan (1973) assessed the impact of news events on a group's cognitive space over a 9-week interval. Both similarity and preference measures were taken at 5 times and a separate group cognitive space was derived for each. The five cognitive spaces were extremely similar except for small position differences of some candidates. At least three factors peculiar to each individual could account for the differences: 1) inconsistency, 2) cognition (i.e., time to think about the comparisons; or 3) information acquisition. The authors favored the latter explanation but since the others were not explored, they cannot be ruled out.

Although the cognitive space did not change appreciably over time, the preferences for the candidates did, and shifts in preferences were shown to be related to major news events, campaign issues, and candidate characteristics. This finding supports Cliff's earlier statements that changing the judgment context had only the effect of changing the use of the cognitive space, not the space itself (Cliff 1966a, 1968).

Jones and Young (1972) performed a longitudinal study which sought changes in perceived social structure for members of a research group during one year. It was predicted that various subgroups (e.g., new graduate students, "old" graduate students, faculty) would systematically change in their perceptions of the relationships among themselves and others; i.e., the stimulus objects, over the year. An INDSCAL analysis was used to form two 3-dimensional research group cognitive spaces based on two annual surveys. From a comparison of the positions of the stimulus persons common to the two group spaces, the authors concluded that the group structure did not change over the intervening year. A clustering analysis of changes in dimensional weights revealed, however, small but significant differences among the various subgroups in the two group spaces. The differences suggest that a subject's perception of the relationships among the various members of the group, including himself, stabilized with increasing seniority in the research group. The inference is that additional (i.e., new) information available about the stimulus persons diminishes over time ("as people get to know one another") which tends to stabilize perception. But some of the weight changes may have been caused by a change in composition of the research group (both in the stimulus persons and the judges) over the two-part study, so that the stimulus set and the subject set were changed. Furthermore, group judgment consistency was not assessed.

3.2.5 Specification of Stimulus Attributes Considered

Three studies required the subjects to judge stimuli on each of several specified attributes separately. This procedure generally resulted in larger than usual cognitive space dimensionalities and approximated the concept of the master space formulated earlier in Chapter 2.

Fenker and Brown (1969) defined a conceptual space as the collection of all linearly independent psychological dimensions underlying the multidimensional scaling of a set of tasks. They reported a total of 10 linearly independent dimensions obtained from a single subject in judging similarity of random polygons under 15 different task conditions which required the subject only to consider each of 15 verbally-defined shape attributes. Green and Carmone (1971) extended this work to four subjects and used bakery-type food items as stimuli and specific attributes such as flavor, caloric content, etc. Four to six linearly independent dimensions were obtained depending on the subject involved.

Finally, Wallace (1969) noted that a limit on the complexity of kinship terminology apparently exists among human cultures, from modern to primitive. He found that for six very diverse cultures, six orthogonally related distinctions, binary due to sex, were needed to contain the definition of all kinship terms. Furthermore, the number of kinship terms bore no relationship to the complexity of the culture.

3.3 General Review Observations

A number of conclusions can be drawn about context research needs or from faults identified in the experiments:

1. None of the studies provides a model of how cognition is formed, influenced, or changed. Context has not been defined and no one has suggested how it might affect a spatial cognitive model. Without supporting theory, use of the spatial cognitive model may be a sterile statistical or geometric exercise.

2. All of the studies, in one form or another, have contrasted the behaviors of different groups. Experimental results concerning the effects of context on group behavior are inconclusive. Part of this inconclusiveness is resolvable through analysis of subject inconsistency and the effects of aggregating subject responses. Intraindividual analysis is essential in the validation of cognitive models, especially where model changes are concerned, yet none of the studies has investigated subjects at the individual level.

3. There is a conspicuous absence of cognitive space replication so that their stability (or alternately, subject consistency) can be

assessed. Consequently little significance can be attached to findings of changes in cognitive spaces in response to changes in experimental conditions when subject response variability may also be an underlying cause of such changes.

4. Aggregation of response data from a group can obscure possible individual changes. Kaplan (1972) has noted that a change in a single element of the cognitive structure of one individual may be offset or outweighted by serendipitous changes in cognitive elements of other individuals. Bass and Wilkie (1973) argued that the use of groups requires very strong assumptions (e.g., meaningfulness of interpersonal utility or dissimilarity comparison, adjustments for within subject variance, and respondent homogeneity) which are often difficult to substantiate. Additionally, group analysis assumes substantial similarity of individual contexts, which implies that all individuals perceive the same meaning of a situation. Consequently aggregation of response data from a group may obscure any context effects by averaging over individual contexts.

5. Cognitive space dimensionalities are not inherently limited to three or less as Shepard (1969) stated. Task instructions may require the subject to consider many different stimulus attributes in making comparison judgments and could result in large cognitive space dimensionalities. Yet the spaces are related sufficiently to be represented by a master cognitive space. It is likewise reasonable to expect that context variations would also result in different cognitive spaces and these spaces could be contained in a master space for an individual.

6. No study has addressed context as an experimental variable and demonstrated how context changes alone can cause changes in a subject's cognitive space. Indeed, up to now it has been an open question as to whether and how context affects the formation and dynamics of cognitive spaces, although as shown in Chapter 1, there has been some speculation that it is influential.

3.4 Research Objectives

The research to be discussed in this report is an attempt to satisfy a need stated in earlier chapters and restated immediately above: To determine how the context in which dissimilarity judgments are made of stimulus application, affects the formation and dynamics of cognitive spaces for an individual. The studies reviewed in this chapter suggested the research procedure used here.

Chapter 2 outlined a theory of how cognition is formed, reviewed the nature of a cognitive structure which behavioral psychologists suggest an individual uses to form judgments, and related the cognitive structure to the spatial cognitive model introduced in Chapter 1. Context was also defined and an account was given of how it would be expected to affect judgments of dissimilarity and how those effects would be represented by changes in the parameters of the general form of the spatial cognitive model.

Four context characteristics were selected for investigation

1. Social environment
2. Specific stimulus application

3. Nonspecific stimulus application

4. Individual perspective

Experiments presented in four subsequent chapters were designed to produce changes in each of the above four characteristics of context and to test the effects of these changes upon individual cognitive spaces. To ensure that any observed changes would clearly be those sought, and to avoid the possibility of compensating changes as Kaplan (1972) had warned, only one characteristic of context was varied in each experiment. Furthermore each cognitive space was replicated in order to show that cognitive space changes were due to context change rather than to inconsistency of judgments or to cognitive model instability over time. Lastly, the experiments were drawn from different areas of application and used different kinds of stimuli. This minimizes the possibility that a demonstrated change in the spatial cognitive model was due only to a fortuitous choice of experimental setting, and it indicates the generality of the context effect.

CHAPTER 4

EXPERIMENT PROCEDURES AND DATA ANALYSES

4.1 Overview

The experiments described in Chapters 5-8 were designed to demonstrate that controlled changes in context can cause changes in a spatial cognitive model for an individual. Each experiment consisted of determining the cognitive space for a particular set of stimulus objects for each of a number of subjects under each of two or more contexts -- context being the manipulated "variable" in the research. The contexts were chosen to represent the types analyzed in Chapter 2 and the stimulus objects were chosen to be suitable for the context to provide meaningful and relevant experimental tasks for the subjects.

To show that the spatial cognitive model changes were due to context rather than to inconsistency of judgments or to cognitive model instability over time, it was necessary to show that:

1. A spatial cognitive model can be formed for each subject under each context.

2. The model is replicable under each context.

3. There are significant changes in the model across context -- changes in the number, identity or importance of dimensions or in the positions of stimuli on dimensions.

The judgments of dissimilarity from which the spaces were created were replicated once for each subject under each context. The judgments and the resulting spaces were then analyzed to determine subject consistency and space stability within context, and the changes in judgments and cognitive spaces across context.

A master cognitive space was formed for each subject, one which spanned his individual cognitive spaces for the various contexts. A set of dimension weights was determined peculiar to each context such that when these weights were applied to the masterspace, they approximated, in a least-sum-of-squares sense, an individual cognitive space.

In addition, an attempt (usually successful) was made to label the dimensions of subjects' spaces. For this purpose, selected subjects under each context were asked the characteristics they thought they might have considered in making their judgments. Then some or all subjects were asked to rate each of the stimuli on these characteristics. These data along with measurable characteristics of the stimuli were analyzed to obtain labeled dimensions for these subjects' spaces. These subjects' master cognitive space was also labeled for dimension identification. The changes in dimension weights and labels across context were interpreted in light of this information.

All four experiments used the same procedures and data analyses and these methods are described in detail below. This chapter thus serves as a reference to the four chapters on the specific experiments.

4.2 Procedures

4.2.1 Dissimilarity Judgments

Nonmetric multidimensional scaling (NMDS) was used to obtain cognitive spaces from subjects' comparison judgments of stimulus objects. The experimental tasks consisted of having the subjects rate all pairs of stimuli. For n stimuli, there are n(n-1)/2 pairs of stimuli since the order is not considered important. Ratings were made on a subjective, presumably ratio, scale of dissimilarity between 0 and 100. Low numbers meant low dissimilarity while a high number meant high dissimilarity.

A set of instructions along with all stimulus pairs was contained in a booklet which also served as a response recording sheet. The instructions introduced the experimental task, the stimulus objects, the judgment context, and the manner of making and recording comparison judgments. No mention was made of spatial thinking.

For each subject and for each context, two sets of judgments were made. The random sequence of stimulus pairs in the second set differe from that in the first, but the pairs were otherwise the same. The second set of judgments was never made immediately after the first, but followed it from about 4 hours to 1 week later depending on the subject and the experiment.

4.2.2 Attribute Specification

After making their judgments under the various contexts, some or all of the subjects were asked to specify the stimulus attributes they thought they might have considered in making the dissimilarity judgments for any of the specified contexts. When possible, known measurable properties of the stimuli were added to the list of attributes provided by the subjects for purposes of analysis.

4.2.3 Attribute Ratings

Some or all of the subjects rated each of the stimuli on each of the nonmeasurable attributes by giving a number to indicate the degree to which the stimulus possessed or was characterized by the attribute. Comery's (1950) technique was used to obtain ratio scaled ratings between 0 and 1 for the first experiment (Chapter 5). A scale value of unity characterized the stimulus having the greatest degree of an attribute. For the attributes used in the remaining experiments (Chapters 6-8) the subjects were required only to rank order the stimuli. The set of ratings of all stimuli on one attribute by one individual is called a property vector. The measurable or otherwise known values of the physical properties of the stimuli also constituted property vectors but these did not depend on subjective judgment. A separate set of property vectors was maintained for each subject in each experiment although in the case of physical properties, some of the property vectors were identical for all subjects within an experiment.

4.3 Analysis

4.3.1 Construction of Spatial Cognitive Models

The comparison judgments for each context and each subject were represented as an individual symmetrical dissimilarity matrix where cell i-j indicated the degree of dissimilarity between stimuli i and j under a given context. Each matrix was analyzed using Kruskal's (1964a, 1964b) iterative nonmetric multidimensional scaling (NMDS) algorithm called MDSCAL-V (Kruskal 1969) to give a spatial representation of the stimuli. The algorithm seeks an m-dimensional spatial representation of points, one for each stimulus, such that the rank order of the interpoint distances approximates the rank order of the input dissimilarity judgements (see Appendix A for a more detailed description of Kruskal's algorithm).

A value of stress S(m) is associated with an m-dimensional representation of a set of stimuli, and indicates the degree of nonmonotonicity between distances in the representation and the dissimilarity judgments. Since stress decreases with increasing spatial dimensionality, a problem exists as to choosing the "correct" value of m. If m is chosen too large, noise is treated as meaningful information resulting in spurious dimensions. If m is chosen too small, the spatial representation inadequately describes the dissimilarity judgments. A statistical test for choosing the "correct" value of m using a simulation derived empirical sampling distribution for stress was used in this research and is described in Appendix A.

4.3.2 Comparison of Judgments

To avoid confusing change due to context with inconsistency of response or instability of the cognitive model over time, analysis of consistency and stability of the judgment data is necessary. If consistency and stability can be established, then a comparison of judgment data over context changes can be used to detect contextual influences. Two direct measurements were used for these comparisons: a product-moment-correlation between sets of judgments, and a matrix similarity measure between the cognitive spaces derived from these judgments. The judgments came either from replications of the experiment under the same context if consistency was being assessed, or from two experiments performed under different contexts when context effects were analyzed. An indirect measurement using a master space to represent several cognitive spaces from one individual was also used to detect contextual influences. These techniques are described in turn.

4.3.2.1 Product-Moment-Correlation. Each subject was required to make two sets of dissimilarity judgments for each context, the second set being a retest. The check for subject response reliability was performed by computing the Pearson product-moment-correlation r_S between the test and retest judgments when the contexts were the same (S). Since the correlations were expected to be high for reliability, accepting a null hypothesis that the population correlation coefficient ρ_S is non-zero between sets of judgments when the context is the same, is a weak test. A stronger test would be to accept the reliability hypothesis that $\rho_S > \rho$, where $\rho = .90$, say. Dissimilarity judgments were assumed to be reliable if the reliability hypothesis could not be rejected at the .05 significance level.

Differences in dissimilarity judgments when the context was changed were detected by computing r_D between sets of judgments made when the contexts were different (D). If these judgments were independent, the population coefficient ρ_D between them would be zero. When the context changes, however, it is expected that the judgments will appear to be from different cognitive spaces, but not so different that no correlation will be observed. Hence a reasonable difference hypothesis is that $\rho_D < \rho$, where, say, $\rho = .40$. Dissimilarity judgments were assumed to be different and therefore influenced by context changes if the difference hypothesis could not be rejected at the .05 significance level.

Although the true sampling distribution of r when $\rho \neq$ zero is very difficult to derive, a large sample approximation to a normal statistic is given by

$$z = \frac{\sqrt{k - 3}}{2} \ln \frac{(1 + r)(1 - \rho)}{(1 - r)(1 + \rho)} \quad . \qquad (1)$$

where k is the sample size (Fisher 1921); here $k = n(n-1)/2$ and n is the number of stimulus objects in the experiment. This statistic can be used for a test of the reliability hypothesis and the difference hypothesis. Curves for a significance level of .05 for these hypotheses were computed using Fisher's normal approximation for n = 9 and n = 14 stimuli and are given in Figure 4-1. In order to simplify the presentation of comparison statistics when several contexts were involved, worst-case estimates were made for the population correlation coefficients ρ_S and ρ_D using worst-case reliability and difference sample correlation coefficients r_S and r_D and Figure 4-1. Worst-case means that the values used for r_S were the lowest of those from the various contexts investigated for each subject for assessment of judgment reliability, and the values of r_D were the highest per subject when the effects of context changes were assessed. This procedure provided the lowest value of ρ_S and the highest value of ρ_D for which the reliability hypothesis and the difference hypothesis could not be rejected at the .05 significance level.

The effect of context changes on dissimilarity judgments was also demonstrated by determining the significance of the difference between the two population correlation coefficients. This tests the hypothesis $\rho_S > \rho_D$ where the subscripts refer to comparisons in which the contexts were the same (S) or different (D). A normal deviate for testing this hypothesis is

$$z = \sqrt{\frac{k - 3}{8}} \ln \frac{\left(1 + r_S\right)\left(1 - r_D\right)}{\left(1 - r_S\right)\left(1 + r_D\right)} \qquad (2)$$

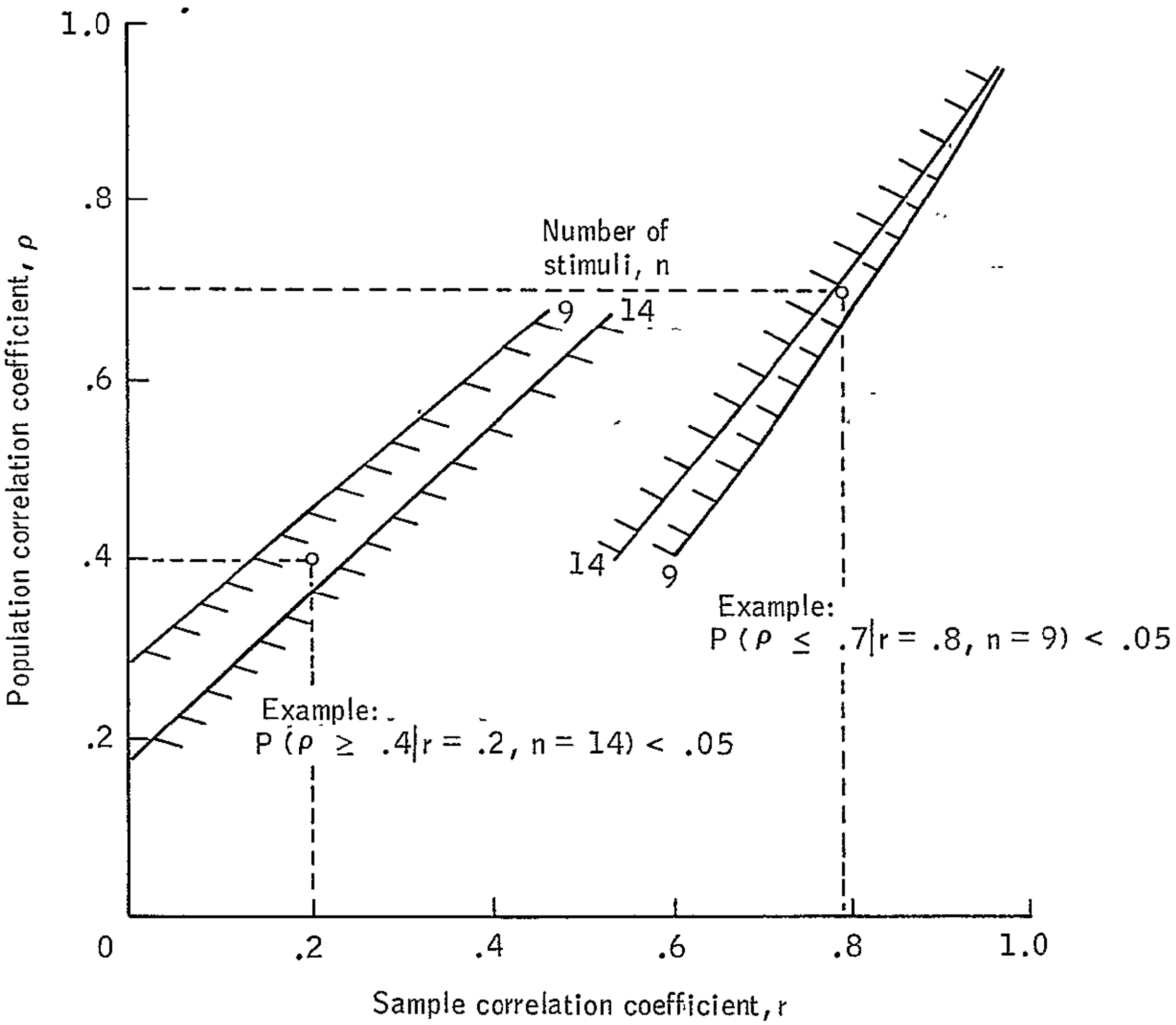


Figure 4-1.- Significance level $\alpha = .05$ for product moment correlation coefficient.

a result also due to Fisher (1921). Curves for a significance level of .05 for this test are given in Figure 4-2. If the worst-case reliability coefficient r_S for each subject is used as a reference value, Figure 4-2 gives a worst-case value of the difference correlation coefficient r_D consistent with the two coefficients being statistically different at a .05 significance level. This value of r_D is referred to as $r_{D_{max}}$.

Although the product moment correlation coefficient can be thought of as simply a measure of linear fit, the use of the above significance tests assumes that the two judgment sets used in comparison tests are bivariate normally distributed. This assumption was not tested rigorously since there was no theoretical reason to suppose that the population of judgment pairs were bivariate normal. The actual experimental data, however, were examined for outliers and appeared to be approximately bivariate normally distributed.

4.3.2.2 Matrix Similarity Measure. Cognitive spaces derived from the original dissimilarity judgments under each context and across context were compared by using a similarity measure based on a matrix fitting technique proposed by Schonemann and Carroll (1970). Since the stimulus coordinates of a cognitive space could be written in the form of a rectangular matrix (stimuli × dimensions), configurations of two spaces could be compared by comparing their matrices. The matrix fitting technique examines the similarity of two cognitive spaces by rotating, translating and rescaling (i.e., a similarity transform) one matrix to attempt to "match" the other (see Appendix C). The matrix

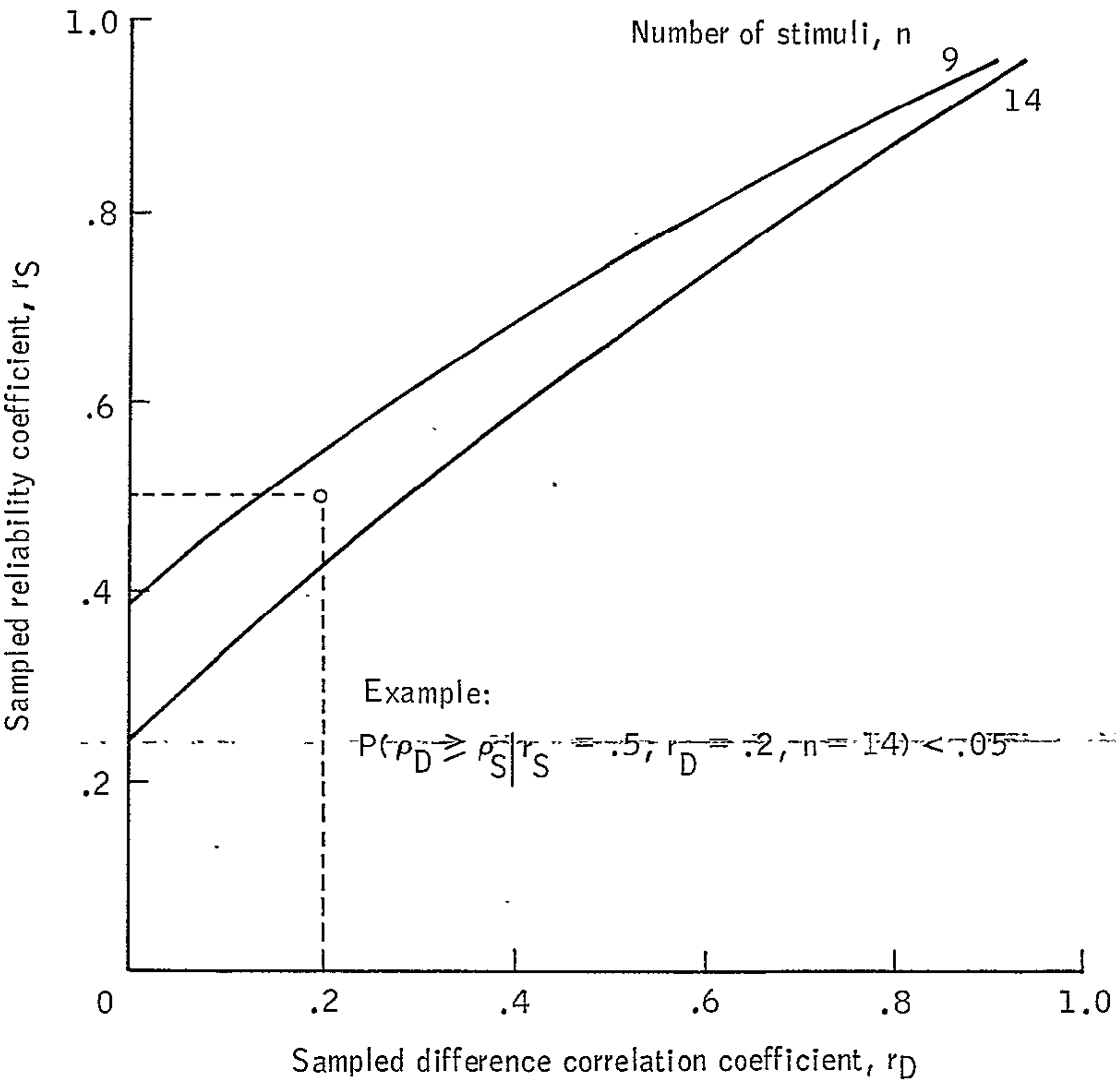


Figure 4-2.- Significance level $\alpha = .05$ for difference between reliability and difference correlation coefficient.

similarity measure (MSM) used to determine the degree of match was adapted from a measure (S) proposed by Lingoes and Schonemann (1974) to measure the success of that technique, where MSM = $\sqrt{1-S}$. MSM varies from 0 (no match) to 1 (perfect match). A perfect match means that an appropriate similarity transform can be found to make the spaces identical. An empirical cumulative distribution function $F(MSM|n,m)$ for the statistic MSM was generated by the present author using Monte Carlo simulation for $n = 9$ and $n = 14$ stimuli for dimensionalities $m = 1-5$. Selected values of this function are given in Table C-1 of Appendix C. The simulation procedure consisted in repeatedly computing the MSM between two random $n \times m$ matrices with uniformly distributed column elements that were scaled to zero mean and unit variance. This distribution was used to test the null hypothesis that the two matrices were random and independent. When cognitive space reliability was being assessed, the test of the null hypothesis was weak since the sampling distribution of MSM under the alternative hypothesis could not be specified. It was expected that in tests for reliability, the null hypothesis would be rejected. The MSM was also used to demonstrate differences between cognitive spaces. Here, the test of the null hypothesis was strong since it was reasonable to expect some similarity in two cognitive spaces from the same experiment even though the context was changed.

Since the application of a matrix similarity measure was new to the area of cognitive spaces, the more familiar correlation coefficient between the judgments was used in parallel in this research. Yet close comparisons between these two measures can not be made since correlations were used to measure similarity of the *input* judgments while the MSM was used to measure the similarity of the *output* cognitive spaces derived from the judgments.

4.3.2.3 Master Cognitive Space. An *indirect* measure of change in cognitive space resulted from the use of a master space which quantified and assisted interpretation of the change. Carroll and Chang (1970) developed an algorithm called INDSCAL for comparison of cognitive spaces from different subjects. It defines a *common space*, a space common to a group of individuals, and a set of dimension weights which are unique to each individual (see Appendix B for a description of INDSCAL). When applied to *the* common space, an individual's dimension weights provide an approximation to *his* cognitive space. In the present work, Carroll and Chang's technique was adapted to comparison of cognitive spaces derived from a single subject under different context conditions. It resulted in a *master space* -- a cognitive space for one individual common to two or more context conditions with a set of dimension weights unique to each context. When applied to his master space, an individual's dimension weights for a context provided an approximation to his cognitive space for that context. Thus all single context spaces were spanned by the master space. The dimensionality of the master space was no less than the greatest dimensionality of the various context spaces and no greater than the sum of their dimensionalities. The basic interpretation is that the individual acted as if he had the master space at his disposal and differentially weighted dimensions according to the context. The weights indicated how the subject emphasized or used certain dimensions in certain contexts and a change in weights demonstrated the effect of context.

