CONTEXT EFFECTS ON CROSS-MODALITY EQUATIONS OF SENSORY MAGNITUDE

by

Ann Howell Hardy

Submitted as an Honors Paper
in the
Department of Psychology

Woman's College of the University of North Carolina
Greensboro
1960-1961

APPROVED BY:

Director:

Kendon Smith

Examining Committee:

W. S. Ray

Laura G. Anderton

ACKNOWLEDGMENTS

To the following people my sincere appreciation is expressed for their help in this Honors Project: the students, who served as subjects; Eugenia Seaman, who assisted with the statistical computations; Dr. William S. Ray, who advised me in the statistical analysis of the data; and Dr. Laura Anderton, who served with Dr. Ray on my Examining Committee.

Special appreciation is expressed to Dr. Kendon Smith, who spent many hours directing, advising, and encouraging me during the course of this project.

TABLE OF CONTENTS

I. INTRODUCTION

Individuals are equipped with sense organs which serve as receptors to handle inputs of physical energy. These inputs exist, for example, in the form of light waves and of sound waves. The characteristics of the sensation which may arise depend upon the nature of the inputs, as well as upon certain physiological events that take place within the sense organ itself and within the brain. In psychology, matters of this sort are the concern of the specialty of psychophysics, which seeks to explain how sensory experiences are related to the different physical energies that arouse them.

One important purpose of psychophysical investigations has been to ascertain information about the strength of sensations or, in other words, to determine how an increase in the physical energy conveyed by a stimulus affects the sensation experienced. As in other attributes of sensation, intensity does not follow a one-to-one relationship with some aspect of the physical energy applied. "Physical events follow one set of laws and have their own natural units of magnitude; mental events follow other laws and have different units."[1]

Quantification of the relationship between stimulus-intensity and sensation-intensity was first attempted by Fechner. Fechner believed the strength of a sensation was something beyond direct measurement, because he could conceive of no way of getting at the

---

[1] C. E. Osgood, Method and Theory in Experimental Psychology, p. 42.

sensory process for purposes of such measurement. He therefore approached the problem of measurement indirectly: he sought to measure a given sensation in terms of another sensation.

The Fechnerian method made use of Weber's law, which purported to be a law governing "the relationship between the intensities of stimulation and the ability to distinguish which of the two stimuli was the greater."[2] Weber's law reads: "A stimulus must be increased by a constant fraction of its value to be just noticeably different."[3] Fechner assumed that each "just noticeable difference" ("j.n.d.") represented a unit of sensation. The magnitude of a sensation could, according to Fechner, be determined by counting the number of j.n.d. units that sensation lay above the threshold. These summated j.n.d. steps could then be arranged in their order of magnitude to obtain an intensity scale for that sensation. Following up the mathematical implications of Weber's law and his own assumption that a j.n.d. represents a unit of sensation, Fechner determined that the magnitude of any sensation, in terms of summated j.n.d.'s, must be a linear function of the logarithm of the strength of the stimulus.

This method of predicting sensory magnitude based on the assumption that the j.n.d. represented a constant fraction presented difficulty from the start. Unfortunately, Fechner made an unwise choice in selecting Weber's law as the basis for measuring sensation,

---

[2]Gardner Murphy, Historical Introduction to Modern Psychology, p. 88.

[3]R. S. Woodworth and H. Schlosberg, Experimental Psychology, p. 194.

for the size of Weber's fraction is actually a variable. Large at low stimulus intensities, Weber's fraction decreases rapidly as the intensity increases; remaining relatively constant for middle intensities, it customarily rises a little at high intensities. Therefore, the law that assumes the psychological intensity of a sensation grows in equal steps as the stimulus increases by a constant fraction seems to be erroneous. Even in Fechner's time this law was disputed; nevertheless, it remained, because no one could offer an alternative theory.[4]

Investigations along this line began to take on a physiological tinge when later electrical recording devices were developed to measure the actual receptor process taking place in audition and in vision. A comparison was made between the physiological findings and the earlier psychophysical theories. Again, the relationship did not appear to be one supporting Fechner's formulation.

