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# INFLUENCE OF VALUE IN THE PERCEPTION OF SPATIAL NUMEROSITY

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Influence of Value In The Perception of Spatial Numerosity" submitted by Eugene C. Lechelt in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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# Abstract

The purpose of this study was to examine the effects of stimulus value and exposure time on a random group of adult's discrimination of number.

Four subject groups were employed. One group was shown displays of valuable targets (Centennial dimes) for 40 msec. and one group was shown displays of valueless targets (aluminum discs) for 40 msec. Another group was shown displays of the valuable targets for 4000 msec., while the last group was shown displays of the valueless targets for 4000 msec. Within each group the number of targets was randomly varied and each S was given four different presentations of each level of number. Target number varied from one to sixteen. Value was thus an intrinsic stimulus property and varied along a number dimension. The 40 msec. exposure condition fell within the time limits of the Bunsen-Roscoe law and was employed so as to have stimulation (number of targets) both within and beyond S's span of discrimination. The 4000 msec. condition permitted S to count the number of targets in a display.

It was suggested that (1) there would be no significant difference in numerosity response to value and non-value targets when the exposure period is 40 msec. and the number of targets falls within S's span of discrimination, (2) there would be a significant difference in numerosity response to value and non-value targets under the 40 msec. condition when the number of targets exceeds the span of discrimination, (3) there would be increased divergence between numerosity responses to value and non-value targets under the 40 msec. condition as targets increase in number beyond the span of discrimination, (4) there would be no significant difference in numerosity response to value and non-value targets regardless of their actual number under the 4000 msec. condition.

The results provided satisfactory support for all 4 predictions and suggest that value does function as a determinant in discriminations of number and that value can operate in such discriminations independently of particular perceiver characteristics. The results are given theoretical and systematic interpretation.

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# Introduction

That there is more to vision or visual perception than meets the eye can be readily demonstrated by the studies of perceptual defence, perceptual constancies, perceptual illusions, and perceptual distortion in magnitude estimation. In all these instances the sensory end result appears to be a resultant of at least two sets of factors or determinants, (1) structural factors pertaining to the organism's sensory apparatus as well as stimulus factors such as brightness, exposure rate, exposure time, target area, wavelength, etc., and (2) personal factors belonging to the perceiving organism itself such as its personality, anxiety level, past learning experiences, motivational state, set, etc.

Traditionally, and in parallel with the above distinction, perceptual determinants have been classed as either autochthonous or behavioral (Allport, 1955; Bruner & Goodman, 1947). Grouped under the former are those properties of the nervous system which in themselves are highly predictable and are used to account for phenomena like contrast, flicker fusion, tonal masking, and light and dark adaptation. Such phenomena are considered nativistic in that their occurrence can be tied to specific functionings of the nervous system, i.e., they "reflect directly the characteristic electrochemical properties of sensory end organs and nervous tissue"

(Bruner & Goodman, 1947). Under the category of behavioral determinants are included properties of the perceiver such as introversion and extraversion, social needs and attitudes, past learning experiences, motivational level, etc. These behavioral determinants are purported to have functional significance in the structuring of the sensory end result in that they can enhance, interfere, or in some way "distort" the contribution of the autochthonous factors in such a manner that the achieved percept is in line with the functional utility of the behavioral factors. Perceptual selectivity and accentuation are the two commonest phenomena cited to demonstrate the operation of behavioral factors.

When autochthonous factors govern discrimination the perceptual response is usually veridical representing a close correspondence between the physicalistic measurement of some discriminable aspect of the stimulus object (size, brightness, etc.) and its phenomenal experience. However, when the experimental conditions are such that the operation of behavioral determinants is induced the organism does not respond to the physical stimulus in relatively fixed ways, and the relationship between some attribute of the physical stimulus and its phenomenal experience is no longer maintained at a veridical level, i.e., the response is now non-veridical. Aspects of the stimulus object, if the object possesses some personal saliency, are distorted in line with the relevance of the object to the perceiver. This non-veridicality makes us realize that "perception far from being an 'epistemology' or a direct representation of truth, is a somewhat variable activity like breathing, or learning, a process by which organisms succeed in adapting themselves, within the limits of a 'tolerable error', to the world in which they live." (Allport, 1955, p. 41).

Due to difficulties in delineating an underlying neurophysiological mechanism for the sometimes useful and adaptive perceptual errors, as of yet no universally accepted account has been put forward to incorporate the distortions or errors in perceptual discriminations within the framework of a general perceptual theory.

Some theorists (Allport, 1955; Forgus, 1966) have however attempted to provide a relatively parsimonious rationale for the operation of the perceptual process which handles the involvement of behavioral factors producing perceptual errors. By incorporating the operation of organic states via the autonomic system and subsequent cortical-visceral feedback mechanisms in a sequential analysis of the perceptual process, these theorists have to some extent accounted for how things "appear" in addition to how things "are". Recent physiological investigations of activational mechanisms (Routenberg, 1967) have further provided a biological rationale for the concomitant operation of behavioral and autothchonous factors in the structuring of a percept. Such investigations have demonstrated a reciprocal relation between the Reticular Activating System (RAS) which maintains arousal and provides for organization of response and the Limbic system which provides control of responses through incentive-related stimuli. However, few of the visual studies have actually involved direct (neurophysiological) consideration of innervation.

Empirical investigations seem to suggest that veridical perception results when the exteroceptive cues are dominant in the structuring of a percept, and non-veridical perception occurs when interoceptive, autonomic, proprioceptive, kinaesthetic, or memoric cues are predominant in the structuring of a percept before it reaches "conscious awareness". These internal mechanisms appear to contribute a biased tone to the percept in tune with one's willingness to perceive the exteroceptive cues as most beneficial to him at a particular moment. The problem as to whether the distortion in the sensory end result is due to the involvement of cognitive or interpretive factors or whether the non-veridicality does in fact occur at the experiencial (perceptual) level will be further elaborated upon in the discussion.

As mentioned previously, perceptual accentuation or the enhancement of a stimulus attribute has been one of the major classes of phenomena used to (1) illustrate the joint operation of autochthonous and behavioral determinants and (2) show how behavioral determinants can be the dominant factors in the formation of a percept. A basic feature of all accentuation research is the employment of value either as it pertains to a particular aspect of the perceiving organism, or as it relates to the status of the stimulus object itself. It is the role of accentuation across response systems due to the manipulation of stimulus value with which this research is primarily concerned.

The history of how value systems might affect perception goes back at least to Wolfe, who in 1898 found overestimation in the size of coins compared to similarily sized drawn circles. Myers in 1913 obtained a similar result. Recent years have also seen many attempts to study and describe the operation of personality and social variables in the visual process to demonstrate effectively the existence of accentuation or autism. The majority of these studies have also been concerned with the role of value in vision (Ansbacher, 1937; Bevan & Dukes, 1951; Bruner & Goodman, 1947; Carter & Schooler, 1949; Dukes, 1955; Dukes & Bevan, 1952a; Gilchrest & Nesberg, 1952; Haigh & Fiske, 1952; Klein, Schlesinger, & Meister, 1951; Landis, Jones, & Reiter, 1966; Luft, 1957; McCurdy, 1956; Pepitone, 1950; Postman, Bruner, & McGuinnes, 1948; Rock & Fleck, 1950; Rosenthal & Levi, 1950; Rosenthal, 1968; Sherif, 1935; Tajfel, 1957, 1959a, 1959b, 1963; Vernon, 1955).

Bruner & Goodman (1947) have perhaps given the greatest impetus to value research by demonstrating the interaction of value and size estimation. Essentially, they found poor children to overestimate coin size more than rich children, and with the poor children the visual mode produced greater overestimation than the memory mode.

Carter & Schooler (1949) in attempting to replicate the Bruner & Goodman study (with improvements in subject selection) found poor children overestimated coin size only when making judgments from memory. The difference between these two studies suggests that memory size is distinct from comparison size and that "need" or value factors may not modify all perceptual processes. This crucial difference in mode of response between simultaneous and successive comparison is in evidence in the earlier observations of Minneart (1954) regarding the moon size illusion and in the studies of Holoway & Boring (1941) on size constancy.

Bruner & Rodrigues (1953) attempted to reconcile the differences in results between Bruner & Goodman and Carter & Schooler by comparing procedural differences between the two studies. They conclude that while value by itself does not directly affect the dimensional judgment (absolute size) of the coins, there is a relative accentuation or overestimation of coin size of varying denominations. This may be interpreted to mean that the increase in size of relative overestimation is a function of size rather than value.

More recently, Landis, Jones, & Reiter (1966) present evidence not entirely consistent with a value interpretation of coin size perception. Employing a homogeneous group of adults (no differences in economic background or "need" factors) they obtained results suggesting that overestimation of coins and disc size should be considered a perceptual phenomenon rather than in terms of need, i.e., the overestimation was due to stimulus factors rather than behavioral factors.

Furthermore, Rosenthal (1950), in complete contradiction to the findings of Bruner & Goodman found that rich children's estimates of coin size were significantly greater for each denomination than the size estimates of the poor children. Rosenthal (1968) also showed "need" factors to be less relevant than attitude toward money in children's size estimation of coins and discs.

Accentuation of the size dimension has even been demonstrated to be the consequent effect of the attitudinal bias of S (Carlson, 1960), the "symbolic value" of valueless objects (Dukes & Bevan, 1952a), and the operation of reward and punishment (Proshansky & Murphy, 1942; Schafer & Murphy, 1943; Smith, Parker & Robinson, 1951; Solley & Engel, 1960).

While all accentuation experiments are common in purpose, i.e., to demonstrate the operation of behavioral determinants in response processes, the majority of the experimental results in this area are equivocal due to a number of factors. Firstly, there are conceptual and methodological problems involved in demonstrating motivational factors. Furthermore, the majority of accentuation research has been criticized for neglecting the role of the perceiver, for the artificiality of the experimental conditions, and for the lack of adequate stimulus control and inadequate empirical definition of terms (Luchins, 1950; Pastore, 1949).

Consequently, researchers turned their attention to making a closer examination of the perceiving organism itself to see if selective factors exist in the visual process and other modalities, i.e., factors causing one to attend to an object of immediate relevance and not to objects possessing no relevance to the organism. There is evidence (Brown, 1960; McClelland & Atkinson, 1958; Postman, Bruner, & McGuinnes, 1948; Vanderplas & Blake, 1949) for the operation of a selective response process demonstrating to a large extent that one structures his world so as to see what he wants to see and hears what he wants to hear. Krechevesky (1938) has even produced results indicating behavioral factors can influence the structure of discriminations in animals.

The general conclusion to be drawn from most of the previous research demonstrating accentuation of size due to value is that personally relevant objects are remembered to be larger than objects of lesser or no relevance for the organism. Due to the conceptual and procedural difficulties listed above in relating motivational factors to size estimation, it would seem that a dimension more fixed and less susceptible to memorial influence than size, such as number, might eliminate one source of uncontrolled variance.

Ansbacher (1937) was the first to systematically investigate the relationship between perceived number and value. In this study groups of stamps varying in number and value were compared. Results showed that value functioned in the perception of number as in size perception in that it increased judgments of estimation.

Others (Kaufman, Lord, Reese, & Volkman, 1949; Lappin, 1967; McCall, 1965; Sperling, 1960; Taves, 1941; and Warrington, Kinsborne, & Merle, 1966) have studied the discrimination of number in terms of the span of discrimination or the span of perception. These researchers have primarily addressed themselves to determining the factors delineating the span of discrimination and those factors which can alter the span. Briefly, the span of discrimination which has also been called the span of immediate memory (Sperling, 1960), span of apprehension (Fernberger, 1921; Hamilton, 1859; and Jevons, 1871), span of attention (Oberly, 1924), and range of attention (Glanville & Dallenbach, 1929) refers to the number of items that can be accurately discriminated during a "single moment of consciousness".

Originally the span was considered to be a fixed quantity independent of either stimulus or subjective factors. However, subsequent research has shown it to vary from moment to moment about an average value and that there are definite factors which can raise or lower its average value. Subjective and objective grouping of the items in an array will systematically vary the span as will the purely stimulus factors of area, density, spatial separation, rate of stimulation, total number of items in an array, intensity of stimulation, and exposure time.

A crucial point to this research is that the span of discrimination can be given a purely sensory formulation explicable by nativistic activity occurring within the visual tissue system. The Bunsen-Roscoe law predicting effects from brief photic exposure is of most immediate interest since in addition to being a classic example of sensory function, it has also been related to the span of discrimination by Hunter & Sigler (1941). They performed one of the most sophisticated and comprehensive investigations of the span of discrimination and sought to determine the number of dots a S could perceive under varying values of exposure time and luminance intensity. In addition to determining variations in the span with variations in viewing time and illumination, they generated precise description of intensity x time relationships as they refer to subjective number. Casperson & Schlosberg (1950) and Miller (1956) later essentially confirmed Hunter & Sigler's results in finding 7 to 8 objects the limit of S's accurate discrimination under limiting time conditions.

The Bunsen-Roscoe law states that for exposure times shorter than the critical duration (approximately 100 msec.) the effective stimulus factor is neither intensity (I) nor time (T) alone but the quantity of energy represented by their product (I x T = C). That is, luminance may rise slowly or rapidly to a maximum or drop slowly or rapidly or it may be presented in discrete pulses; the temporal form of energy distribution has no influence provided the critical duration is not exceeded, i.e., temporal distribution of energy is immaterial and the critical factor is the total energy. Thus in terms of sensation, a bright short light exposure is the same as a longer and correspondingly less intense exposure. The essential feature of this law is that as exposure time exceeds the critical duration, temporal integration ceases and the response is defined solely in terms of luminance, i.e., I x T does not form a reciprocal relationship equalling some constant (C) but rather intensity equals this constant (I = C). For durations greater than the critical duration the reciprocity fails, presumably because the initial events which influence the response have already been determined. Mathewson, Miller, & Crovitz (1968) suggest that as time increases beyond 100 msec. very complicated interactions between space and time begin to occur and it appears as if when time is very short (less than the critical duration), imput trains are processed as a single package. A more comprehensive discussion of the Bunsen-Roscoe law can be found in Graham (1965).