The degree to which the master space approximates a cognitive space is determined in INDSCAL by the product-moment-correlation between the squares of the stimulus interpoint distances in the original space and the respective distances in the dimensionally-weighted master space. The choice of minimum dimensionality can be based on either 1) the lowest correlation among those for a set of cognitive spaces, or 2) an average correlation over a set of spaces. Both parameters are available from INDSCAL. This research derived the minimum dimensionality by increasing the dimensionality until no appreciable gain in average correlation between the input interpoint distances and the reconstructed interpoint distances was realized. The sum of the squares of the dimension weights for a context space measured the goodness of fit between the dimensionally-weighted master space and that context space.

4.4 Cognitive Space Dimension Labeling

Nonmetric multidimensional scaling (NMDS) analysis of dissimilarity judgments results in individual cognitive spaces in which objects are represented by their projections on m dimensions. However, the analysis does not reveal the nature of the dimensions. If the dimensions can be identified or labeled, they can suggest how the subject arrived at his judgments and how they are affected by context. Since the individual can describe the stimuli in terms of attributes, either measurable ones of the stimuli, or subjectively perceived ones, it would seem reasonable to assume a relationship between the attributes he would name and the spatial cognitive dimensions. One might then expect to infer the identity of, or to derive labels for the dimensions from this set of attributes. For analysis, a *property vector* P was formed for each subject for each named attribute. A component of this vector p_j indicated the degree to which, for him, stimulus j possessed or was characterized by the attribute. The property vector P was defined on either an interval scale or a rank order scale depending on how the attribute's components were assessed.

A *label* is a directed line in the cognitive space and constitutes a new dimension in that space. Both of the labeling techniques used in this research and described here are concerned with finding labels in the cognitive space such that, the projections of the stimulus points in the space on the label are maximally correlated with a property vector. The directional cosines of the label are determined from a linear regression of a property vector (the coordinates of which are values of the dependent variable) over the stimulus coordinates (the independent variables). The label, or new dimension in the cognitive space is thus linked to a property vector and the identity of that dimension is based upon the attribute that the property vector represents. The labels do not necessarily identify "old" cognitive space dimensions, although they might, but generally define "new" dimensions for which the identity (label) is known. Simply, a label defines a direction with known identity.

A cognitive space is considered to be labeled if the property space (a space that has property vectors parallel to the corresponding labels) spans the original cognitive space. That is, each cognitive space dimension (viewed as a vector defined by the projection of the stimulus points on that dimension) is a linear combination (in a vector algebra sense) of one or more of the property space dimensions (i.e., labels). This requires that 1) there are at least as many labels (i.e., property vectors) as there are cognitive space dimensions, 2) the labels are sufficiently independent (measured by correlation), and 3) the labels correlate well with the cognitive space. The possibility that one or more of these requirements may be unsatisfied will be taken up subsequently.

Two techniques were used in this research to construct labels for the cognitive spaces, linear regression and monotonic linear regression. The choice depended on whether the property vector had been measured on an interval scale or a rank order scale, respectively. The regression techniques are sometimes referred to as "fitting" techniques since their aim is to orient or "fit" the property vector in the cognitive space in order to label the space.

4.4.1 Linear Fitting

Linear fitting is a technique of finding directed lines (labels) in the cognitive space so that the projections of the stimulus points on the lines are maximally correlated with the values of the property vectors. Linear fitting is only appropriate if the property vector is defined on at least an interval scale. Then the directional cosines of the line are defined by the beta coefficients from a multiple linear regression of the components of a property vector (dependent variable) over the stimulus coordinates in the cognitive space (independent variables). The goodness of fit is determined by the multiple correlation coefficient and measures the ability of the attribute on which the property vector is based, to identify or label a direction (or dimension) in the cognitive space where the direction is defined by the constructed line. That the correlation is nonzero is tested with the two-tailed student's-t distribution. This research used the linear fitting technique available in the "maximum r method" (i.e., maximum product moment correlation coefficient) procedure of Miller, Shepard and Chang (1964) which has been conveniently implemented into Chang and Carroll's (1964) computer program PROFIT (Property Fitting).

4.4.2 Monotonic Linear Fitting

When the property vector was defined on a rank order scale, a fitting technique called CM5 (Conjoint Measurement) devised by Lingoes (1973) was used to find labels. The objective of this technique is to find directed lines (labels) in the cognitive space so that the projections of the stimulus points on the lines are maximally correlated with a set of ratio scaled numbers (called a psuedo property vector) which have the same rank order as the components of the original property vector. This objective is tantamount to maximizing the rank order correlation between the property vector and the projections of the stimulus points on the label. The term conjoint is derived from the fact that the lines and the set of numbers with the specified rank order are simultaneously or conjointly determined. Lingoes' technique begins with an arbitrary pseudo property vector which is monotone with the rank order of the property vector. Then a standard linear multiple regression model is used to relate the pseudo property vector to the cognitive space stimulus coordinates. Next, the pseudo property vector is adjusted based on the results of the linear regression and another linear multiple regression is performed. This process is repeated until a multiple correlation coefficient between the pseudo property vector and the stimulus coordinates is maximized. The beta coefficients from the final regression provide the directional cosines of a line in the cognitive space such that the stimulus projections on this line have the same rank order (or nearly so) as the respective property vector.

The collection of lines produced by these fitting techniques define a new coordinate system (and new stimulus point coordinates) for the cognitive space. Since the identities of these lines are known as they represent known properties, the new coordinate system and the original cognitive space are said to be labeled.

4.4.3 Nonorthogonal Labels

It is frequently the case that the labeled dimensions obtained in the above manner are not mutually orthogonal. This situation may occur when the number of property vectors available exceeds the dimensionality of the cognitive space, or when the labeled dimensions (and the underlying property vectors) are interdependent. The interdependency of the labels can be described by their label intercorrelation matrix. A problem may then exist as to finding a set of orthogonal dimensions that labels the cognitive space. The solution lies in factor analyzing the intercorrelation matrix. The application of factor analysis to the problem of finding orthogonal lines, or the labeling of a cognitive space is original to this research. The reader is referred to other sources (e.g., Fruchter 1954) for information on factor analysis.

The general goal of factor analysis is the redefinition or reduction of a set of intercorrelated variables (scores) used to represent data from subjects to a smaller set of new, uncorrelated scores (factors) which are defined solely in terms of the original scores, and which retain the most "important" information in the original scores. This relationship can be represented by the matrix equation

$$S = FV \tag{3}$$

where S represents the standard scores (zero mean, unit variance), F the uncorrelated factors, and V the factor loadings of the scores. A basic assumption of factor analysis is that the intercorrelation between the scores can be accounted for by the nature and extent of their common factor loadings. This results in the basic equation factor analysis for independent (orthogonal) factors

$$R = FF' \tag{4}$$

where R is the intercorrelation matrix of the scores and F' is the matrix transpose of F.

When factor analysis was applied to the labeling problem, the directed lines or labels obtained by either of the above fitting procedures were viewed as correlated "scores" and represented as matrix L. Factor analysis determined a set of independent labels (i.e., factors) represented as matrix $\hat{L}$ which were the most "important" information from the total set of labels. That is, factor analysis determined the m independent lines that underlie the p lines, where m was the dimensionality of the cognitive space to be labeled and p was the number of property vectors ($m \leq p$). The m-dimensional cognitive space could then be defined in terms of these m orthogonal lines. Since the identities of these dimensions were known, the cognitive space was said to be <u>labeled</u> by the m lines.

Let R_{pp} be the intercorrelation matrix among the p lines. Then this matrix can be factored to find factor loadings F_{pm} such that

$$R_{pp} = F_{pm}F'_{mp} \tag{5}$$

and the matrix of m independent lines L_{mm} can be obtained from

$$L_{pm} = F_{pm}\hat{L}_{mm} \tag{6}$$

where L_{pm} is the matrix of p intercorrelated lines in the m-dimensional cognitive space.

Although factor analysis can determine a set of orthogonal labels, it does not indicate how these labels are correlated to the cognitive space. This information is obtained from the fitting techniques and is contained in the multiple correlation coefficients between the labels and the cognitive space stimulus coordinates. Label and cognitive space relatedness was incorporated in the labeling process by weighting the original factor loadings for each label by the respective multiple correlation coefficient and then rotating this new factor loading matrix to a varimax condition (Kaiser 1958). The varimax condition results in a simple structure in which the variances of all the coordinates (factor loadings) are maximized. In other words, each column is "simplified" as much as possible in keeping with the restrictions of orthogonality of columns. Ideally a factor loading matrix with simple structure would have only one nonzero loading in m of p rows and only one nonzero loading in each of the m columns.

In general, one must make a judgment as to what labels are appropriate for describing the cognitive space. The procedure suggested here and used in this research was to examine the rotated multiple correlation coefficient-weighted factor loading matrix for the m rows (representing lines) which had the largest values in the columns and rows in which they appeared, where m was the dimensionality of the cognitive space. Additionally, the other values in these rows and columns should have been small. Then the cognitive space was said to be labeled with the attributes represented by the lines associated with the m rows (lines) so chosen.

4.4.4 Cognitive Space Labeling: Quantitative Measure

The labels chosen for a cognitive space are required to be mutually orthogonal (or nearly so), to be significant descriptors, and to span the space. While the first two requirements have been addressed above, the ability of the chosen labels to span the cognitive space can be assessed by computing the matrix similarity measure (MSM) between the component factor scores and the cognitive space. (The MSM is an index developed for this research to determine the similarity of two cognitive spaces and is discussed in detail in Appendix C.)

If the original property vectors (or in the case of monotonic linear fitting, pseudo property vectors) are rescaled as z scores, then the following formula expresses the method of computing component factor scores:

$$\hat{X}_{nm} = Z_{np} F_{pm} E_{mm}^{-1} \qquad (7)$$

where $\hat{X}$ = component factor scores, an approximation to the cognitive space

Z = z scores of property vectors

F = factor loadings

E = diagonal matrix of eigenvalues of R_{pp}

The ability of $\hat{X}$ to span the original cognitive space X is then measured by computing the MSM between $\hat{X}$ and X. A high value of MSM (approaching unity) indicates that the cognitive space can be approximated by a linear combination of the set of property vectors and strongly suggests that the individual acts as if the respective attributes were directly used in making the comparison judgments. Conversely, the MSM can approach zero if 1) the set of property vectors analyzed does not represent one (or more) attributes actually used by the individual, or 2) the labels are poorly correlated with the property vectors, or both.

4.5 Summary of Analyses

This section lists the analyses performed for each experiment. For some experiments, because the number of subjects was so large, either a summary of certain results of the analysis is given, or detailed analyses are provided for a typical subject in the experiment. The following analyses were performed for *each* subject in each experiment:

1. Development of and selection of an appropriate dimensionality for a spatial cognitive model of original and replicated judgments for each context.

2. Comparison of dissimilarity judgments for the same context and across different contexts.

3. Comparison of cognitive models for the same context and across different contexts.

4. Development of and selection of an appropriate dimensionality of a master space for all contexts.

5. Examination of the change in dimensional weights of the master space with a change in context.

The following analyses were performed for <u>some</u> of the subjects randomly selected in each experiment:

1. Development of property vectors

2. Labeling of cognitive space for each context

3. Labeling of the master space

4. Comparison of the individual cognitive space labels with the master space labels with consideration of the master space dimension weights

5. Examination of the change in cognitive space labels with a change in context

6. Comparison of cognitive model and a spatial model represented by component factor scores from labeling for each context

CHAPTER 5

THE EFFECTS OF SOCIAL ENVIRONMENT CHANGES UPON SPATIAL COGNITIVE MODELS OF TV PROGRAMS

5.1 Summary

Twenty-three subjects judged the dissimilarity of the same set of 14 popular TV programs while assuming different contexts in which viewing would take place. The specified contexts were the social environments defined by the other persons (spouse, close friends, young children, church minister) who viewed the programs along with the subject.

Four different cognitive spaces, one for each context, were developed for each subject and the four spaces generally differed in dimensionality, dimension labels and stimulus point configuration. For each subject, it was found that the four cognitive spaces could be contained within a high dimensional (often 6 or more) master space. Each of the four spaces obtained with the four contexts was represented in the master space by a set of unique weightings for the orthogonal dimensions with some near zero weights indicating that the associated dimensions or attributes were not necessary for discrimination among the TV programs in certain contexts.

5.2 Experiment Background

Probably the most pervasive and influential environment effects are social. The social environment can be described by the additional participants to the task action, their apparent roles, and their interpersonal relationships with the subject. This chapter presents the results of an experiment dealing with the effects of social environment on spatial cognitive models. The experimental results have implication for marketing, especially in the use of visual media and TV programming.

Predicting individual choice is critical to effective marketing. Many researchers have attempted to predict purchase rates or brand choice from respondents' demographic or personality characteristics, but results have not been encouraging (Evans and Roberts 1963). Some more recent research shows that individual choice among similar alternatives appears to be governed by specific attributes of those alternatives (e.g., Frost 1969). Lehmann (1971) examined the effectiveness of a preference model for TV programs based on specific attributes. The model assumed that the programs were points in a multidimensional space and that preference was inversely related to the distance of a point from an ideal point (defined by the ideal amount of each attribute). The model was somewhat successful in that the average correlation between subjects' stated preference ratings of TV programs and model predictions of preference ratings was .49.

Context may also alter the relationships among attitude, choice, and preference. Friedman and Fireworker (1977) have noted an apparent belief among TV executives that certain types of programs should only be shown during specific time slots when certain audiences are watching. This suggests that the executives consider context to influence program preferences.

~~It was not the purpose of this experiment to consider choice or~~ preference, but the results demonstrated that changes in the context, the social environment in which a program was viewed, produced substantial changes in the perception of the program. These changes, in turn, would be expected to exert significant influences on individual preference and choice behavior.

5.3 Method

5.3.1 Stimuli

The stimuli were the names of 14 TV programs selected from a (then current) 1975 TV Guide (see Table 5-1). All programs were scheduled for prime time viewing, thought to be familiar to most people who at least occasionally watched TV, and representative of the variety of available shows.

5.3.2 Subjects

Twenty-three subjects participated in the phases of the experiment requiring dissimilarity judgments, but due to subsequent unavailability of the remainder of the subjects, only five were carried through all phases with accompanying analyses. The subjects included 15 men and

TABLE 5-1.- STIMULI FOR TV PROGRAM EXPERIMENT

1. The Smothers Brothers
2. The Rookies
3. Adam-12
4. National Geographic Special
5. M*A*S*H
6. Hawaii Five-0
7. Marcus Welby
8. Little House on the Prairie
9. Petrocelli
10. The Waltons
11. Wide World of Sports
12. All in the Family
13. 60 Minutes
14. Hot'l Baltimore

8 women ranging in age from about 25 to 50 who were volunteers from a book discussion group.

5.3.3 Procedures

The 23 subjects rated the subjective dissimilarities of the 91 pairs of the 14 TV programs in accordance with the general procedures detailed in Chapter 4. The subjects were instructed to make the dissimilarity judgments by considering that they would view the programs under each of four social environments; (1) good, close adult friends, (2) one's church minister, (3) one's children, and (4) one's spouse. All judgments for each context were replicated using different random orderings of the stimulus pairs and different orders of context presentation, but the stimulus pairs were otherwise the same.

All subjects were asked to specify the attributes of the programs they considered in making the dissimilarity judgments. Because ~~collectively their 9 attributes covered those most frequently mentioned,~~ 10 of the 23 subjects were interviewed individually to solicit words or phrases descriptive of the 9 attributes mentioned. These are given in Table 5-2.

TABLE 5-2.- STIMULUS ATTRIBUTES USED IN TV PROGRAM EXPERIMENT

1. Maturity, average age level
2. Invites personal involvement
3. Humorous, comical
4. Suspenseful, mysterious
5. Educational, informative, value-laden
6. Active, dynamic
7. Well-produced and directed
8. Depicts goodness, well-being, harmony
9. Controversial, satirical
10. Personal preference

Only 5 of the original 23 subjects completed the remaining part of the experiment which required these subjects to rate the programs on the 9 attributes and also on personal preference. A set of 10 ratio-scaled property vectors was formed for each of the 5 subjects from these ratings. The description of the analysis and the discussion which follow refer, for convenience, to one subject chosen at random from the

5 who completed all phases of the experiment because his data are typical. He is referred to as subject A. (Results for the other 4 subjects, for whom property vectors were also derived, will be referred to where appropriate.) Subject A's property vectors for the 14 programs are given in Table 5-3; intercorrelations are given in Table 5-4.

5.4 Analysis

5.4.1 Construction of Cognitive Spaces

Four cognitive spaces were developed for each of the 23 subjects under the 4 contexts using the techniques discussed in Chapter 4. One- to 4-dimensional spaces resulted for each context. The stress values for each number of extracted dimensions for subject A is shown in Figure 5-1. Using the dimensional selection procedure described in Chapter 4, spatial models dimensionalities for the friend, minister, child, and spouse context were selected to be 3, 4, 3 and 2, respectively, for subject A. The dimensionalities selected for each of the 23 subjects are given in Table 5-5.

5.4.2 Comparison of Judgment Data

Chapter 4 described procedures for comparing sets of dissimilarity judgments using the Pearson product-moment-correlation coefficient (r), and for comparing cognitive spaces derived from the judgments using the matrix similarity measure (MSM). Table 5-6 presents worst-case summary statistics for comparison of judgments for the 23 subjects. Worst case means that the values listed are the lowest comparison statistics

TABLE 5-3.- PROPERTY VECTORS FOR SUBJECT A:
TV PROGRAM EXPERIMENT*

Television program	Maturity	Personal	Humorous	Suspenseful	Educational	Active	Produced	Goodness	Controversial	Preference
Smothers	87	84	31	98	27	71	26	43	34	36
Rookies	100	45	60	49	36	75	42	52	53	42
Adam-12	65	61	27	89	27	79	21	37	28	15
Geographic	82	91	40	70	21	47	46	63	57	29
M*A*S*H	71	70	13	71	78	70	46	63	23	32
Five-O	87	53	27	100	88	78	56	41	30	42
Welby	58	41	18	72	84	100	69	66	30	48
Little House	54	100	27	73	51	90	45	62	29	51
Petrocelli	78	99	41	83	74	72	65	100	23	100
Waltons	80	79	29	64	95	79	74	66	47	26
Sports	70	82	18	20	100	65	100	93	20	55
Family	95	73	100	23	17	51	27	44	100	29
60 Minutes	80	62	60	75	33	71	44	47	71	28
Hot'l	92	61	84	33	56	42	63	48	96	58

*Decimals omitted.

TABLE 5-4.—INTERCORRELATIONS OF PROPERTY VECTORS:
SUBJECT A OF THE TV PROGRAM EXPERIMENT*

Attribute	Maturity	Personal	Humorous	Suspenseful	Educational	Active	Produced	Goodness	Controversial
Personal	-22								
Humorous	69	-12							
Suspenseful	-26	03	-52						
Educational	-33	-06	-56	-04					
Active	-63	-21	-65	52	38				
Produced	-21	07	-30	-37	84	07			
Goodness	-33	50	-34	-27	58	09	73		
Controversial	63	-19	93	-53	-51	-68	-25	-44	
Preference	-05	33	-00	-07	40	03	50	71	-22

*Decimals omitted.

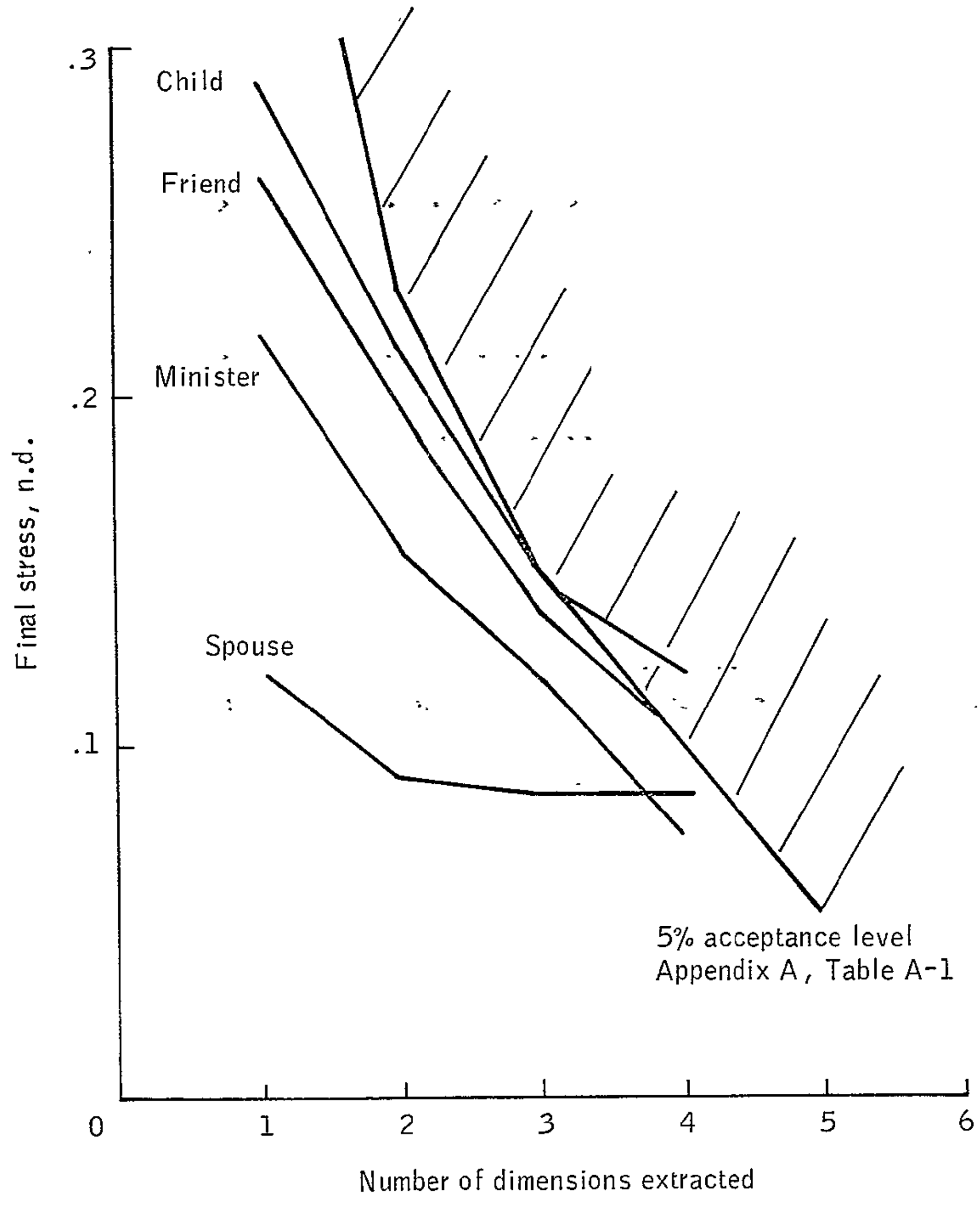


Figure 5-1.- Final stress vs. number of dimensions extracted for four social environments: Subject A of TV program experiment.

TABLE 5-5.- COGNITIVE SPACE DIMENSIONALITY SELECTED FOR EACH SUBJECT: TV PROGRAM EXPERIMENT

$[p < .05]$

Context	Subject –																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Friend	3	2	2	2	3	1	3	2	2	2	4	3	1	4	2	4	1	4	3	3	2	4	3
Minister	4	4	4	1	3	2	4	1	4	1	4	3	2	2	2	2	4	2	3	3	4	4	2
Child	3	2	3	2	2	2	2	4	2	3	3	2	2	2	2	4	4	4	4	2	2	3	3
Spouse	2	2	4	2	2	1	2	3	3	2	1	3	2	3	4	2	2	2	2	3	4	2	2

of those from the various contexts compared for each subject for assessment of judgment reliability, and the highest comparison statistics when the effects of context changes were assessed. Table 5-6 also gives a worst-case value of the difference correlation coefficient such that it ~~is statistically different than the sampled reliability correlation coef~~ficient at the .05 significance level.

Table 5-6 shows that the reliability hypothesis can be accepted at the .05 level for each subject for $\rho_S > .41$. That is, when the con~~text is fixed, the probability is .05 that a set of test-retest dissimi~~larity judgments are related with a population reliability correlation coefficient ρ_S of less than or equal to .41. Similarly, the difference hypothesis can be accepted at the .05 level for each subject given a population difference correlation coefficient $\rho_D < .63$. With the exception of 6 subjects (E, K, M, R, S, and V), the worst-case (lowest) population reliability correlation coefficient exceeded the worst-case (highest) population difference correlation coefficient. But, for all subjects except M, a difference between the two correlation coefficients was statistically significant at the .05 level or better.

Table 5-5 demonstrates that for most subjects the cognitive model undergoes a change in dimensionality, but even more convincing data that support a change in the cognitive model are found in Table 5-6. The generally low values of the difference coefficients show that the change in context caused substantial repositioning of the stimuli in an individual's cognitive space. That this repositioning is not attributable to inconsistency of subject responses or instability of

TABLE 5-6.- CORRELATIONS (r) BETWEEN DISSIMILARITY JUDGMENTS AND SIMILARITY MEASURES (MSM) BETWEEN COGNITIVE SPACES FOR EACH SUBJECT: TV PROGRAM EXPERIMENT* ($p < .05$)

[Sample Size = 91]

Relationship	Subject -																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Context compared: Same																							
r_S	86	80	57	87	57	78	75	82	67	71	73	69	54	91	95	79	76	66	72	91	90	56	87
ρ_S	80	72	44	81	44	69	66	75	54	61	63	59	41	84	90	71	67	55	62	84	83	43	82
MSM$_S$**	84	81	62	91	72	83	84	85	71	83	74	88	50	97	87	89	74	89	83	85	88	53	92
Context compared: Different																							
r_D	37	47	19	17	34	05	40	34	25	21	49	16	45	34	13	48	08	45	49	20	47	33	13
ρ_D	51	61	35	33	48	22	54	48	41	37	63	32	59	48	29	62	25	59	63	36	61	47	29
MSM$_D$**	43***	20	11	05	50***	05	30	23	19	44***	48***	14	27	46***	09	33	03	51***	43***	36	36	41***	19
$r_{D_{max}}$	78	70	38	80	38	65	62	72	51	58	60	54	34	86	92	68	64	50	58	86	85	37	80

*Decimals omitted.
**$p < .01$
***$p < .10$

the cognitive model is supported by the reliability coefficients. The worst-case difference coefficient is substantially less than the worst-case reliability coefficient and the difference in correlation coefficients is statistically significant. This implies that each cognitive space represents a unique context for an individual. These data provide strong support that changes in the context of stimulus application (social environment) can cause the spatial cognitive model for an individual to change.