Due to the inconsistency of early results, the so-called "direct" methods of sensory scaling were developed. In 1890 Merkel had subjects "double" or "halve" the intensity of tones to obtain scales of subjective intensity. In these experiments the subjects listened to a fixed tone of a certain loudness and then adjusted it to be "twice" or "one half" as loud. After a number of judgments had been made, the judgments could be combined to construct a scale

---

[4]Account of Fechnerian method of measuring sensation taken from:

E. G. Boring, Sensation and Perception in the History of Experimental Psychology, pp. 34-45.
Murphy, op. cit., pp. 85-94.
Woodworth and Schlosberg, op. cit., pp. 235-237.

of loudness. The similar scale which was later established by Stevens defined one "sone" as the "loudness of a 1,000-cycle tone at 40 db above absolute threshold -- a reference point used for other purposes in audition."[5] A tone sounding twice as loud as a one-sone tone (40 db) is found to be 47 db, so its loudness value is two sones, and so on. It was found that, as the sone scale increased, it took 40 db to compose one sone, but only an additional seven decibels to obtain two sones, and on up the scale until a 25-sone level was reached at 80 db. Comparing this loudness scale with the one obtained by Fechner, we see that they are quite incompatible, inasmuch as the Fechnerian scheme constitutes a logarithmic scale and the other a power scale. On the basis of direct judgments, the latter has seemed to have a certain amount of validity.[6]

Many methods of obtaining these direct scales of apparent sensory magnitude have been developed. The one of particular relevance to this project is that having to do with magnitude estimation. Richardson and Ross[7] were the first to employ a method of this type, but it has been used extensively by Stevens in obtaining scales of sensory intensity. In a typical experiment, using magnitude estimation, the subject is presented a standard stimulus which has been assigned some arbitrary sensory value by the experimenter. Then the variable stimuli, to be rated in

---

[5] Ibid., p. 239.

[6] Ibid., p. 237-240.

[7] L. F. Richardson and J. S. Ross, "Loudness and Telephone Current," J. Gen. Psychol., III, pp. 288-306.

relation to the standard, are presented. The subject reports how loud the variables seem to him in relation to the standard stimulus. From estimations or ratings, a subjective scale of intensity for a given sensation can be synthesized. Scales of this type have yielded consistent results, but some sort of validation is needed to see whether consistency is due to "true" sensory growth or to artifacts in procedure.

The cross-matching of sensations of two different modalities is the test which Stevens, in response to this latter sort of challenge, has devised for his scales of apparent magnitude. Since the scales that have been obtained by direct estimation grow as power functions in a consistent manner, the sensations of the two modalities have a feature in common: they are related to the physical stimulus by some exponential value. If the two physical stimuli (light and sound, for example) are now equated psychologically at several levels of intensity, the resulting curve of the equated cross-matches should show an exponential value equal to the ratio of the exponents of direct estimation. According to empirical tests by this method, scales of sensory magnitude are at least "reliable", and thus may possibly be "valid".[8]

---

[8]For a complete review of rationale, and of work done on direct estimates of sensory magnitude and cross-modality equations, see S. S. Stevens, "The Psychophysics of Sensory Function," American Scientist, XLVIII, pp. 226-253.

Several recent studies[9,10] have indicated that this reliability may be a superficial phenomenon. The fact that the context of stimuli in which judgments are made can be influential is exemplified by these studies. Garner's study particularly demonstrates how context can affect sensory judgments. He found, in three groups hearing different ranges of stimuli in which they were to make half-judgments in relation to the same standard tone, that all groups tended to give as the chosen value the mid-point of the range of their own variable stimuli. He concluded "that such judgments are reliable, but not valid for purposes of loudness scale construction."[11] Subjects showed great ability to make judgments in a reliable fashion if given a good set of instructions with which to align them. Under these conditions one cannot conclude that a basic sensory process is implied by the reliability of the results. Helson states that, in psychophysical judgments, what is probably going on is "that, upon presentation of the comparison-stimulus, the organism may be 'set' at a given level due to effects of previous stimulation."[12]

---

[9] W. R. Garner, "Context Effects and the Validity of Loudness Scales," _J. of Exper. Psychol._, XLVIII, pp. 218-224.

[10] R. M. Warren and E. C. Poulton, "Basis for Lightness Judgments of Grays," _Amer. J. Psychol._ LXXIII, pp. 380-387.

[11] Garner, _op. cit._, p. 224.