Returning briefly to the study of Hunter & Sigler, they interpret their results to mean that where the span is a single discriminatory event (1 to 7 dots) the Bunsen-Roscoe law holds up to that duration at which the sensory pathway elaboration is complete, i.e., discrimination of number of dots from 1 to 7 can be considered largely sensory in determination. They conclude that "For spans of 8 and more dots, I x T is not a constant; but time is a more important factor than intensity until the long durations are reached where the relationship is reversed. The 'span of attention' thus resolves itself into a span of discrimination, a form of behavior which in the field of vision is controlled on the receptor side by time and intensity factors" (p. 178). Suffice it to say that discriminative responses made within the limits of stimulation defining the Bunsen-Roscoe law can be given a sensory (nativistic) interpretation, and that the critical duration reflects an early sensory event in the visual process.

## Problem

One basic distinction to be made in the discrimination of number is that between physical and subjective number, i.e., the distinction between the cardinality attribute of a group of items and the subjective attribute observed when looking at, but not counting, a collection of objects. Stevens (1951) uses the terms numerosity and numerousness in delineating this distinction. Numerosity is a property descriptive of the magnitude of physical number and numerousness the subjective (i.e. perceptual) counterpart. Numerousness, or the "manyness" property of a collection of items which can be discriminated without counting does not have connotation with respect to accuracy. Taves (1941) developed psychophysical functions relating the visual perception of numerousness to physical numerosity and found (1) a 1:1 correspondence between numerousness and numerosity with numbers less than seven and (2) a tendency for numerousness to increase at a less rapid rate with further increases in number.

On the behavioral side, at least three different response systems have been formulated to account for the discrimination of number. Although not entirely mutually exclusive, these systems appear to operate in a somewhat independent fashion.

Subitizing is a term referring to that process governing the "manyness" discrimination when number is small or can be considered the ability to perceive at a glance the number of items present and does have definite connotations with respect to accuracy. Hunter and Sigler (1940), Casperson and Schlosberg (1950), and Miller (1956) found skilled observers to show subitization until a display exceeds 7 or 8 items; Glanville and Dallenbach (1929), Jevons (1871); and Sperling (1960) found children and unskilled observers to subitize to a limit of approximately 4 items.

Subitizing is usually studied using timed exposure so as to preclude counting and thus represents more of an immediate than a mediate type of response. In addition to exposure time, also intensity, size, area, and density of objects have all been shown to vary effectively numerosity discrimination of greater number but to have no appreciable affect on subitizing (French, 1953; Hunter and Sigler, 1940; Karn, 1936; Kaswan, 1958; Kaswan and Young, 1963; Porter and Wiseman, 1965; Teichner, Reilly, and Sadler, 1961; and Teichner and Sadler, 1962).

Subitizing appears to be a relatively primitive mode of discrimination since it has been demonstrated to occur at various levels on the phylogenetic scale, i.e., birds, squirrels and humans. Such features would tend to place this mode of number reckoning at a more innate level than other learned forms of number discrimination which in part or in whole appear to be dependent upon past experience.

Estimating may be considered another, slightly more advanced, form of number discrimination and differs from subitizing primarily in being more judgmental in character. It essentially refers to the process of guessing the number of objects in an array without counting. As with subitizing it is usually studied under timed exposure to prevent counting, but unlike subitizing usually does not have connotations with respect to accuracy. Estimation, as a form of number discrimination, would appear to encompass both certain attributes of nativistically based forms of discrimination such as subitizing and discriminations which require mediation or are cognitively based, yet without being solely identified with either.

Counting is a procedure employed when "a class of objects or events occurs in a serial fashion or the events are so many as to preclude immediate discrimination" (Nelson and Bartley, 1961, p. 181). As such it is largely unique from subitizing and estimating in the ascertainment of "manyness" since it is an exclusively mediate form of discrimination and involves the employment of a human convention, namely a number syntax. In the discrimination of number, counting thus represents the most sophisticated complex form of behavior in comparison to the grouping process of estimating or the immediate, largely innate process of subitizing.

"Value", whether considered broadly in terms of a social value system or more restrictively in terms of a personal value system, is a complex term, but it may be unambiguously and objectively defined within a modern monetary system. Various non-perceptual factors such as familiarity (Wolfe, 1898), reinforcement (Lambert, Solomon and Watson, 1949), need (Bruner and Goodman, 1947), hypnosis (Ashley, Harper and Runyon, 1951), and sound and economic status (Dorfman and Zajonc, 1963) have all been related to the visual discrimination of size of objects possessing value, i.e., coins.

Ansbacher (1937) attempted what is essentially a linkage between monetary value and numerousness and suggests that "value" not only is a dimension of numerousness, but can function as a determinant of number discrimination. His experiment, however, determined that numerousness of objects (stamps) is a function of familiarity with the monetary "value" of the object and further showed that numerousness increased for "value" objects with which Ss were familiar but not for those objects whose "value" was unknown.

The general result in such "value" research has been accentuation or overestimation of certain discriminable aspects of the monetary units. In all cases, except for a study by Landis, Jones and Reiter, (1966), researchers have attributed the enhancement of the valuable objects to behavioral factors (primarily need and economic status).

In the experiment to be described, displays varying in number along a "value" dimension and displays varying in number along a "non-value" dimension will be related to subjective numerousness. A random group of adults (in terms of behavioral factors as need and economic status) will be employed to relate the influence of object utility ("value") to spatial numerosity to determine if accentuation in number can operate at a purely perceptual level. Such a procedure will hopefully overcome the criticism of Hartley (1965) "... yet if we look at the current evidence we find not a single study of accentuation in which the E has attempted to get reasonably direct evidence that the effect is visual."

The hypotheses tested are the following:

1. There will be no significant difference in numerosity response to value and non-value targets when stimulation is within the limits of the Bunsen-Roscoe law and the number of targets falls below some critical number delineating the span of discrimination.

2. There will be a significant difference in numerosity response to value and non-value targets when stimulation is within the limits of the Bunsen-Roscoe law but the number of targets exceeds the span of discrimination. More specifically, this difference will be in the direction of overestimation of value targets relative to the estimation of non-value targets.

3. There will be increased divergence between numerosity responses to value and non-value targets when stimulation is within the limits of the Bunsen-Roscoe law and targets increase in number beyond the span of discrimination.

4. There will be no significant difference in numerosity response to value and non-value targets regardless of their actual number when stimulation is not within the limits of the Bunsen-Roscoe law, i.e., when exposure time greatly exceeds the critical time limit of the Bunsen-Roscoe law.

# METHOD

## Subjects

Sixty (60) students without visual difficulties from an introductory psychology course at the University of Alberta, Edmonton, Alberta served as Ss. All were between the ages of 17 and 21 and volunteered to participate in this experiment as part of a course requirement.

## Apparatus and Equipment

Research was conducted in an all-purpose research room modified so as to produce an experimental setting without incidental illumination.

The apparatus is illustrated in Figure 1. A model 900 AV Kodak Carousel projector with a 500 watt incandescent lamp light source was used to project 35 mm. transparancies of dimes and discs onto a fine grained glass beaded Micro Flect screen. The transparancies were 35 mm. positives of dimes and aluminum discs on a black background. A shutter was connected to a power supply which in turn was connected to two Hunter timers set to give an exposure of either 40 msec. or 4000 msec. with an intertrial interval of 6000 msec. Light source output was controlled by means of a variac and was continuously monitored through a voltmeter. With the shutter open the projected slide covered an area of 8" by 11" on the screen resulting in a visual angle of

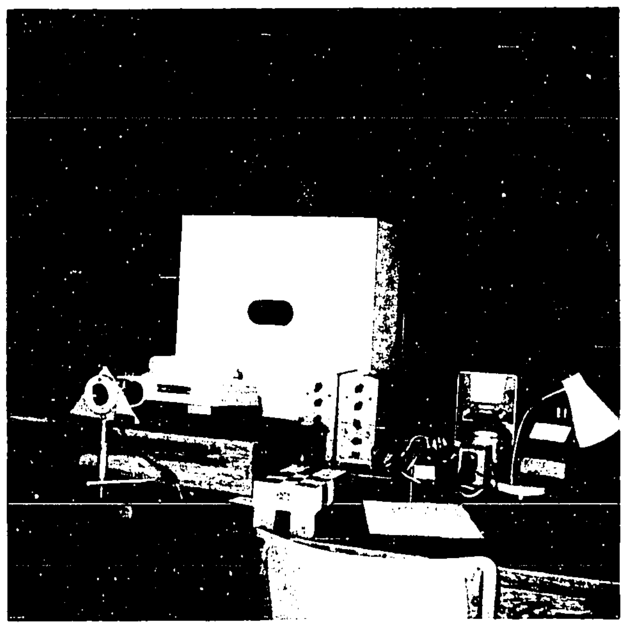

Figure 1 Apparatus.

3.82 degrees. Each target (dime or disc) subtended a visual angle of only 28 min. 65 secs. Luminance of the dime and disc slides was equated by a method to be described in the procedure section.

Stimuli

The stimuli consisted of 1967 Canadian Centennial dimes and aluminum discs of equal area and reflectance. In the actual photographing of the stimuli, the targets (dimes and discs) were randomly distributed on a black cloth surface in a haphazard order which in the opinion of the E did not give rise to obvious configurations or extremes of distribution. The only alterations were that all targets were separated by at least 2/3", the approximate diameter of a target, and in the case of dimes to make sure that all targets were "heads". The area and density of each field were made irregular, minimizing the likelihood of Ss employing either of these discriminable aspects in making their judgments.

Procedure

In this study three variables were manipulated: targets (either dimes or aluminum discs), exposure time (either 40 or 4000 msec.), and number (1 to 16). In this 2 x 2 x 16 factorial design with repeated measures, each S served under one condition of target type and exposure time but under every level of number.

The 60 Ss were randomly assigned to one of four (4) subject groups. Group 1 was shown displays of dimes ranging in number from 1 to 16 with a 40 msec. exposure period. Group 2 was shown aluminum disc displays ranging in number from 1 to 16 with a 40 msec. exposure period. Group 3 was shown displays of dimes ranging in number from 1 to 16 for a 4000 msec. exposure period. Group 4 was shown displays of aluminum discs ranging in number from 1 to 16 for a 4000 msec. exposure period. The 40 msec. exposure period fell within the time limit of the Bunsen-Roscoe law and was employed so as to have stimulation (number of targets) both within and beyond S span of discrimination. The 4000 msec. condition was used to permit the S to count the number of targets in each display. Four random patterns of each number level (1 through 16) were shown to each S in all of the four subject groups. In addition to Ss being randomly assigned to one of the subject groups, within each group the order of presentation of the displays was independently randomized for each S. This was done to control for anchor effects in the discriminations since such effects have been shown to effectively vary numerical estimates (Helson & Kozaki, 1968). Appendix A contains a sample of the data sheets used and illustrates the various orders employed.

Instructions were set up so E did not induce motivation into the experimental situation. Each S was tested individually and was escorted by E to the experimental room. Ss were shown the apparatus and given an explanation as to the function of each piece of equipment. The following general instructions were then given to Ss in all groups:

"This is a visual perceptual experiment in which I am interested in determining the number of objects you can discriminate during a certain interval of time. A series of slides will be shown to you and I want you to tell me how many objects you think there were on each slide. As soon as each slide is finished being exposed I want you to tell me how many objects you think were on that slide."

The instructions and procedure then differed depending upon group assignment. Ss in Groups 1 and 3 were then taken over to a table and shown a display of 10 dimes. E then stated:

"These are valuable 1967 Canadian Centennial dimes which are the objects you will be seeing on each slide. On some of the slides there will be only a small number of dimes and on some slides there will be a great number. That is, sometimes there will be more dimes and sometimes fewer dimes than are displayed here. This is only a sample of the numbers used to show you what the objects are you will be seeing on each slide."

Ss in Groups 2 and 4, after being given the initial instructions were taken to a table and shown a display of 10 aluminum discs. E then stated:

"These are valueless scrap pieces of aluminum which are the objects you will be seeing on each slide. On some slides there will be only a small number of metal discs and on some slides there will be a great number. That is, sometimes there will be more and sometimes fewer scrap metal discs than are displayed here. This is only a sample of the numbers used to show you what the objects are you will be seeing on each slide."

Ss in Groups 1 and 3 were then given one minute to view the dimes and Ss in Groups 2 and 4 one minute to view the aluminum discs during which time all Ss were encouraged to inspect and handle the targets.

Following this inspection period all Ss were seated behind a reduction screen 10' from the projection screen and given the following instructions:

"I want you to always look straight ahead through the slit in this box (reduction screen) at the screen in front of you on which the slides will be shown."

Ss in Groups 1 and 2 were then informed:

"You will only be shown each slide for a fraction of a second so it is very important that I have your absolute attention throughout the experiment. It is very important that you are looking straight ahead at the screen so you won't miss any slides. Since the slides will be shown for only a very brief period of time, I do not expect you to be certain of how many dimes (discs) there were on every slide. Sometimes you may be sure but most of the time you will just have to estimate or guess the number of dimes (discs) on a slide. Regardless of whether you are certain of the number of dimes (discs) on a slide or are just guessing, I want you to tell me how many you think were on each slide as soon as the slide goes off. There will be a 6 second rest period between each slide and I will say 'ready' 1 second before each slide is presented. Remember, as soon as the slide goes off the screen I want you to tell me the number of dimes (discs) you think were on that slide. Are there any questions?"