Subject A (among others) was a possible exception to some of these statements. Detailed results of the comparison analysis of A's judgments appear in Table 5-7. The subject was quite consistent for fixed contexts. When the context changed, the cognitive space changed

TABLE 5-7.- CORRELATIONS BETWEEN DISSIMILARITY JUDGMENTS AND COGNITIVE SPACE SIMILARITY MEASURES (IN PARENTHESES) BETWEEN COGNITIVE SPACES UNDER FOUR SOCIAL ENVIRONMENTS: SUBJECT A OF TV PROGRAM EXPERIMENT*

[Diagonal terms are values of r_S and (MSM_s); off-diagonal terms are r_D and (MSM_D)]

	Friend	Minister	Child	Spouse
Friend	92 (84)**			
Minister	27 (19)	87 (92)		
Child	17 (16)	37** (21)	94 (85)	
Spouse	28 (43)	15 (07)	21 (10)	86** (96)

*Decimals omitted.
**Values shown in table 5-6.

substantially except for the apparent relationship between the friend and spouse cognitive spaces. The moderate similarity between these two cognitive spaces is not surprising and may be a reflection of the fact that there is a moderate similarity in the relationships between adult friends and between spouses. A similar relationship between the friend and spouse cognitive spaces for subjects E, K, M, R, S, and V accounted for the worst-case (lowest) reliability correlation coefficient being less than the worst-case (highest) difference correlation coefficient as noted in Table 5-6 and discussed above.

5.4.3 Master Cognitive Space

A master cognitive space for one individual is an approximation to the union of the cognitive spaces formed under different contexts. An INDSCAL analysis of subject A's 4 context spaces indicated that 6 linearly independent dimensions could reasonably span the spaces. The dimensional weights for the master space of subject A are given in Table 5-8. The sum of the squares of the weights measures the goodness of fit between the dimensionality-weighted master space and the separate cognitive spaces. The manner in which the master space spans each cognitive space can be examined by identifying the dimensions with the k largest weights where k is the dimensionality previously chosen for the cognitive space based on an MDSCAL analysis. For the friend context, the dimensionality chosen was 3, and according to Table 5-8, the 3 largest weights are for dimensions 3, 4 and 6. Such weights are circled in Table 5-8 and indicate the manner in which the master space spans those

TABLE 5-8.- DIMENSION WEIGHTS FOR THE 6-DIMENSIONAL MASTER SPACE: SUBJECT A OF THE TV PROGRAM EXPERIMENT*

Dimension	Cognitive space -			
	Friend	Minister	Child	Spouse
1		(55)		
2		(64)	(79)	
3	(74)	㊼		(88)
4	㊹			42
5			㊺	11
6	㉙	⑯	㉕	14
Fit**	83	97	89	98

*Decimals omitted; weights < .10 deleted.
**Sum of squared weights.

cognitive spaces under the noted context. The minister and child context appear to use unique dimensions that no other spaces use, dimensions 1 and 5. The remaining dimensions are shared in various ways ove the four contexts.

Master cognitive spaces were developed for each of the 23 subjects and Table 5-9 presents a summary of pertinent results extracted from these analyses. The upper bound on dimensionality is the sum of the dimensionalities of the individual spaces. The master space dimensionality for any subject is at least half of the upper bound implying that about half of the dimensions of the individual cognitive spaces are unique. Dimension sharing, however, is more common than dimension uniqueness. Only for subject B did the number of unique dimensions (4) exceed the number shared (3). Subject M had complete sharing of

TABLE 5-9.- SUMMARY OF MASTER COGNITIVE SPACE ANALYSIS FOR EACH SUBJECT:
TV PROGRAM EXPERIMENT

Parameter	Subject –																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Dimension upper bound	12	10	13	7	10	6	11	10	11	8	12	11	7	11	10	12	11	12	12	11	12	13	10
Dimensionality	6	7	8	4	5	4	6	5	7	5	6	5	4	5	5	6	5	6	7	6	6	7	6
Worst fit*	86	78	81	68	88	65	78	61	59	85	94	81	70	84	67	79	64	87	91	83	74	89	82
Best fit*	98	95	93	87	95	83	84	90	83	96	99	91	79	91	94	88	92	96	98	97	92	93	96
Average fit*	92	88	86	76	86	86	82	78	73	91	96	87	76	88	83	84	83	91	94	90	86	91	91
Shared dimensions	4	3	5	3	2	3	4	3	4	4	4	3	4	4	4	5	3	3	4	3	5	4	3
Unique dimensions	2	4	3	1	3	1	2	2	3	1	2	2	0	1	1	1	2	3	3	3	1	3	3

*Decimals omitted.

dimensions meaning that the four contexts evoked a set of four independent dimensions but they were differentially weighted in each context.

5.5 Dimension Labeling

Five of the 23 subjects supplied information that could be used to label their cognitive spaces. A set of 10 property vectors were obtained for each of the 5 subjects using this information according to the procedures discussed in Chapter 4. The vectors represented the subject's ratings of the 14 TV programs according to the 10 attributes specified in Table 5-2. Property vectors for subject A are given in Table 5-3. Cognitive space labels were developed for each of the 4 context spaces for the 5 subjects investigated using the linear regression property fitting technique discussed in Chapter 4. Table 5-10 presents the results of a factor analysis of the interlabel correlation matrix for subject A's cognitive space under the *friend* context. The factor loadings have been weighted by the multiple correlation coefficient between the property vector and the cognitive space stimulus coordinates and rotated to a varimax condition.

The *maturity*, *action* and *goodness* attributes have the highest individual weighted loadings on the three dimensions that define this space and are noted in Table 5-10. Hence, the *friend* cognitive space can be defined for subject A by the labels representing these attributes.

Dimension labeling for the four individual cognitive spaces and the master space for subject A is summarized in Table 5-11. A check mark appears in an attribute-cognitive space cell if labeling analyses

TABLE 5-10.- WEIGHTED FACTOR LOADINGS OF INTERLABEL CORRELATION MATRIX FOR FRIEND CONTEXT: SUBJECT A OF THE TV PROGRAM EXPERIMENT*

Attribute	Factor**			r^2***
	1	2	3	
1. Maturity	12	-11	93	95
2. Personal	02	21	61	64
3. Humorous	-10	00	78	79
4. Suspenseful	24	48	22	58
5. Educational	-19	38	-28	51
6. Action	88	-09	-13	89
7. Produced	19	30	14	38
8. Goodness	10	87	16	89
9. Controversial	24	-08	47	73
10. Preference	-13	57	19	70

*Decimals omitted.

**Loadings rescaled to rms value of r^2.

***Multiple correlation coefficient from linear regression ($r_{\alpha=.01}$ = .78).

TABLE 5-11.- SUMMARY OF LABELING ANALYSIS FOR FOUR COGNITIVE SPACES: SUBJECT A OF THE TV PROGRAM EXPERIMENT

Attribute	Cognitive space -				
	Master	Friend	Minister	Child	Spouse
Personal	✓		✓		
Educational	✓		✓	✓	
Action	✓	✓	✓		✓
Goodness	✓	✓			✓
Controversial	✓			✓	
Maturity		✓	✓		
Humorous				✓	
Unidentified	✓				

indicated that the particular attribute was used in making dissimilarity judgments in that context. Of the 10 attributes mentioned by the subjects, 7 were sufficient to identify dimensions in the four spaces for subject A. The suspenseful, well-produced, and preference attributes did not figure in any of subject A's spaces. The strong similarity between the pattern of checks in Table 5-11 and the pattern of relative sizes of the master space dimension weights in Table 5-8 confirms the ability of the master space to span the 4 cognitive spaces since the master space uses a majority of the same labels used in the 4 spaces. Table 5-11, for example, indicates that only the minister context evoked the personal attribute and Table 5-8 indicates that only dimension 1 has a substantial weight under the minister context and no other contexts. This suggests that dimension 1 of the master space is linked to the personal attribute. In like manner, the master space dimension labels can be compared with the individual space labels in Table 5-11.

The labeling analysis, however, did not identify the sixth dimension of the master space, yet Table 5-11 suggests its identity. The attributes of maturity and humorous, applied to 3 of the 4 individual spaces, were not represented among the 5 attributes identified for the master space. Because of their apparent subjective similarity, it is conjectured that these two missing attributes are somehow blended (their intercorrelation of .69 noted in Table 5-4 supports this possibility) into the unidentified sixth master space attribute; perhaps adult humor. Finally, in order for the master space to represent the first three contexts adequately (and the goodness-of-fit values in Table 5-8 indicate that it does), the unidentified attribute must be a combination of humorous and maturity, or else the dimensionality of the master space must be increased to include these attributes.

The ability of selected labels to span the cognitive space they described was determined by computing the cognitive space similarity measure (MSM) between the cognitive space and the cognitive space represented by the component scores obtained from the factor analysis of label intercorrelations. Table 5-12 indicates the MSM's for the four context spaces and the master space for each of the 5 subjects investigated in the labeling study. The generally high values indicate that the selected labels provide a good description of the respective space.

TABLE 5-12.--SIMILARITY MEASURES BETWEEN COGNITIVE SPACE AND COMPONENT SCORES FOR FOUR CONTEXT SPACES AND MASTER SPACE: 5 SUBJECTS OF THE TV PROGRAM EXPERIMENT*

Space	Subject -				
	A	G	K	M	U
Friend	79	67	84	52	83
Minister	84	73	91	74	89
Child	81	76	79	66	80
Spouse	86	74	87	71	79
Master	76	71	74	64	75

*Decimals omitted.

5.6 Conclusions

The change in context produced different spatial cognitive models for all 23 subjects. Some of the differences were structural in that the number and identity of dimensions of the models changed. Others were shifts in dimensional emphasis (weighting) and modification of the stimulus configuration. These changes support the major hypothesis of this research that changes in the context of judging stimulus objects can cause changes in a spatial representation of their perception (i.e., spatial cognitive model) for a given individual.

The preference attribute did not feature in any of the labels used in the cognitive spaces of the 5 subjects studied in detail. That is, preference did not explain any of the cognitive space dimensions so these subjects judged dissimilarity of the TV programs without reference to preferences. Only one set of preferences was obtained from each of the 5 subjects who rated the programs for labeling purposes. The context, however, was not specified when preferences were solicited. Had a set of preferences been obtained for each context, the conjecture that context affects perception and ultimately preference, might have been tested.

CHAPTER 6

THE EFFECTS OF CHANGES IN TASK PURPOSE UPON A SPATIAL COGNITIVE MODEL OF AERIAL PHOTOGRAPHS

6.1 Summary

One subject, skilled in the visual and mathematical interpretation of satellite photo data, judged the dissimilarity of computer processed black and white aerial photos of a yacht basin. The 14 photos presented an identical view but appeared to be different because of different amounts of noise and blur introduced in their generation from the original photo. The context was manipulated in the experiment by changing the stated purpose for which the photos would be used.

The subject was asked first to judge the dissimilarity of the photos for the purpose of identifying unspecified objects generally (unspecified objects context). This task would essentially be akin to using them for general photo interpretation. Next the task was changed to judging dissimilarity of the photos for the purpose of surveying boat classes; i.e., with objects specified (specified objects context). The first context produced a 3-dimensional space while the second a 2-dimensional space. The judgments were replicated with the same subject about one week later and the entire experiment with replication was repeated one year after the original study with virtually identical results.

C-2

It was found that context change, in this case, change in the stated purpose for which the objects would be used, produced a difference in spatial cognitive models for the subject. The differences were both structural and spatial; i.e., the spaces differed in dimensionality, dimension labels and stimulus configuration. A 3-dimensional master cognitive space was developed to span the two spaces for the subject. Each space was represented in the master space by a unique set of weightings for the three dimensions, with a near zero weight for the dimension unnecessary for discriminating among the aerial photos for the objects specified context.

6.2 Experiment Background

This chapter addresses the task definition characteristic of context. It presents the results of an experiment to study the effects of changing the stated purpose for which the stimuli would be used on spatial cognitive models. Since the experiment setting deals with the effects of context on image perception, this topic is discussed and some application of experimental results are given, especially in the area of visual displays.

Zatoni (1978) has indicated that making the picture of a large-screen TV display acceptable to the average viewer is a difficult problem. Since the eye and the brain form a complicated system for interpreting images, simple measures like brightness and contrast can't always determine if the picture is good. Huang, Tretiak and Schreiber (1971), Marmolin and Nyberg (1975), and Hunt and Sera (1978) have suggested that there are different image properties of importance to image quality, and their importance may depend on the observer's experience, the type of task to be performed with the images, the nature of the information sought from the image, and so on. Consequently, image quality is likely to be a function of a number of different perceptual dimensions.

It is the thesis behind the present research that perception depends upon context. If so, it would be reasonable to expect to find that the relationship between subjective picture quality and physical properties also depends upon the context of picture quality evaluation. As Hunt and Sera suggest, human beings may adapt to circumstances in a way that depends on the perceived context. A given level of image quality can be acceptable to an individual if associated with a human portrait, but unacceptable if the same quality is associated with an aerial military reconnaissance photo. The same physiological vision processes are involved in both cases, but the context is radically different because of different viewing purposes. Specifically, one should expect to find that a model used to predict image quality and based upon subjective data gathered under one context will not perform satisfactorily when the context changes sufficiently. Hunt and Sera recognized this problem by limiting their study to nonperformance environments (i.e., situations) characterized as viewing images for recreational, entertainment, or aesthetic purposes. Context effects are likely to be more pronounced in performance or task-oriented situations where the image is a tool employed in achieving a particular goal. The study reported here supports this possibility, although image quality was not directly assessed.

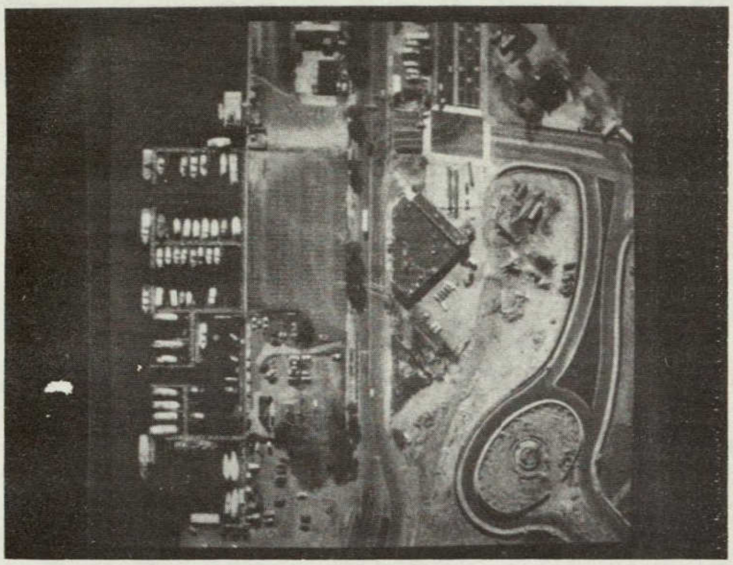
6.3 Method

6.3.1 Stimuli

The stimuli were 14 digitally processed images of an aerial photograph of a yacht basin. Black and white Polaroid photographs were taken of CRT representations of the images. The pictures were identica except that different amounts of noise (giving an appearance of graininess) and blur (giving the appearance of different numbers of gray levels) were introduced by computer in production of the pictures from the original photograph. The "best" and the "worst" pictures are illustrated in the top and bottom portions of Figure 6-1, respectively. The stimuli were those used in previous studies by Hunt and his associates and their production is described in detail in Hunt and Sera (1978 The loan of the stimuli by Dr. B. R. Hunt of the University of Arizona Digital Image Analysis Laboratory is gratefully acknowledged.

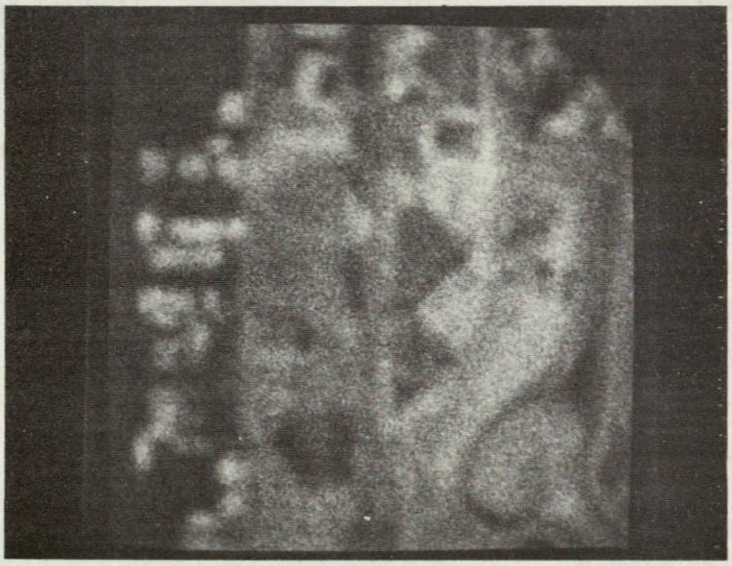
6.3.2 Subject

One subject, skilled in the visual interpretation and mathematical analysis of satellite photo data, participated in the experiment. The subject routinely processes and uses digital images in her employment.



"Best"

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



"Worst"

Figure 6-1.- Examples of two "extreme" photos from the aerial photo experiment.

6.3.3 Procedures

The subject judged the relative dissimilarity of the 91 pairs of the 14 photographs in accordance with the general procedures outlined in Chapter 4. Pair judgments were performed by randomly arranging the 14 stimulus photos enclosed in individual opaque envelopes on a table in front of the subject. The procedure then required the subject to obtain the next pair of photo index numbers from a questionnaire, remove the two appropriate photos from their envelopes, judge the dissimilarity of the pair according to the stated context, record her judgment on the response sheet, and finally return the photos to their respective envelopes. The 91 judgments took about an hour.

Two context conditions were used. The first required the subject to consider the pictures for the purpose of discerning unspecified objects; i.e., for the general photo interpretation task of determining what is in the photograph. Under the second context, the judgments were repeated considering the pictures for surveying boat classes or sizes. For this context, the objects were specified. Judgments under each context were replicated and all sets of judgments used different random sequences of the 91 pairs of photos, but otherwise the procedures and stimuli were the same.

The experiment was administered twice, first in 1976 and again approximately a year later in 1977, with the same subject and stimuli and with virtually identical results. Except where noted, the results from the later version of the experiment are reported.

Candidate attributes were needed to identify the dimensions of the spatial model so the subject was asked to specify as best she could the attributes used in making the dissimilarity judgments. Six were obtained and the subject rated each photo on each of these. Table 6-1 contains the definition of these 6 attributes as supplied by the subject. Two known physical properties of the photos were available, blur and noise, and they served as additional attributes. Thus there were 8 attributes used to describe the photos. The 8 corresponding property vectors are given in Table 6-2 and the rank order correlations between these vectors are given in Table 6-3. No property vectors were obtained for the 1976 experiment since it essentially served as a pilot study.

TABLE 6-1.- DEFINITION OF SUBJECTIVE STIMULUS ATTRIBUTES: AERIAL PHOTO EXPERIMENT

Attribute	Definition
Sharpness	A lack of sharpness has a tendency to diffuse the outlines of objects and makes them appear ragged
Clarity	The degree to which certain features of an object can be discerned sufficiently to establish its identity
Contrast	Difference or number of steps between gray levels (tones) of contiguous objects
Granularity	The average size of the unit cell (grain) of which an image is composed
Density	The overall average gray level (tone) of the image
Chroma	The apparent number of different gray levels (tones) used in the image

TABLE 6-2.- PROPERTY VECTORS USED IN AERIAL PHOTO EXPERIMENT

Attribute	Photo number -													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Blur, pixels	1.6	5.0	5.0	0	1.6	1.6	1.0	0	4.0	0	5.0	2.5	1.6	0
2. Noise, dB	6	6	15	∞	15	9	∞	9	∞	15	9	∞	∞	6
3. Sharpness; min (1), max (14)	5	2	3	14	10	7	12	9	4	13	1	6	11	8
4. Clarity; min (1), max (14)	6	2	1	14	11	5	13	10	4	12	3	7	9	8
5. Contrast; low (1), high (14)	5	1	2	14	9	7	11	12	4	13	3	6	8	10
6. Granularity; coarse (1), fine (14)	3	5	7	13	11	4	12	2	8	14	6	9	10	1
7. Density; light (1), dark (14)	1	14	13	2	8	11	6	5	10	4	12	9	7	3
8. Chroma; few (1), many (14)	2	1	3	13	10	9	12	7	6	14	4	8	11	5

TABLE 6-3.- RANK ORDER CORRELATIONS OF PROPERTY VECTORS USED IN AERIAL PHOTO EXPERIMENT*

Attribute	Blur	Noise	Sharpness	Clarity	Contrast	Granularity	Density
Noise	-31						
Sharpness	-24	-13					
Clarity	-20	23	06				
Contrast	-30	48	40	33			
Granularity	36	-24	32	-25	05		
Density	00	41	-27	64	26	-40	
Chroma	00	08	23	13	02	25	06

*Decimals omitted.

6.4 Analysis

6.4.1 Construction of Cognitive Spaces

Cognitive spatial models were developed for the subject under the two contexts using the techniques discussed in Chapter 4. The stress values as a function of extracted dimensions for the models for the two context conditions are given in Figure 6-2. From this figure it was concluded that the appropriate number of dimensions to associate with the _unspecified objects_ context was 3 and with the _specified objects_ context, 2. The significance levels associated with the 3- and 2-dimensional cognitive spaces are about .08 and .01 for the 1977 experiment and .12 and .05 for the 1976 experiment, respectively. Although a minimum significance level of .05 had been arbitrarily established for selecting model dimensionalities, the 3-dimensional _unspecified objects_

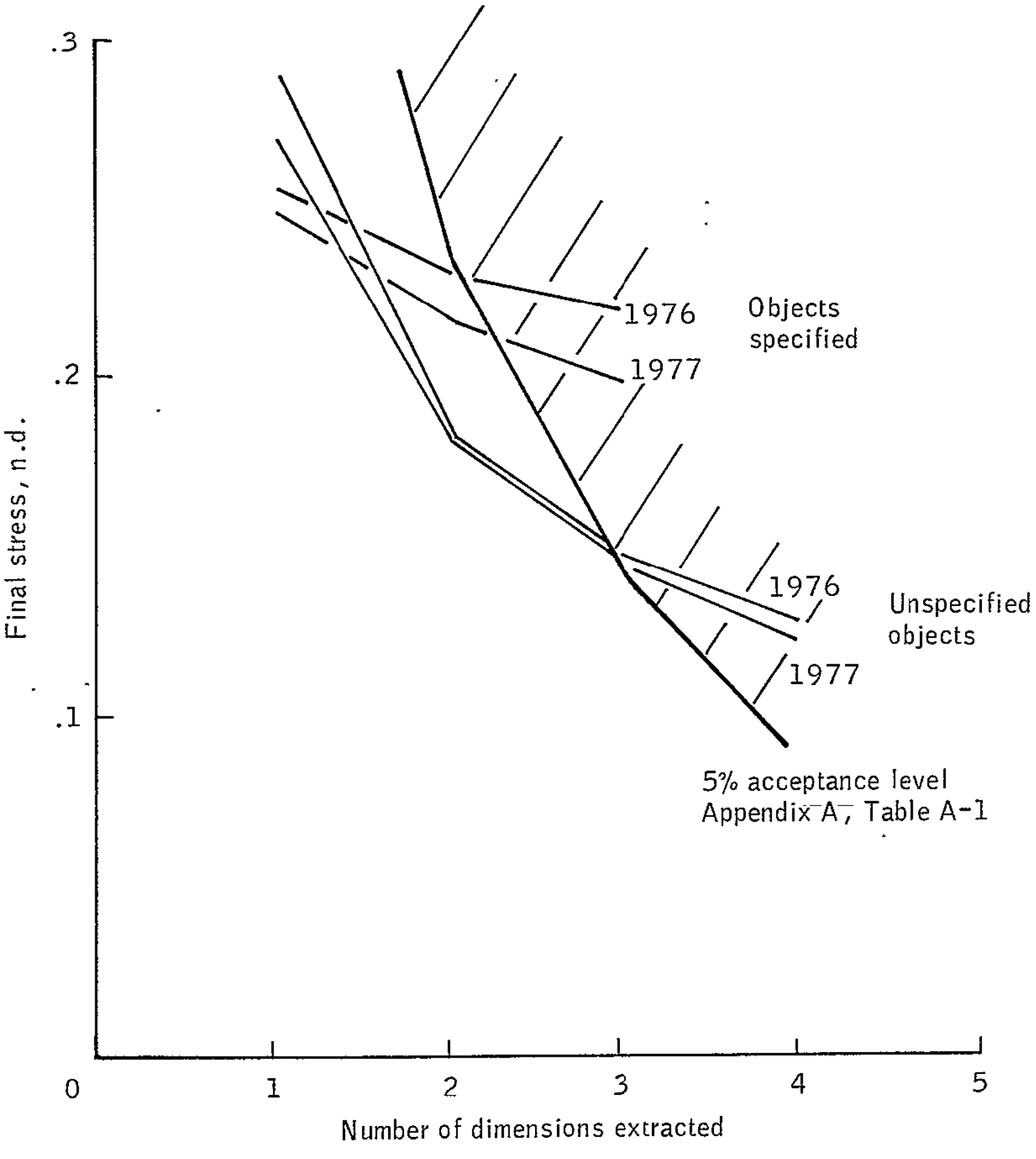


Figure 6-2.- Final stress vs. number of dimensions extracted for aeria
photo experiment.

context was 3 and with the specified objects context, 2. The significance levels associated with the 3- and 2-dimensional cognitive spaces are about .08 and .01 for the 1977 experiment and .12 and .05 for the 1976 experiment, respectively. Although a minimum significance level of .05 had been arbitrarily established for selecting model dimensionalities, the 3-dimensional unspecified objects context model was retained in this case because (1) the 3-dimensional model consistently and adequately described the subject's responses in the two experiments a ~~year apart; (2) choosing only 2 dimensions would have been very conserva~~tive (significance level << .01), and (3) there was a substantial reduction in stress in going from a 2- to a 3-dimensional model.