[12] Harry Helson, "Adaptation-level as a Frame of Reference for Prediction of Psychophysical Data," _Amer. J. Psychol._, LX, p. 2.

Deliberately creating conditions under which variable stimuli are presented to the subject and measuring the effect on sensory scales of magnitude is one method of testing the extent to which the scales have been contaminated by context effects. This is exactly what Garner did in his experiment in relation to direct sensory judgments. The present experiment represents an attempt to determine the effect of context on cross-modality equations.

II. PURPOSE OF THE STUDY

The purpose of this experiment was to determine the effect of context on the kind of cross-modality equations commonly used to validate scales of sensory magnitude, the context effect to be created by presenting selected ranges of stimuli prior to the matching of sensory intensities in two different modalities. In addition, the exponents governing the growth of reported sensory magnitude of visual and auditory stimuli obtained in this experiment were to be compared with those obtained in previous ratio-scaling experiments. Finally, the extent to which subjects vary in judging the relative intensity of tones and lights was to be investigated.

III. PROCEDURE

Subjects

The subjects were 36 female undergraduates from the Woman's College of the University of North Carolina. Subjects were recruited for participation in the experiment on a voluntary basis. None of the subjects had prior knowledge of the purpose of this experiment.

Apparatus

Each subject was tested alone in a soundproof, lightproof experimental room measuring approximately 9-1/2 feet by 12 feet. The subject sat on a low, adjustable seat facing a port in the wall. Eighteen inches from the wall, in front of the subject, was a stationary headrest used to control the distance of the subject's eyes from the stimulus. It also served to restrict the subject's field of vision to the visual stimulus which was projected through the port in the wall. On a table to the right of the subject, a "Teletalk" communication unit was situated. All stimulus and communication controls were external to the experimental room.

Visual stimulus. The visual stimulus was a green light (Eastman No. 58 Wratten filter) projected by a 200-watt slide projector. Filtered illumination was used to prevent changes in the hue of the stimulus. The form of the light ultimately viewed by the subject was that of a circular disk projected through translucent plastic and surrounded by a field of black poster board. A General Radio Variac, monitored by a Hickok Model 225 electronic voltmeter, connected to the projector provided the experimenter with a means of controlling manually the intensity of the light. The stimulus was initiated and remained on for two seconds when the experimenter closed a telegraph key connected to an intervening Hunter timer.

Auditory stimulus. A Western Electric 6B audiometer served as the sound source for the auditory stimulus, a tone of 1,024-cycles whose purity had been confirmed by oscilloscopic examination. The subject listened to the tone through a headpiece constructed for monaural listening. As were the visual stimuli, the auditory stimuli were presented automatically for two-second periods.

Method

Brightness judgments. The subject took a position in front of the visual stimulus, and care was taken to adjust the seat so that the subject viewed the stimulus at eye-level. Then, the following instructions were read to the subject:

> In this experiment several pairs of lights will be presented to you. Each light will be seen for two seconds. The first of each pair is the standard light to which an arbitrary brightness value of 10 is assigned. The brightness of this light will remain the same throughout the experiment. The second of each pair is the variable and will differ from one pair to another. Your task is to

estimate the brightness of each variable. In other words, the question is: if the standard or the first light of each pair is called 10, what would you call the variable or the second light in relation to it? Use numbers that seem appropriate to you. For example, if the variable or the second light seems seven times as bright as the standard, call it 70; if the variable or the second light seems 1/5 as bright as the standard or the first light, call it 2, etc. After the second light has been presented, make your estimate and tell me what it is. Try not to worry about being consistent in your estimations. Try to assign an appropriate number to each light regardless of what you may have called the last one. The testing will be carried out with the door closed and the lights out. I will be seated outside the door, but you may communicate with me at all times over the intercom system. Do you have any questions? After a three minute dark adaptation period, you will be given five practice trials during which you will see lights representative of the brightnesses that you will see during the regular trials and which will also acquaint you with the procedure to be followed during the regular trials. Before each trial you will be given a "ready" signal [experimenter said "ready" before each standard was presented] to make sure you are attending to the stimulus.