__S__s in Groups 3 and 4 were informed:

"You will be shown each slide for 4 seconds. During this period of time I want you to determine the number of dimes (discs) on each slide. As soon as the slide goes off the screen I want you to tell me how many dimes (discs) were on the slide. There will be a 6 second rest period between each slide and I will say 'ready' 1 second before each slide is presented. Remember, as soon as each slide goes off the screen I want you to tell me how many dimes (discs) there were on that slide. If you are sometimes not certain of the number then I want you to guess. Are there any questions?"

Following the final sets of instructions room lights were turned off except for a lamp on the desk by E to provide for some general room illumination and to enable E to record Ss' responses. Ss in all groups were then given 2 blank slides to familiarize them once again with the general procedure and primarily in the case of Groups 1 and 2 to illustrate the briefness of the exposure period.

As mentioned, while the areas of the targets (dimes and aluminum discs) were equal, reflectance from the discs was slightly greater than from the dimes. Since in the Bunsen-Roscoe law time and intensity are reciprocal, it was necessary to reduce illumination for the discs in order to keep luminance constant. A slight adjustment to the variac was used to cut down the illumination while the luminance was equated by employing a Macbeth illuminometer. The intensity of the dimes was set at 32 $cdls/ft.^2$ with the voltmeter reading 110 volts. The aluminum discs were equated to this level by adjusting the variac down until the voltmeter read 106 volts. Luminance of the field itself was slightly more than 1 $cdl./ft.^2$. This procedure minimized difference in spectral composition of the targets attributable to variation in temperature of the source.

By requesting Ss to respond immediately after the exposure period of each slide and by allowing some general room illumination after image counting was precluded.

A total of 64 observations were recorded from each S taking approximately 6 1/2 minutes for Ss in Groups 1 and 2 and 10 3/4 minutes for Ss in Groups 3 and 4. In no case did any S ever fail to respond to a slide.

## Results

The main hypothesis was that with stimulation within the limits of the Bunsen-Roscoe law there are no reliable differences in numerosity response to value and non-value targets when the number of targets falls below the span of discrimination, but when the number increases beyond this point significant differences occur. Furthermore, these differences will increase in reliability as number increases in magnitude beyond the span of discrimination. No differences in numerosity response are predicted when stimulation is extended in time so as to greatly exceed the critical time limit of the Bunsen-Roscoe law.

Data were analyzed graphically and also statistically by means of analysis of variance, regression analysis, t tests and by establishing power functions.

Figure 2 plots the relation between numerousness (judgment of the "manyness" of a display without counting) and number. It may be noted from Figure 2 that (1) curves give little evidence for differences between treatments when number is small, i.e., less than 8, (2) sizable differences do occur between groups when number is greater than 8, (3) differences between subject groups appear only under the 40 msec. exposure condition, and (4) it is the subject group viewing displays of targets possessing value which gives

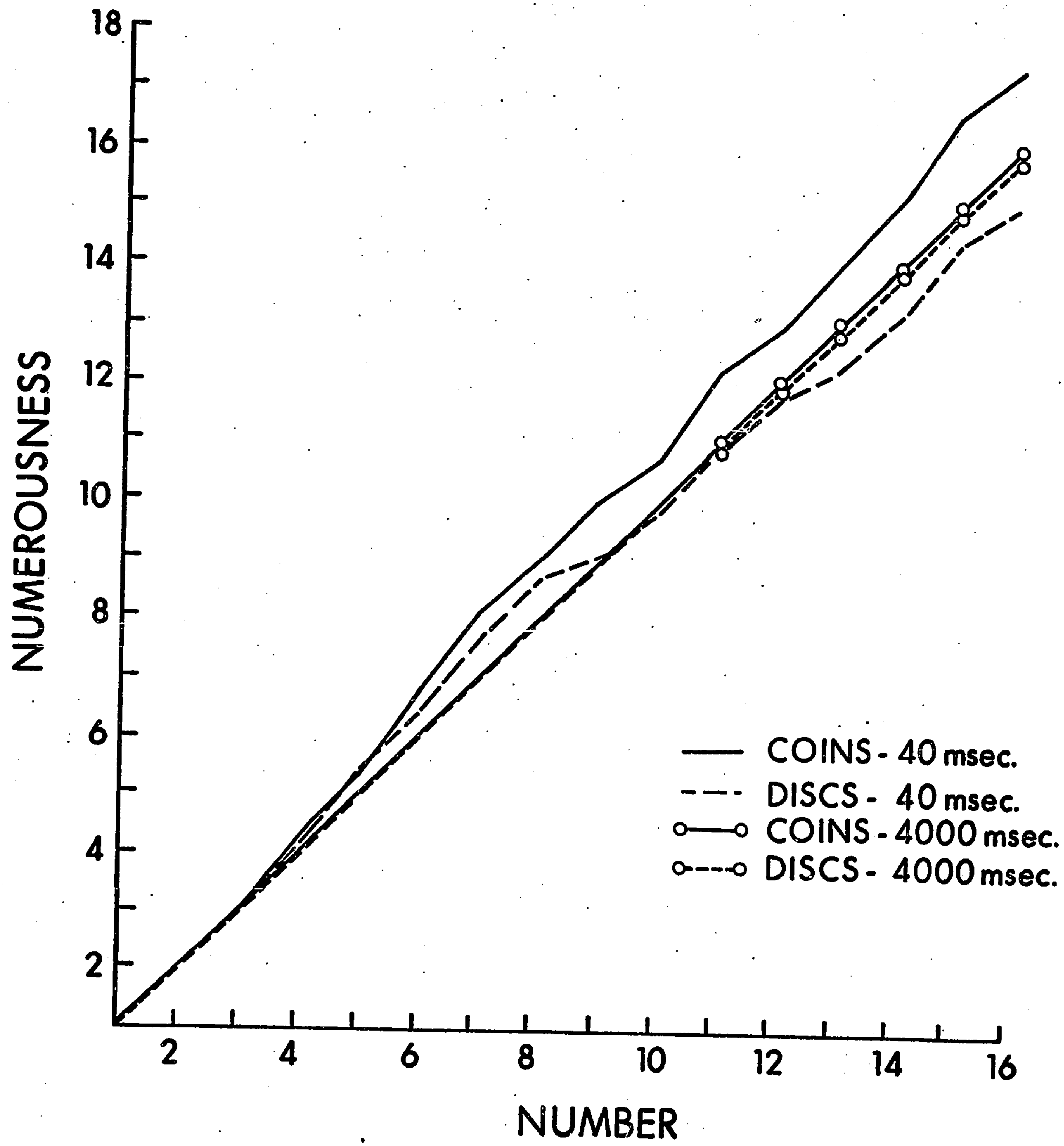


Figure 2 Numerousness shown as a function of number of targets. Responses from four subject groups are depicted (see key).

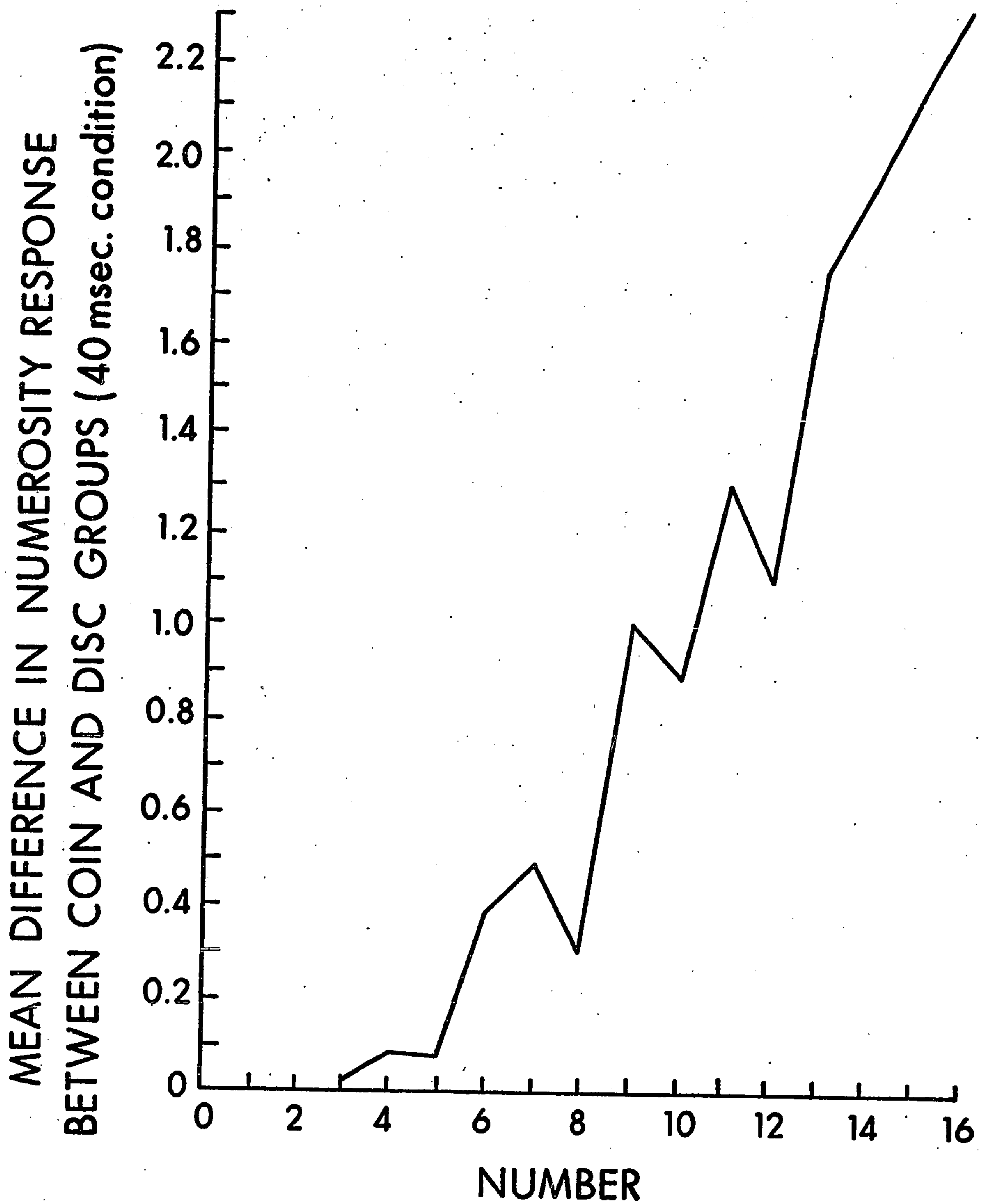


Figure 3 Divergence in numerosity response between value and non-value targets shown for each level of number.

higher average numerosity responses when displays are great in number, i.e., beyond the span of discrimination.

Figure 3 illustrates the general trend, under the 40 msec. exposure period, for increased divergence in numerosity response between value and non-value targets as number increases. Thus the primary data confirm the hypothesis in all respects.

Analysis of variance of the effect of value, exposure time and number on numerosity discrimination showed that the main effects of value vs. non-value target type, brief vs. extended exposure time, and number level each had a significant effect on numerosity responses (F = 6.30, d.f. 1,56, p .015; F = 8.93, d.f. 1,56, p .004; F = 2,372, d.f. 15,840, p .005, respectively).

The analysis of variance also revealed that all of the two factor interactions as well as the triple interaction was reliably significant. The significant exposure time x target type interaction (F = 5.70, d.f. 1,56, p .020) indicates the differences in numerosity response under the two exposure times are different for the two target types, i.e., the exposure time effect is not the same for the two levels of value of target type. This is shown in Figure 4. The significant interaction of exposure time x number (F = 2.11, d.f. 15,840, p .010) as shown in Figure 6 can be interpreted as indicating that numerosity estimates of

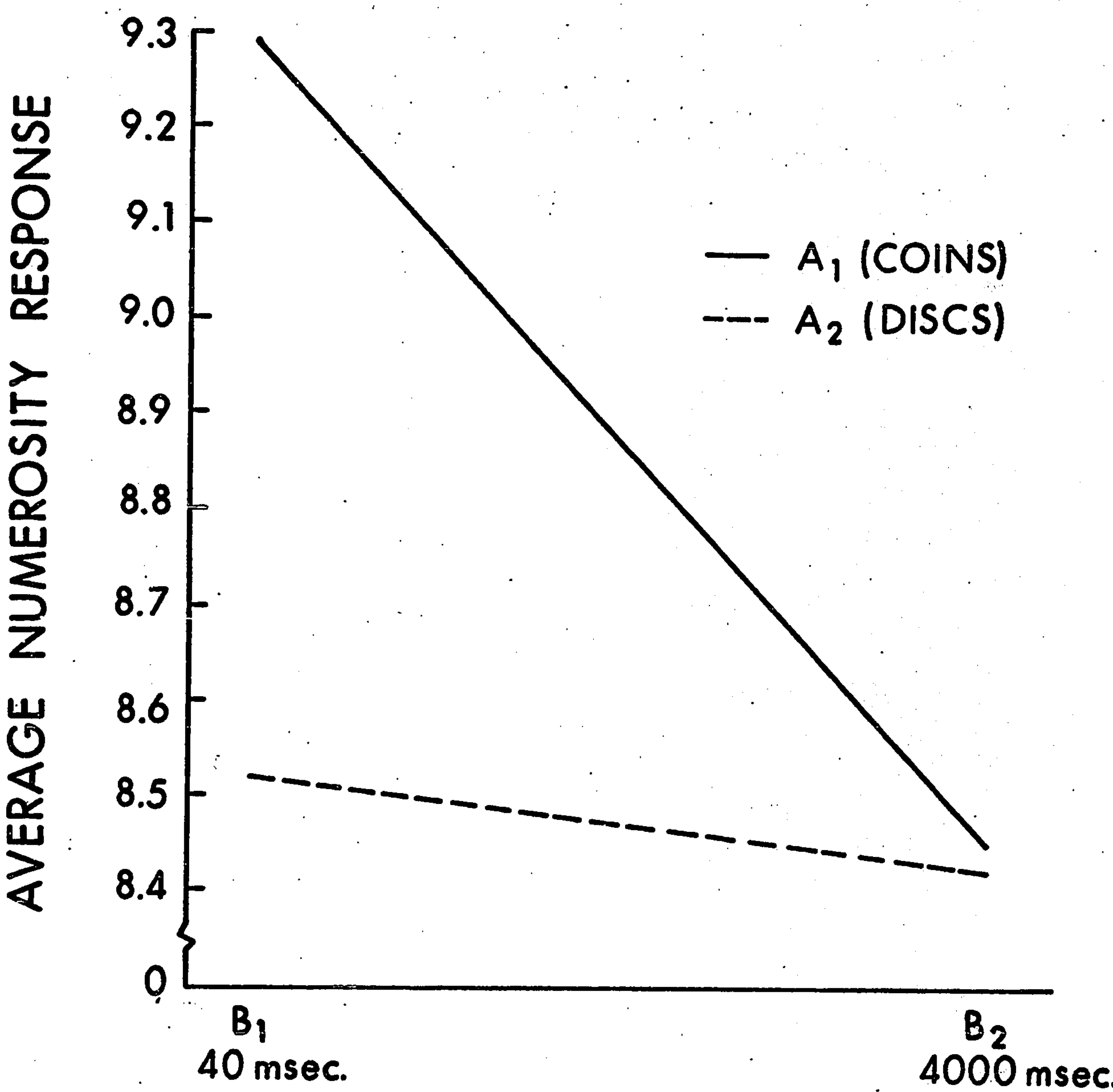


Figure 4 Average numerosity response to value and non-value targets as a function of exposure time.