6.4.2 Comparison of Judgment Data

Chapter 4 described procedures for comparing sets of dissimilarity judgments using the Pearson product-moment correlation coefficient (r) and for comparing cognitive spaces derived from the judgments using the matrix similarity measure (MSM). Table 6-4 presents worst-case summary statistics for comparison of judgments for the subject. Listed are r_S and the MSM_S (reliability coefficients) for assessing reliability of judgment and stability, of cognitive spaces respectively, and r_D and the MSM_D (difference coefficients) for assessing the effects of context change on judgments and cognitive spaces. The highest value of the difference correlation coefficient $r_{D_{max}}$ such that it is statistically different from r_S at a .05 significance level is also given. Table 6-4

TABLE 6-4.- CORRELATIONS (r) BETWEEN DISSIMILARITY JUDGMENTS AND SIMILARITY MEASURES (MSM) BETWEEN COGNITIVE SPACES FOR THE AERIAL PHOTO EXPERIMENT ($p < .05$)

[Sample size = 91]

Contexts compared	Parameter	Value[a]
Same	r_S	75[b]
	ρ_S	66
	MSM_S	84[c]
Different	r_D	34
	ρ_D	48
	MSM_D	38[d]
	$r_{D_{max}}$	62

[a] Decimals omitted.
[b] Lower of two values.
[c] $p < .001$
[d] $p < .100$

shows that the reliability hypothesis can be accepted at the .05 level for $\rho_S > .66$. Similarly, the difference hypothesis can be accepted at the .05 level for a population difference correlation coefficient $\rho_D < .48$.

As an additional check on subject consistency, r's were computed between dissimilarity judgments made under the same context, but in different years (1976, 1977). The lowest r of 8 values, including replication judgments, was .53, with an average of .68.

The difference coefficients show that the change in context caused substantial repositioning of the stimuli in the subject's cognitive space. That this repositioning is not attributable to inconsistency of subject responses or instability of the cognitive model is supported by the reliability coefficients. The worst-case reliability coefficient is substantially greater than the respective worst-case difference coefficient, and the difference between them is statistically significant. This supports the conclusion that each context evokes a unique cognitive space for the individual; the same one is evoked for the same context. When the context changes, another appropriate cognitive space is evoked. In light of the reliability analyses, the difference analyses provide strong evidence that changes in the judgment context (task purpose) can cause changes in perception which cause the spatial cognitive model for an individual to change.

6.4.3 Master Cognitive Space

An INDSCAL analysis of the subject's 2 context spaces indicated that a 4-dimensional master space could reasonably span the spaces. The dimensional weights for the subject are given in Table 6-5. The weights indicate that the two contexts share dimension 1. Dimensions 2 and 3 belong only to the unspecified objects context, while dimension 4 belongs only to the specified objects context. Changing the stated purpose of the task from discerning unspecified objects to specified objects appears to cause the subject to increase the relevance of one attribute slightly, to drop the other two attributes and adopt another more important one.

TABLE 6-5.- DIMENSION WEIGHTS FOR THE 4-DIMENSIONAL MASTER SPACE USED IN THE AERIAL PHOTO EXPERIMENT*

Dimension	Cognitive space -	
	Unspecified objects	Specified objects
1	44	59
2	62	
3	47	
4		66
Fit**	84	82

*Decimals omitted; weights < .10 deleted.
**Sum of squared weights.

6.5 Dimension Labeling

A set of 8 property vectors was obtained from the subject using information supplied according to the procedures discussed in Chapter 4. Six of the vectors represented the subject's ratings of the 14 photos according to attributes specified in Table 6-1; the remaining two vectors represented known physical properties of the photos. Cognitive space labels were developed for the subject's 2 context spaces using the monotonic linear regression property-fitting technique dis~~cussed in Chapter 4. Table 6-6 represents the factor loadings weighted~~ by the multiple correlation coefficients for the subject's cognitive

TABLE 6-6.- WEIGHTED FACTOR LOADINGS OF INTER-LABEL CORRELATION MATRIX FOR UNSPECIFIED OBJECT CONTEXT: AERIAL PHOTO EXPERIMENT

Attribute	Factor**			r^2***
	1	2	3	
Blur	78	18	-04	80
Noise	-17	-67	13	70
Sharpness	36	27	-75	87
Clarity	35	-49	14	62
Contrast	37	73	13	83
Granularity	-18	-35	23	46
Density	25	17	-61	68
Chroma	-24	41	26	54

*Decimals omitted.

**Loadings rescaled to rms value of r^2.

***Multiple correlation coefficient from monotonic linear regression ($r_{\alpha=0.1} = .78$).

space under the unspecified objects context. The blur, sharpness, and contrast attributes have the highest individual weighted loadings on the three dimensions that define this space and are noted in Table 6-6. Hence, the unspecified objects cognitive space can be defined for the subject by the labels representing these attributes.

Dimension labeling for the two individual cognitive spaces and the master space is summarized in Table 6-7. A check mark appears in an attribute-cognitive space cell if labeling analyses indicated that the particular attribute was used in making dissimilarity judgments in that context. The physical attribute noise which was used in the generation of the photos was apparently incorporated in the subjective dimensions. The strong similarity between the pattern of relative sizes of the master space dimension weights in Table 6-5 and the pattern of checks under

TABLE 6-7.- SUMMARY OF LABELING ANALYSIS FOR AERIAL PHOTO EXPERIMENT

Attribute	Cognitive space -		
	Master	Unspecified objects	Specified objects
Blur	✓	✓	✓
Noise			
Sharpness	✓	✓	
Clarity			
Contrast	✓	✓	
Granularity	✓		✓

the two cognitive spaces in Table 6-7 confirms the ability of the master space to span the two spaces. Table 6-7, for example, indicates that only the <u>specified objects</u> context evoked the <u>granularity</u> attribute and Table 6-5 indicates that dimension 4 alone has a substantial weight under this context and no other context. This suggests that dimension 4 of the master space is linked to the <u>granularity</u> attribute. In like manner, the master space dimension labels can be compared with the individual space labels in Table 6-7.

~~The ability of the selected labels to span the cognitive space~~ they described was determined by computing the matrix similarity measure (MSM) between the cognitive space and the cognitive space represented by the component scores obtained from the factor analysis of label intercorrelations. Table 6-8 indicates the MSM's for the two cognitive spaces and the master space for the subject. The high values indicate that the selected labels provide a good description of the respective space.

TABLE 6-8.- SIMILARITY MEASURES (MSM) BETWEEN COGNITIVE SPACE AND COMPONENT SCORES FOR TWO COGNITIVE SPACES AND MASTER SPACE: AERIAL PHOTO EXPERIMENT*

Space	MSM
Unspecified objects	83
Specified objects	79
Master	86

6.6 Conclusions

The change in context produced different spatial cognitive models for the subject. Some of the differences were structural in that the number and identity of dimensions of the models changed. Others were shifts in dimensional emphasis (weighting) and modification of the stimulus configuration. These changes support the major hypothesis of this research that changes in the context of judging stimulus objects can cause changes in a spatial representation of their perception (i.e., a spatial cognitive model) for a given individual.

The subject displayed remarkable consistency; the judgments over a year apart correlated fairly well. This was due, probably, to the subject's high proficiency. She possessed an operational skill in procedures that were very similar to those performed in the experiment and an appreciation of the difference and importance of the differences in the purposes for which photographs may be used. Considering the subject's skill in image discrimination and the inherent complexity of the photos, it is somewhat surprising that higher dimensional cognitive spaces did not result in this study.

Since the photos differed only on two objective attributes, blur and noise, it might be argued that the cognitive spaces ought to be 2-dimensional and based on blur and noise. But noise did not feature in either of the spaces because the mathematically measurable physical attributes might be quite different from the resulting subjective attributes of images. The noise objective attribute may be only a part of the noise subjective attribute, perhaps even a minor part.

Noise may have been overshadowed by blur since the subject reported that blur tended to obliterate distinguishing characteristics of photos, more so than noise. The importance of blur to the subject is suggested by its appearance in both cognitive spaces. Finally, when image quality was an issue, Hunt and Sera (1978) stated that low correlation between noise and quality should be expected due to the profound capability of man to "filter out" noise. This also suggests that noise is not a significant discriminator of photos and should not feature in cognitive models of photos.

The use of the sharpness and contrast attributes in the unspecified objects cognitive space seems reasonable because the task purpose in this context was to identify objects in general. Object identification requires edge detection and local region analysis which, according to the definitions of Table 6-1, should be compromised without sharpness and contrast. These attributes have also been reported in other studies on image perceptions (Marmolin and Nyberg 1975).

When the purpose of the photos was changed to that of identifying boat sizes (specified objects context), the subject appeared to retain blur, dropped two other attributes, and adopted a granularity attribute with major emphasis. She acted as if these two attributes were quite relevant in detecting the presence of a boat (distinguishing a boat from its background) and finally determining its size. This suggests that an excess amount of either blur or granularity can cause an object to blend into the background.

For all replications of the study, the subject consistently yielded higher dimensional spatial models when the image application was to look for unspecified objects than when it was to look for specific objects. From this fact, it might appear that for unspecified objects the subject uses all attributes that might be of any value in detecting objects. Then, when a specific object is stated, the subject selects only those attributes from the previous set which are relevant to the new context. The second space should then be a subset of the first. But this was not found to be the case as was determined by the master space dimension weights and the labeling analyses. Whether the consistent difference in dimensionality is peculiar to this experimental task or to the subject cannot be determined from the data.

CHAPTER 7

THE EFFECTS OF CHANGES IN STIMULUS APPLICATION UPON A SPATIAL COGNITIVE MODEL OF SIMULATED FLOOD HISTORY PROFILES

7.1 Summary

Fifteen subjects judged the dissimilarity of "high water level histories in Houston bayous." The 14 "histories" were presented as five points on a line with a reference mark, but with no indication of the sequence in which they were supposed to have occurred. The points were actually samples from a normal distribution. The context was varied by connoting a change in the use or application of the samples. In the first part of the experiment the subjects were asked to judge the dissimilarities of the histories (history context). In the second part, they were asked to judge the dissimilarities of the meteorological processes that supposedly caused the histories (process context).

The results for 12 of the subjects were that the history context produced cognitive spaces of 3 or more dimensions and were based on visual pattern attributes of the stimuli. The subjects appeared to perform this task as a pattern comparison activity. The process context produced spaces with less than 3 dimensions and were based on sample estimates of the parameters of the underlying random processes. The data for 2 of the 15 subjects were not consistent with spatial cognitive models at all and for a third subject the spaces were not stable over replication.

The effect of context change was to produce different spatial cognitive models for each subject. The differences were both structural and spatial and were demonstrated by changes in dimension weights of a master space for each subject that spanned his two context spaces. But the cognitive spaces were sufficiently similar across individuals that a common cognitive space was developed for each context, spanning all subjects.

Generated data suggested that subjects familiar with stochastic phenomena would have lower dimensional cognitive spaces than others without this background, and that for them the difference in dimensionality across context change would be reduced. The data, however, were not statistically significant.

7.2 Experiment Background

This experiment is similar to the one reported in Chapter 6. Both address the task definition facet of context, or more specifically, stimulus use or application. The difference in the two experiments, however, lies in the manner in which the statement of stimulus application was made. Whereas the experiment in Chapter 6 explicitly specified the purpose for which the stimuli should be used, this experiment only connoted a stimulus use. It did not suggest how the subjects were to apply the stimuli to the judgment task. Consequently the subjects were free to select any application they perceived to be relevant.

The study was performed at a time when the rainfall had been particularly heavy in the Houston area. In fact, since many bayous are used for runoff in most of Houston, there had been recent serious water damage caused by bayou overflows. These points indicate the relevance of the experiment to the subjects' recent perceptions and thinking. The judgment was seen less as a laboratory artifact and more as research on a current problem. Because the results of this experiment have implications for human assessment of uncertainty, this section provides a brief background of that area.

People often make decisions concerning the outcome of uncertain events on the basis of fallible or incomplete data, a state of mind, or the perception of a particular situation (i.e., context) without the conscious use of well-defined reasoning. In some cases, they rely on heuristics by which they reduce the complex tasks of assessing likelihoods and predicting values to simpler judgmental operations. Tversky and Kahneman (1974) have noted that, in general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors. They further note that it is possible to learn to recognize the contexts in which judgments are likely to be biased, and to make appropriate allowances for the biases (Tversky and Kahaneman 1973). One such circumstance is that in which the person making decisions does not interpret the phenomena as stochastic, but instead uses a deterministic internal model (Alberoni 1962). Gaines (1976) demonstrated that people commonly generate elaborately complex internal deterministic explanations or models of a stochastic phenomenon if determinism is postulated and often these models produce erroneous results.

Based on these authors' findings, a change in context which would make it more appropriate to view a stochastic phenomenon as stochastic rather than deterministic, would be expected to cause a change in the spatial cognitive model of that phenomenon. The model should change from a more complex deterministic-based representation toward a simpler stochastic-based representation. The experiment described in this chapter was designed to see if such a context change would effect a change from a cognitive space related to patterns of the stimuli (deterministic-based), to one related to statistical descriptors of the stimuli (stochastic-based). The descriptors would be expected to be estimates of the characteristics of the stochastic phenomenon.

7.3 Method

7.3.1 Stimuli

The stimuli were 14 random samples, computer generated from normal distributions with known means and variances. The samples were posed as water level histories of Houston bayous. The stimuli are illustrated in Figure 7-1.

7.3.2 Subjects

The study began with 15 subjects who were employees of a large government facility. Their professions ranged from secretary to senior

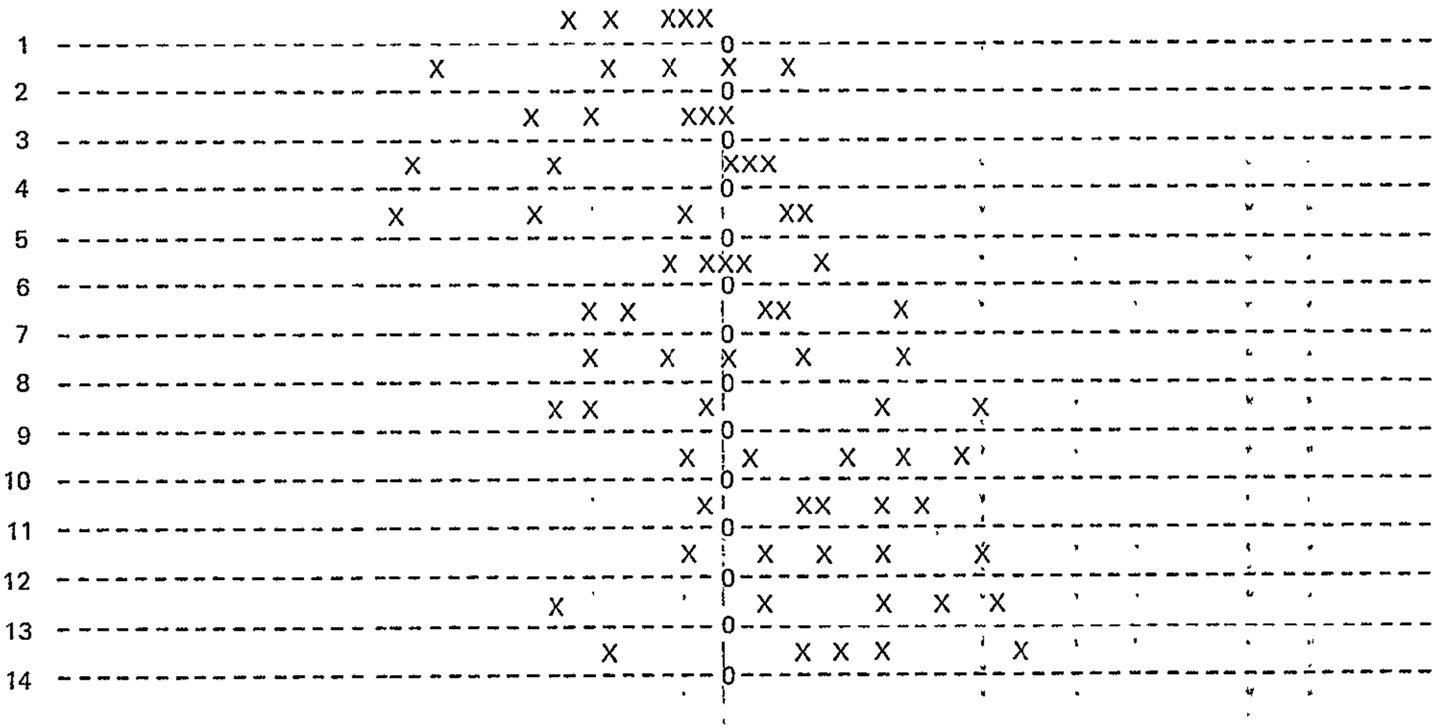


Figure 7-1.- Stimuli used in water level history experiment.

engineer and their ages ranged from about 25 to 45 years. Five of the subjects were female.

7.3.3 Procedures

The 15 subjects rated the subjective dissimilarities of the 91 pairs of the 14 samples in accordance with the general procedures detailed in Chapter 4. The subjects were told that the stimuli were the last five yearly high water levels at gaging stations along various bayous in Houston. The subjects were advised that the data were not given in chronological order, but only ranked from low to high levels, and in addition that the "0" on each line was an arbitrary but fixed reference mark. The dissimilarity judgments were considered under two different contexts. For the first context (history context), the subjects were requested to judge the dissimilarity of the histories of the water levels. Approximately a week after the first set of judgments, the subjects received essentially the same instructions for the second context (process context) as they did for the history context. The subjects were requested to judge the dissimilarity of the processes that produced the water levels. All judgments for each context were replicated a few days later using different random orderings of the stimulus pairs, but they were otherwise the same. Each subject completed each set of judgments for both contexts in less than 30 minutes. Three subjects failed to give reliable dissimilarities and were dropped from further consideration and analyses, leaving 12 to complete all experimental requirements.

Six different subjects were interviewed after each context presentation (excluding the replications) to determine the stimulus characteristics they perceived or considered in making their judgments. The 7 most commonly mentioned attributes can be expressed as: sample mean; sample standard deviation; regularity of interpoint spacing; number of point clusters; local symmetry (the degree of internal symmetry of the sample ignoring the reference mark); global symmetry (the degree of overall symmetry of the sample with respect to the reference mark); and degree of shift (with respect to the reference mark).

Following an explanation of the attributes, the final phase of the experiment required the subjects to rate the stimuli on the 5 subjective attributes (the last 5 above). A rating was to indicate the degree to which a water level sample possessed the attribute. A set of 7 property vectors was formed for each of the 12 subjects from these ratings; the 2 property vectors of sample mean and sample standard deviation were common to all subjects. The description of the analysis and the discussion which follow refer, for convenience, to one subject chosen at random from the 12 who completed all phases of the experiment because his data are typical. He is referred to as subject H. (Results for the other 11 subjects for whom property vectors were also derived, will be referred to where appropriate.) Subject H's property vectors for the 14 water level samples are given in Table 7-1; intercorrelations are given in Table 7-2.

TABLE 7-1.- PROPERTY VECTORS FOR SUBJECT H: WATER LEVEL HISTORY EXPERIMENT

Attribute	History sample –													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sample mean	-4.2	-4.2	-4.0	-4.4	-4.4	0.4	0.4	0.6	0.8	5.2	5.2	5.2	5.2	5.4
Sample standard deviation	5.3	6.9	4.3	7.9	8.9	2.9	6.4	6.2	9.5	5.7	4.2	5.7	9.1	7.7
Regularity*	2	12	3	1	7	11	5	14	8	9	6	13	4	10
Number of clusters*	2	11	3	5	9	1	4	13	8	10	7	14	12	6
Global symmetry*	9	1	5	3	2	14	11	13	12	7	8	6	4	10
Local symmetry*	7	3	2	1	4	9	8	13	5	12	10	14	6	11
Degree of shift**	14	12	13	9	11	8	6	7	10	3	5	4	1	2

*Rank orders, most (14) to least (1).
**Rank orders, most left (14) to most right (1).

TABLE 7-2.- RANK ORDER CORRELATIONS OF PROPERTY
VECTORS FOR SUBJECT H: WATER LEVEL
HISTORY EXPERIMENT*

	Mean	Std. dev.	Regularity	Clusters	Global sym.	Local sym.
Standard deviation	27					
Regularity	20	20				
Clusters	43	22	33			
Global symmetry	16	21	52	59		
Local symmetry	59	26	38	34	27	
Shift	-85	03	-19	-52	-09	-55

*Decimals omitted.

7.4 Analysis

7.4.1 Construction of Cognitive Spaces

Two cognitive spaces were developed for each of the 15 subjects under the two contexts using the techniques discussed in Chapter 4. One to four-dimensional spaces resulted for each context. The stress values for each number of extracted dimensions for subject H are shown in Figure 7-2. Using the dimensional selection procedures described in Chapter 4, subject H's spatial models for the <u>history</u> and <u>process</u> context were defined to be 3- and 2-dimensional, respectively. Figure 7-2 indicates that these values of dimensionality are statistically significant at better than the .05 level.

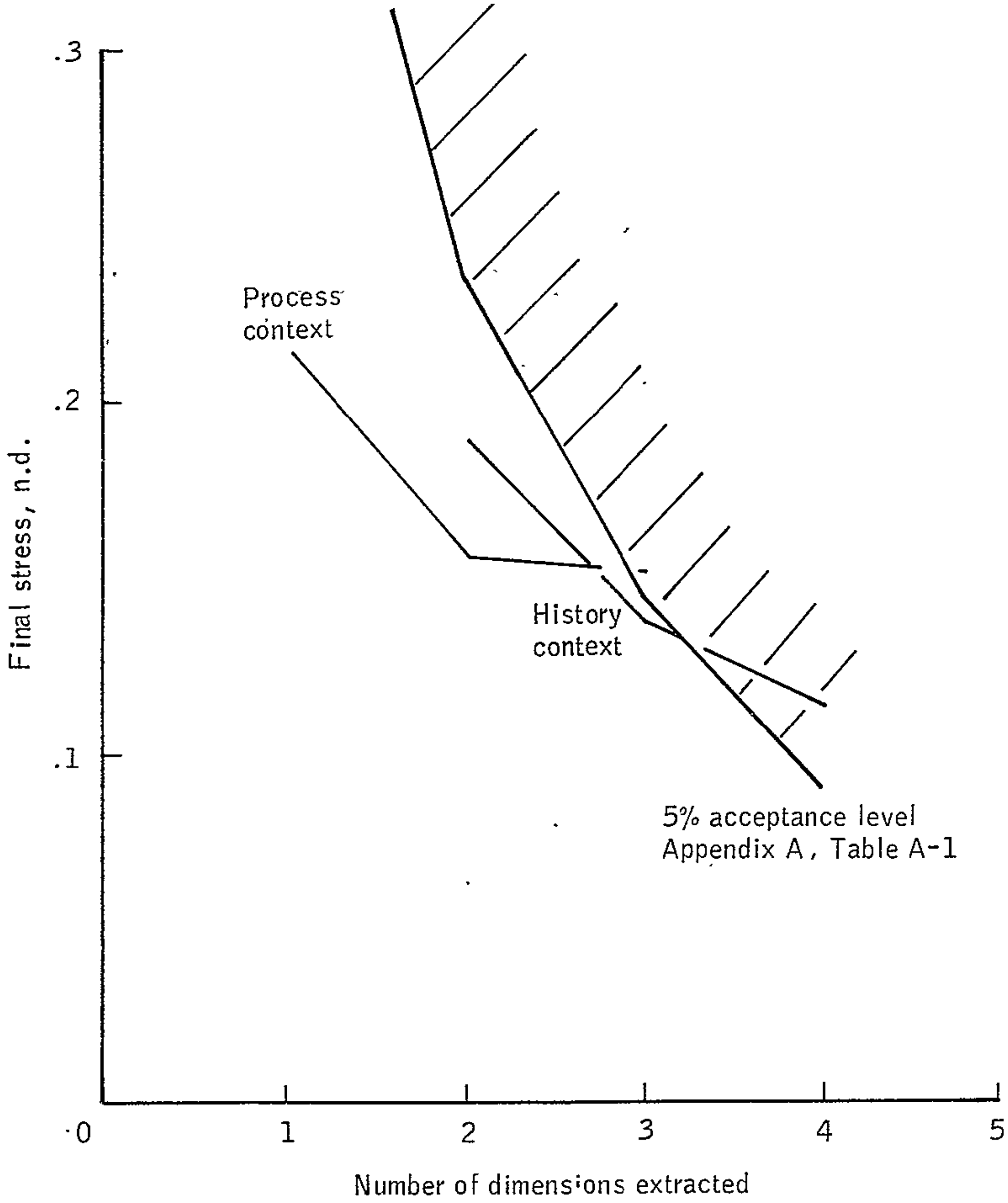


Figure 7-2.- Final stress vs. number of dimensions extracted for subject H: Water level history experiment.

Two subjects' data were dropped from further consideration because the stress measures for their spatial models were not significant for even 1 extracted dimension. An analysis of their dissimilarity judgments revealed a substantial number of violations of the triangle inequality, an important assumption in the construction of a Euclidean metric (see Appendix A for further discussion). The various dimensionalities selected at a significance level of .05 or better for each of the remaining 13 subjects are provided in Table 7-3.

TABLE 7-3.- COGNITIVE SPACE DIMENSIONALITY SELECTED FOR EACH SUBJECT: WATER LEVEL HISTORY EXPERIMENT ($p < .05$)

Context	Subject												
	A	B	C	D	E	F	G	H	I	J	K	L	M
History	2	4	3	3	3	4	3	3	4	2	2	4	3
Process	2	2	2	2	2	2	3	2	3	1	2	2	2

7.4.2 Comparison of Judgment Data

Procedures defined in Chapter 4 described how sets of dissimilarity judgments were compared using the Pearson product-moment-correlation coefficient r, and cognitive spaces derived from the judgments were compared using the matrix similarity measure MSM. Table 7-4 presents

TABLE 7-4.- CORRELATIONS (r) BETWEEN DISSIMILARITY JUDGMENTS AND SIMILARITY MEASURES (MSM) BETWEEN COGNITIVE SPACES FOR EACH SUBJECT: WATER LEVEL HISTORY EXPERIMENT
($p < .05$)

[Sample size = 91]

Parameter	Subject												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Contexts compared: Same													
r_S	91	85	87	77	83	78	92	82	71	80	73	79	63
ρ_S	87	79	82	69	76	70	88	75	61	72	63	71	51
MSM_S^{**}	93	88	91	85	89	87	90	88	78	83	77	83	58
Contexts compared: Different													
r_D	39	41	28	20	35	49	45	21	31	27	39	33	50
ρ_D	53	55	43	36	50	63	59	36	46	42	53	48	64
MSM_D^{**}	37	40	31	25	37	47***	47***	27	36	35	37	39	49**
$r_{D_{max}}$	86	75	80	65	74	67	88	72	57	70	60	68	46

*Decimals omitted.
**$p < .01$
***$p < .10$

worst-case summary statistics for comparison of judgments for the remaining 13 subjects. Listed are r_S and MSM_S (reliability coefficients) for assessing reliability of judgments and stability of cognitive spaces, respectively, and r_D and MSM_D (difference coefficients) for assessing the effects of context change on judgments and cognitive spaces. The highest value of the difference correlation coefficient $r_{D_{max}}$ such that it is statistically different from r_S at a .05 significance level is also given. Table 7-4 shows that with the exception of subject M the reliability hypothesis can be accepted at the .05 level for each subject for $\rho_S > .61$ and the difference hypothesis can be accepted at the .05 level for each subject (except M) for a population difference correlation coefficient $\rho_D < .55$.