All subjects were given the same levels of illumination (25, 0, 5, 20, 30 db, in that order) to be judged in relation to a standard of 15 db on the five practice trials; the range of 0 db to 30 db constituted a series of medium intensities. The regular trials consisted of 35 judgments, five judgments at each of seven levels of illumination (0, 5, 10, 15, 20, 25, 30 db), estimated in relation to a standard of 15 db. The intensity levels were numbered from one to seven and arranged in random order for presentation by consulting a table of random numbers. Each subject was presented a unique random order of variables. Each variable was presented once every seven trials so each variable would be presented an equal number of times throughout the experiment. A data sheet, prepared prior to each experimental session, was used by the experimenter for purposes of recording judgments as well as for setting the variable stimuli. An example of the data sheet used for the light judgments appears in Appendix A. This portion of the experiment took approximately 15 minutes, with a two minute rest after the twentieth judgment.

Loudness judgments. After a five-minute break, during which she was allowed to leave the experimental room, the subject was assigned to a loudness group in the following manner: the experimenter tossed a coin to place the first subject; if the coin landed on heads, she was placed in the group hearing the fainter range of stimuli (Group I);however, if the coin landed on tails, she fell in the group hearing the louder range of stimuli (Group II). The second subject was automatically assigned to the other group. The third subject was assigned by the flipping of a coin again, and the fourth subject was assigned to the opposing group, and so on throughout the experiment until each group was finally composed of 18 subjects.

The subject returned to her former position and was read the following instructions:

> In this experiment several pairs of tones will be presented to you. Eabh tone will be heard for two seconds. The first of each pair is the standard to which an arbitrary loudness value of 10 is assigned.

This tone will remain the same throughout the experiment. The second of each pair is the variable and will differ from one pair to another. Your task is to estimate the loudness of the variable. In other words, the question is: if the standard is called 10, what would you call the variables? Use numbers that seem appropriate. For example, if the variable sounds seven times as loud as the standard, call it 70; if the variable sounds 1/5 as loud as the standard, call it 2, etc. After the variable has been presented, make your estimate and tell me what it is. Try not to worry about being consistent. Try to given the appropriate number to each tone regardless of what you may have called some previous one. You will be given five practice trials during which you will hear tones representative of the loudnesses that you will hear during the regular trials and which will also acquaint you with the procedure to be followed during the regular trials.

Practice trials consisted of variables (50, 25, 30, 45, 55 db) of stimulus intensity estimated in relation to a standard of 40 db for Group I (low group) and of variables (80, 55, 60, 75, 85 db) of stimulus intensity estimated in relation to a standard of 70 db for Group II (high group), all acoustic calibration being specified in decibels relative to normal threshold intensity.

During the regular trials, subjects in the "low" group made five judgments at each of seven levels (25, 30, 35, 40, 45, 50, 55 db) with a standard of 40 db, while each of the seven levels of intensity (55, 60, 65, 70, 75, 80, 85 db) with a standard of 70 db was the basis for 35 judgments made by the subjects in the "high" group. The order of presentation for the variables was determined according to the manner described above. Appendices B and C contain data sheets for the direct estimations of loudness.

This phase of the experiment took approximately 15 minutes, with a two-minute rest interpolated after the twentieth trial.

Cross-matches between the light and the tone. Immediately after the loudness judgments, the subject made 15 cross-modality matches between the illuminated disk and the pure tone. The following instructions were given to the subject:

> You have now completed the auditory portion of this experiment. There remain a few additional trials which involve a cross match between the brightness of the light and the loudness of the tone. I will present a light and a tone to you simultaneously for two seconds. If the tone seems as loud as the light is bright, then tell me; but, if you think the tone needs adjusting, tell me whether to make it louder or softer. Any questions?

In the initial presentation of each pair, the subject dealt with a tone of 55 db (a tone common to each group) and a light variable of either 0, 15, or 30 db. The variables were again presented in a unique random order for each subject, and the order of presentation was determined by the method previously described. Appendix D contains a data sheet for the cross-modality equations.

After the initial presentation of each pair, the experimenter adjusted the tone in five-decibel steps in accordance with the direction requested by the subject. After each adjustment by the experimenter, the two intensities were presented for another two-second interval to the subject. The physical intensity of the tone was recorded when the subject was satisfied that the two were equal psychologically.

Many times the subject naïvely anticipated the purpose of the experiment and asked if the light standard and the tone standard were to be considered as equal in making her equations. Care was taken not to suggest in any way that the subject was to make her matches on this basis, but it was emphasized that the task was to match the intensity of the sensations.