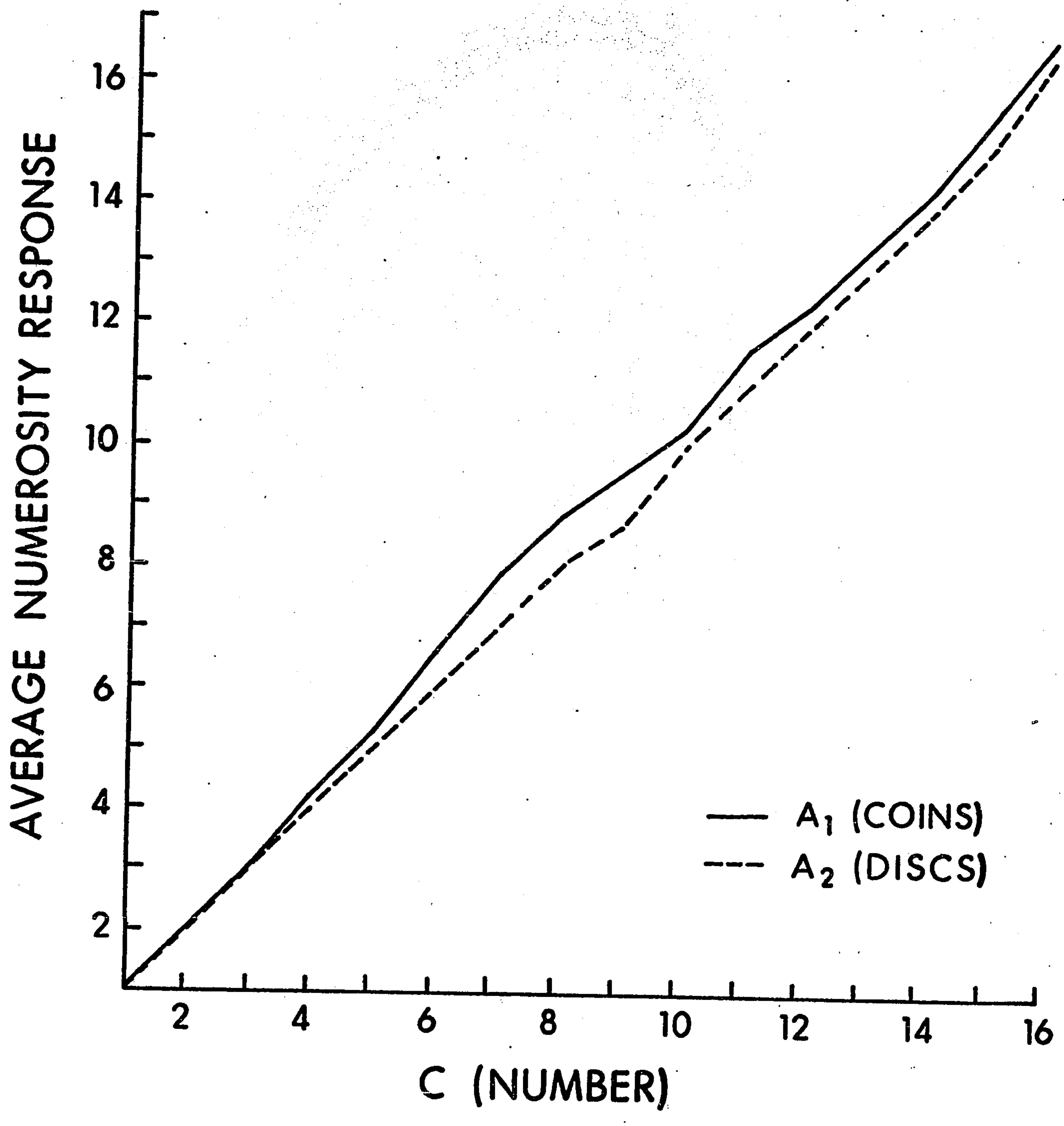


Figure 5 Average numerosity response to value and non-value targets as a function of number.

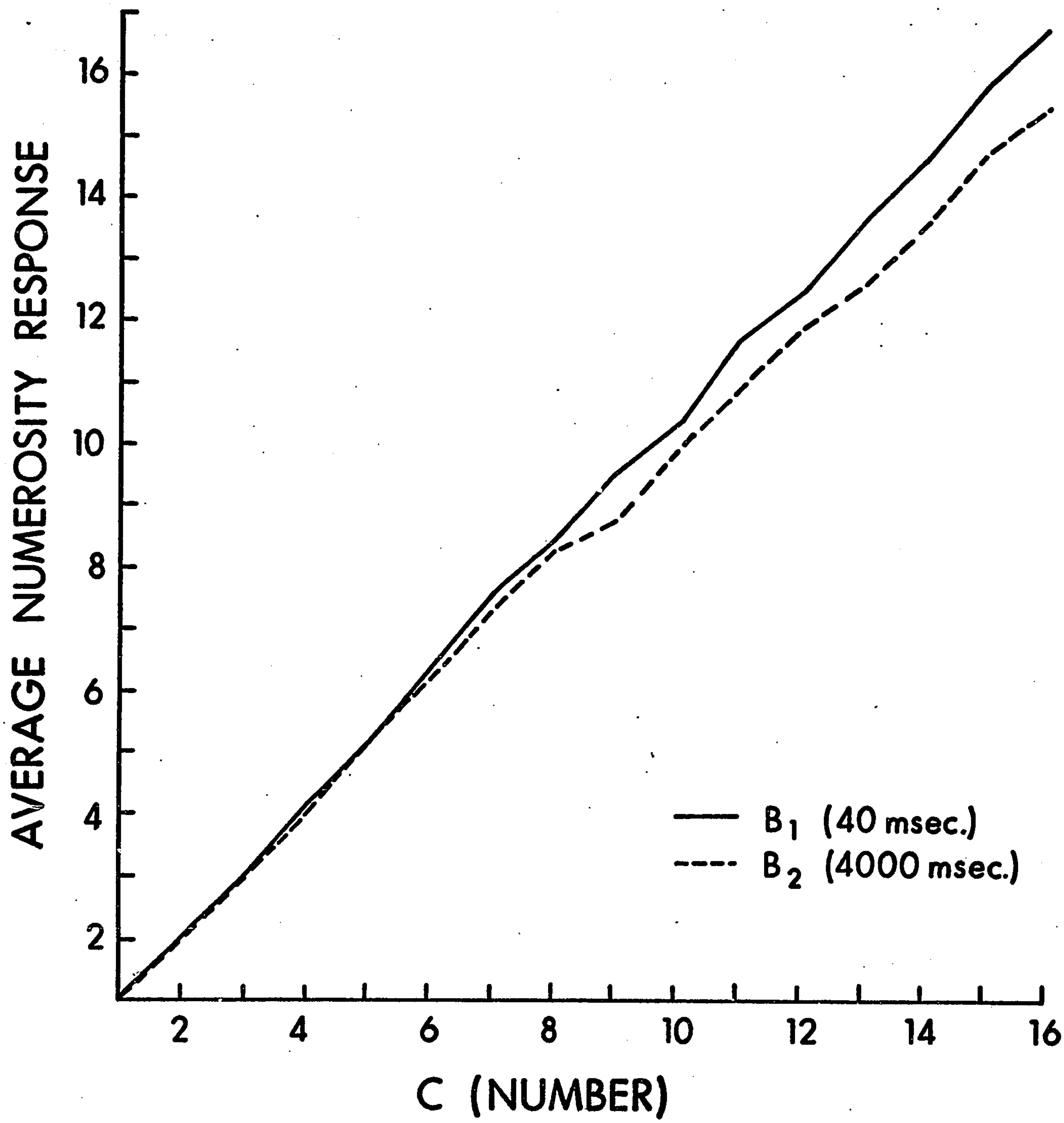


Figure 6 Average numerosity response under two different exposure times as a function of number.

TABLE 1

Summary of Analysis of Variance of the Effect of Value, Exposure Time, and Number on Numerosity Discrimination

| Source | Sum of Squares | D.F. | Mean Square | F | P |
|---|---|---|---|---|---|
| Between Subjects | 452.13 | 59 | | | |
| Exposure time | 37.00 | 1 | 37.00 | 6.30 | .015 |
| Target type | 52.50 | 1 | 52.50 | 8.93 | .004 |
| Exposure time x Target type | 33.50 | 1 | 33.50 | 5.70 | .020 |
| Subjects Within Group | 329.13 | 56 | 5.88 | | |
| Within Subjects | 21313.19 | 900 | | | |
| Number | 20725.81 | 15 | 1381.72 | 2372.29 | .005 |
| Exposure time x Number | 18.44 | 15 | 1.23 | 2.11 | .010 |
| Target type x Number | 47.06 | 15 | 3.14 | 5.39 | .005 |
| Exposure time x Target type x Number | 32.63 | 15 | 2.17 | 3.73 | .005 |
| Number x Subject Within Group | 489.25 | 840 | 0.58 | | |

the actual number of targets is not independent of the exposure time, i.e., that numerosity estimates were different under the two exposure times. Finally, the significance of the target type x number interaction (F = 5.39, d.f. 15,840, p .005) suggests that differences in numerosity responses to the different levels of number employed is further dependent on whether or not targets possessed value, i.e., that levels of number affected numerosity responses to value targets differently than numerosity responses to non-value targets. This interaction is depicted in Figure 5. The significant triple interaction signifies that the differences in numerosity responses to value and non-value targets are different for the two time exposures. Table 1 summarizes the analysis of variance.

A finding which might be expected (but which may not be of special interest) is the increase in variability of Ss' responses as number increases. It seems intuitive that response should become increasingly inaccurate as number increases and especially so when viewing conditions are marginal. The variances for each number level are plotted separately for the four subject groups in Figure 7.

The "t" test was employed to determine at which number levels significant differences in numerosity responses existed. In performing this analysis, data were analyzed separately for the 40 msec. and the 4000 msec. exposure conditions because the only valid mean comparisons were those between numerosity responses under the same exposure condition.

The mean numerosity responses to coins and discs under the 40 msec. condition and a summary of the "t" tests is presented in Table 2. It can be seen that when number was greater than 8 the mean numerosity responses to coins and discs differed significantly.

Table 3 contains the mean numerosity responses to coins and discs under the 4000 msec. condition. As was expected, due to the extended viewing time no significant differences in numerosity responses occurred at any level of number. However, at number level 10 slight differences in numerosity response did appear and these differences generally increased with increases in number. Although none of the differences approached significance, the trend established here was the same as that under the 40 msec. condition, i.e., a tendency for larger numbers of value targets to be overestimated and for non-value targets to be underestimated. These facts will have importance when theoretical statements are later developed.

Further statistical evaluations and interpretations of the results will be developed in the discussion section.