The reliability correlation coefficient r_S for subject M was substantially less than those of the other subjects. While there was no *a priori* minimum acceptable value for r_S or maximum acceptable value of r_D that would lead to rejection of a subject, the value of $r_{D_{max}} = .46$ compared with the sampled value of $r_D = .50$ indicates that the hypothesis $\rho_S > \rho_D$ cannot be accepted at the .05 level for subject M. The analysis indicates that for subject M, the reliability of judgments within context was not statistically greater than the difference in judgments across context. In isolation, the difference coefficients suggest that the change in context influences and modifies this subject's judgments. But the reliability coefficients indicate that replication within the same context also affects his decisions, and to about the same degree as a context change. Hence, this subject was dropped from further analysis, leaving 12 subjects.

The difference coefficients in Table 7-4 show that the change in context causes substantial repositioning of the stimuli in an individual's cognitive space. That these changes are not attributable to inconsistency of subject responses or instability of the cognitive model is supported by the reliability coefficients. For the remaining 12 (of the original 15) subjects, the worst-case difference coefficient is substantially less than the respective worst-case reliability coefficient; for the correlation coefficients, the difference is statistically significant. This supports the conclusion that each context evokes a unique cognitive space for an individual and the same one is evoked for the same context. When the context changes, another appropriate cognitive space is evoked.

7.4.3 Master Cognitive Space

INDSCAL analyses of subject H's 2 context spaces indicated that 5 linearly independent dimensions were required to account for the spaces. The dimensional weights for subject H are given in Table 7-5. The two contexts appear to use different dimensions, indicating that the two respective cognitive spaces are independent. There is little or no dimensional sharing between the history context and the process context.

Master cognitive spaces were developed for each of the 12 remaining subjects with results strikingly similar to those of subject H. Table 7-6 presents a summary of pertinent results extracted from these

TABLE 7-5.- DIMENSION WEIGHTS FOR THE 5-DIMENSIONAL MASTER SPACE FOR SUBJECT H: WATER LEVEL HISTORY EXPERIMENT*

Dimension	Cognitive Space	
	History	Process
1	69	
2	50	13
3	18	25
4	13	79
5	10	38
Fit**	79	86

*Decimals omitted; weights < .10 deleted.

**Sum of squared weights.

TABLE 7-6.- SUMMARY OF MASTER COGNITIVE SPACE ANALYSIS FOR EACH SUBJECT: WATER LEVEL HISTORY EXPERIMENT

Parameter	Subject											
	A	B	C	D	E	F	G	H	I	J	K	L
Dimension upper bound	4	6	5	5	5	6	6	5	7	3	4	6
Dimensionality	4	5	5	4	5	4	4	5	5	3	4	5
History fit*	83	95	88	75	89	96	83	79	88	83	87	91
Process fit*	80	86	86	83	91	94	87	86	79	84	86	90
Shared dimensions	0	2	1	0	0	0	0	0	1	0	0	0

*Decimals omitted.

analyses. The upper bound on dimensionality is the sum of the dimensionalities of the individual spaces and is noted for reference. The master space dimensionality for the majority of subjects is equal to the upper bound of dimensionality. A 7-dimensional common space was constructed from the 24 individual cognitive spaces (12 subjects x 2 contexts) in order to investigate the commonality of the various dimensions among the subjects. The weights for the common space are given in Table 7-7.

The number of significant weights (i.e., >.10) suggests the dimensionality for each context space for each subject. This number matches perfectly the dimensionality listed in Table 7-3 except for two cognitive spaces. The history context space for subject G is one dimension shy, and the process context space for subject J has two extra dimensions. The low values of fit indicate that these spaces are only marginally spanned by the common space.

There is almost complete segregation of weights between the history and process contexts; the first context uses only the first 4 dimensions while the second context uses the last 3 (subject G's process context space is an exception). This suggests that when the context changed from history considerations to process considerations in making dissimilarity judgments, every subject appeared to drop one set of attributes and adopt another set. The labeling analysis below tended to confirm this by identifying the dimensions used.

TABLE 7-7.- DIMENSION WEIGHTS FOR THE 7-DIMENSIONAL COMMON SPACE (ALL SUBJECTS): WATER LEVEL HISTORY EXPERIMENT*

Dimension	Subject -																							
	A		B		C		D		E		F		G		H		I		J		K		L	
	H**	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P
1	18		66				49		59		65		58		77		66				40		69	
2			60		62		55				17		53		48		16		64		79		45	
3	87		26		29		43		66		53						57		60				15	
4			22		63				26		44			64	16		25						40	
5		62		79		87		46		88		59				82		56		71		74		89
6		61		43		20		77		12		71		16		38		39		33		54		13
7														55				23		17				
Fit***	82	77	91	83	87	82	74	82	87	80	93	88	63	75	81	85	86	77	79	68	81	86	87	83

*Decimals omitted; weights < .10 deleted.

**Cognitive space contexts: H = history; P = process.

***Sum of squared weights.

7.5 Dimension Labeling

All of the 15 subjects supplied information that could be used to label their cognitive spaces. However, 3 of the subjects were dropped from the experiment for reasons discussed above, and no attempt was made to label their spaces. A set of 7 property vectors was obtained for each of the 12 remaining subjects using the information according to the procedures discussed in Chapter 4. The vectors represented the subject's ratings of the 14 water level samples according to the 5 attributes specified in Table 7-3; two vectors represented sample statistics and were the same for all subjects. Cognitive space labels were developed for each subject's two context spaces using a linear or monotonic linear regression (depending on the property vector measurement scale) property fitting technique as discussed in Chapter 4. Table 7-8 represents the factor loadings weighted by the multiple correlation coefficients for subject H's cognitive space under the *history* context. The *regularity*, *local symmetry*, and *shift* attributes have the highest individual weighted loadings on the three dimensions that define this space. Hence, the *history* context space for subject H can be defined by the labels representing these attributes.

Table 7-9 summarizes the results of dimension labeling for all subjects. A check mark appears in an attribute-cognitive space combination if labeling analyses indicated that the particular attribute was used in making dissimilarity judgments in that context. Of the 5 attributes mentioned by the subjects, 4 appeared to be sufficient to identify dimensions in the 2 spaces for all subjects. The comparison of labeling

TABLE 7-8.—WEIGHTED FACTOR LOADINGS FROM INTERLABEL CORRELATION MATRIX FOR HISTORY CONTEXT: SUBJECT H OF WATER LEVEL HISTORY EXPERIMENT

Attribute	Factor**			r^2***
	1	2	3	
Mean	-57	35	31	74
Standard deviation	14	01	54	56
Regularity	-86	-19	10	89
Clusters	21	08	41	47
Global symmetry	68	06	-11	69
Local symmetry	19	27	75	82
Shift	-25	61	45	80

*Decimals omitted.

**Loadings rescaled to rms value of r^2.

***Multiple correlation coefficient from monotonic linear regression ($r_{\alpha=.01} = .78$).

TABLE 7-9.- SUMMARY OF COGNITIVE SPACE LABELING FOR EACH SUBJECT AND FOR EACH CONTEXT: WATER LEVEL HISTORY EXPERIMENT

Attribute	Subject -																							
	A		B		C		D		E		F		G		H		I		J		K		L	
	H*	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P
Mean		X		X		X		X		X		X				X		X		X		X		X
Standard deviation		X		X		X		X		X		X		X		X		X		X		X		X
Regularity	X		X				X		X		X		X		X		X				X		X	
Clusters			X		X		X				X		X				X		X		X		X	
Global symmetry			X																					
Local symmetry	X		X		X		X		X		X				X		X		X				X	
Shift					X				X		X				X		X						X	
MSM**	78	72	91	89	69	74	83	76	85	80	74	79	71	84	86	83	91	86	53	31	81	76	94	88

*Cognitive space contexts: H = history; P = process.

**Comparison between cognitive space and the cognitive space represented by the component scores for that context; decimals omitted.

results across context shows a clear tendency for subjects to use characteristics of the water-level samples closely related to the statistically relevant properties of mean and standard deviation when the process context is considered, but to be concerned with pattern peculiarities of the samples when the history context is considered.

The statistical properties of the samples were used to label two dimensions of the common space. The results in Tables 7-7 and 7-9 suggest that dimensions 5, 6, and 7 of the common space should be related to the statistical properties of the samples. The labeling analysis for the common space confirmed this, as the sample mean and standard deviation labels were found to be essentially orthogonal and significantly correlated with dimensions 5 and 6 of the common space (r^2 of .78 and .81, respectively). This strongly suggests that these two attributes were considered by the subjects under the process context. None of the candidate labels seemed appropriate for identifying dimension 7. On the assumption that the label for 7 would be statistical in nature, various statistical measures were tried as alternatives; coefficient of variation (ratio of standard deviation to mean) of the samples produced the largest correlation ($r^2 = .46$) and hence seemed the most satisfactory for this last dimension.

7.6 Conclusions

The change in judgment context produced different spatial cognitive models for 12 of 15 subjects. All of the differences were due to changes in the number and identity of dimensions of the models, and most subjects completely replaced one set of dimensions with another. These changes strongly support the major hypothesis of this research that changes in the context of judging stimulus objects can cause changes in a spatial representation of their perception (i.e., a spatial cognitive model) for a given individual.

The cognitive space dimension weights and labels clearly showed that the subjects considered the history context to be one requiring what could be called a visual pattern comparison task. All the labels selected were based on visual or pattern attributes of the water histories. The subjects appeared to consider the samples to be no more than just a pattern of points.

In the process context, the subjects acted as if a stochastic process caused the water histories and they switched to attributes more appropriate for describing such processes. The dimensional weighting in this context indicated that sample mean was generally more important than standard deviation in discriminating among the histories. This seems reasonable if a shift of central tendency or average is easier to detect or quantify than a measure of scatter. The apparent emphasis on sample mean may be due to the fact that water level (and not, for example, the chance of flooding) was the variable emphasized in the experiment.

Based on the dramatic shift in attribute weighting, it appears that the subjects did not consider the stochastic nature of the underlying process in the history context. Initial consideration of the stochastic nature by the subjects could have lead to the statistical descriptors being more relevant for use under the *history* context. Consequently, had the order of context presentation been reversed (i.e., *process* before *history*), one might expect to find more weight for the statistical dimensions under the *history* context. But if sufficient time was allowed between different context exposures, say a week as was used here, then the effects of a prior consideration of the stochastic nature of the samples might have decayed sufficiently, and the results would not differ much from those reported here.

A secondary hypothesis of this experiment was that subjects familiar with stochastic phenomena would have lower dimensional cognitive spaces and less change in dimensionality across context change than others without this background. To evaluate this hypothesis, subjects were asked at the end of the experiment to report the number of years of work experience and formal education they had in dealing with stochastic phenomena. The author also rated each subject on statistical sophistication based on his own knowledge of the subject. These two ratings were each used as independent variables to predict the dimensionality of each context space, and the algebraic difference of dimensionalities between context spaces for each subject. Six linear regressions were performed using each independent variable (2) to predict each dependent variable (3) for each subject, but none resulted in a statistically significant correlation coefficient. Though not significant, there was a slight trend: The more background the subject had, the lower the cognitive space dimensionality produced, and the less change in dimensionality across context changes.

Three subjects were dropped from the experiment; two because their dissimilarity judgments were not consistent with a spatial cognitive model, and the third because his judgments did not appear to be replicable. There was little noticeable similarity between the first two subjects. One was a female secretary and the other was a male engineer with about 5 years of background in stochastic phenomena. The latter was interviewed after the experiment and informed that his judgments appeared to violate the triangle inequality, a basic assumption of the spatial cognitive model. He could offer no explanation for the violations but concluded with the observation "I guess that model doesn't fit my judgment style."

Discussions with the subject whose judgments did not appear replicable suggested that, because of his "dedication" to the experiment he continued to think about the samples between experiment sessions. He admitted that, as a consequence, this caused him to consider the stimuli with a new perspective and to change relevant attributes between replications for judging the stimuli. Effectively, this subject changed his judgment context for every experiment session.

The finding that the dimensionalities of the spaces from the <u>history</u> context were as least as great as those from the <u>process</u> context parallels a similar result from the previous experiment. In Chapter 6 it was conjectured that the second context space might be a subset of the first context space. But as was also found for that experiment, the weights and labeling analyses for this experiment showed the two context spaces to be completely independent.

CHAPTER 8

THE EFFECTS OF CHANGES IN JUDGMENT PERSPECTIVE UPON A SPATIAL COGNITIVE MODEL OF MICROPROCESSOR COMPUTERS

8.1 Summary

To demonstrate the change in comparison judgments caused by a change in judgment perspective, subjects were asked to make dissimilarity judgments about microprocessor computers (micros) from their own viewpoints as sellers and from the viewpoint of a purchasing agent or buyer. The situation was part of an actual procurement process for the National Aeronautics and Space Administration (NASA), and the micros were offered in proposals in response to the client's advertised needs. One of the subjects (the buyer) was a principal member of the team established to evaluate and ultimately select one of the nine micros offered. The other three subjects were micro marketing salesmen (salesmen) who represented three of the seven companies bidding on the proposed contract.

Under the first context, the experiment required of each subject his own individual judgments of the dissimilarity of the micros with respect to appropriateness for the stated needs of the buyer. A spatial cognitive model was formed for each subject using his individual judgment perspective. Under the second context, the experiment required the salesmen to judge the micros as each thought the buyer would. This change required a buyer judgment perspective and created a form of role playing for the salesmen. Cognitive models were formed for the salesmen using the buyer perspective and comparisons were drawn between the two perspectives for each salesman.

The change in judgment perspective produced differences in the cognitive spaces for the salesmen. The differences were both structural and spatial and were demonstrated by changes in dimension weights of a master space for each salesman that spanned his two cognitive spaces. The dimensionality of the individual cognitive spaces was high (i.e., 3 or more); the objective physical attributes of the micros proved to be better labels for cognitive space dimensions than were the subjectively-supplied attributes.

Of the three salesmen investigated, the one most able to emulate the buyer's perspective represented a micro that was a more serious contender for winning the contract than those of the other two. That salesman's knowledge of the buyer and of what the buyer "actually" considered to be important may have enabled him to understand the buyer and influence his selection process in a more effective way.

8.2 Experiment Background

In Chapter 2 the individual perspective was defined as the relationship of the person judging the stimulus objects to the task, to the objects, or to the purposes which the task or the objects serve. It is essentially the role the person plays in relation to the other aspects of the task. This chapter presents the results of an experiment dealing with the effects of individual perspective on spatial cognitive models. This section discusses the background of the experiment setting because of the implications of the experimental results for marketing tactics, especially in the area of influencing industrial purchasing decisions.

Classical economic theory assumes that a consumer's behavior is motivated solely by rational economic considerations. However, in addition to such considerations, empirical evidence has led to an increasing recognition that industrial buyers, for example, can be significantly influenced by psychological (non-economic) motives (Lazo 1960). Research findings further suggest that the selection of one vendor from several competing ones is always accompanied by some perceived risk on the part of the individual buyer (McMillan 1972). Consequently, the buyer, by selecting that vendor for which the least risk is perceived, selects a course of action which reduces or at least allows him to handle the perceived risk (Bauer 1960, Cardozo and Cagley 1971). McMillan (1974) lists three sources of buyer risk: product, salesman, and company. However, the uncertainty assigned to each of these sources will vary greatly with the individual buyer involved. Each buyer views the buying process with a unique perceptual bias reflecting his own psychological perspective and the specific characteristics of the particular purchase under consideration. It is therefore plausible that the extent to which a vendor can understand the buyer's perspective affects his ability to sell to the buyer. A discrepancy in the perception of the purchase between the buyer and the salesman, if it exists, could have an impact upon the buying decision. A spatial cognitive model provides a means of quantifying the relation between the buyer's perception and the salesman's understanding of it.

A NASA facility recently issued a request for proposals (RFP) for a microprocessor computer to control subsystems of a manned vehicle simulator. The proposals were to be evaluated by a team composed of control engineers and computer systems analysts in two steps, point-by-point comparison, then overall evaluation. The evaluation would be based on predefined criteria applicable to all micros.

Nine micros were proposed by seven companies. The experiment reported here deals with three of the seven micro sales representatives and one of the evaluation team members. The three salesmen, referred to in the experiment as A, B, and C, represented micros 2, 1, and 8, respectively. The experiment was performed after the team had completed the previously mentioned comparison step and prior to the actual evaluation step. However, some data were obtained after the evaluation step.

Legal aspects of letting U.S. Government contracts formalize any communication between themselves and suppliers or vendors. In the subject case, specific requirements for the micros (required interfaces, application, etc.) and criteria for selecting the contract winner were contained in the written RFP issued to all companies interested in bidding on the contract. No other communications to the companies or their salesmen were allowed. Furthermore the companies could only communicate their response to the RFP through a formal written proposal. Request for further clarification, etc. by any company, or by the Government selection team are strictly prohibited. At the Government's option, however, if sufficient general ambiguity exists, they can make an oral presentation of contract requirements to all companies, or each company can make an oral presentation of their written response. These options were not exercised for this contract.

Study of this industrial purchasing case provided an excellent opportunity to demonstrate that experimental changes in the perspective characteristic of judgment context can cause substantial changes of practical significance in spatial cognitive models for an individual. There are no known studies of cognitive models that have made use of such real situations of comparable importance to the participants, that have had subjects as highly skilled in their professions, and have had stimuli as complex as the experiment reported here.

8.3 Method

Nine micros offered in proposals, served as stimuli. Relevant attributes were obtained from the proposals and company brochures listing the characteristics of each micro. Subsequent discussions with micro salesmen not in competition for the subject contract helped to facilitate data presentation. Twelve attributes common to all micros (listed in Table 8-1) were used to describe them on 3 x 5 cards.

8.3.1 Procedures

Experimental tasks consisted of having the 4 subjects rate the subjective dissimilarity of the 36 pairs of 9 micros in accordance with the general procedures detailed in Chapter 4. Under the first context, the dissimilarity judgments were to represent the individual's own perception of the appropriateness of the micros to the stated requirements of the buyer (i.e., the RFP). These instructions specified the judgment context to be that of individual perspective.

Under the second context, the salesmen were instructed to re-judge the micros, but this time from the perspective of how each thought the buyer would perceive the micros. Essentially, the salesmen were asked to play the role of the buyer when they considered the buyer perspective. Judgments were replicated for each context on the same day using different random orderings of the stimulus pairs, but the pairs were otherwise the same. The buyer perspective was introduced to the salesmen about a week after the individual perspective.

All subjects were asked to specify, in addition to those listed in Table 8-1, the attributes of the micros they considered in making their dissimilarity judgments. Because of legal requirements of the proposal evaluation, the buyer declined participation in this phase of the experiment. Collectively, the salesmen offered 6 attributes. These are listed in Table 8-2. Because McMillan's (1974) list of sources and characteristics of perceived risk by a buyer in choosing a vendor is similar, that list is also included in Table 8-2 for comparison. Contrary to McMillan's results, the salesmen did not list themselves as a significant factor in a buyer-salesman transaction.

The salesmen were then asked to rate the micros on the 6 attributes checked in Table 8-2. A set of 6 property vectors was formed for each salesman from these ratings; 12 property vectors formed from the

TABLE 8-1.- PHYSICAL PROPERTY VECTORS USED IN MICROPROCESSOR EXPERIMENT

Attribute	Computer index number -								
	1	2	3	4	5	6	7	8	9
1. Number of instructions available	46	50	45	28	60	27	70	46	96
2. Typical cycle time, μsec	12	24	10	15	10	1	6	20	2.5
3. Program addressing range, kilo words	2	1.3	1.5	0.756	8	0.512	65	65	4
4. Data addressing range, words	128	96	1000	64	1000	32	65,000	65,000	320
5. Decimal arithmetic*	0	1	1	0	1	0	1	1	1
6. Address stack depth, number of jumps	1	2	2	2	7	2	1	3	8
7. Number of conditional jumps	1	30	10	5	16	3	9	3	14
8. Input/output expandability**	2	1	2	1	3	1	3	3	3
9. Memory expandability*	0	0	0	0	1	0	1	1	1
10. Program memory, kilo words	2	1.8	1.5	0.76	1	0.51	1	2	1
11. Data memory, words	128	94	96	64	80	32	64	256	64
12. Number of input/output lines	28	31	18	33	21	24	32	23	27

*Yes (1), No (0).

**Yes (3), limited (2), No (1).

TABLE 8-2.- COMPARISON OF SALESMEN-SUPPLIED ATTRIBUTES WITH MCMILLAN'S (1973) LIST OF SOURCES OF BUYER-PERCEIVED RISK

McMillan	Salesmen-supplied
Source	
Product:	
Cost	✓
Performance	✓
Quality	✓
Quality consistency	
Salesman:	
Honesty	
Dependability of promises	
Competency	
Effectiveness	
Company:	
Ability to deliver on schedule	✓
Innovative nature	
Dependability of promises	
Capability of supplying future demand	✓ (Service)
Reciprocity	
Technical capability	
Emergency assistance	✓

physical properties listed in Table 8-1 were common to all subjects. The description of the analysis and the discussion which follow refer, for convenience, to one subject chosen at random from the 3 salesmen because his data are typical. He is referred to as subject A. (Results ~~for the buyer and the other 2 salesmen will be referred to where appro~~priate.) Subject A's property vectors for the 6 subjective attributes are given in Table 8-3; intercorrelations for all 18 property vectors are given in Table 8-4.

TABLE 8-3.- SUBJECTIVE PROPERTY VECTORS* FOR SALESMAN A: MICROPROCESSOR EXPERIMENT

Attribute	Computer index number								
	1	2	3	4	5	6	7	8	9
Cost	2	7	5	6	3	4	9	1	8
Performance	7	6	5	9	1	3	2	8	4
Quality	4	2	8	5	9	7	3	6	1
Delivery	5	9	6	4	8	7	2	3	1
Service	9	6	7	4	5	8	2	1	3
Emergency assistance	5	6	1	7	3	8	4	9	2

*Rank orders, most (1) to least (14).

TABLE 8-4.- RANK ORDER CORRELATIONS OF PROPERTY VECTORS
FOR SALESMAN A: MICROPROCESSOR EXPERIMENT

	Instructions	Cycle time	Program range	Data range	Decimal	Stack depth	No. jumps	I/O expand	Memory expand	Program memory	Data memory	No. I/O lines	Cost	Performance	Quality	Delivery	Service
Cycle time	12																
Program range	37	-33															
Data range	-07	-30	26														
Decimal	26	02	23	40													
Stack depth	15	-25	19	35	85												
No. jumps	-44	31	-55	-25	35	41											
I/O expand	29	-20	55	35	68	38	-13										
Memory expand	29	-45	35	45	78	68	07	70									
Program memory	21	-04	-42	-22	-22	-22	-27	-10	-25								
Data memory	22	-04	-42	-22	-22	-22	-27	-10	-25	99							
No. I/O lines	-15	40	-73	13	10	-13	28	-18	02	32	32						
Cost	-42	40	-12	25	-27	-73	35	38	18	13	13	10					
Performance	-72	37	-23	-30	07	15	28	-33	-28	20	20	50	42				
Quality	50	-40	38	12	37	-62	25	35	-20	07	07	-48	13	-62			
Delivery	15	-58	15	-50	62	-25	47	-08	-68	12	12	-13	07	27	32		
Service	-17	-37	-20	-22	68	-07	67	-30	-70	20	20	48	08	47	08	75	
Assistance	-47	13	35	-28	-23	13	-42	05	05	23	23	07	07	62	-60	17	00

*Decimals omitted.

8.4 Analysis

8.4.1 Construction of Cognitive Spaces

Two cognitive spaces were developed for each of the 3 salesmen under the 2 contexts using the techniques discussed in Chapter 4. One cognitive space was developed for the buyer. Two to four dimensional spaces resulted from each context. The stress values for each number of extracted dimensions for all subjects are shown in Figure 8-1; dimensionalities selected for each subject are given in Table 8-5.

TABLE 8-5.- COGNITIVE SPACE DIMENSIONALITY SELECTED FOR EACH SUBJECT: MICROPROCESSOR EXPERIMENT ($p < .05$)

Context	Buyer	Salesman		
		A	B	C
Individual	---	3	3	3
Buyer	4	4	2	3

8.4.2 Comparison of Judgment Data

Table 8-6 presents worst-case summary statistics of comparison of judgments for the 4 subjects (intrasubject comparison) and for comparison of the judgments and cognitive spaces between salesmen and buyer (salesmanbuyer comparison). The latter part of the table is discussed later. Listed here r_S and MSM_S (reliability coefficients) for assessing

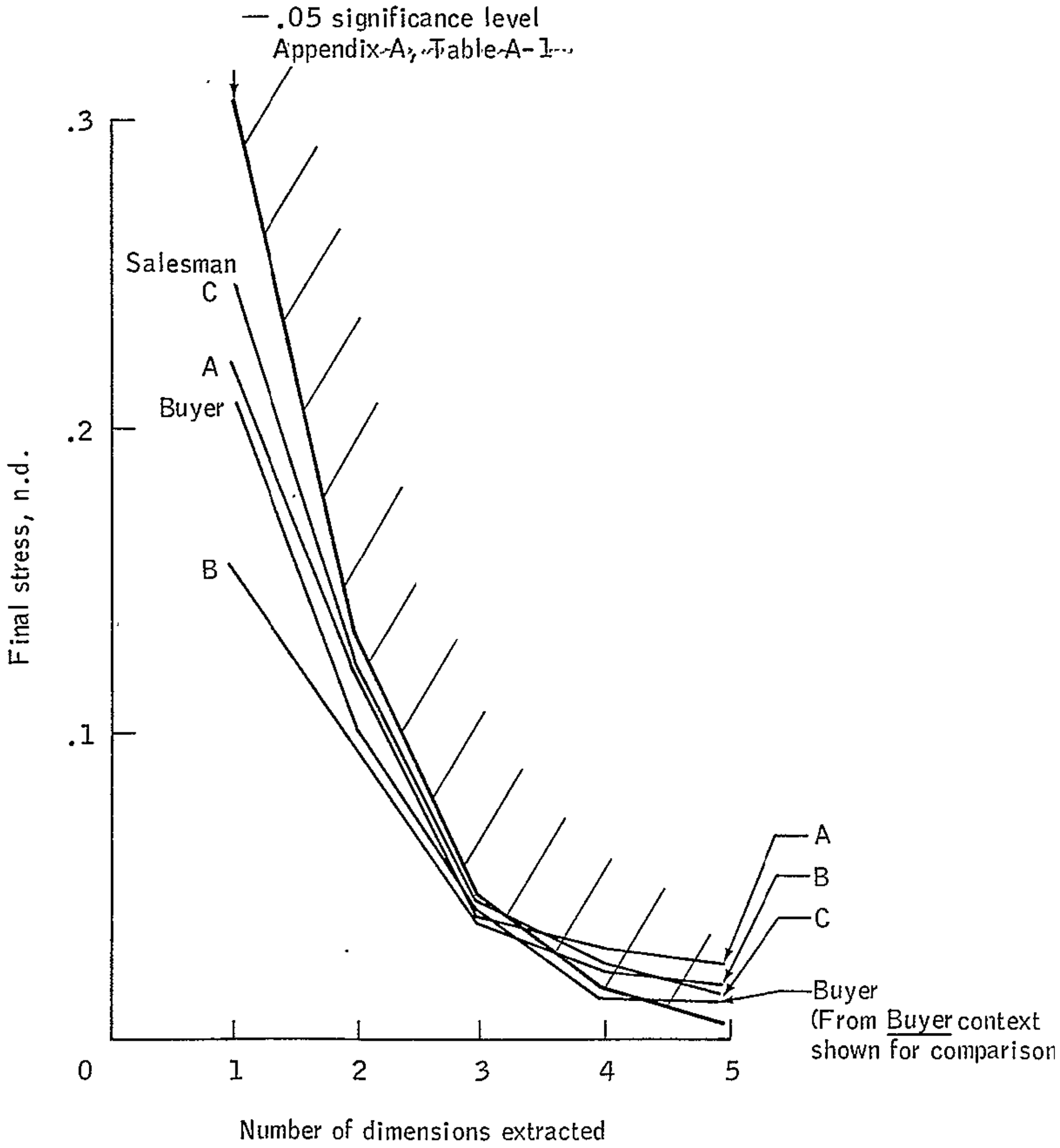


Figure 8-1(a).- Stress vs. number of dimensions extracted for <u>individual</u> context: Microprocessor experiment.