The procedure followed in this experiment was identical insofar as possible to that of recent studies using cross-modality equations as a means of validating intensity scales.

IV. RESULTS

To test the principal hypothesis of this experiment, the mean of the five equations at each level (0, 15, 30 db) employed in the cross-modality matching was obtained for each subject in the "high" and "low" groups. The means for each subject were used to obtain a mean representative of each group's equation at each stimulus level. The means for each group at each of the three levels of illumination are shown in Figure 1, page 17. The vertical lines mark off $\pm$ 1 σ about each mean. The next step in the analysis of the data was to find a single typical equation score for each group by finding the mean of the deviations from the over-all mean at each level. The results were 60.76 db for the "high" group and 53.28 db for the "low" group; and, a σ of 2.82 for the "high" group and a σ of 2.57 for the "low" group. A $\underline{t}$ test was used to determine the significance of the difference between the means of the two groups, and $\underline{t}$ was found to be 8.31 ($p < .0_5 1$). The results were thus highly significant, in a statistical sense.

Figure 2, page 18, graphically represents the direct estimations of the intensity of the sensations. Points along the graph represent the means of estimations at each level. The slope of each line, determined by the method of orthogonal polynomials, indicates the rate of growth of the intensity scale. The slope of the light line based on the judgments of 36 subjects is .50; the slope is .43 for the "high" group of sound (based on the judgments of 18 subjects), .40 for the "low" group of sound (based on the judgments of 18

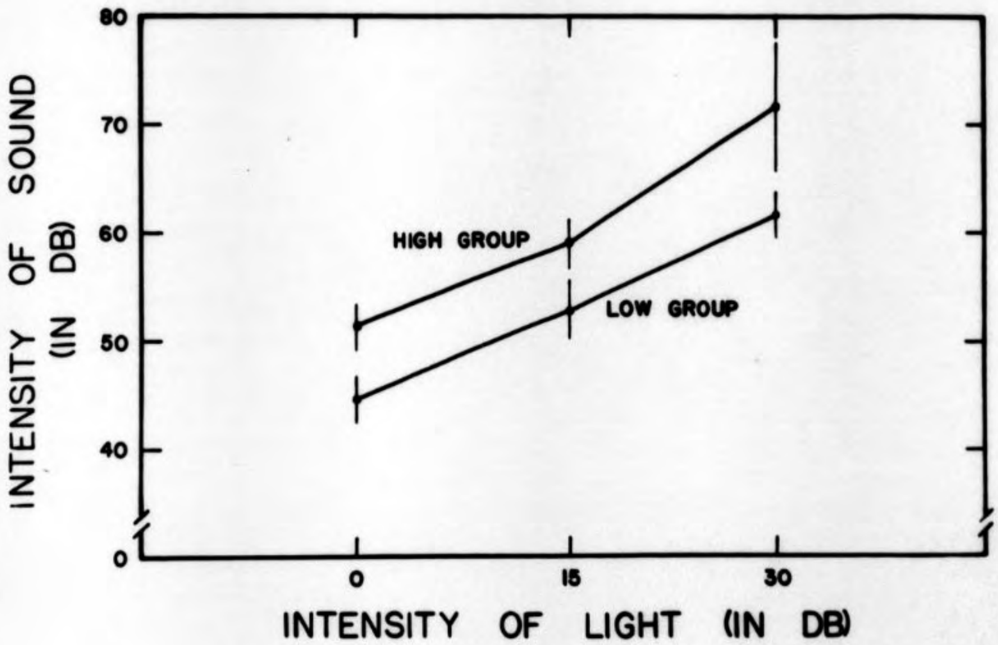

FIGURE 1

MEAN CROSS-MODALITY EQUATIONS FOR TWO GROUPS OF SUBJECTS

Cross-modality equations for two groups of subjects having previously made direct magnitude estimations on the basis of two different ranges of stimuli: "high" (55-85 db) and "low" (25-55 db). Each point represents the mean decibel level of sound required for equation at that illumination level. The vertical lines mark off one standard deviation above and below the mean.