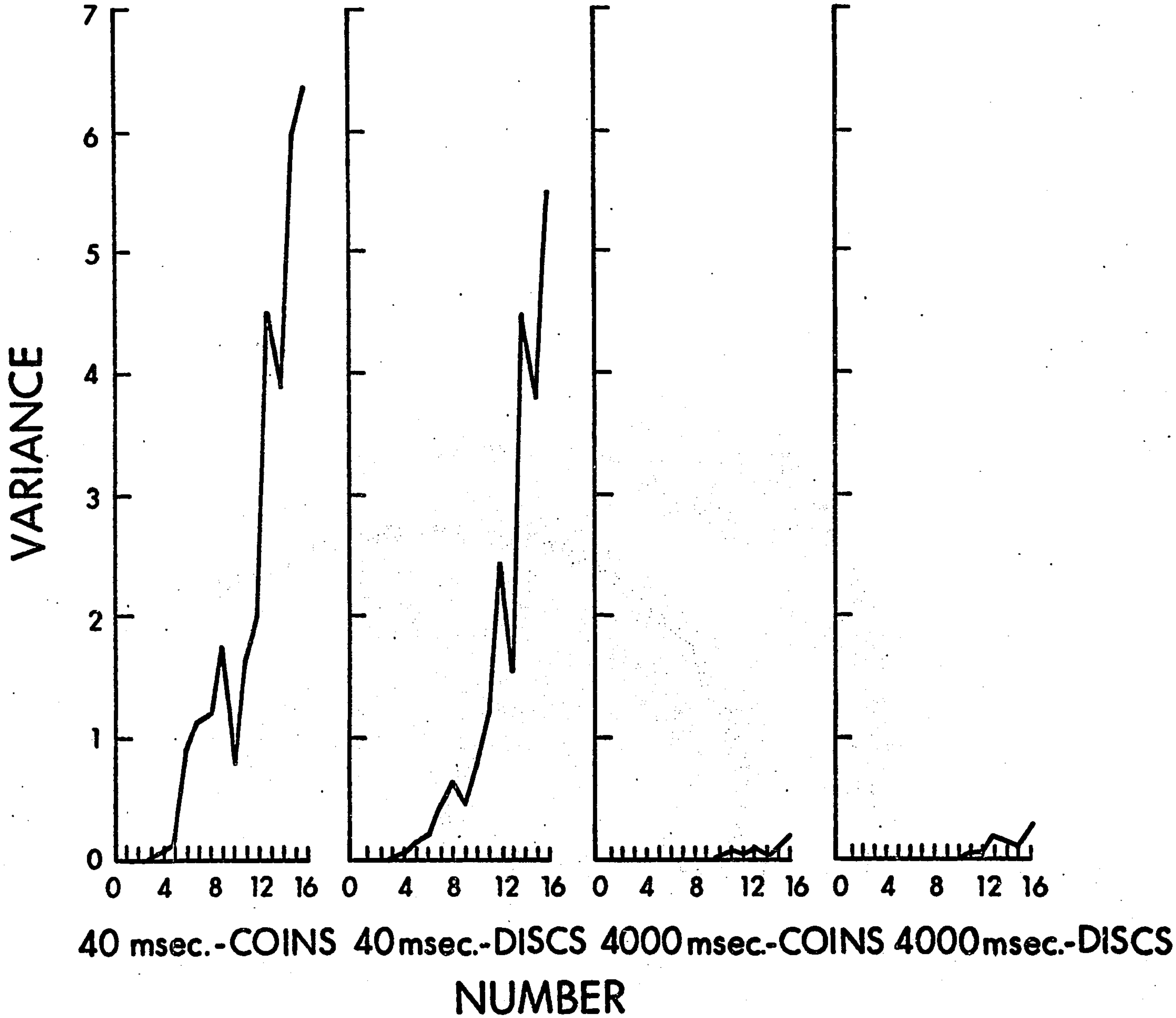


Figure 7 Variance in numerousness as a function of number for four subject groups.

TABLE 2

Summary of t test analysis under
40 msec. exposure period

| No. | Coin Mean Numerosity Response | Disc Mean Numerosity Response | Mean Differ-ence | d.f. | Value of t | Signifi-cance Level |
|---|---|---|---|---|---|---|
| 1 | 1.00 | 1.00 | 0.00 | 28 | -- | -- |
| 2 | 2.00 | 2.00 | 0.00 | " | -- | -- |
| 3 | 3.00 | 3.02 | -0.02 | " | -- | -- |
| 4 | 4.25 | 4.17 | 0.08 | " | -- | -- |
| 5 | 5.28 | 5.35 | -0.07 | " | -- | -- |
| 6 | 6.78 | 6.40 | 0.38 | " | -- | -- |
| 7 | 8.10 | 7.62 | 0.48 | " | 1.45 | -- |
| 8 | 8.97 | 8.68 | 0.29 | " | .853 | -- |
| 9 | 10.05 | 9.07 | 0.98 | " | 2.58 | .01 |
| 10 | 10.73 | 9.85 | 0.88 | " | 2.67 | .01 |
| 11 | 12.23 | 10.93 | 1.30 | " | 3.20 | .005 |
| 12 | 12.91 | 11.83 | 1.08 | " | 2.00 | .05 |
| 13 | 14.13 | 12.38 | 1.75 | " | 3.17 | .005 |
| 14 | 15.20 | 13.26 | 1.94 | " | 2.69 | .01 |
| 15 | 16.57 | 14.48 | 2.09 | " | 2.68 | .01 |
| 16 | 17.40 | 15.08 | 2.32 | " | 2.67 | .01 |

TABLE 3

Mean Numerosity Responses for 4000 msec. condition

| No. | Coin Mean Numerosity Response | Disc Mean Numerosity Response | Mean Difference |
|---|---|---|---|
| 1 | 1.00 | 1.00 | -- |
| 2 | 2.00 | 2.00 | -- |
| 3 | 3.00 | 3.00 | -- |
| 4 | 4.00 | 4.00 | -- |
| 5 | 5.00 | 5.00 | -- |
| 6 | 6.00 | 6.00 | -- |
| 7 | 7.00 | 7.00 | -- |
| 8 | 8.00 | 8.00 | -- |
| 9 | 9.00 | 9.00 | -- |
| 10 | 10.00 | 9.98 | .02 |
| 11 | 11.05 | 10.95 | .10 |
| 12 | 12.05 | 11.96 | .09 |
| 13 | 13.07 | 12.83 | .24 |
| 14 | 14.02 | 13.86 | .16 |
| 15 | 15.08 | 14.95 | .13 |
| 16 | 16.07 | 15.88 | .19 |

## Discussion

In general, the results of this research lend definite support for the value or accentuation hypothesis, i.e., valuable objects were estimated to be more numerous than comparable valueless objects. Value functioned in such a manner as to increase the subjective number of an array of objects and thus appears to act, at least under certain conditions, as a determinant of numerosity perception.

The structure of the present results may in part depend upon four specific factors which were simultaneously incorporated into this study in an attempt to (1) provide more unequivocal findings to establish greater validity for the accentuation hypothesis and (2) determine if accentuation can occur under more pervasive circumstances than has previously been demonstrated.

One factor of particular relevance is the mode of subject selection in this study. The critical studies of Bruner and Goodman (1947) and Carter and Schooler (1949) defined subject groups a-priori on the basis of place of residence and family income. Such indexes however, are unreliable in obtaining a uniform socio-economic group (Rosenthal, 1968). Regardless of the quantity of the criteria employed in establishing subject groups which differ with respect to socio-economic class membership, the possibility always exists that such groups may possess some qualitative distinctions which cannot be accounted for and which may be crucial in producing response differences. To eliminate the problem of equivocality in subject groups, a random group of subjects (see Subject section) was employed in this study. This procedure provides a twofold function: (1) to "average out" qualitative distinctions across subject groups and consequently, (2) to eliminate the necessity of ascribing group differences in response to distinctions between the "rich" and the "poor".

The employment and role of motivational involvement in value research is also a factor crucial in producing accentuation effects. Almost exclusively, researchers such as Gilchrist & Nesberg (1952), Lambert & Lambert (1953), Lambert, Solomon & Watson (1949), Levine, Chein & Murphy (1942), McClelland & Atkinson (1948), Minturne & Reese (1951), Proshansky & Murphy (1942), Rock & Fleck (1950), Sanford (1936), Sanford (1937), Shafer & Murphy (1943), Smith & Hochberg (1954), Solly & Engel (1960), Ashley, Harper & Runyon (1951), and Saltzman, Browne & Green (1966) have employed solely operational manipulations in defining motivational properties of the S. That is, actions of the experimenter during the experimental situation were such as to induce motivation operationally. Largely due to equivocality in the results and interpretations in these studies, the relationship between motivation and response accentuation was quite confounded and situation specific. In contrast to this earlier work, this study employed a motivational construct only as it existed "naturally" or through non-experimentally induced processes. Stimuli either did or did not possess inherent value and only to the extent that these stimuli aroused differences in personal relevancy was motivation manipulated.

The results of this study also appear to depend considerably upon a third factor, namely, the identification of value as a number property. When value is placed along a number dimension it is possible to define it in terms of a ratio scale. Previous research of Bruner and Goodman (1947), Carter and Schooler (1949), Dukes & Bevan (1952a), Landis, Jones & Reiter (1966), Rosenthal & Levi (1950) and Rosenthal (1968) used size as a measure of value. The relationship between size and value seems tenuous at best with a dime being twice as valuable as a nickle and yet substantially smaller in size. Such a relation would only be ordinal and the continum limited to coins. Furthermore, size increase need not represent an increase in value and it seems unusual that value should be so expressed. On the other hand, the numerousness of monetary units perceived seems to be a property more closely associated with value and one which would reflect better increase in motivation. Tajfel (1957) states that in order to demonstrate legitimately the existence of accentuation there should be a concomitant variation of value and some physical dimension. Numerosity fits such a stipulation while size does not.

Lastly, a factor upon which the results of this study are not really dependent, but which in itself is significant is the employment of an adult subject sample. The majority of the research already cited has been concerned with demonstrating accentuation across various types of discriminations (size, number, brightness, length, weight) in children. Children are usually considered to perceive in a more autistic (less veridical) manner than adults. According to Piaget (1930), this is the result of children being "less socialized" than adults and thus less tied to "reality". Piaget also considers children's perceptions to develop through stages from quite autistic to veridical and that the adult veridical perceptions are based on the earlier more autistic modes of perceiving.

By incorporating these four features into this study, response variance due to subject differences, artificial motivational states, and variations in the discriminative aspects of the stimuli, were minimized.

Results indicate satisfactory conformity of data to prediction. It is appropriate therefore to proceed to a discussion of theoretical and systematic issues mentioned in the introduction. A theoretical issue which has received considerable impetus through Allport (1955) and Pastore (1949) is whether value and other so-called behavioral determinants directly affect primary sensory (neurophysiological) processes. Implied in this issue is the malleability of perception or the extent to which modifications in the perceptual process can be demonstrated. It is generally conceded that sensorily based discriminations are not modifiable while discriminations which are basically cognitive in nature can be readily manipulated, e.g., Kohler (1964) and Rock's (1966, 1968) work on behavioral adaptation to perceptual distortion.

One feature of the results seems clear. Since when number was less than eight (8) subject groups differing with respect to target type or exposure duration did not differ in numerosity response, the same processes controlled discrimination of number for all groups. A 1:1 relationship exists between numerousness (R) and number (S) when number is less than eight (8), i.e., R = f (S) and this condition holds for all four subject groups. (See Figure 2). Using Allport's (1955, pp. 345-357) terminology, one may therefore say that variations in cognitive or "means-value" (degree of "positive relevance" an object has in a need-fulfilling situation) or variations in "end-value" (degree of "motivational involvement" in a need-fulfilling situation) produced no effects under such conditions.

Immediate accurate discrimination of small number, (less than 8) governed by the process of subitization, may be considered a psychophysical function dependent largely upon activity within the visual pathway. That is, it would appear that discrimination of small number is sensorily based and largely non-cognitive in character. Such discriminations would be dependent upon number only for nominal purposes, i.e., the use of number by the S in response only as a means of naming or categorizing the stimulus display. Price-Williams (1962), Nelson & Bartley (1961) and Piaget (1952) provide evidence suggesting this is possible.

Immediate accurate discriminations such as occur in subitization would appear to have some basis for explanation in the Bunsen-Roscoe law. This law has been found to hold for both physiological and psychophysical measures of visual response under a variety of conditions and for various types of discriminations: absolute threshold (Karn, 1936; Graham & Margaria, 1935; Sperling & Jolliffe, 1965), intensity (Graham & Kemp, 1938), visual acuity (Graham & Cook, 1935), velocity (Brown, 1955), digit identification (Kahrneman & Norman, 1964), number (Hunter & Sigler, 1940), and shape (Liebowitz, Toffey & Searle, 1966). All of these measures of visual discrimination can be predicted from the reciprocity relationship I x T = C. As was mentioned in the introduction, discriminations made under conditions where the relationship holds and equals a constant are considered to reflect an early "sensory" event in the visual process.

Customarily, the Bunsen-Roscoe law is explained on the basis of transduction in the receptor cell, i.e., conversion of photic energy over time into frequency of discharge. Hartline (1934) has confirmed the presence of this process by making direct recordings from a single fiber of the optic nerve of Limulus. (See Figure 8). Although it may appear difficult at an intuitive level, it seems clear that where small numbers are discriminated, numerosity response is totally determined by rate of discharge in the receptor cell system. Nelson & Bartley (1963), Nelson, Bartley, & Jewell (1963), and Mathewson, Miller, & Crovitz (1968) have produced neurological explanations of the Bunsen-Roscoe law that includes but goes beyond sense cell phenomenon.

Displays consisting of a greater number of items (more than 8) show a discontinuity of function as a rather abrupt divergence between the curves begins at 9 and continues up and through 16. (See Figure 9b). This dis-

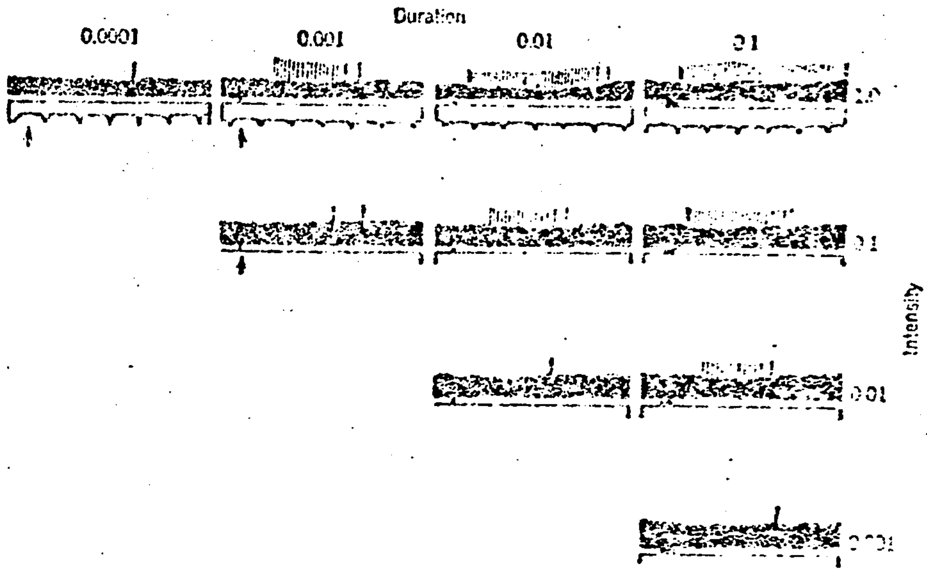


Figure 8 Oscillograms depicting bursts of impulses in a single optic nerve fiber of a horseshoe crab in response to short pulses of light under varying Intensity (I) and Time (T) conditions. Relative intensity ($1.03 \times 10^6$ meter candles) is given on right. Duration of pulse (in seconds) is given on top. Position of signal for short pulses are marked by arrows.