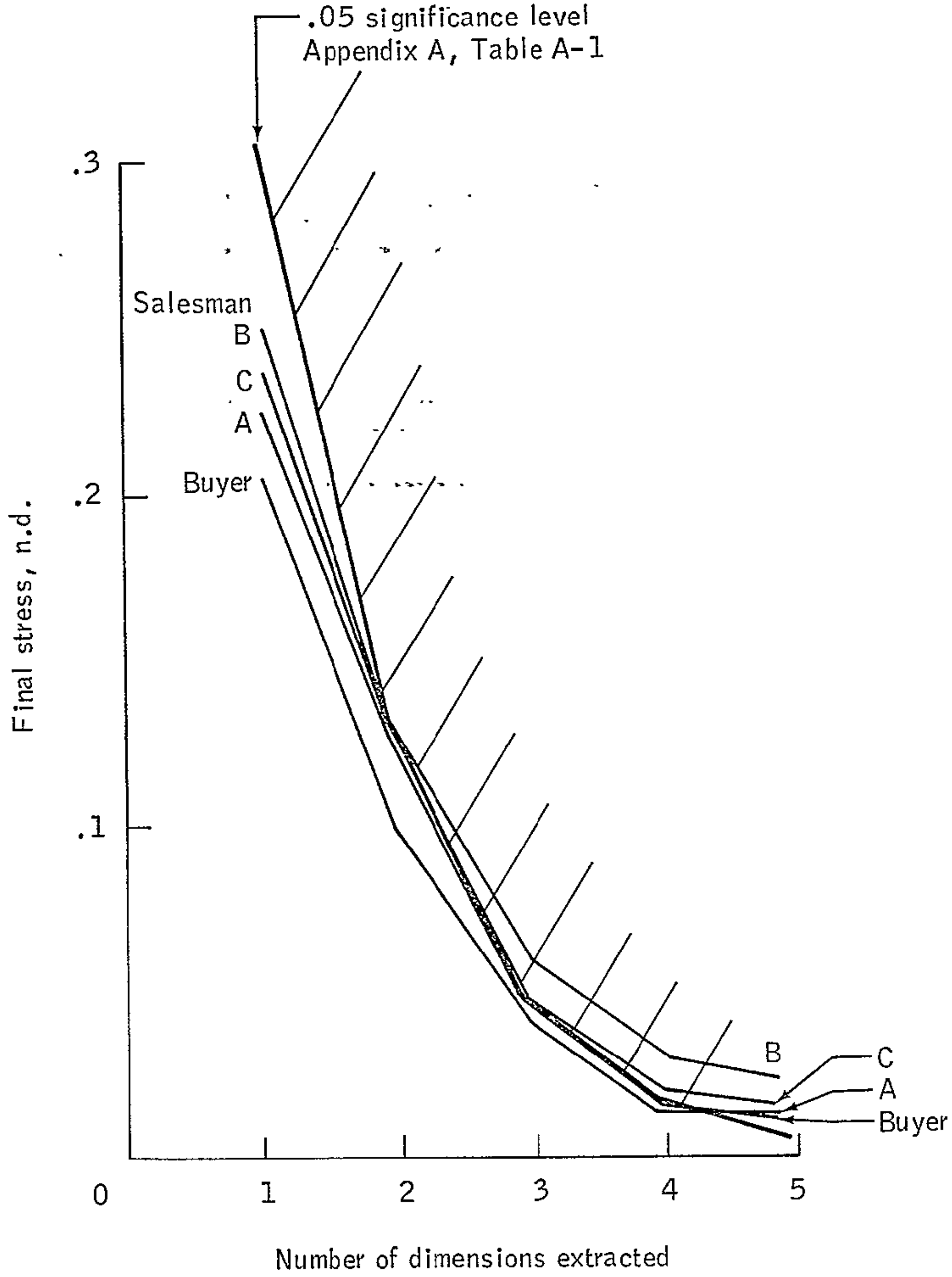


Figure 8-1(b).- Stress vs. number of dimensions extracted for buyer context: Microprocessor experiment.

TABLE 8-6.- CORRELATIONS (r) BETWEEN DISSIMILARITY JUDGMENTS AND SIMILARITY MEASURES (MSM) BETWEEN COGNITIVE SPACES FOR EACH SUBJECT: MICROPROCESSOR EXPERIMENT ($p < .05$)*

[Sample size = 36]

Parameter	Intra-subject comparison				Salesman-buyer comparison		
	Buyer	A	B	C	A	B	C
Contexts compared: Same							
r_S	84	88	79	75	76	64	39
ρ_S	73	80	65	60	61	44	11
MSM_S	76	78	86	71	78	53**	13**
Contexts compared: Different							
r_D	---	38	41	36	36	41	28
ρ_D	---	59	62	57	59	62	32
MSM_D	---	31	40***	43***	42***	46***	06
$r_{D_{max}}$	---	75	56	50	---	---	---

*Decimals omitted.
**Not significant.
***$p < .10$.

reliability of judgments and stability of cognitive spaces, respectively. Values of r_D and MSM_D (difference coefficients) for assessing the effects of context change on judgments and cognitive spaces, and the highest values of the difference correlation coefficient $r_{D_{max}}$ such that it is statistically different at a .05 significance level are also given. Table 8-6 shows that the reliability hypothesis can be accepted at the .05 level for each subject for $\rho_S > .60$ and the difference hypothesis can be accepted at the .05 level for each salesman (the buyer was not exposed to a context change) for a population difference correlation coefficient $\rho_D < .62$.

The difference coefficients in Table 8-6 show that the change in context causes substantial repositioning of the stimuli in each salesman's cognitive space. That this repositioning is not attributable to inconsistency of subject responses or instability of the cognitive models is supported by the reliability coefficients. For each salesman, the worst-case difference coefficient is substantially less than the worst-case reliability coefficient; the difference between the correlation coefficients is statistically significant. This supports the conclusion that each context evokes a unique cognitive space for an individual and the same one is evoked for the same context.

Since one part of the experiment required the salesmen to judge the micros from the buyer's perspective, comparisons were made between each salesman's cognitive space developed under the <u>buyer</u> perspective and the buyer's cognitive space. Those comparisons are also given in Table 8-6, and indicate that salesman A's <u>buyer</u> perspective space is the best approximation to the buyer's space ($r_S = .76$) while salesman C's *buyer* perspective space is the worst approximation ($r_S = .39$). Salesman B's *individual* perspective space, however, was a better approximation to the buyer's space ($r_D = .41$) than was A's *individual* perspective space ($r_D = .36$). The nature of these approximations is addressed in subsequent sections.

8.4.3 Master Cognitive Space

An INDSCAL analysis of salesman A's two context spaces indicated that 6 linearly independent dimensions were required to account for the spaces. The dimensional weights for salesman A are given in Table 8-7. For the *individual* perspective, the dimensionality previously chosen for salesman A's cognitive space was 3. According to Table 8-7, the three largest weights are for dimensions 1, 2 and 6 which suggests that these master space dimensions are used in this context. The *buyer* perspective appears to use dimensions 3, 4 and 5 in addition to dimension 1 featured in the *individual* perspective. Master cognitive spaces were developed for the other two salesmen with results similar to those of salesman A. Table 8-8 presents a summary of pertinent results extracted from these analyses.

The primary objective of this experiment was to determine if one individual could adopt another's perspective in making comparison judgments. In particular, it was of interest to assess the ability of the salesmen to adopt the buyer's perspective in judging the micros. This assessment was made by defining a *common* space for all the subjects and

TABLE 8-7.- DIMENSION WEIGHTS FOR THE 6-DIMENSIONAL MASTER SPACE FOR SALESMAN A: MICROPROCESSOR EXPERIMENT*

Dimension	Cognitive space	
	Individual perspective	Buyer perspective
1	40	57
2	80	
3		65
4		14
5		32
6	13	
Fit**	83	89

*Decimals omitted; weights < .10 deleted.
**Sum of squared weights.

TABLE 8-8.- SUMMARY OF MASTER COGNITIVE SPACE ANALYSIS FOR EACH SALESMAN: MICROPROCESSOR EXPERIMENT

Parameter	Salesman		
	A	B	C
Dimension upper bound	7	5	6
Dimensionality	5	4	5
Individual fit*	83	91	86
Buyer fit*	89	87	93
Shared dimensions	1	1	1

*Decimals omitted.

a set of dimension weights which were unique to each individual. When applied to the common space, an individual's dimension weights provide an approximation to his cognitive space. Three different collections of cognitive spaces were used to form common spaces: (1) all cognitive spaces for all subjects; (2) all individual perspective spaces; and (3) the buyer's space and the salesmen's buyer perspective spaces. The last two collections were no more informative than the first, and hence, subsequent discussions will address that common space using the seven (buyer + 3 salesmen × 2 perspectives) cognitive spaces. A common space dimensionality of 8 was selected. Table 8-9 provides the dimensional weights for this common space.

A comparison of each salesman's judgment data under the buyer perspective to judgment data from the buyer (see the values for r_S in Table 8-6) suggests that the salesmen should be ranked A-B-C (best to worst) based on their ability to adopt the buyer's perspective. The dimensional weights in Table 8-9 indicate why this ranking might be appropriate. Salesman A achieved a good approximation to the buyer's space by appearing to adopt three of the four attributes the buyer used and having about the same weighting (emphasis). C appeared to adopt one of the attributes the buyer used (dimension 8) but underemphasized it. The fact that salesman's C buyer perspective space was marginally included in the common space suggests that he used other attributes to judge the micros; ones that the other subjects did not use and are not represented in the common space. Salesman C's two context spaces are included in the common space only because of his strong emphasis on dimensions 3

TABLE 8-9.- DIMENSION WEIGHTS FOR THE 8-DIMENSIONAL COMMON SPACE (ALL SUBJECTS): MICROPROCESSOR EXPERIMENT*

Dimension	Subject						
	Buyer	AI**	AB	BI	BB	CI	CB
1	66	41	53	10			
2	19						
3	10					65	
4		82					
5			62		41	12	
6						16	61
7	34		14	39	81		
8	45		33	85			16
Fit***	81	87	85	94	87	51	48

*Decimals omitted; weights < .10 deleted.
**Contexts: I = individual; B = buyer.
***Sum of squared weights.

and 6. Furthermore, one of the three dimensions from C's *buyer* perspective space (see Table 8-5) is missing from the common space. Because of the poor fit between these two spaces, it is obvious that this unknown dimension constitutes a significant portion of C's *buyer* perspective space which the common space fails to represent. The analysis below tended to confirm this by identifying the dimensions used.

8.5 Dimension Labeling

Twelve property vectors derived from known physical measures of the micros were used to label cognitive spaces. The salesmen also supplied rating information on 6 attributes (listed in Table 8-3) and these data were used to form an additional set of 6 property vectors for each subject.

Cognitive space labels were developed for each salesman's two context spaces and the buyer's one context space using a linear or a monotonic linear regression property fitting technique (depending on the property vector measurement scale) as discussed in Chapter 4. Table 8-10 represents the factor loadings weighted by the multiple correlation coefficients for salesman A's cognitive space under the *buyer* perspective. The *number of instructions*, *I/O expandability*, *program memory size*, and *data memory size* attributes have the highest individual weighted loadings on the four dimensions that define this space. Hence, the *buyer* perspective space for salesman A can be defined by the labels representing these attributes. Table 8-11 summarizes the results of dimension labeling for all subjects. Of the 6 attributes collectively

TABLE 8-10.- WEIGHTED FACTOR LOADINGS FROM INTERLABEL CORRELATION MATRIX FOR BUYER PERSPECTIVE: SALESMAN A OF MICROPROCESSOR EXPERIMENT*

Attribute	Factor **				r^2***
	1	2	3	4	
Instructions	04	-09	85	16	87
Cycle time	08	-41	-06	-06	43
Program range	-54	-38	08	05	67
Data range	-22	-13	23	16	38
Decimal	36	20	22	41	62
Stack depth	-32	-08	38	-28	58
Number jumps	-21	31	13	23	46
I/O expand	-88	-14	17	-08	91
Memory expand	-01	-09	22	12	27
Program memory	-10	78	05	08	79
Data memory	17	-11	13	79	83
Number I/O lines	21	11	09	16	31
Cost	30	-14	-08	11	36
Performance	26	01	39	-27	54
Quality	13	33	-29	04	46
Delivery	66	03	13	10	68
Service	09	-04	26	-04	28
Assistance	08	-01	-15	02	17

*Decimals omitted.

**Loadings rescaled to rms value of r^2.

***Multiple correlation coefficient from monotonic linear regression ($r_{\alpha=.01} = .94$).

TABLE 8-11.- SUMMARY OF COGNITIVE SPACE LABELING FOR EACH SUBJECT AND FOR EACH CONTEXT: MICROPROCESSOR EXPERIMENT

Attribute	Subject						
	Buyer	AI*	AB	BI	BB	CI	CB
Number of instructions	✓	✓	✓	✓			
Cycle time	✓						
Program range						✓	
Decimal arithmetic							✓
Number of jumps		✓					
I/O expandability			✓		✓	✓	
Memory expandability						✓	✓
Program memory	✓		✓	✓	✓		
Data memory	✓		✓	✓			
Number I/O lines		✓					✓
MSM**	78	82	84	91	86	37	42

*Contexts: I = individual; B = buyer.

**Comparison between cognitive space and the cognitive space represented by the component scores for that context; decimals omitted.

mentioned by the salesmen, none appeared to be adequate for identifying cognitive space dimensions. Of the 12 physical attributes available from micro company brochures, only the *data addressing range* and *address stack depth* attributes did not feature in any subject's space.

The matrix similarity measure (MSM) computed between the cognitive space and the cognitive space formed from the component scores obtained from the factor analysis of label intercorrelation for each context space is given in Table 8-11. The generally high values of the MSM indicate that the selected labels provide a good description of the respective context space. The low values for salesman C, however, support earlier observations that C appeared to use attributes other than 12 physical or 6 subjective attributes analyzed in this study.

Table 8-12 provides a binary classification (above or below) of how a micro compared to the "average" micro in competition for the contract, on the attributes the salesman representing that micro appeared to use in each context. For example, a plus appears under A's *individual* perspective for the *number of jumps* attribute because that attribute was used by A in that context (see Table 8-11) and A's micro (micro #2) has a 30 *jump* capability compared to the overall micro average of 10, i.e., #2 was above average. From this table it can be seen that with an *individual* perspective the salesmen generally appeared to choose attributes for which their micros surpassed the average micro but with a *buyer* perspective they seemed to choose attributes for which they were surpassed by the average micro. C was an exception. In both contexts, he appeared to use attributes on which his micro excelled. What this signifies is not clear. The results suggest that salesmen A and B believed that the buyer would rate the micros on attributes for whic their micros would rate only fair—a somewhat pessimistic attitude. C, on the other hand, seemed to take an optimistic view.

TABLE 8-12.- COMPARISON OF EACH SALESMAN'S MICRO TO "AVERAGE" MICRO ON ATTRIBUTES USED IN CONTEXT SPACES: MICROPROCESSOR EXPERIMENT

Attribute	Subject*					
	AI	AB	BI	BB	CI	CB
Number instructions	–	–	–			
Program range					+	
Decimal						+
Number jumps	+					
I/O expand		–		–	+	
Memory expand					+	+
Program memory		+	+	+		
Data memory		–	+			
Number I/O lines	+					+

*Contexts: I = individual, B = buyer; symbols: "–" is less than average micro, "+" is equal to or greater than average.

8.6 Conclusions

The change in judgment context produced different spatial cognitive models for all salesmen. Some of the differences were structural in that the number and identity of dimensions of the models changed. Others were shifts in dimensional emphasis (weighting) and modifications of the stimulus configuration. These changes support the major hypothesis of this research that changes in the context of judging stimulus objects can cause changes in a spatial representation of their perception (i.e., spatial cognitive model) for a given individual.

The reliability analysis of the salesmen's judgment data indicated cated more variability using the buyer perspective than using the individual perspective (i.e., their own). This is quite reasonable. Taking on another's value system and using it to make certain judgments skillfully (i.e., as the other person would have), requires a complex cognitive process. Because of the individual's unfamiliarity with another's process, the individual would be expected to be prone to biases, etc., which might appear as judgment replication errors.

Although 6 subjective property vectors were supplied by each salesman to aid in identifying the dimensions of his cognitive space, they were of limited value (see, for example, Table 8-10) in comparison to the 12 commonly known physical attributes of the computers. It appears that although the subjects could suggest what characteristics they felt were important to their judgments, they were not consciously aware of which attributes they actually used.

Of the 3 micro salesmen considered (out of 7 bidding on the micro contract), A apparently did the best job of role-playing, while C was the worst if role-playing success can be measured by the number of attributes that a salesman chose in common with the buyer and weighted by about the same amount. The ability to perceive which attributes a buyer considers important constitutes a powerful asset for marketing strategy formation. These attributes are of major interest to industrial marketing researchers who are concerned with "What factors affected the buyer selecting vendor X instead of Y?" (Wind, Green and Robinson 1968). Kelly and Hensel (1974) suggest that in his role as gatekeeper of the flow of information, the salesman can increase his effectiveness by concentrating his efforts on using only sources of information considered to be of high value by the buyer and favorable to the salesman's product. The salesman who does not (or cannot) perceive what the buyer wants might present his product in a poor light (i.e., emphasize the wrong qualities in a written or oral proposal) and have his product rejected. On the other hand, a good salesman (in terms of ability to role-play or perceive what the buyer wants) may be able to get a mediocre product accepted. There is some evidence to suggest that A's good and C's poor perception of the buyer's viewpoint may have been reflected in the buyer's perception of the salesmen's proposals.

After the experimental data were obtained, salesman C's company challenged the legality of the original request for proposals, claiming ambiguous and biased requirements. The charge was made after the evaluation team's comparison of the micros and before its evaluation. Following the charge, the proposal request was withdrawn pending review of the charges. At this point, the buyer was asked his view of the salesmen's proposals. His response was to the effect that C didn't know what the contract required, what the competition was, or even what his product could offer, whereas A would have been a serious contender for winning the contract.

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CHAPTER 9

CONCLUSIONS

9.1 Summary

This chapter briefly summarizes the results of research on the effects of context on spatial cognitive models from the four experiments and draws some conclusions about the methodology used. (For specific results from each experiment refer to the appropriate chapter.) Possible areas of practical application of the context sensitivity of spatial models are then outlined. Areas of promise include project implementation, diagnostic information, product perception, analysis of decision making, attitudes and beliefs, and context specification.

9.2 Experimental Conclusions

9.2.1 Conclusions About Context

Previous work on spatial cognitive models has shown that an individual appears to simplify judgments of the dissimilarity of stimuli by reducing them to comparison of the stimuli on a few relevant dimensions. The present research investigated whether the dimensions or attributes used depend upon the context of the judgments required of the individual. Context involves a perceptual interpretation and cognitive understanding of a judgment situation, and cannot be directly assessed or manipulated. In the experiments reported here, the stimuli were kept the same but the situation was redefined by asking the subjects to give it a different interpretation or to adopt a different perspective. In effect, they were asked to assume a different context. This had a substantial and replicable effect on the cognitive spatial model.

As the result of analysis, context was classified with respect to five characteristics, physical environment, social environment, task definition, individual perspective and temporal setting. Attention was focused on the social environment, task definition and individual perspective. Experiments selected to demonstrate that changing these context characteristics would change individual spatial cognitive models were notably successful. This confirms a speculation by certain authors (e.g., Attneave 1950, Green and Carmone 1972, and Day 1972) that context might affect a spatial cognitive model and discredits Cliff's view (Cliff 1966a, Cliff and Young 1968) that it would not. This research found that the effects on the models were both structural and spatial. Structural changes were statistically significant changes in the number and nature of dimensions when context was modified. Spatial changes were changes in the representation of stimulus points and could be described by changes in attribute weighting. That the spatial models actually changed was always verified by replication.

Structural and spatial changes in the cognitive model show that the individual can be characterized as using a master cognitive space in making the dissimilarity judgments. The perception of a specific situation (i.e., context) appears to cause the individual to weight the stimulus dimensions (some perhaps with zero weight) such that the stimulus interpoint distances in the individual's cognitive space reflect the perceived dissimilarities among the stimuli under that context. When the context changes, the individual appears to change the dimension weights such that the new spatial configuration of the cognitive model represents a different set of dissimilarity judgments made under the new context. The master space concept is that a specific context evokes a specific subspace of the master space, and results suggest that it would be rare to find a context so comprehensive that it would evoke the entire master space.

9.2.2 Methodology Conclusions

The uncommonly high dimensional (e.g., 3 or more) cognitive spaces formed in this research may be due to the subjects attempting to make interval scaled dissimilarity judgments. This contrasts with most other studies which produced only 2-dimensional spaces but required only rank order judgments.

The use of factor analysis in the interpretation of cognitive space dimensions provided insight to the labeling problem and is unique to this research. Cognitive space labels were selected by factor loadings where the loadings represented correlations between each label and a set of independent factors. The factors were derived from a factor analysis of label intercorrelations. Factor analysis was an important aid in identifying labels which were significantly correlated with the cognitive space but mutually orthogonal.

In spite of the many studies which have used some form of a spatial model, no one has proposed a statistical test whereby cognitive spaces can be compared. Consequently, a matrix fitting procedure was adopted from another application along with a goodness-of-fit measure for comparing two cognitive spaces. In addition, this research developed an empirical significance test for a modified goodness-of-fit measure. Present application of the test, however, is limited to comparing two cognitive spaces from different contexts (i.e., testing whether the two spaces are independent). The use of such techniques for cognitive space replication analyses would require the development of the sampling distribution for the test statistic under the alternate hypothesis that the two cognitive spaces are not independent. This development is expected to be complicated by the need to incorporate the effects of an error distribution due to subject inconsistency or response measurement biases.

9.3 Applications

The fact that the spatial cognitive model is sensitive to context has implications for a variety of practical situations in which context is important. There is, of course, the very practical implication that all those who use spatial models in their research should control carefully for context or else consider it to be a relevant variable. Aside from that, particular applications of interest are (1) human performance measurement, (2) congruence of individual perspectives, (3) measurement of consumer perception, and (4) research about context.

9.3.1 Human Performance Measurement

An individual may change the perspective with which he views a set of stimuli through experience with the stimuli or acquisition of a skill in dealing with them. Since the spatial cognitive model is sensitive to changes in perspective, it can be used to determine whether or not an individual has mastered a skill or attained a certain skill level. This may be useful in analyzing complex man-machine systems (e.g., helicopter pilot ability in Zavala et al. 1965). In particular, current studies of the perception of workload (Siapkaras 1977, Sheridan et al. 1978) using cognitive spatial models should take context into account since it is likely to have a strong effect on the perceived difficulty and demand of a task.

Spatial model sensitivity to context can also illuminate biases in subjective decision-making. Wise (1970) has shown that a spatial cognitive model can be used to model subjective probabilities with stimulus events represented as points in the space. The present research suggests that one would expect to find systematic biases in probability assessment due to context effects (see Tversky and Kahneman 1974 for a review of certain biases).

9.3.2 Congruence of Individual Perspectives

Congruence of individual perspectives is basic to the efficient functioning of most project teams. The effective implementation of a project, for example, depends upon certain psychological factors which can be examined with a spatial cognitive model (DeBrabander and Edstrom

1977). Context effects in general and individual perspectives in particular are especially important in the light of Ulrich's (1977) six points of view which a project implementer must consider to get acceptance by managers. To the degree that the implementer's perspective of the project is at odds with the manager's, the project will have limited success (Doktor and Hamilton 1973, Bariff and Lusk 1977). Spatial cognitive models can be used to detect such differences in individual perspectives. Erlandson (1978) uses cognitive models to integrate the value systems of various individuals to establish a reference point for specific systems evaluation.

In a similar way, the spatial cognitive model can be used to detect and quantify the extent to which one person can "empathize" with, or adopt another's viewpoint. This can have important application in areas ranging from choosing or training sales personnel (Churchill, Collins and Strang 1975), to conflict resolution (Janis 1959) and to determining advertising strategy (Wright 1973).

9.3.3 Measurement of Consumer Perception

Consumer product perception can be altered for marketing purposes by context manipulation. Slovic and MacPhillamy (1972) and Tversky (1977) have shown that common attributes of stimulus objects are more heavily weighted in comparison judgments than are distinctive attributes. This phenomenon could be precipitated by appropriate context manipulation (e.g., product advertising messages) designed to invite consumer comparison of competing products along a few common attributes.