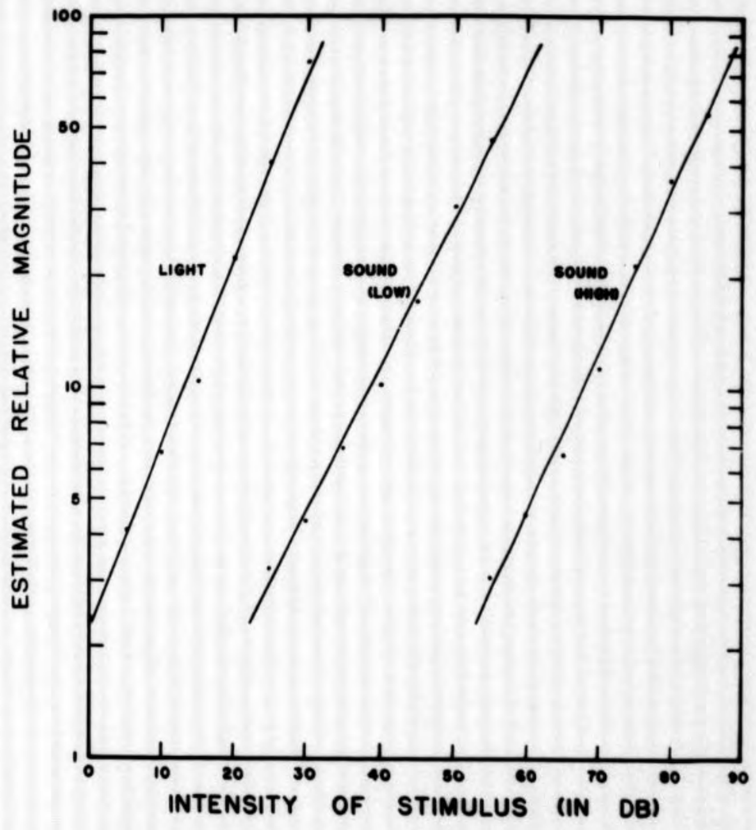

FIGURE 2

MEANS FOR DIRECT ESTIMATIONS OF APPARENT SENSORY MAGNITUDE

Subjects made 35 judgments of apparent sensory magnitude under three experimental conditions: light (N=36), low sound (N=18), and high sound (N=18). Points represent the mean estimation for all subjects at a given level of intensity. Slopes of lines (.50 for light, .40 for low sound, and .43 for high sound) represent the exponent value governing the growth of psychological magnitude.

subjects also). The slopes for the estimates of loudness are in terms of sound energy.

Table 1, below, contains results showing variation in slope among the magnitude functions generated by the individual subjects. The mean slope, standard deviation, and range are reported. The results for the loudness judgments are again in terms of sound energy.

TABLE 1
INDIVIDUAL VARIATION IN INTENSITY SCALES OBTAINED BY MAGNITUDE ESTIMATION

TYPE OF JUDGMENT	N	MEAN OF SLOPES	RANGE	σ
Light	36	.49	.24-.78	.11
Sound (high)	18	.42	.23-.60	.10
Sound (low)	18	.39	.18-.56	.11

V. DISCUSSION

When the hypothesis of this experiment was subjected to an empirical test, the results showed that context indeed appears to be an important factor in cross-modality investigations which attempt to validate scales of sensory magnitude. Tones of less intensity were typically used by subjects in the "low" group for cross-modality equations, while subjects in the "high" group consistently chose tones of higher intensities to make their equations. These results concerning the use of cross-modality equations in validating scales already obtained for growth of sensory magnitude supplement other data which imply that context effects are present in such experiments. Garner states that "O's do not know what they are doing (with respect to instructions), they do, in fact do something quite consistently, and judging from reliabilities [obtained in his experiment], feel quite sure that they know what they are doing."[13] This something that they are apparently doing is to assign numbers to variables by the rules the experimenter sets for them in relation to stimuli presented, rather than actually possessing any ability to use a set of numbers to determine a magnitude scale. Throughout this present experiment, the experimenter suspected that subjects were doing just this when they made the cross matches. Many of the subjects (as already indicated) asked the experimenter if they were to equate the auditory and visual stimulus in terms of

---

[13] Garner, op. cit., p. 222

the two standards they had observed in the direct estimations.