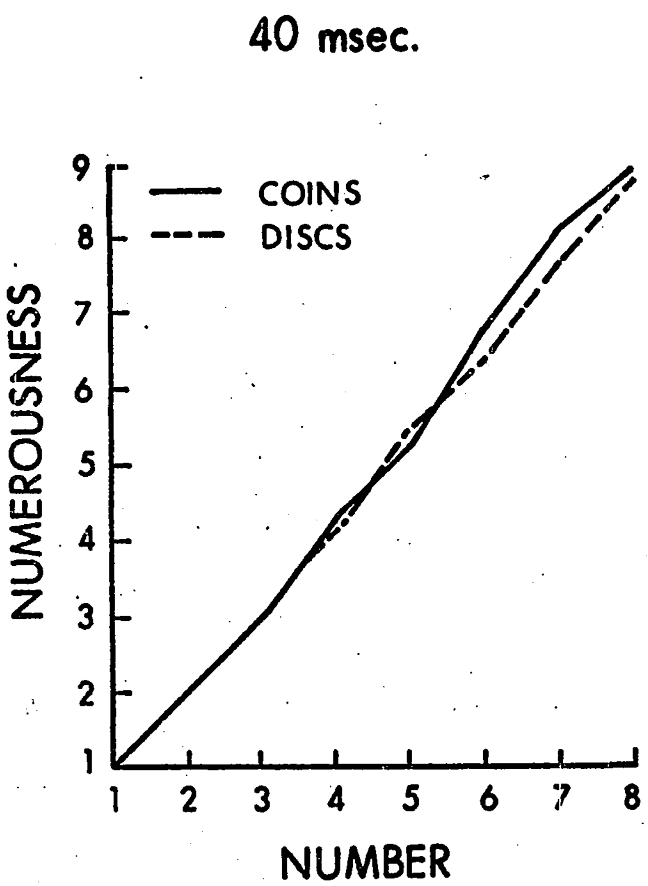


Figure 9a Numerousness of value and non-value targets as a function of number.

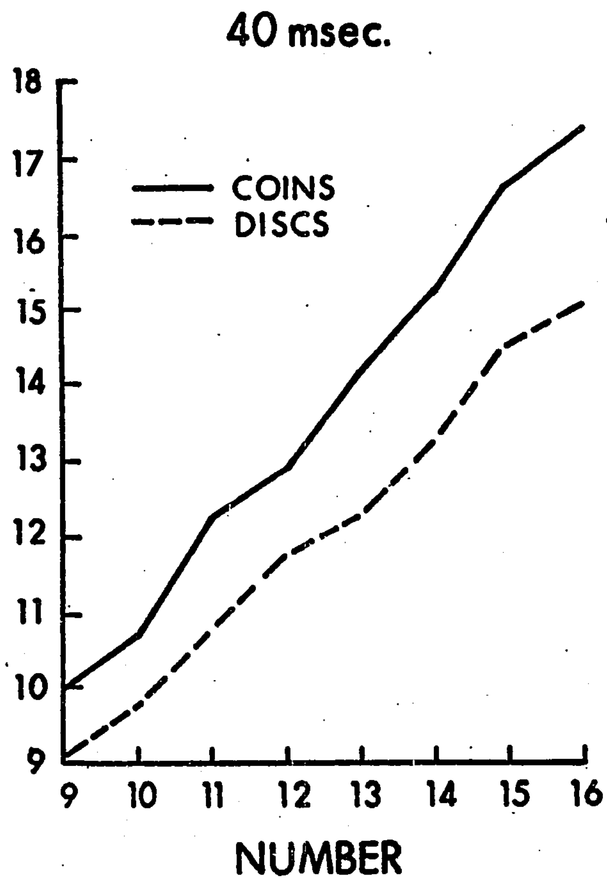


Figure 9b Numerousness of value and non-value targets as a function of number.

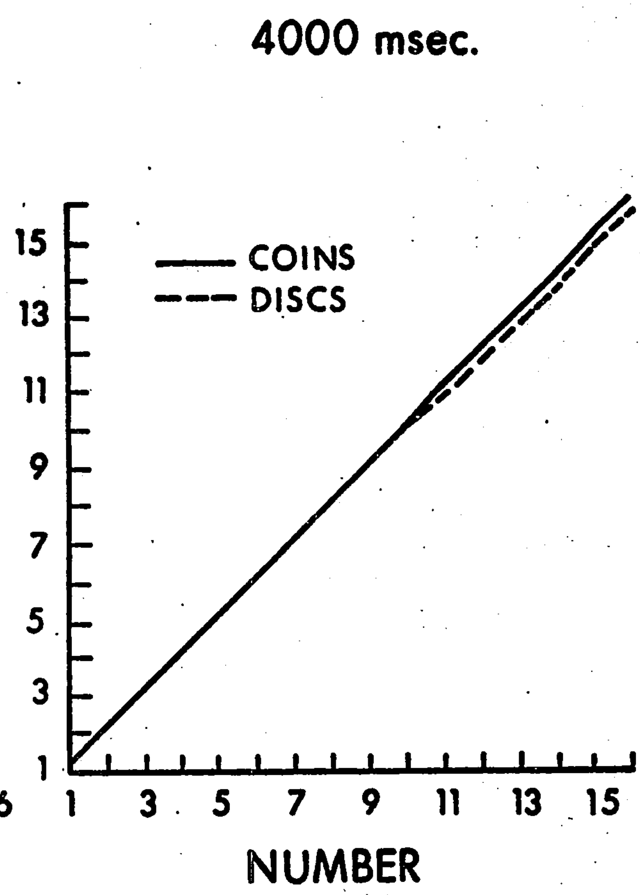


Figure 9c Numerousness of value and non-value targets as a function of number.

continuity is, as expected, only evident under the 40 msec. exposure condition since it is only this condition that tests the span of discrimination. The point of deflection between the two curves may be considered to be the origin where factors in addition to sensory factors become operative since it is the beginning of significant differences in numerosity responses between targets possessing value and targets possessing no value. At this number level value targets now begin to be overestimated compared to valueless targets and the relative overestimation generally increases with increases in number. Thus differences in "end-value" and "means-value" are now influential in exerting an effect in numerosity discrimination. The deflection also illustrates the breakdown in veridical discrimination and delineates the span of discrimination. Below 8 number discrimination is within the span of discrimination and handled largely by sensory pathway, but above 8 this process is insufficient to cope adequately with the stimulation. Discrimination of greater number, as opposed to smaller number, is therefore not really a psychophysical function (1:1 correspondence between physicalistic measurement and phenomenal experience), but rather dependent upon factors in addition to number, in this case presumably motivational. (See Figures 9a and 9b). This distinction parallels the previously made distinction between the lower order response of subitizing and the higher order response of estimating.

Under the 4000 msec. condition no discontinuity of function is evident suggesting that value plays no role in such discriminations. (See Figure 9c). This is to be expected since under extended viewing conditions one is supposedly dealing with cognitive (judgmental) processes more related to classification, conceptualization and free recall learning than to sensory processes (Garner, 1966). Mediational processes can now be employed by the S allowing him to "go beyond the immediate givens" of the stimulation. Thus under extended temporal conditions it would appear (1) another form of number discrimination is being utilized, namely counting, and (2) the conditions are such that the S can adequately handle the stimulation via the use of judgmental processes and that value and motivational properties are less influential factors in determining the discrimination. As with discrimination of small number under restricted temporal conditions, it is again apparent that variations in "means-value" or "end-value" produce no effect in number discrimination employing a judgmental framework. It is interesting to note however, that although the difference in numerosity response between value and valueless targets is far from significant, a trend does exist in the predicted direction.

Thus there appears to be clear evidence for the operation of at least three mechanisms in the discrimination of number, one for small number and two or more mechanisms for greater number. Recognizing that the subitizing process for the discrimination of small number is different from the estimating and counting processes for the discrimination of large number, Kaufman, Lord, Reese, & Volkman (1949), Jensen, Reese, & Reese (1950) and Saltzman & Garner (1948) sought not only to determine influential factors in number discrimination, but also to explain how discriminations of displays of large numbers takes place. Following their line of analysis, judgmentally based number discriminations reflect the use of number as a description of position within an ordered relation, e.g., sequential counting of the number of items in an array. In dealing with greater number it would thus appear that Ss employ ordinal, interval, or ratio scales and hence judgmental processes. However Nelson & Bartley (1961) suggest that number may be a nominal name for a pattern of discrimination or refer to non-formalized cognitive structures based on individual past experience. It is a well accepted fact that behavioral factors will affect judgmental processes including counting responses (Smith, Parker, & Robinson, 1948) as well as pattern estimating of a display made under marginal viewing conditions. The present results, while in agreement with the latter part of the previous statement, do not correspond with the generally accepted finding that value or motivational factors readily influence judgmental processes.

Motivational theorists have been primarily concerned with relating motivation and judgmental forms of discrimination. Pastore (1949) and Allport (1955) consider judgmental processes as the sole processes upon which behavioral determinants act. That is, that need and value are not effective factors in determining the perceptual organization of the individual's world, but rather influence the interpretative process (judgmental) accompanying a perceptual response. The results of this study appear to contradict such an analysis and at least suggest that value can function as a determinant of perception itself, i.e., that the perception of an array itself can be distorted by virtue of its relation to the value of the items in that array. Examination of the results shows that value was uninfluential in affecting judgmental processes (See Figure 9c) and sensory processes (See Figure 9a), but was influential when discriminations were perceptual in nature (See Figure 9b).

Of considerable relevance is the fact that differentiated subject "need states" and other behavioral factors were not employed in this study thus permitting value to operate essentially in an independent fashion. Previous researchers have consistently varied behavioral factors in conjunction with value and defined value in terms of these factors, for instance, familiarity (Ansbacher, 1937), hypnosis (Ashley, Harper & Runyon, 1951), need (Bruner & Goodman, 1947; Carter & Schooler, 1949), personal values (Klein, Schlesinger & Meister, 1951), and reward and punishment (Holzkamp & Keiler, 1967). The only conclusion supported from such research strategies was that the accentuation effect (in terms of perceptual distortion) obtained was due to the differential action of the behavioral factors. However, since in this investigation factors did not systematically vary in connection with value and since differences in numerosity response between value and valueless objects did occur under perceptual discriminations, it would appear as if accentuation of numerousness of value objects occurred as a result of their being simply perceived (experienced) as greater in number and not being interpreted as such.

Another systematic issue briefly discussed earlier is the delineation of sensory, perceptual, and cognitive processes in number discrimination (similar discussions of this issue can be found in Bartley (1958) and Lechelt (1966).) Although subitizing clearly has a sensory explanation one cannot completely differentiate judgmental and estimating responses, i.e., the two are not entirely mutually exclusive.

Estimating responses, under conditions of brief time exposure with the exclusion of after images, forces the S to relate an uncertain discrimination to a number syntax. In agreement with the hypothesis of Murphy, Proshansky and others, it seems difficult to see how estimating response of the S may be considered independent of cognitive involvement. While it would appear that cognitive processes are involved in discriminations based upon estimating procedures, it also seems fallacious to consider estimating response as synonymous with judgment. Judgments usually reflect converging mediational operations as opposed to the relative immediacy of estimating responses.

Since estimating response seems to occupy a position between sensorily based responses and cognitive responses and yet not to be identified totally with either, it would seem to be a response type identifiable with perception. According to Bartley (1958) perception represents an immediate discrimination to be distinguished from judgment: judgment considered to be a terminal reaction following a converging series of primary sensory or perceptual responses. Although such categorization is in keeping with distinctions between subitizing, estimating, and counting sequences the data of this study seem to require, Bartley fails to provide explicit means for differentiating the perceptual from the judgmental class of responses. A more complete distinction can be formulated if (1) cognitive features are separated such that those related to formal ways of thinking (logical and mathematical syntax) be associated with judgment and those embodied only in past experience be identified with perception, and (2) immediately be interpreted as referring to situations in which response is contiguous with stimulation.

Each of these response realms is further specific to certain temporal features and usable distinctions can also be drawn on this basis. Since judgment involves a series of responses, it may be considered mediational in contrast to the aspect of immediacy shared by sensory and perceptual processes. Perceptual and sensory response classes are to be distinguished on the basis that perception has symbolic significance in that it reflects the integrative action of a nervous system functionally modified by specific previous stimulation, while sensory response makes reference to processes which can be explained in terms of activity taking place within a single tissue system without any reference to cognitive strategies.

Quantitative techniques can also be employed to treat the results in a theoretical fashion. Numerousness, the response (R) is always at least partly a function of number, the stimulus (S). By expressing this relationship quantitatively in terms of $R = cS^m$, where "c" is an arbitrary coefficient reflecting unit of measurement and denoting point of intercept, and "m" is the exponent descriptive of the actual inclination of the slope, it is possible to give algebraic meaning to the slope and so express differences in numerosity response as a function of value. An exponential value of 1.00 would represent a perfect linear relationship or R = S; in this case numerousness = number. Deviations from linearity may be in either direction from unity with an exponential value of less than 1.00 indicating the response to increase at a less rapid rate than concomitant increases in stimulus value and an exponential value of greater than one indicating the response to increase more rapidly than increases in stimulus value.