These attributes are carefully preselected to enhance the marketing image of an advertising sponsor's product. (See Kelly and Hensel 1974 for further details.) Methods of affecting attribute selection and weighting by context manipulation could be explored with spatial cognitive models. Such research would be of tremendous value in product design. There the objective is not only to develop the product with the "best" attributes, but also to determine how these attributes should be displayed to the consumer and in what context they should be presented for effective marketing.

9.3.4 Research About Context

Several studies which have attempted to classify the characteristics of context have either been too detailed with respect to the situational factors (e.g., Sells 1963) or else lacked measurement (e.g., Moos 1973). These problems stemmed from an apparent failure to realize that context results from an individual perception of situation. Since perception is unique to the individual, the same situation can yield different contexts for different individuals. Yet context could be "standardized" for an individual by constructing a spatial cognitive model using a standard set of stimulus objects. The context would then be considered to change to the degree that the "standard" cognitive model changes.

Wyer and Goldberg (1970) have suggested that many social phenomena (e.g., attitudes and beliefs) can be viewed in terms of processes of classifying objects or events on the basis of their attributes, or of inferring attributes on the basis of class membership. This suggests that such phenomena can be represented as spatial cognitive models. Since a cognitive model is expected to be sensitive to context, use of the model would enable one to assess the effect of context manipulation on attitudes (Wyer 1970a) or beliefs (Wyer 1970b). If attitudes or evaluations are context dependent, one could use the spatial cognitive model, for example, to probe the widely observed phenomenon of people maintaining different values in different spheres of activity.

9.4 Final Word

There appears to be an extraordinarily consistent pattern that emerges from this research. Experimental treatments intended to be manipulations of context (although they cannot be proven independently to be manipulations of context except by the original arguments as to the nature of context), have resulted in very clear, distinct, and unambiguous changes to individual spatial cognitive models. These changes are of a sort that can be explained in a reasonable way with the master cognitive space and the labeling of axes.

The weight of the evidence appears to this author to be that context has been affected and it is the context changes that have produced the observed effects on the cognitive spaces. The results seem to be too consistent and clear of interpretation to admit any other explanation. It would appear now that context must be explicitly taken into account in this kind of work simply because judgments are so dependent upon it.

APPENDIX A

AN OVERVIEW OF NONMETRIC MULTIDIMENSIONAL SCALING (NMDS)

A.1 Introduction

The typical problem to be handled by multidimensional scaling (MDS) procedures might be roughly stated as follows: Given a set of stimuli which vary with respect to a number of dimensions (not all of which may be known to the subject nor the the experimenter), determine from comparison judgments of the stimuli

a. A configuration of points representing the stimuli in a Euclidean space of minimum dimensionality

b. Projections (scalar values) of the stimuli on each of the dimensions involved

The procedures attempt to assign these scalar values so that the numbers, when considered in terms of a specified geometric space, reflect relations among the stimuli. These relations are usually dissimilarities (or similarities) which are interpreted to be psychological distances and are represented by the interpoint distances in the spatial model. The Euclidean geometric space is chosen for a number of distinct advantages: It is familiar; graphical representation is convenient for two and possibly up to three dimensions; and it has particularly simple mathematical properties.

A.2 MDS Types

There are two basic types of MDS analysis, metric and nonmetric or NMDS. The difference depends on how the dissimilarities are measured and used. If δ_{ij} is the psychological dissimilarity measured on an interval scale (at least) between stimuli i and j and if d_{ij} is the distance to be derived between the two stimuli represented in n-space then metric MDS analysis requires

$$\delta_{ij} = ad_{ij} + b \tag{1}$$

where a is non-negative. The parameter b is determined so that all distances satisfy the triangle inequality ($d_{ik} \leq d_{ij} + d_{jk}$). The triangle inequality requires that if stimuli i and j are close in the cognitive space (i.e., if they are viewed as being similar), and stimuli j and k are close, then stimuli i and k <u>must</u> also be close (i.e., be similar). (For further discussion see Beals and Krantz 1968). Torgerson (1958) was the first to develop systematic procedures for deriving the distances based on interval-scaled dissimilarity measures.

Algorithms to produce NMDS configurations were lacking until a major advance was made by Roger Shepard (1962a, 1962b) who pioneered two significant innovations: First, he introduced, as a central feature of MDS, the goal of obtaining the same rank order in the experimental dissimilarities and the interstimulus distances. He clearly stated that the satisfactoriness of a proposed solution should be judged by the degree to which this condition is approached. Second, he showed that simply by requiring a high degree of satisfactoriness in this sense, one generally obtains very tightly constrained solutions: If the rank orders of interpoint distances are input, then the interpoint distances can be accurately recovered. In other words, he showed that the rank order of the dissimilarities is itself enough to determine the solution. In addition, Shepard described and used a practical iterative computer procedure for finding his solution. Since then, Kruskal (1964a, 1964b, 1969), and Young (1972), among others, have developed what each considers to be an improvement over the original Shepard program. One of Kruskal's versions, MDSCAL-V was used in the research reported here.

The NMDS procedures require only that the dissimilarity judgments be made on an ordinal scale. (Although judgments in this research were obtained on a presumed interval scale, only the rank order information was used.) The solution technique used for MDSCAL begins with a random or assumed starting configuration which is used to compute stimulus interpoint distances. The distances are then used to compute psuedo dissimilarity measures (δ^*) from a regression equation:

$$\delta^*_{ij} \doteq ad_{ij} + b \qquad (2)$$

with special conditions that

$$\delta^*_{ij} \geqslant \delta^*_{st} \qquad (3)$$

whenever

$$\delta_{ij} > \delta_{st} \qquad (4)$$

MDSCAL offers alternate forms other than (2) and special techniques for handling tied ranks in (4) and the reader is directed to Kruskal for these details. The starting configuration is iteratively adjusted until (3) is satisfied and a goodness-of-fit measure, stress, is minimized. Stress is generally measured by

$$S = \sqrt{\frac{\sum_{ij}\left(d_{ij} - \delta^*_{ij}\right)^2}{\sum_{ij} d_{ij}^{\,2}}} \qquad (5)$$

Since the minimization of stress requires an iterative algorithm for solution, there is the problem of obtaining a local minimum. MDSCAL uses a technique of steepest descent for solution search, however, which seems quite robust to the local minimum problem as evidenced from several studies on the sampling distribution of stress (Klahr 1969, Spence and Ogilvie 1973). In addition, both MDS and NMDS procedures must be concerned with proper choice of dimensionality, and with the statistical significance of goodness-of-fit measures. Fortunately, recent studies have begun to address these issues. Before these topics are discussed, however, an example of the use of NMDS with MDSCAL will be given.

A.3 Hypothetical Example

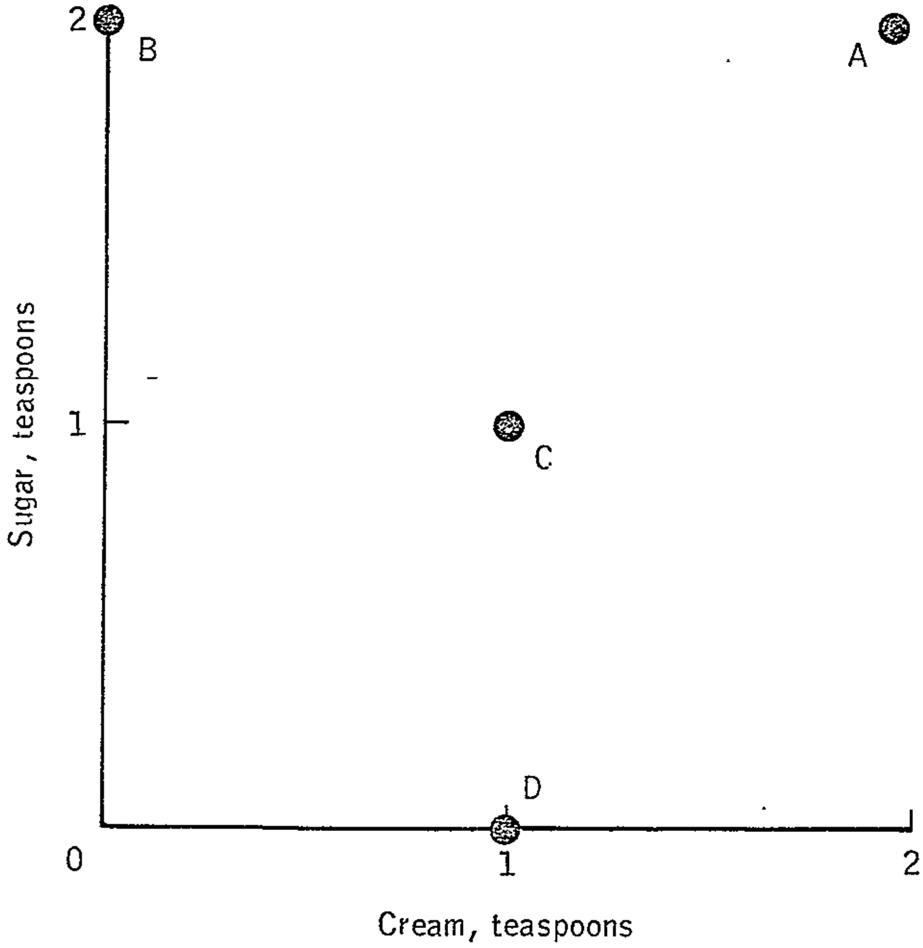
Consider an example of a hypothetical subject who judges 4 cups of coffee, A through D. The cups have 2, 2, 1, and 0 teaspoons of sugar, and 2, 0, 1, and 1 teaspoons of cream, respectively. The subject is asked to judge the dissimilarity of the cups and his judgments are translated into the matrix in the upper part of Figure A-1, where 1 indicates least dissimilar and 6 indicates most dissimilar.

The cups can be represented as points in a 2-dimensional property space (lower part of Figure A-1). Of course this space says nothing about how this particular judge views the cups of coffee. The property space can be looked upon as an input to the cognitive process, but it does not result from the process. The cognitive space, on the other hand, is purported to represent the psychological dissimilarity of the cups of coffee and can be derived by an NMDS analysis of the dissimilarity judgments.

One of the first questions concerning the space deals with its dimensionality. What dimensionality is required to represent the

	A	B	C
B	4		
C	2	3	
D	5	6	1

Hypothetical dissimilarity judgments



Property space

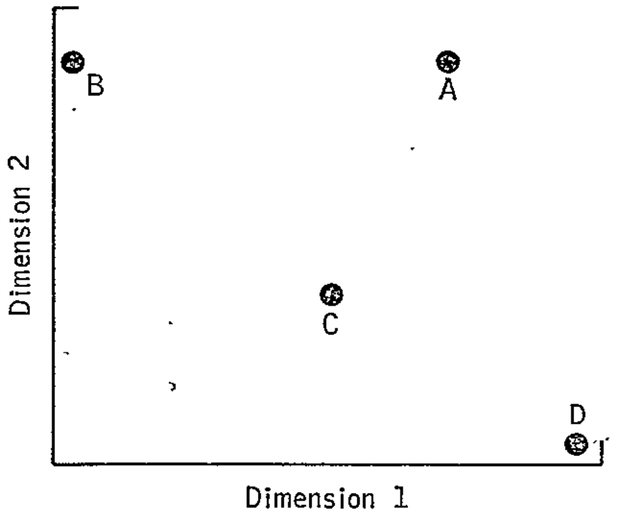
Figure A-1.- Dissimilarity judgments and property space for four hypothetical cups of coffee.

dissimilarity judgments adequately. Cognitive spaces of 1 through 4 dimensions were constructed from the dissimilarity data of Figure A-1 using MDSCAL. In all but the 1-dimensional space, the stress was zero to three significant figures; for the 1-dimensional case, it was .272. The following discussion will contrast the 1- and 2-dimensional spaces.

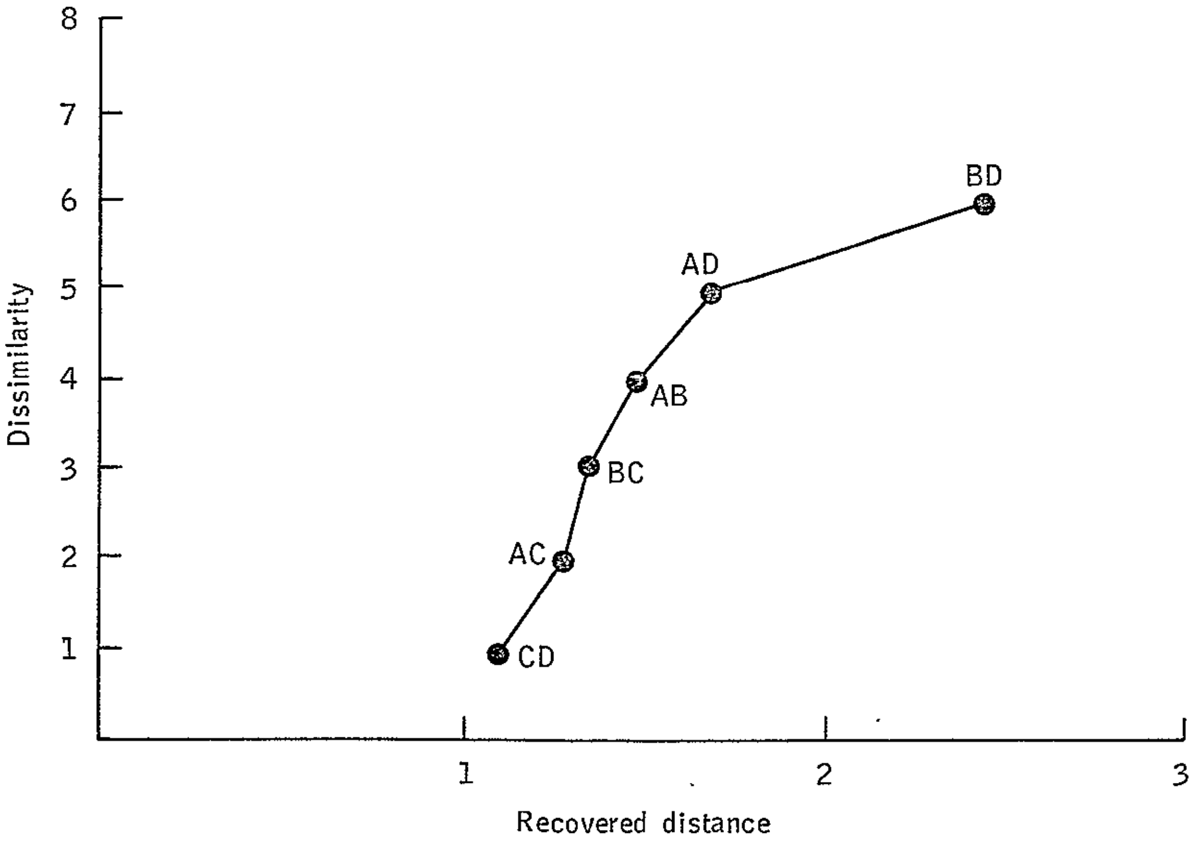
The 2-dimensional cognitive space is given in the upper part of Figure A-2 and the Shepard Diagram (named for Roger Shepard who introduced it) is presented in the lower part. The (rotated) cognitive space is quite similar to the property space. It appears that dimensions 1 and 2 can be related to the property attributes, cream and sugar, respectively. One of the main differences is that cup D lies at an extreme along dimension 1 in the cognitive space, whereas D does not occupy such a position in the property space. While the rank order of stimulus coordinates for dimension 2 matches that of the sugar dimension, the rank order of coordinates for dimension 1 does not match that of the cream dimension. There is, of course, no a priori reason the order should match. The problem of identifying or labeling the dimensions of the cognitive space is discussed at length in Appendix C.

The Shepard diagram demonstrates the satisfaction of the monotonicity criterion: for increasing dissimilarity, the recovered distance must not decrease. The depicted relationship between these two measures is nonlinear.

Figure A-3 represents the lowest stress 1-dimensional solution (cognitive space) for the problem and the Shepard Diagram is in the

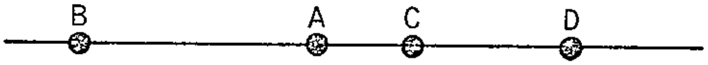


Two-dimensional cognitive space

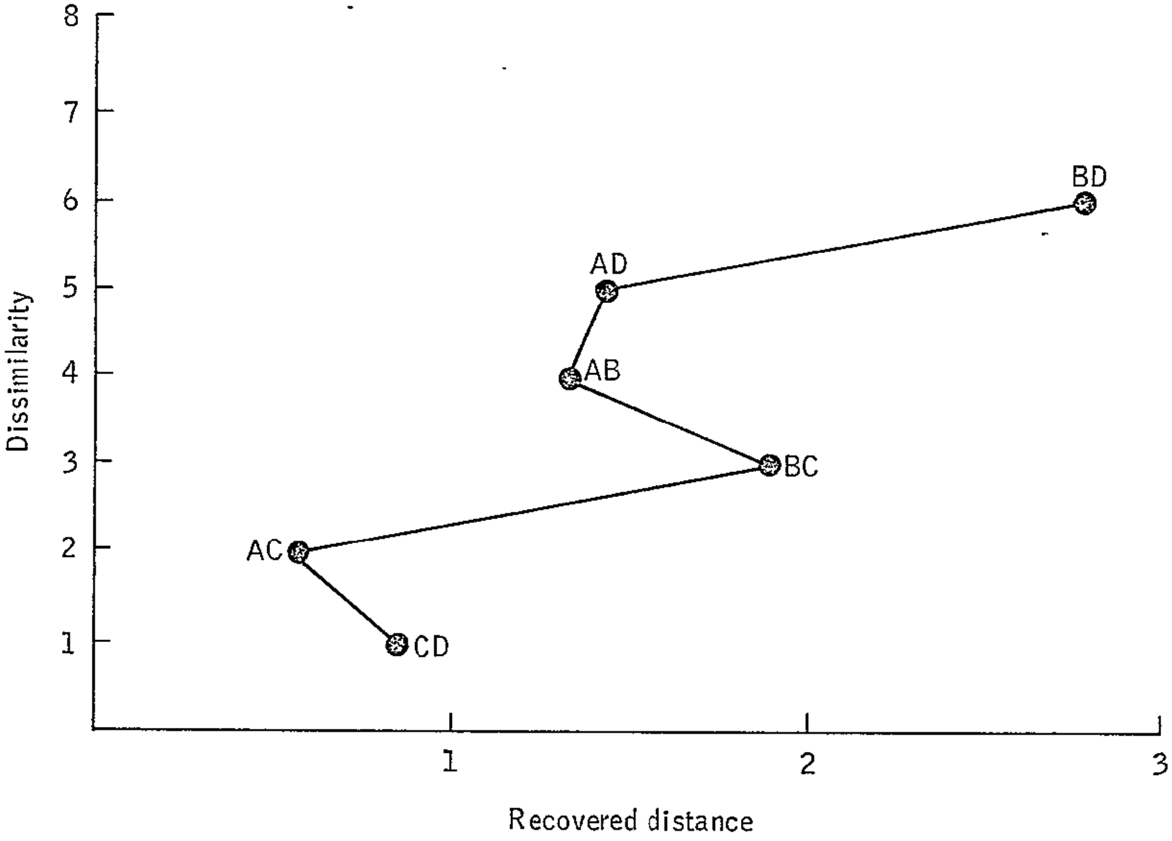


Shepard diagram: Dissimilarity vs. recovered distance in two dimensions

Figure A-2.- Two-dimensional cognitive space and Shepard diagram for four hypothetical cups of coffee.



One-dimensional cognitive space



Shepard diagram: Dissimilarity vs. recovered distance in one dimension

Figure A-3.- One-dimensional cognitive space and Shepard diagram for four hypothetical cups of coffee.

lower part of this figure. The Shepard Diagram indicates that the monotonicity criterion was not satisfied for this solution. The configuration in the upper part of Figure A-2 suggests that the problem is with stimulus A; it cannot lie on the same line with the other stimuli and still satisfy the monotonicity criterion. The stress measures this lack of fit and its magnitude suggests that the 1-dimensional cognitive space is an unacceptable representation of the dissimilarity judgments.

A.4 Statistical Analysis

A.4.1 Significance of NMDS Results

Kruskal's iterative NMDS analysis technique seeks to find an n-dimensional spatial representation of points representing the stimuli such that the rank order of the interpoint distances matches the rank order of the input dissimilarity measures. The degree of match at a given number of extracted dimensions is determined by stress which indicates the degree of non-monotonicity between the computed distances and the original dissimilarities. Other measures of fit have been suggested (Sherman and Young 1968, Hall and Young 1975, and Trunk 1968) but these have not proved to be popular.

Kruskal (1964a) describes a resultant stress of .10 as a "fair" fit, .05 as "good", and .025 as "excellent." He further suggests that one pick the dimensionality of the cognitive space corresponding to the "elbow" of the stress vs. dimensionality curve -- the point at which an increase in dimensionality gives no appreciable decrease in stress. Most researchers have taken this suggestion as a criterion (if they take any at all) for dimensionality selection in NMDS analyses. But stress is only a descriptive statistic. Stress may be due to having extracted fewer dimensions E than actually underlie the data, or it may be due to variability unrelated to the spatial representation, or both. Thus statistical hypothesis tests are needed to test for the true underlying dimensionality T of a particular matrix of dissimilarity data for n stimulus objects. Desirable tests are:

1. Significant structure in the data

$$H_0: T = 0$$
$$H_1: T > 0$$

2. Tests for dimensionality

$$H_0: T < E$$
$$H_1: T \geqslant E$$

In neither of these cases has a completely satisfactory test been developed. This is because few researchers have recognized the two sources of stress and that separate statistical tests (i.e., those above) are needed to deal with these sources. A number of authors have developed an approximate test for the hypotheses.

$$H_0: T = 0$$

$$H_1: T \geqslant E$$

by obtaining the conditional distributions of stress given the number of dimensions extracted using Monte Carlo methods. Their work is described below.

Klahr (1969), Wagennar and Padmos (1971), Stenson and Knoll (196 and Spence and Ogilvie (1973) have approached the problem of attempting to identify the underlying stress distribution by experimentation. Ramsay (1969) and Young (1970) have treated the problem theoretically but neither provide for direct application of their analyses. The experimental approaches consist of a Monte Carlo simulation in which randomly formed n × n matrices are analyzed by an NMDS algorithm, generally MDSCAL. The matrices are usually formed from random samples of permutations of the first (n(n-1)/2 integers which represent dissimilarities (or rank orders of dissimilarities) among n stimulus objects. The occurrence frequency of different stress values as a function of the number of dimensions extracted E are collected for selected values of n and E. In spite of the differences in randomization techniques or number of replications, the reported means and variances of these stress values by the various authors are quite close. This agreement justified the present author's regressing the stress mean and variance over extracted dimensionality to obtain predictions of these parameters for dimensionalities not considered by these authors but which were of interest to the present research. Based on a technical discussion by Young (1970) indicating that stress can be assumed to be normally distributed (which Klahr's empirical data supports), Table A-1 lists selected percentile points from an empirically derived cumulative distribution function of stress for 9- and 14-stimuli dissimilarity matrices as a function of the number of dimensions extracted.

At a chosen extracted dimensionality E, one can use these results to test the null hypothesis H_0 that the dissimilarity matrix is random with no meaningful structure, represented against the alternative hypothesis H_T that this is not so, and that the proper dimensionality is T, where T is not known. A reasonable interpretation of the test is that if H_0 is accepted at the number of extracted dimensions E, then the true dimensionality T, if nonzero, is less than E. When the null hypothesis is rejected at E, the true dimensionality is assumed to be no less than E. There is no direct test for the true value of T.

If s(E) is the observed stress value of the random variate S at extracted dimensionality E and $F(s|n,E)$ is the cumulative probability distribution function for S given n and E, then the procedure used in the present research is to choose T equal to the highest dimensionality E for which $s(E) \leq s_\alpha(E)$ where $s_\alpha(E)$ is the stress level such that

TABLE A-1.- SELECTED PERCENTILE POINTS FROM CUMULATIVE DISTRIBUTION OF FINAL STRESS FOR DISSIMILARITY MATRICES AS A FUNCTION OF NUMBER DIMENSIONS EXTRACTED*

Dimensions	Percentile				
	0.01	0.05	0.10	0.25	0.50
9 stimuli					
1	.277	.308	.325	.353	.384
2	.113	.133	.144	.161	.181
3	.031	.047	.055	.070	.085
4	.000	.017	.023	.028	.035
5	.000	.005	.009	.016	.023
14 stimuli					
1	.409	.424	.431	.444	.458
2	.224	.234	.240	.249	.259
3	.134	.143	.147	.155	.164
4	.079	.088	.092	.100	.109
5	.045	.054	.059	.067	.077

*Based on regression results using data obtained from Klahr (1969), Spence and Oglivie (1973), and Stenson and Knoll (1969).

$F(s_\alpha | n,E) = \alpha$. Thus the procedure is to:

$$\text{Accept } H_0 \text{ iff } s(1) \geq s_\alpha(1)$$

or

$$\text{Accept } H_M \text{ iff } s(M) < s_\alpha(M)$$

and

$$s(M + 1) \geq s_\alpha(M + 1)$$

The functions s and s_α are well-behaved so that

$$s(M + 1) \leq s(M)$$

$$s_\alpha(M + 1) < s_\alpha(M)$$

A.4.2 Extracted vs. True Dimensionality

In his development of the MDSCAL procedure, Kruskal (1964a, pp. 1-2) criticized the rationale of previous MDS procedures which used the variability of the data as a critical element in forming the distances in a spatial configuration. Torgerson (1958), for example, incorporated Thurstone's (1927) case V of the law of comparative judgments ("equally often noticed differences are equal") into his MDS scaling algorithm to obtain interval scaled dissimilarity measures for analysis. Conventional NMDS methods (e.g., MDSCAL) make no provision for variability or error in judgment data, although it seems likely that this situation arises in practice. The error could, in fact, be caused by the subject's inconsistency in replicating judgments, or it could originate with the researcher's imprecise tools in measuring the judgments, or both. The source is really irrelevant -- the importance lies in acknowledging the existence of error and incorporating error in the consideration of dimensionality analysis. Although no one has stated it to date, it would appear that stress should be considered to be a multivariate probability distribution function dependent upon true dimensionality T, extracted dimensionality E, and judgment data error e such that

$$S = f(T, E, e)$$

The next section reviews studies which have examined special cases of this distribution function.