Furthermore, context effects appear to be potent, not only in the equations between the visual and auditory stimuli, but also in the direct estimations. The results show that the exponent values which relate the rate of the growth of sensory magnitude are larger than those obtained in previous experiments. Former studies show exponent values of 0.3 for loudness in terms of sound energy and 0.33 for brightness, while our results are somewhat higher.[14] This steepness of slope can perhaps be accounted for by the narrow range of intensities presented to the subject. Stevens states that the subject does two things when making this type of judgment: "he estimates the variable relative to a standard - as he is suppose to do, but he also weighs his judgment to a slight extent by a factor related to the absolute level of the variable tone."[15] If the range of intensities presented is narrow, then he will tend to overestimate at the high end of the range and underestimate at the low end. Thus, varying the standard or presenting a wider range of stimuli would perhaps flatten out the line in agreement with previously found power functions.

---

[14] Stevens, op. cit., p. 236.

[15] S. S. Stevens, "The Direct Estimation of Sensory Magnitude -- Loudness," American Journal of Psychology, LXIX, p. 7.

Finally, the variability in slopes demonstrated in this experiment is quite striking. Stevens has said,

> "Despite the considerable variability that attaches itself to numerical estimates of sensory effects, it seems clear that the typical, intelligent person can give meaningful estimates of relative subjective magnitude. Over and over again, the averages (geometric means or medians)[16] of groups of ten or so people have shown a great degree of stability whenever reasonable care had been taken to eliminate constraints and biases."[17]

Indeed, Stevens's procedure was followed almost identically, but individual differences did crop up which makes it seem unlikely that the slopes are necessarily typical of all individuals. This would seem to make Stevens's proposal of using magnitude estimation in detecting abnormalities in sensory abilities somewhat precarious.[18]

Where do these findings leave investigations of sensory magnitude which have used magnitude estimation as the method of determining magnitude and which have validated the scales obtained by cross-modality equations? It appears that our results are in strong agreement with Warren and Poulton, who conclude that "sensory transducers do not follow that simple power-function relating sensation to stimulus, but instead appear to be related to context, range of stimuli presented, and individual perceptual differences."[19]

---

[16] Medians, as well as means, were computed from the data in this experiment, but the difference between these two measures of central tendency did not warrant reporting both.

[17] S. S. Stevens, "Cross-Modality Validation of Subjective Scales for Loudness, Vibration, and Electric Shock," J. of Exper. Psychol., LVII, p. 207.

[18] Stevens, op. cit., "The Psychophysics of Sensory Function," p. 250.

[19] Warren and Poulton, op. cit., p. 386.

VI. CONCLUSION

The "reliability" of the results obtained in experiments of magnitude estimation and cross-modality equations of sensory processes appears not to be an indication of their "validity" on the basis of the results in this experiment. This investigation indicates that:

1) The context effect is operative in cross-modality equations used to validate scales of sensory magnitude.

2) Direct estimations of the growth of sensory magnitude also appear to be influenced by context.

3) Subjects vary widely in their judgments, further demonstrating that judgments appear to be perceptual rather than "characteristics of the sensory transducers."

BIBLIOGRAPHY

References:

BORING, E. G. Sensation and Perception in the History of Experimental Psychology. New York: D. Appleton-Century Company, 1942.

GARNER, W. R. "Context Effects and the Validity of Loudness Scales." Journal of Experimental Psychology, XLVIII (September, 1954), 218-224.

HELSON, HARRY. "Adaptation-level as a Frame of Reference for Prediction of Psychophysical Data." American Journal of Psychology, LX (January, 1947), 1-29.

MURPHY, GARDNER. An Historical Introduction to Modern Psychology. New York: Harcourt, Brace and Company, 1929.

OSGOOD, C. E. Method and Theory in Experimental Psychology. New York: Oxford University Press, 1953.

RICHARDSON, L. F. and ROSS, J. S. "Loudness and Telephone Current." Journal of General Psychology, III (April, 1930), 288-306.

STEVENS, S. S. "The Direct Estimation of Sensory Magnitude - Loudness." American Journal of Psychology, LXIX (March, 1956), 1-25.

___________. "Cross-Modality Validation of Subjective Scales for Loudness, Vibration, and Electric Shock." Journal of Experimental Psychology, LVII (April, 1959), 201-209.