Numerosity responses to the valueless targets under the 40 msec. condition was best satisfied by $R = .04S^{.95}$. The exponential value obtained signifies a slight deviation from linearity and indicates numerousness to increase less rapidly than number. This result implies that when a S is viewing displays of items possessing no intrinsic value, there is a tendency to underestimate the actual number of items in a display. This tendency expresses itself in such a manner that as number becomes progressively larger, the numerousness for the S becomes progressively less, i.e., there is a relative increased divergence between S (number) and R (numerousness) as the S increases in magnitude. Similar findings were obtained by Jevons (1871) and Taves (1941).[1]

The equation $R = .10S^{1.12}$ was found to best describe numerosity responses to the value targets under the 40 msec. condition. The deviation from linearity so expressed by this exponent indicates numerousness to increase more rapidly than number. Thus, when the items of a display do possess value there is again a relative increased divergence between S (number) and R (numerousness), but now the divergence is in the opposite direction. As the number of objects in the display increases in magnitude there is a greater increase in subjective numerousness.

Since the only difference between these two conditions was the absence or presence of value in the displays, differences in magnitude between the two exponents may be considered to (1) represent quantitatively the influence of value in the perception of numerosity, (2) show that value does function as a determinant in perceptual discrimination of number, and most important of all, (3) show that value can operate in such discriminations independently of particular perceiver characteristics. No equations were solved for under the 4000 msec. condition since differences in numerousness did not approach significance and any statistical treatment of these results would be meaningless.

Regression analysis was also performed on the data to further analyze deviations from linearity and to geometrically express differences in numerosity response. Figure 10 illustrates the regression lines fitted to average numerosity responses to value and valueless stimuli under the 40 msec. condition. Equations for predicting numerousness ($Y^1$) from number (X) for the value and valueless conditions are also shown. The opposite deviations from linearity of the two regression lines resulted in an angular separation between the lines of approximately 6 degrees.

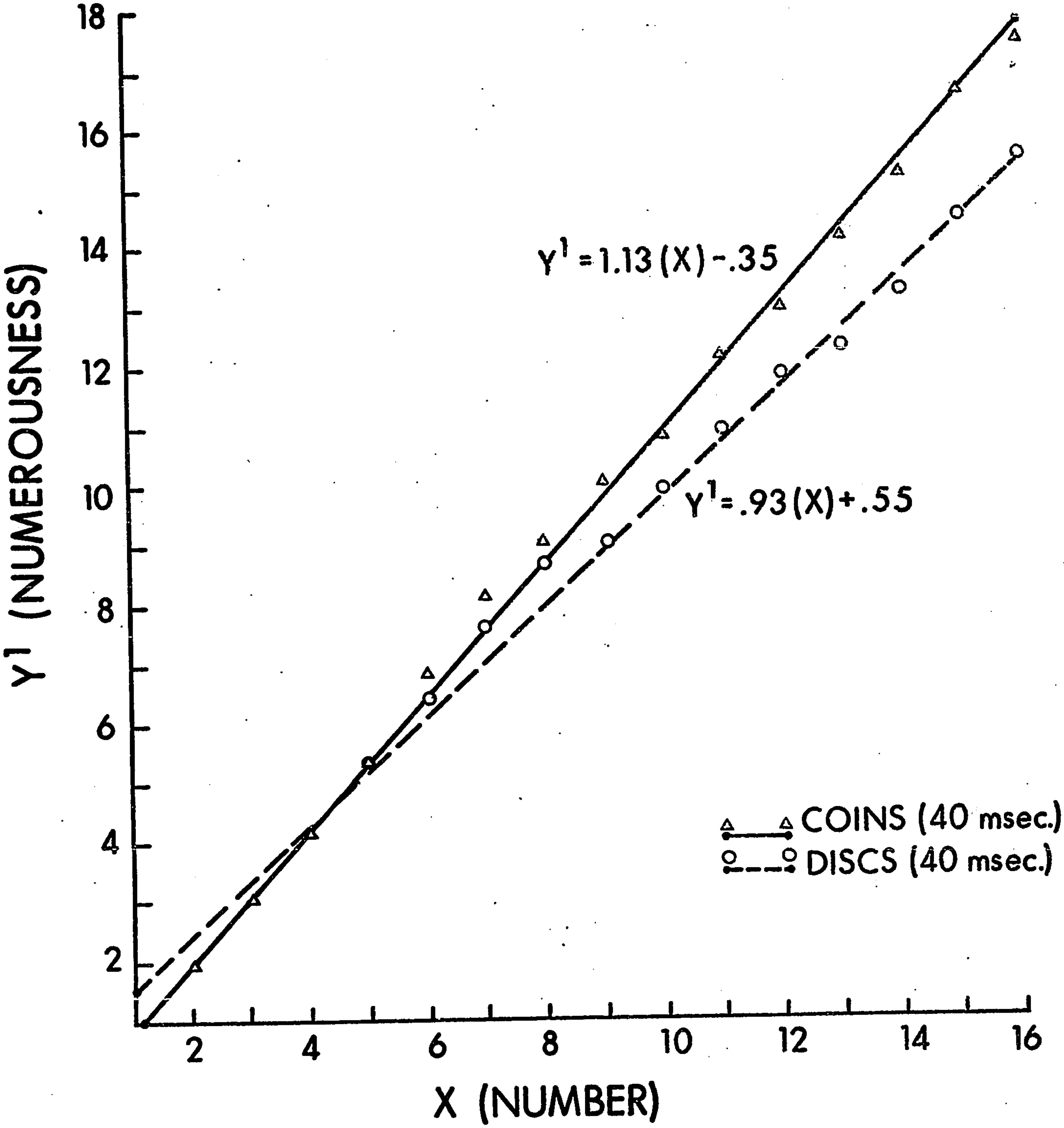


Figure 10 Best fitting curves and formulas for numerousness of value and non-value targets under the 40 msec. exposure period.

## Summary and Conclusions

Two levels of value, two levels of exposure time, and sixteen levels of number were combined into a 2 x 2 x 16 factorial experiment with repeated measurements to determine if value can function as a determinant in a random group of adult's discrimination of number. Half of the S in each of a 40 msec. exposure group and a 4000 msec. exposure group were shown displays of economically valueless discs varying in number from one to sixteen and half were shown displays of Centennial dimes varying in like manner. The 40 msec. exposure period fell within the time limits of the Bunsen-Roscoe law and was used so as to have stimulation (number of targets) both within and beyond S's span of discrimination. The 4000 msec. condition was of sufficient duration to permit each S to accurately count the number of targets in the displays.

It was found, under the 40 msec. exposure condition, that when number was greater than eight, valuable targets were overestimated while valueless targets were underestimated. The divergence between the value and non-value targets at this number level was significant and generally increased as the number of targets increased from eight to sixteen. Under the 4000 msec. condition no significant differences in numerosity response between value and valueless targets resulted at any level of number employed. Results confirmed expectations.

It was concluded that intrinsic stimulus value, operating independently of perceiver characteristics, can function to effectively modify perceptual discriminations of number, but that judgmental responses and responses controlled by processes of the visual pathway are relatively unaffected. Modes of number discrimination were related to response systems employed by Ss in ascertaining degrees of "manyness" in a display.

FOOTNOTES

1 That numerousness of valueless targets does not keep up with increases in number is thus a well established empirical fact and of interest in itself. Two possible explanations of this reliable phenomenon are (1) it reflects the channel capacity of the perceiving organism, and (2) it is due to the interaction of stimulus factors. Those favoring the first explanation refer to a short term memory (STM) process which exhibits a rapid deterioration of performance over short intervals of time. Although the nature of the events producing such a deterioration have not yet been established, there is empirical evidence which is at least suggestive that such a process may exist. Sperling (1960) states that there is briefly preserved in the visual system much more than the S can report, i.e., there is a temporary storage of information in the sensory system that is pre-memorial and exhibits rapid decay. With a very brief exposure of a large number of items the S is only able to report a few of the actual number even though he believes he has seen all of them clearly during the exposure. Sperling (1960) suggests that subsequent to STM information goes into storage and that there is a considerable loss of information during this transition. Subitizing (span of discrimination) presumably reflects the STM process prior to decay (prior to encoding) in that the

discriminations are accurate indicating no loss of information and delineating the channel capacity of the organism. Beyond the span of discrimination, however, there is decay in the processing of the increased information which is reflected by underestimations of physical number. Whether the forgetting or loss of information in STM is due to effects of interference or some time-dependent decay process is as yet unresolved. The second explanation has reference to stimulus features rather than to the discriminating organism. As mentioned in the introduction, the span of discrimination is not appreciably affected by variations in size, area, and density of items, but numerosity discriminations of greater number are susceptible to systematic variations in these stimulus features. Miller's statement "When the subject can subitize, area and density may not be the significant variables; but when the subject must estimate, perhaps they are significant" (1956, p. 95) summarizes the findings that interactions between size, area, and the relative spatial separation between items in an array decrease the estimate of the number of items when the number is beyond the span of discrimination.

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# APPENDIX A

## Data sheets illustrating random orders of presentation of targets

## DATA SHEET

## ORDER #1

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 13 | ___ | 12 | ___ | 6 | ___ | 7 | ___ |
| 2 | ___ | 15 | ___ | 4 | ___ | 12 | ___ |
| 1 | ___ | 1 | ___ | 7 | ___ | 11 | ___ |
| 13 | ___ | 2 | ___ | 8 | ___ | 7 | ___ |
| 15 | ___ | 11 | ___ | 14 | ___ | 12 | ___ |
| 2 | ___ | 5 | ___ | 4 | ___ | 16 | ___ |
| 5 | ___ | 10 | ___ | 3 | ___ | 3 | ___ |
| 8 | ___ | 14 | ___ | 15 | ___ | 10 | ___ |
| 11 | ___ | 14 | ___ | 1 | ___ | 14 | ___ |
| 10 | ___ | 9 | ___ | 4 | ___ | 6 | ___ |
| 16 | ___ | 4 | ___ | 2 | ___ | 16 | ___ |
| 13 | ___ | 16 | ___ | 15 | ___ | 13 | ___ |
| 5 | ___ | 3 | ___ | 10 | ___ | 5 | ___ |
| 9 | ___ | 8 | ___ | 1 | ___ | 9 | ___ |
| 8 | ___ | 12 | ___ | 3 | ___ | 6 | ___ |
| 6 | ___ | 7 | ___ | 9 | ___ | 11 | ___ |

DATA SHEET

ORDER #2

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 4 | | 8 | | 1 | | 10 | |
| 11 | | 13 | | 9 | | 6 | |
| 15 | | 15 | | 3 | | 4 | |
| 12 | | 16 | | 1 | | 1 | |
| 6 | | 10 | | 16 | | 9 | |
| 5 | | 3 | | 14 | | 14 | |
| 11 | | 15 | | 14 | | 2 | |
| 5 | | 11 | | 1 | | 5 | |
| 7 | | 6 | | 8 | | 4 | |
| 10 | | 13 | | 4 | | 8 | |
| 6 | | 2 | | 2 | | 15 | |
| 12 | | 12 | | 16 | | 12 | |
| 7 | | 9 | | 5 | | 9 | |
| 13 | | 14 | | 13 | | 3 | |
| 8 | | 7 | | 10 | | 11 | |
| 7 | | 2 | | 3 | | 16 | |

DATA SHEET
ORDER #3

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 12 | ___ | 8 | ___ | 7 | ___ | 11 | ___ |
| 16 | ___ | 16 | ___ | 1 | ___ | 6 | ___ |
| 1 | ___ | 3 | ___ | 9 | ___ | 3 | ___ |
| 11 | ___ | 4 | ___ | 14 | ___ | 10 | ___ |
| 4 | ___ | 6 | ___ | 12 | ___ | 4 | ___ |
| 10 | ___ | 13 | ___ | 3 | ___ | 6 | ___ |
| 6 | ___ | 15 | ___ | 8 | ___ | 9 | ___ |
| 2 | ___ | 4 | ___ | 7 | ___ | 13 | ___ |
| 16 | ___ | 15 | ___ | 9 | ___ | 15 | ___ |
| 5 | ___ | 7 | ___ | 5 | ___ | 8 | ___ |
| 1 | ___ | 5 | ___ | 13 | ___ | 12 | ___ |
| 2 | ___ | 12 | ___ | 3 | ___ | 16 | ___ |
| 10 | ___ | 2 | ___ | 9 | ___ | 2 | ___ |
| 5 | ___ | 11 | ___ | 14 | ___ | 15 | ___ |
| 14 | ___ | 1 | ___ | 7 | ___ | 11 | ___ |
| 13 | ___ | 8 | ___ | 10 | ___ | 14 | ___ |

# DATA SHEET
## ORDER #4

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 9 | | 11 | | 12 | | 2 | |
| 6 | | 6 | | 12 | | 5 | |
| 11 | | 16 | | 1 | | 14 | |
| 15 | | 7 | | 7 | | 13 | |
| 2 | | 1 | | 3 | | 10 | |
| 6 | | 7 | | 13 | | 16 | |
| 12 | | 10 | | 8 | | 4 | |
| 5 | | 3 | | 3 | | 8 | |
| 7 | | 1 | | 8 | | 11 | |
| 4 | | 13 | | 14 | | 6 | |
| 10 | | 1 | | 5 | | 15 | |
| 9 | | 10 | | 8 | | 5 | |
| 12 | | 2 | | 3 | | 4 | |
| 13 | | 4 | | 16 | | 14 | |
| 11 | | 9 | | 14 | | 2 | |
| 16 | | 15 | | 15 | | 9 | |