A.4.2.1 Dissimilarity Data With Error. A rather large number of studies (Sherman and Young 1968, Young 1970, Wagennar and Padmos 1971, Sherman 1972, Issac and Poor 1974, and Cohen and Jones 1974) have been conducted to assess the "robustness" of NMDS when varying degrees of systematic error were built into the input dissimilarity data. Their technique was to randomly perturb a fixed but arbitrarily chosen spatial configuration of points of known dimensionality T. The perturbation was introduced by multiplying each interpoint distance by a variate with distribution $N(1,\sigma^2)$ where σ took on various values. MDSCAL was then used to scale the modified distances (taken as dissimilarity measures) and extract the same number of dimensions as the original (error-free) configuration (i.e., E = T). The resulting value of stress was noted in each case. Finally, this procedure was repeated in a Monte Carlo fashion and provided an empirical sampling distribution of stress when recovering a configuration of known dimensionality which had been subjected to error.

With the exceptions of Wagennar-Padmos and Isaac-Poor, these Monte Carlo studies did not deal specifically with the problem of determining the true, but unknown, dimensionality of a configuration. Shepard (1966) found that the true configuration was found satisfactorily with "moderately high" amounts of error added, but there was no mention of the problem of finding the true dimensionality when it is not known *a priori*.

A.4.2.2 Probability Distribution of True Dimensionality

Isaac and Poor (1974) described an elegant approach by defining an index of "constraint" C for a NMDS solution

$$C_k = E[S(k)] - s(k)$$

where

$E\,[S(k)]$ = expected stress of a configuration based on random data with extracted dimensionality k

$s(k)$ = sampled stress from a configuration with extracted dimensionality k

The authors argue that the true dimensionality T should be chosen such that

$$C_T = \max_k C_k$$

The primary virtue of the index is its simplicity, having a rough analogy to hypothesis testing of means. An obvious drawback is that it gives a single point estimate of true dimensionality since it does not use the entire stress distribution.

While the previous authors analyzed dissimilarity data and extracted the same number of dimensions as the original (error-free) configuration (i.e., $E = T$), the Wagennar and Padmos (1971) study was unique in that these authors extracted dimensionalities other than the "true" dimensionality (i.e., $E \neq T$). Their study produced an empirical sampling distribution for stress as a function of any dimensionality extracted (less than 5), given a known true dimensionality and error distribution $N(1,\sigma^2)$. This is a significant contribution since a researcher generally does not know the true dimensionality, and the Wagennar-Padmos study provides additional information whereby one may determine the most probable dimensionality.

Their procedure involves plots of stress against amount of error introduced, with a different curve being plotted for each extracted dimensionality. A different set of such plots is required for each true dimensionality T and number of points n. Thus, their procedure, in effect involves comparing an obtained stress curve s(E) with curves with known true dimensionality and amount of error $F(s|E, T, N(1,\sigma^2))$. The authors' example suggests that one select that true dimensionality T for which the interval defined by one standard deviation from the mean stress contains the sampled stress for E = T, given a known error distribution. This procedure is illustrated in Figure A-4. In this example, the "true" dimension should be selected as 2; the stress is too high for T to be 1 and too low for T to be 3. The implied strategy is to reject as true, dimensionalities which give extreme values of stress.

Based on their brief example, it appears that Wagennar and Padmos did not realize the possible limitations of their approach. First, the authors appear to ignore the sample stress values when $E \neq T$; their example only examined the stress values when E = T. Second, they do not address the possibility of Type I and Type II errors. That is, the suggested procedure could easily lead to rejection of the true dimensionality or acceptance of an untrue dimensionality.

A.4.2.3 Suggested Procedure. The proper dimensionality underlying a set of dissimilarity data could be posed in the form of hypotheses and a probability could be formed concerning the truth of each hypothesis. The probabilities could be derived from likelihood ratios

$$L_{ij} = \frac{f\left[s(1),\ s(2),\ \ldots,\ s(m)\middle|\ T_i,\ e\right]}{f\left[s(1),\ s(2),\ \ldots,\ s(m)\middle|\ T_j,\ e\right]}$$

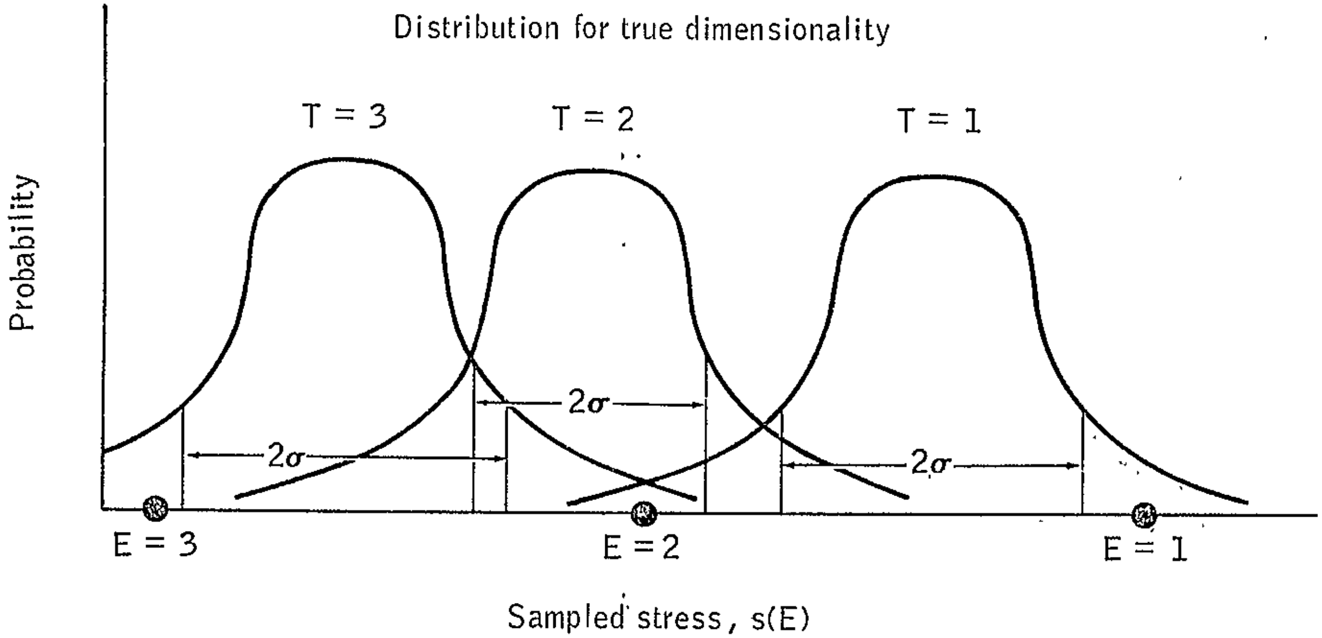


Figure A-4.- Distributions for sampled stress for extracted dimensionality, s(E), given a true dimensionality T and error distribution: Example problem.

which provides the likelihood that the sampled stress history s(E) in 1 to m dimensions would result from a set of dissimilarity data having an underlying dimensionality of T_i rather than T_j , given an error e in the data. This technique would require, however, joint multivariate probability distributions of stress. Unfortunately, previous studies considered or developed only conditional distributions. Generating the required joint probability distributions was considered to be an effort beyond the objectives of this research.

APPENDIX B

AN OVERVIEW OF THE INDSCAL MODEL

B.1 Introduction

Multidimensional scaling (MDS) was originally developed to determine a Euclidean space underlying a two-way matrix of dissimilarity data; two-way meaning n stimuli are compared with each other and the resulting data are represented by a two-dimensional matrix. But situations arose in the social and behavioral sciences, and elsewhere, in which several dissimilarity matrices for the same stimuli were available and a three-way MDS was needed; n stimuli are compared with each other N times and the dissimilarity data are represented by a three-dimensional matrix. One would generally like to account for all of these data matrices in a single comprehensive analysis, based on an appropriate and psychologically plausible model. The most typical situation arises when one wishes to compare dissimilarity matrices for each of N different individuals. The INDSCAL (Individual Differences Scaling) method (Carroll and Chang 1970) derives its name from just this situation. INDSCAL offers some special advantages over other three-way methods (such as Tucker and Messick 1963, Bloxom 1968): (a) unique determination of dimensions which eliminates (in most cases) the need for rotation of coordinate axes to obtain interpretability; (b) a composite multidimensional space with respect to which different "cognitive

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types" can be directly and reliably compared; and (c) quantitative information about the cognitive saliences of different dimensions for each subject, and about the degree to which the multidimensional space as a whole reflects the perceptions or judgments of any individual.

B.2 The INDSCAL Model

The input to INDSCAL normally consists of two or more dissimilarity matrices, all pertaining to the same stimulus objects. Each matrix typically represents one subject's dissimilarity data, but it could be one judgment context, as in this research. It is assumed that a set of M dimensions underlie n stimuli and these dimensions are common to the N cognitive spaces (or individuals). For example, it is as if different individuals perceive the same stimuli in terms of a common set of dimensions but that these dimensions are differentially important or salient in the perception by these individuals. If the salience is zero, the corresponding dimension does not affect the subject's cognition at all.

Distances between stimuli are linearly related to a kind of modified Euclidean distance between points representing stimuli in a composite cognitive space. The mathematical equivalent of this assumption is

$$\delta_{ijk} = ad_{ijk} + b \tag{1}$$

where δ_{ijk} is the dissimilarity associated with stimulus pair ij in matrix k (for subject k), while d_{ijk} is the derived Euclidean distance between these stimuli for subject k computed from his unique dimension weights and the stimulus coordinates in the common cognitive space. The modified Euclidean distance for subject k is given by

$$d_{ijk} \doteq \sqrt{\sum_{t=1}^{M} w_{kt}\left(x_{it} - x_{jt}\right)^2} \qquad (2)$$

where x_{it} is a stimulus coordinate representing the value of stimulus i on dimension t and w_{kt} represents the salience or importance of dimension t to subject k in forming the dissimilarity judgments. The symbol $\doteq$ means approximation in a least sum of squares sense.

The parameter b in equation (1) is chosen such that the computed distances will satisfy the triangle inequality. Techniques developed by Torgerson (1958) are used. This transformation is necessary since INDSCAL assumes that the input dissimilarity data are defined on an interval scale (at least). A judicious value of b will produce minimum dimensionality m. The parameter a (non negative) is chosen by the program and serves only to scale the common configuration.

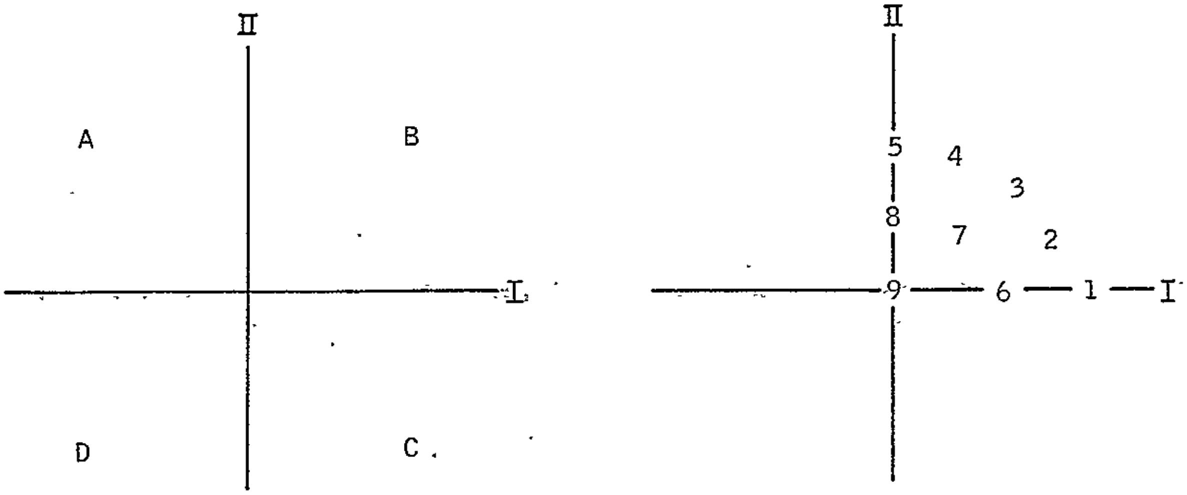
The INDSCAL procedure determines, by means of an iterative least squares procedure, the stimulus coordinates common to the group and dimension weights unique to each subject that maximally account for the variance in all the dissimilarity data (the variance is the goodness-of-fit measure). (See Carroll and Chang for mathematical details of the algorithm.) When the stimulus space is normalized so that the sum of squared coordinates on each dimension equals one, a subject's weight on a dimension is approximately equal to the product moment correlation between differences in stimulus coordinates on that dimension and dissimilarity values in that subject's matrix. The squared weight indicates the proportion of variance in the matrix which can be accounted for by that dimension. The square of a weight underestimates the proportion of variance accounted for it when, as is frequently the case, the dimensions of the common space are correlated. If, however, the dimensions of the space are orthogonal, then the square will exactly equal the proportion of the variance accounted for. A dimension weight of zero can be thought of as meaning that the attribute associated with the dimension is irrelevant to the subject when he makes his judgment; i.e., he just does not perceive the stimulus differences specified by the dimension, or in any case, acts in that particular task as if he does not.

The procedure used in the research on context differed, however, from the usual application of INDSCAL. A modified version of INDSCAL (written by this author) accepts individual cognitive spaces (configurations) as input previously determined by the MDSCAL program from individual dissimilarity data), computes the interpoint distances based on the input space, and uses the distances as dissimilarity data. Since only interval scaling is required of the data, the parameter b is discarded in equation (1) and the usual INDSCAL procedures is applied. Effectively, this <u>ad</u> <u>hoc</u> version of INDSCAL accepts individual cognitive spaces from one subject under several judgment contexts, and produces a master cognitive space. A master space refers to a cognitive space for one individual that is common to several judgment contexts and dimension weights which are unique to each context. The basic interpretation is that the individual acts as if he had the master space at his disposal and differentially weights dimensions according to the context. The weights indicate how the subject emphasizes or uses certain dimensions in certain contexts and a change in weights demonstrates the effect of context.

B.3 Hypothetical Example Using INDSCAL (From Carroll 1972)

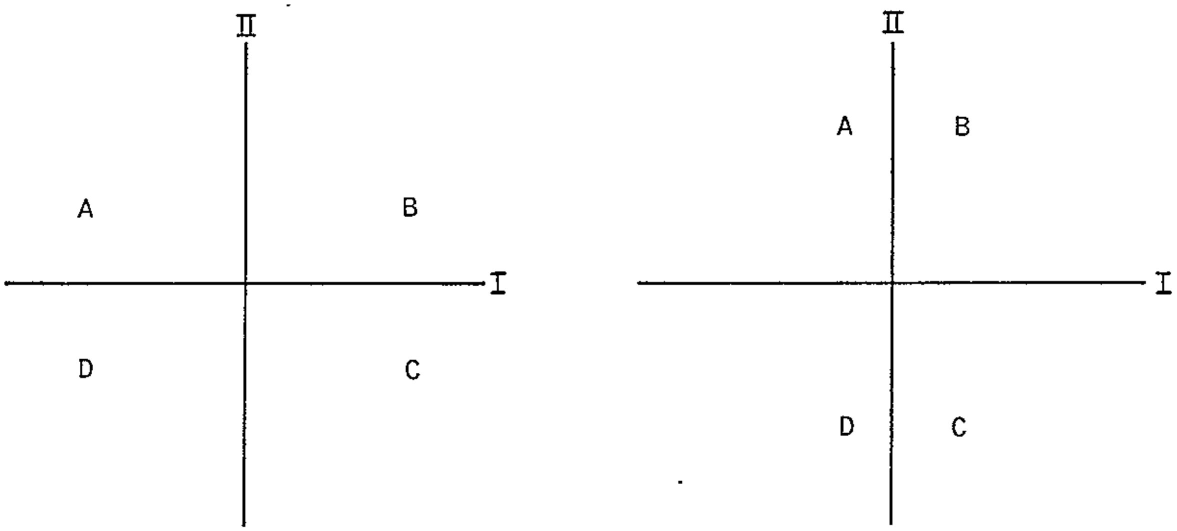
Consider an example in which 9 subjects judge 4 stimuli, A through D. The common cognitive space in the upper left of Figure B-1 shows the stimuli arranged in a lattice configuration; the subject space in the upper right shows the weights or perceptual saliences of the dimensions for the 9 hypothetical subjects. These weights can be thought of as stretching factors that if applied to the dimensions of the group stimulus space would produce the individual space.

The differential weights have the effect of producing, for each subject, a "private" cognitive space by rescaling (stretching and contracting) the dimensions of the common space. In the illustration, for example, subject 3 has equal weights for the two dimensions. His private space would therefore look exactly the same as the common space (except for an overall scale factor that could stretch or contract both dimensions uniformly, leaving their relative saliences unchanged).



Master cognitive space

Subject weight space



Subject 2 cognitive space

Subject 4 cognitive space

Figure B-1.- Hypothetical illustration of INDSCAL: Individual differences in multidimensional scaling.

The private spaces for subjects 2 and 4 are shown in the lower left-hand and right-hand corners of Figure B-1 respectively. Subject 2, who weights dimension I more highly than dimension II, has his cognitive space compressed along the dimension II axis (or what amounts to the same thing, stretched in the dimension I direction). The reverse applies to subject 4 who has a higher weight on the second than on the first dimension.

Although subjects 3 and 7 have the same pattern of dimension weights, a higher proportion of the variance in subject 3's data can be accounted for by the hypothetical INDSCAL solution. The data for subjects closer to the origin are generally less fully accounted for by the analysis, so that all dimensions of the common space are less relevant for them. The lower commonality for subjects closer to the origin may be due to their being idiosyncratic dimensions not contained in the M-dimensional solution or to lower reliability (more random error) in their data.

Subject 9, who is precisely at the origin, is completely removed from this analysis. Either he responded randomly or he appeared to do so by responding reliably to a completely different set of dimensions.

APPENDIX C

COMPARISON OF SPATIAL COGNITIVE MODELS

C.1 Summary

Comparison between spatial cognitive models is important when the effects of context on the models are to be investigated. Comparison distinguishes differences in cognitive models due to context change from differences due to inconsistency of subject response or instability of the cognitive spaces over time. This Appendix reviews techniques related to a matrix similarity transform that was used to compare two spaces. Disadvantages of each technique are identified. Finally, a matrix similarity measure (MSM) used in this research for cognitive space comparison is described along with certain statistics for testing hypotheses concerning the relationship between two cognitive spaces.

C.2 Introduction to the Problem

The researcher may often want to compare the result of two multidimensional scaling solutions (i.e., cognitive spaces). Comparison is especially important when the effects of context are to be investigated. If a cognitive space is replicated with the same context, a comparison is needed to determine if the space is sufficiently stable or defined to serve as a basis for quantifying subsequent changes. If the context is

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varied between two cognitive spaces, then a comparison can identify the changes in the spaces.

Comparisons may be simple if the spaces are 2-dimensional and "look" the same. However, a comparison index is still needed to quantify space similarity and often the dimensionality is larger than 2 making visual comparison quite difficult. Sometimes the dimensionality of the two spaces may not be the same. Since the cognitive spaces can be represented as n × m rectangular matrices (n stimuli × m dimensions), most of the techniques to be discussed approach the problem of cognitive space comparison as a matrix comparison problem and that convention is adopted here. If A and B are two cognitive spaces, B is said to compare to or "fit" A if a matrix similarity transform S can be found such that

$$\hat{A} = S(B)$$

where $\hat{A}$ is an approximation to A. A similarity transform does not affect the rank order of the stimulus object interpoint distances defined by the cognitive space. The goodness of the approximation or the fit is given by f(E) where E denotes an error matrix or a "spatial difference" between A and B;

$$E = A - \hat{A}$$

and where f is a monotonic decreasing function of the norm of E, bounded between 0 and 1 (perfect fit). The matrix comparison techniques reviewed in the next section differ in the generality of the similarity transform S, or in the fit metric f.

C.3 Review of Previous Comparison Techniques

C.3.1 Identity Transform

One frequently occurring technique uses the identity matrix for a similarity transform and compares B directly to A; i.e.,

$$\hat{A} = BI$$

or

$$\hat{A} = B$$

and

$$E = A - B$$

The goodness of fit measure is the product moment correlation r of interpoint distances d calculated from the n × m matrices (e.g., Green, Maheswari and Rao 1969), i.e.,

$$\text{Fit} = r\left(d_A, D_B\right)$$

Similarity transforms allow orthogonal rotations, translations and rescaling, but the identity transform does not. Consequently, this restriction may mask possible systematic relationships between the two spaces, so that very precisely related spaces will be rejected as being different. Furthermore, as Cohen and Jones (1974), among others, have pointed out, the use of r has certain undesirable properties:

1. Since r is computed on all n(n-1)/2 interpoint distances which are intrinsically interdependent, displacement of a single point in a space affects n-1 interpoint distances. In this manner, a large displacement of one or two points in a space could lead to a misleading value of r.

2. The coefficient r is not a suitable measure of the relationship between two ratio scaled variables (i.e., distances) since r is invariant under transformation of either or both variables by an additive constant whereas distances are not.

C.3.2 Orthogonal Rotation

Cliff (1962) proposed an orthogonal rotation to replace the rigid identity transform and later operationalized the technique

$$\hat{A} = BP$$

where P was now an $m \times m$ orthogonal rotation matrix (Cliff 1966b). Schonemann (1966) produced a similar technique but his solution is an optimal one for minimizing the sum of squares of the error matrix E, (i.e., trace EE' is minimized) and is more amenable to computer implementation. The problem with Schonemann's solution is that it does not allow the general similarity transformation; matrix translation and dilation are lacking.

C.3.3 General Similarity Transform

Goodness of fit in nonmetric multidimensional scaling (NMDS) is generally assessed in terms of the degree of monotonicity between observed dissimilarity measures and the interpoint distances of the reproduced configuration as measured by stress (see Appendix A for further details). The coordinates of the reproduced configuration (spatial cognitive model) are arbitrary in the sense of being defined up to a similarity transform; a central rescaling (a uniform expansion or contraction for every coordinate axis), a translation (a shift of the origin), and a rotation of the entire configuration, as these transformations in no way affect the monotonicity measure of stress. Since a cognitive space is uniquely defined only up to a similarity transform, two cognitive spaces ought to be compared by assuming that a similarity transform exists between the two. Schonemann and Carroll (1970) developed such a procedure

$$\hat{A} = cBT + GH'$$

where $G' = (1, 1, \ldots, 1)$ and where the orthogonal $m \times m$ matrix T, the $m \times 1$ vector H, and the scalar c are to be chosen so as to minimize trace EE'. Schonemann's computer program (a copy of which he supplied to the author) provides a solution to this problem and has been used throughout this research for comparing cognitive spaces.

Schonemann and Carroll (1970) also proposed two measures of fit. These were later criticized by Lingoes and Schonemann (1974) as being dependent upon the norm of the target matrix A; i.e, the goodness of fit to A would be different from that to kA where k is a scalar constant. Lingoes and Schonemann instead proposed the goodness of fit measure F

$$F = 1 - \frac{(\text{trace } T'B'WA)^2}{\text{trace } B'WB \cdot \text{trace } A'WA}$$

$$\text{where } W = I - (GG'/n)$$

F is norm invariant and bounded by 0 (perfect fit) and 1. A more intuitively satisfying matrix similarity measure MSM was defined by the present author as

$$MSM = (1 - F)^{\frac{1}{2}}$$

MSM is also norm invariant and bounded by 0 and 1, where 1 means cognitive spaces A and B are identically related by a similarity transform.

C.4 Significance Data for MSM

The MSM (or its equivalent F) is a descriptive measure for a goodness of fit between two cognitive spaces. No significance test, however, was proposed by Lingoes and Schonemann, and with the exception of a product moment correlation measure of fit, no significance test is available for any comparison technique. Since a comparison index and a significance test for space comparison were essential to the objectives of this research, an empirical distribution for MSM was generated.

Matrices A and B were generated randomly for various values of n and m, using coordinates uniformly distributed between 0 and 1. The choice of the uniform distribution follows Sherman (1972) and is supported by empirical evidence from this research which suggests that the distribution of stimulus coordinates appears uniform. Then, in keeping with most NMDS procedures, the matrix columns were shifted and scaled to give zero mean and unit variance. Finally the goodness of fit measure MSM was computed between matrices A and B and the results accumulated for 1000 pairs of A and B. Table C-1 presents selected percentile points from the empirical cumulative distribution of MSM for 9 and 14 stimuli.

As an example, suppose two cognitive spaces existed for 14 objects in 3 dimensions. If the MSM between the two spaces was found to be .626, then Table C-1 indicates there would only be a .01 probability that two random spaces would produce a higher value of the MSM. Then one might state with 99% confidence, that such a fit did not come from random cognitive spaces.

TABLE C-1.- CRITICAL VALUES FOR THE GOODNESS-OF-FIT MEASURE (MSM) BETWEEN TWO RANDOM COGNITIVE SPACES*

$P\{MSM \leq \text{tabulated value}\} = \gamma$

Dimensions	γ equal to --					
	0.001	0.010	0.050	0.950	0.990	0.999
9 stimuli						
2	080	124	184	649	733	816
3	192	258	324	672	748	822
4	291	360	412	709	756	802
5	381	436	490	746	788	830
6	453	499	550	774	799	859
14 stimuli						
2	048	096	150	520	641	708
3	139	194	251	548	626	705
4	253	277	323	574	619	645
5	289	342	384	606	655	678
6	365	395	442	635	679	716

*Decimals omitted.

The significant test used above assumes for a null hypothesis, that the two cognitive spaces A and B are independent and randomly generated with uniformly distributed coordinates. This would be a conservative hypothesis when the effects of context change are being examined. For this hypothesis to be accepted a changed context must completely change a cognitive space, making it appear independent of the cognitive space prior to the context change. The significance test, however, is weak when cognitive space stability is analyzed since the sampling distribution for the test statistic under the alternate hypothesis that the two cognitive spaces are not independent is unknown.

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16. Abstract

Human decisionmaking can be viewed as comparison and evaluation of alternatives within a cognitive structure. Spatial cognitive models obtained by multidimensional scaling represent cognitive structure by defining alternatives as points in a coordinate space based on relevant dimensions such that interstimulus dissimilarities perceived by the individual correspond to distances between the respective alternatives. The research reported here investigates whether spatial models depend upon the context of the judgments required of the individual, where context is defined as a perceptual interpretation and cognitive understanding of a judgment situation. Context was analyzed and classified with respect to five characteristics: physical environment, social environment, task definition, individual perspective, and temporal setting. Details are given on four experiments designed to produce changes in the characteristics of context and to test the effects of these changes upon individual cognitive spaces. Discussion includes experiment design, objectives, statistical analysis, results, and conclusions. Based on this study, the hypothesis is advanced that an individual can be characterized as having a master cognitive space for a set of alternatives. When the context changes, the individual appears to change the dimension weights to give a new spatial configuration. In this report, factor analysis was used for the first time in the interpretation and labeling of cognitive space dimensions.

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