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MAGNITUDE ESTIMATION: THE EXPONENT AND RANGE OF RESPONSE

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SUMMARY

Ss made magnitude estimation judgments of the apparent distance of a space vehicle in a reduced cue setting. The effects of stimulus range on response range and the exponent of a Stevens type power function were investigated. Limitations upon the generality of previous findings about the effects of this variable were discussed.

INTRODUCTION

A fact clearly emerging from recent research in psychophysical scaling is that exponent of a Steven's type power function varies with changes in stimulus range. The numerical value of the exponent has been found to be sensitive to several factors in addition to the modality of the stimuli (Poulton, 1968). This second order variation limits the appropriateness of the power law as a model of sensory or perceptual processes. Also restricted is the usual interpretation of the exponent as a parameter indicative of the nature of the stimuli being judged. Poulton (1968), in a review of most of the available reports of range effects, estimates that about 1/3 of the variance of a set of published exponents can be accounted for by the range variable. His first model suggests that Ss will increase their range of response with an increase in stimulus range but that the increase is not of the same magnitude as the physical change.

Vincent, Brown, Markley, and Arnoult (1968), in a study of apparent distance, reported additional range effects. These authors found, as others had before them, that the exponent decreased with an increase in stimulus range. But the response ranges used by Ss did not go along with this trend. The actual ranges of responses used were more directly related to the number of discriminable stimuli in a physical range not the absolute range. There was an interaction between the length of the stimulus range and the location of that range in the entire set of potential stimuli.

The present study attempts to further examine range effects by manipulating stimulus range length and location independently. A within Ss design examined the effects of these variables on the performance of the individual S. Distance judgments were obtained in the same reduced cue setting, simulating outer space, as were the data of Vincent et. al. (1968). However the target (object whose distance was to be judged) was different.

METHOD

Observers--Twenty-four Ss volunteered to serve in this study. All were paid and had no experience with psychophysical scaling research. Four Ss were familiar with the apparatus from a previous discrimination study. All Ss had 20/20 vision (or better) as determined by an examination conducted by an optometrist.

Apparatus--Distance judgments were made in the NASA-TCU Space Vision Simulator (Arnoult, Vincent, Brown, Markley, and Hensleigh, 1969). The simulator presents a high fidelity three dimensional representation of a space vehicle (Lunar Excursion Module, ascent phase, or LM) in a star free setting otherwise simulating outer space. The appropriate object configuration, retinal image sizes, binocular cues, light ray configurations, and relative brightness changes over a range of 150 ft to 20,000 ft are presented by the simulator. Distance cues provided by terrain, context, texture gradients, atmospheric haze, aerial perspective and the like were absent.

The ascent stage of the LM is a complex, irregularly shaped object, at that time unfamiliar to the Ss. The LM faced the S and was oriented slightly to the left and away from the S. The simulated visible dimensions of the front of the LM were approximately 14 ft wide at the base, 8.5 ft. wide at the top and 9 ft tall.

Stimuli--Four sets of stimulus distances were used : 500, 560, 620, 720, 780, 900, and 1000 ft for range NS; 250, 400, 560, 700, 900, 1200, and 1500 ft for range NL; 5000, 5600, 6200, 7000, 7800, 9000, and 10,000 ft for range FS; and 4000, 5000, 6000, 7000, 9000, 12,000, and 15,000 ft for range FL. Seven hundred ft served as the standard distance for NS and NL. Seven thousand ft was the standard distance for FS and FL. NS and NL were near ranges. FS and FL were far ranges. NS and FS were short ranges while NL and FL were long ranges.

Procedure--All Ss made magnitude estimation judgments of the distance of the LM over all four distance ranges. Each S participated singly in two 40 minute sessions on consecutive days. Two ranges were judged on each day. Each S judged the four ranges in a different order. Prior to the first day's distance judgments, S made 20 magnitude estimations of the lightness (or darkness) of a set of Muncell neutral greys. This served to familiarize the S with the task of making magnitude estimation (prescribed modulus) responses. Ss were then introduced to the simulator and informed about the nature and approximate size of the space craft. Ss were installed in the observer's station and after a period of dark adaptation, allowed to view the LM moving back and forth over a range of 250 to 15,000 ft. Then the LM was located at the standard distance (700 ft or 7000 ft) and S received magnitude estimation instructions similar to those reported by Vincent et. al. (1968). However, in the present study the standard distances were assigned the value 100. For each range the stimuli were presented in an irregular order in four separate series. Between the second and third series <u>Ss</u> were allowed to view the standard distance again. No judgments were made of a moving target. An inter-trial interval of 10 sec. was required to change distances. During this time a shutter occluded the visual scene.