# DATA SHEET
## ORDER #5

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 4 | ____ | 14 | ____ | 7 | ____ | 5 | ____ |
| 13 | ____ | 6 | ____ | 14 | ____ | 13 | ____ |
| 3 | ____ | 9 | ____ | 15 | ____ | 8 | ____ |
| 6 | ____ | 10 | ____ | 6 | ____ | 9 | ____ |
| 16 | ____ | 3 | ____ | 13 | ____ | 5 | ____ |
| 16 | ____ | 2 | ____ | 4 | ____ | 2 | ____ |
| 10 | ____ | 12 | ____ | 10 | ____ | 4 | ____ |
| 13 | ____ | 11 | ____ | 15 | ____ | 5 | ____ |
| 7 | ____ | 14 | ____ | 2 | ____ | 1 | ____ |
| 14 | ____ | 8 | ____ | 16 | ____ | 1 | ____ |
| 3 | ____ | 15 | ____ | 12 | ____ | 11 | ____ |
| 11 | ____ | 10 | ____ | 16 | ____ | 7 | ____ |
| 3 | ____ | 8 | ____ | 7 | ____ | 4 | ____ |
| 6 | ____ | 9 | ____ | 12 | ____ | 2 | ____ |
| 8 | ____ | 5 | ____ | 15 | ____ | 1 | ____ |
| 11 | ____ | 1 | ____ | 12 | ____ | 9 | ____ |

DATA SHEET
ORDER #6

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 4 | ___ | 12 | ___ | 15 | ___ | 16 | ___ |
| 11 | ___ | 3 | ___ | 7 | ___ | 12 | ___ |
| 5 | ___ | 6 | ___ | 1 | ___ | 13 | ___ |
| 2 | ___ | 9 | ___ | 6 | ___ | 6 | ___ |
| 3 | ___ | 3 | ___ | 8 | ___ | 16 | ___ |
| 7 | ___ | 8 | ___ | 5 | ___ | 12 | ___ |
| 1 | ___ | 11 | ___ | 12 | ___ | 16 | ___ |
| 15 | ___ | 8 | ___ | 4 | ___ | 10 | ___ |
| 9 | ___ | 13 | ___ | 13 | ___ | 5 | ___ |
| 4 | ___ | 10 | ___ | 14 | ___ | 14 | ___ |
| 8 | ___ | 15 | ___ | 14 | ___ | 10 | ___ |
| 15 | ___ | 11 | ___ | 5 | ___ | 7 | ___ |
| 2 | ___ | 3 | ___ | 1 | ___ | 2 | ___ |
| 1 | ___ | 13 | ___ | 16 | ___ | 11 | ___ |
| 4 | ___ | 2 | ___ | 6 | ___ | 9 | ___ |
| 9 | ___ | 14 | ___ | 7 | ___ | 10 | ___ |

**DATA SHEET**
**ORDER #7**

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 9 | ___ | 12 | ___ | 7 | ___ | 8 | ___ |
| 13 | ___ | 3 | ___ | 3 | ___ | 10 | ___ |
| 8 | ___ | 12 | ___ | 14 | ___ | 8 | ___ |
| 2 | ___ | 8 | ___ | 2 | ___ | 16 | ___ |
| 6 | ___ | 5 | ___ | 12 | ___ | 13 | ___ |
| 7 | ___ | 15 | ___ | 6 | ___ | 4 | ___ |
| 13 | ___ | 1 | ___ | 15 | ___ | 14 | ___ |
| 16 | ___ | 1 | ___ | 16 | ___ | 5 | ___ |
| 3 | ___ | 16 | ___ | 12 | ___ | 9 | ___ |
| 14 | ___ | 9 | ___ | 2 | ___ | 4 | ___ |
| 11 | ___ | 10 | ___ | 11 | ___ | 1 | ___ |
| 7 | ___ | 5 | ___ | 10 | ___ | 2 | ___ |
| 9 | ___ | 14 | ___ | 11 | ___ | 10 | ___ |
| 15 | ___ | 5 | ___ | 4 | ___ | 4 | ___ |
| 6 | ___ | 13 | ___ | 15 | ___ | 1 | ___ |
| 3 | ___ | 7 | ___ | 6 | ___ | 11 | ___ |

# DATA SHEET
## ORDER #8

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 3 | ____ | 13 | ____ | 8 | ____ | 5 | ____ |
| 5 | ____ | 10 | ____ | 16 | ____ | 12 | ____ |
| 8 | ____ | 6 | ____ | 4 | ____ | 2 | ____ |
| 13 | ____ | 7 | ____ | 5 | ____ | 16 | ____ |
| 3 | ____ | 3 | ____ | 13 | ____ | 6 | ____ |
| 4 | ____ | 4 | ____ | 15 | ____ | 7 | ____ |
| 9 | ____ | 9 | ____ | 9 | ____ | 10 | ____ |
| 16 | ____ | 4 | ____ | 13 | ____ | 8 | ____ |
| 10 | ____ | 15 | ____ | 12 | ____ | 5 | ____ |
| 2 | ____ | 11 | ____ | 8 | ____ | 16 | ____ |
| 9 | ____ | 7 | ____ | 15 | ____ | 1 | ____ |
| 1 | ____ | 2 | ____ | 10 | ____ | 6 | ____ |
| 14 | ____ | 6 | ____ | 14 | ____ | 3 | ____ |
| 12 | ____ | 11 | ____ | 11 | ____ | 1 | ____ |
| 11 | ____ | 2 | ____ | 15 | ____ | 7 | ____ |
| 1 | ____ | 12 | ____ | 14 | ____ | 14 | ____ |

DATA SHEET

ORDER #9

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 9 | | 11 | | 13 | | 13 | |
| 15 | | 1 | | 7 | | 1 | |
| 9 | | 1 | | 9 | | 5 | |
| 2 | | 14 | | 16 | | 15 | |
| 10 | | 7 | | 8 | | 16 | |
| 4 | | 4 | | 4 | | 3 | |
| 16 | | 14 | | 10 | | 15 | |
| 7 | | 9 | | 12 | | 6 | |
| 2 | | 2 | | 14 | | 10 | |
| 12 | | 13 | | 12 | | 5 | |
| 9 | | 10 | | 3 | | 11 | |
| 6 | | 14 | | 13 | | 3 | |
| 16 | | 5 | | 6 | | 12 | |
| 15 | | 1 | | 3 | | 5 | |
| 6 | | 11 | | 7 | | 11 | |
| 4 | | 8 | | 8 | | 2 | |

DATA SHEET
ORDER #10

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 7 | ___ | 12 | ___ | 15 | ___ | 12 | ___ |
| 3 | ___ | 16 | ___ | 2 | ___ | 1 | ___ |
| 14 | ___ | 5 | ___ | 8 | ___ | 5 | ___ |
| 2 | ___ | 5 | ___ | 9 | ___ | 4 | ___ |
| 15 | ___ | 14 | ___ | 4 | ___ | 7 | ___ |
| 14 | ___ | 13 | ___ | 9 | ___ | 16 | ___ |
| 11 | ___ | 10 | ___ | 11 | ___ | 6 | ___ |
| 10 | ___ | 12 | ___ | 4 | ___ | 9 | ___ |
| 4 | ___ | 6 | ___ | 5 | ___ | 6 | ___ |
| 3 | ___ | 8 | ___ | 13 | ___ | 3 | ___ |
| 13 | ___ | 10 | ___ | 16 | ___ | 16 | ___ |
| 3 | ___ | 12 | ___ | 2 | ___ | 15 | ___ |
| 11 | ___ | 8 | ___ | 8 | ___ | 1 | ___ |
| 2 | ___ | 15 | ___ | 9 | ___ | 13 | ___ |
| 6 | ___ | 7 | ___ | 7 | ___ | 1 | ___ |
| 14 | ___ | 10 | ___ | 1 | ___ | 11 | ___ |

# DATA SHEET
## ORDER #11

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 6 | ___ | 2 | ___ | 11 | ___ | 6 | ___ |
| 11 | ___ | 1 | ___ | 7 | ___ | 16 | ___ |
| 6 | ___ | 13 | ___ | 14 | ___ | 5 | ___ |
| 2 | ___ | 12 | ___ | 8 | ___ | 11 | ___ |
| 16 | ___ | 8 | ___ | 11 | ___ | 1 | ___ |
| 9 | ___ | 3 | ___ | 12 | ___ | 12 | ___ |
| 4 | ___ | 13 | ___ | 7 | ___ | 15 | ___ |
| 16 | ___ | 2 | ___ | 10 | ___ | 5 | ___ |
| 4 | ___ | 9 | ___ | 8 | ___ | 4 | ___ |
| 15 | ___ | 14 | ___ | 15 | ___ | 10 | ___ |
| 10 | ___ | 5 | ___ | 3 | ___ | 3 | ___ |
| 7 | ___ | 3 | ___ | 9 | ___ | 13 | ___ |
| 14 | ___ | 16 | ___ | 14 | ___ | 13 | ___ |
| 9 | ___ | 6 | ___ | 1 | ___ | 5 | ___ |
| 15 | ___ | 1 | ___ | 8 | ___ | 10 | ___ |
| 7 | ___ | 12 | ___ | 2 | ___ | 4 | ___ |

DATA SHEET
ORDER #12

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 11 | ___ | 3 | ___ | 14 | ___ | 9 | ___ |
| 5 | ___ | 6 | ___ | 4 | ___ | 16 | ___ |
| 14 | ___ | 2 | ___ | 15 | ___ | 5 | ___ |
| 6 | ___ | 9 | ___ | 6 | ___ | 1 | ___ |
| 16 | ___ | 3 | ___ | 10 | ___ | 5 | ___ |
| 12 | ___ | 12 | ___ | 16 | ___ | 12 | ___ |
| 2 | ___ | 14 | ___ | 14 | ___ | 2 | ___ |
| 1 | ___ | 1 | ___ | 8 | ___ | 10 | ___ |
| 13 | ___ | 10 | ___ | 11 | ___ | 11 | ___ |
| 4 | ___ | 8 | ___ | 3 | ___ | 8 | ___ |
| 16 | ___ | 4 | ___ | 12 | ___ | 3 | ___ |
| 7 | ___ | 11 | ___ | 5 | ___ | 13 | ___ |
| 13 | ___ | 15 | ___ | 7 | ___ | 2 | ___ |
| 9 | ___ | 7 | ___ | 13 | ___ | 8 | ___ |
| 6 | ___ | 10 | ___ | 15 | ___ | 15 | ___ |
| 1 | ___ | 9 | ___ | 4 | ___ | 7 | ___ |

**DATA SHEET**

**ORDER #13**

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 8 | ____ | 8 | ____ | 12 | ____ | 4 | ____ |
| 11 | ____ | 4 | ____ | 9 | ____ | 12 | ____ |
| 4 | ____ | 15 | ____ | 16 | ____ | 3 | ____ |
| 15 | ____ | 5 | ____ | 3 | ____ | 13 | ____ |
| 2 | ____ | 1 | ____ | 13 | ____ | 6 | ____ |
| 10 | ____ | 7 | ____ | 13 | ____ | 7 | ____ |
| 5 | ____ | 16 | ____ | 6 | ____ | 14 | ____ |
| 10 | ____ | 9 | ____ | 11 | ____ | 7 | ____ |
| 8 | ____ | 9 | ____ | 2 | ____ | 15 | ____ |
| 12 | ____ | 14 | ____ | 12 | ____ | 1 | ____ |
| 9 | ____ | 8 | ____ | 1 | ____ | 13 | ____ |
| 5 | ____ | 14 | ____ | 4 | ____ | 2 | ____ |
| 1 | ____ | 7 | ____ | 15 | ____ | 6 | ____ |
| 10 | ____ | 10 | ____ | 11 | ____ | 6 | ____ |
| 3 | ____ | 16 | ____ | 3 | ____ | 16 | ____ |
| 5 | ____ | 2 | ____ | 14 | ____ | 11 | ____ |

DATA SHEET

ORDER #14

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 14 | ____ | 12 | ____ | 6 | ____ | 13 | ____ |
| 5 | ____ | 2 | ____ | 15 | ____ | 1 | ____ |
| 6 | ____ | 14 | ____ | 12 | ____ | 12 | ____ |
| 1 | ____ | 7 | ____ | 9 | ____ | 5 | ____ |
| 6 | ____ | 8 | ____ | 4 | ____ | 14 | ____ |
| 9 | ____ | 11 | ____ | 5 | ____ | 10 | ____ |
| 13 | ____ | 10 | ____ | 8 | ____ | 15 | ____ |
| 1 | ____ | 2 | ____ | 11 | ____ | 5 | ____ |
| 4 | ____ | 4 | ____ | 9 | ____ | 2 | ____ |
| 8 | ____ | 10 | ____ | 10 | ____ | 3 | ____ |
| 13 | ____ | 7 | ____ | 2 | ____ | 12 | ____ |
| 15 | ____ | 13 | ____ | 7 | ____ | 6 | ____ |
| 4 | ____ | 1 | ____ | 3 | ____ | 11 | ____ |
| 16 | ____ | 15 | ____ | 7 | ____ | 9 | ____ |
| 3 | ____ | 3 | ____ | 8 | ____ | 16 | ____ |
| 16 | ____ | 14 | ____ | 16 | ____ | 11 | ____ |

**DATA SHEET**

**ORDER #15**

| NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE | NO. | RESPONSE |
|---|---|---|---|---|---|---|---|
| 7 | | 9 | | 1 | | 12 | |
| 14 | | 12 | | 10 | | 11 | |
| 6 | | 5 | | 13 | | 8 | |
| 9 | | 11 | | 3 | | 11 | |
| 1 | | 15 | | 6 | | 3 | |
| 13 | | 13 | | 6 | | 12 | |
| 15 | | 5 | | 1 | | 8 | |
| 8 | | 10 | | 4 | | 6 | |
| 2 | | 9 | | 11 | | 13 | |
| 3 | | 5 | | 8 | | 3 | |
| 10 | | 10 | | 4 | | 2 | |
| 15 | | 16 | | 16 | | 15 | |
| 7 | | 2 | | 2 | | 7 | |
| 14 | | 9 | | 5 | | 4 | |
| 7 | | 12 | | 16 | | 16 | |
| 1 | | 14 | | 4 | | 14 | |