___________. "The Psychophysics of Sensory Function." American Scientist, XLVIII (June, 1960), 226-253.

WARREN, R. M. and POULTON, E. C. "Basis for Lightness Judgments of Grays." American Journal of Psychology, LXXIII (September, 1960), 380-387.

WOODWORTH, R. S. and SCHLOSBERG, H. Experimental Psychology. New York: Henry Holt and Company, 1954.

Supplementary Readings:

HANES, R. M. "A Scale of Subjective Brightness." Journal of Experimental Psychology, XXXIX (August, 1949), 438-452.

LUCE, R. DUNCAN. "On Possible Psychophysical Laws." Psychological Review, LXVI (March, 1959), 81-95.

STEVENS, J. C. "Stimulus Spacing and the Judgment of Loudness." Journal of Experimental Psychology, LVI (September, 1958), 246-250.

__________, MACK, J. D. and STEVENS, S. S. "Growth of Sensation on Seven Continua as Measured by Force of Handgrip." Journal of Experimental Psychology, LIX (January, 1960), 60-67.

__________, and TULVING, E. "Estimations of Loudness by a Group of Untrained Observers." American Journal of Psychology, LXX (December, 1957), 600-605.

STEVENS, S. S. "Problems and Methods of Psychophysics." Psychological Bulletin, LV (July, 1958), 177-196.

__________, and GALANTER, E. H. "Ration Scales and Category Scales for a Dozen Perceptual Continua." Journal of Experimental Psychology, LIV (December, 1957), 377-411.

__________, and POULTON, E. C. "The Estimation of Loudness by Unpracticed Observers." Journal of Experimental Psychology, LI (January, 1956), 71-78.

WARREN, R. M. "A Basis for Judgments of Sensory Intensity." American Journal of Psychology, LXXI (December, 1958), 675-687.

__________, SERSEN, E. A. and PORES, E. B. "A Basis for Loudness Judgments." American Journal of Psychology, LXXI (December, 1958), 700-709.

WEVER, E. G. and ZENER, K. E. "The Method of Absolute Judgment in Psychophysics." Psychological Review, XXXV (November, 1928), 466-493.

APPENDIX

A. DATA SHEET FOR BRIGHTNESS JUDGMENTS

B. DATA SHEET FOR LOW LOUDNESS JUDGMENTS

C. DATA SHEET FOR HIGH LOUDNESS JUDGMENTS

D. DATA SHEET FOR CROSS-MODALITY EQUATIONS

APPENDIX A

DATA SHEET

✓ Brightness
____ Group I
____ Group II
____ Cross Match

SUBJECT'S NAME ____________________

Variables	(1) 0	(2) 5	(3) 10	(4) 15	(5) 20	(6) 25	(7) 30
10							
15							
20							
30							
5							
0							
25							
25							
20							
15							
0							
10							
5							
30							
10							
25							
30							
5							
15							
20							
0							
30							
5							
20							
25							
15							
10							
0							
0							
15							
10							
5							
2-							
25							
30							

APPENDIX B

DATA SHEET

_____ Brightness
__✓__ Group I
_____ Group II
_____ Cross Match

SUBJECT'S NAME ______________________________

Variables	(1) 25	(2) 30	(3) 35	(4) 40	(5) 45	(6) 50	(7) 55
30							
35							
55							
25							
50							
40							
45							
50							
25							
55							
35							
45							
40							
30							
55							
30							
50							
45							
35							
40							
25							
50							
45							
25							
40							
55							
30							
35							
40							
25							
35							
30							
55							
50							
45							

APPENDIX C

______	Brightness
______	Group I
✓	Group II
______	Cross Match

DATA SHEET

SUBJECT'S NAME ______________________________

Variables	(1) 55	(2) 60	(3) 65	(4) 70	(5) 75	(6) 80	(7) 85
60							
85							
55							
65							
80							
70							
75							
70							
75							
80							
85							
55							
60							
65							
60							
55							
80							
70							
65							
75							
85							
65							
75							
70							
85							
60							
80							
55							
65							
70							
55							
60							
80							
75							
85							

APPENDIX D

DATA SHEET

________ Brightness
________ Group I
________ Group II
__✓__ Cross Match

SUBJECT'S NAME ____

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
0							
15							
30							
0							
30							
15							
0							
30							
15							
30							
15							
0							
30							
0							
15							