RESULTS AND DISCUSSION

The geometric mean response for each <u>S</u> to each stimulus distance was computed. Individual and group psychophysical power functions were computed by finding the regression of the log geometric mean responses to the logs of the distances.

Table 1 summarizes the group results. In addition, the last column of Table 1 gives the group means for the ratio of each <u>S</u>'s mean response for nearest stimulus in a range to mean response for the farthest distance.

TABLE 1

EXPONENTS OF THE PSYCHOPHYSICAL FUNCTION

$$\Psi = a\phi^n$$

UNDER FOUR DIFFERENT STIMULUS RANGES

FOR A SINGLE GROUP OF <u>Ss</u>

Stimulus Set	Range	No. of JNDs	Exponent	SD of Exponents	Mean Ratio of Low to High Responses
NS	500 - 1000 ft	16	1.62	.69	.348
NL	250 - 1500 ft	43	1.43	.49	.090
FS	5000 - 10,000 ft	9	1.32	.69	.442
FL	4000 - 15,000 ft	17	1.18	.55	.258

Unlike the exponent, this ratio is a pure measure of range of response unbiased by the physical measures used to describe the stimuli. A small ratio indicates a large range of response.

The exponents in Table 1 indicate that, in accord with previous findings, an increased range brought about a lower exponent. The rank order of the exponents was the same as the rank order of the absolute physical ranges. However, the effect is not as clear as it appears. The exponents do not vary systematically with the dynamic ranges (ratio of smallest to largest distance) of the stimuli. Furthermore, increasing the stimulus range (from short to long) while holding the standard constant did not produce a statistically significant decrease in exponent value ($F_{1,69} = 2.87$, $p < .10$). However, the change in standard location (near to far) from 700 to 7000 ft did significantly lower the exponent ($F_{1,69} = 8.22$, $p < .01$). There was no interaction between the near-far and large-small variables.

These exponents are unusual in other ways. The group values are higher than previous group exponents reported by Vincent et. al. (1968) for distance in a similar setting and by Markley, Brown, and Arnoult (1968). This may be due to the unusual configuration of the target. There is some agreement with the results of Kunnapas (1960) but no agreement with the exponents obtained by Kunnapas (1968) in a reduced cue setting.

Furthermore, the inter-individual variation in exponents is relatively large. For example, the SD for exponents from visual magnitude estimation, reported by Rule (1969), ranged from .21 to .31, less than half those reported in Table 1. The large variation observed here may be the cause of the insignificant changes in exponents found when range was increased while holding the standard constant.

Analyses of variance of the individual response ratios indicated that stimulus location (near-far) and stimulus range length both significantly affected range of response (Near vs. Far: $F_{1,23} = 17.33$, $p < .01$; Long vs. Short: $F_{1,23} = 133.65$, $p < .01$). Again there was no interaction. A logarithmic transformation of the ratios as was used by Ekman et. al. (1968) did not alter the results of these analyses. Subjects generally increased the range of numbers they used in responding as the length of the stimulus series relative to a constant standard increased. Shifting from a near to far set of distances decreased the range of numerical responses even though the absolute physical range increased. The response ratios did vary directly with the approximate number of JNDs contained in each stimulus set (Table 1). The number of JNDs was obtained from the Weber function reported by Worley and Markley (1969). It is interesting to note that, from the standpoint of discriminability, the NS and FL ranges were nearly of equivalent length. These two ranges produced the two extreme group exponents. Yet, the ranges of responses used by the Ss to describe these distances were not significantly different. ($t_{.348-.259} = 2.678$; $t'_{.05} = 3.45$. See Edwards, 1967, p. 265 ff.)

Stimulus range has been shown to be a major contributor to group differences in performance on a psychophysical scaling task. The present data extends this finding to individual Ss. Subjects adjust their response ranges with changes in stimulus range. However, the critical measure of stimulus range affecting response range appears to be the number of discriminable steps contained in the stimulus rather than the absolute physical range. These results point to boundary conditions for Poulton's (1968) Model I in that there are situations in which Ss will decrease their range of numerical responses in the face of a five fold increase in physical range.

Variation in subjective range may not effect the exponent when discriminability is variable over different portions of the physical continuum.

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