The role of response processes in the formation of cross-modality assimilation effects¹

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The enhanced judgments of intensity of soft tones judged along with a series of bright lights (assimilation effect) was found to be dependent on the fact that the lights were judged coincidentally. This dependence was not observed in a parallel investigation of contrast effects in the judgments of tones alone. Both the form of the assimilation effect and its specific dependence on judging both stimulus modalities argues against a sensory explanation. Instead, it is argued that this cross-modality assimilation effect represents a resolution of the specific difficulties involved in judging two qualitatively different modalities on one judgment scale.

Anchoring or contextual effects in psychophysical judgments may take the form of either contrast effects or assimilation effects. The former occurs when the presentation of an anchor produces a shift in the judgment of control stimuli toward that portion of the judgment scale most distant from that used for judging the anchor. An assimilation effect occurs when the effect of the anchor is to move the judgments of the control stimuli toward the portion of scale used in judging the anchor.

The theory of adaptation level (Helson, 1964) offers a rather parsimonious explanation of contextual effects. This theory presupposes that scaled psychophysical judgments represent the distance of the stimulus from a point of sensory indifference (the adaptation level), based upon the S's experience with the focal stimuli, background stimuli, and residual stimuli from his previous contact with the stimulus domain. The effect of presenting an anchor is to shift the adaptation level toward the anchor. As the distance between the original set of stimuli and the adaptation level has changed, and the scale judgments are proportional to distance from the adaptation level, the judgments of these stimuli will shift toward the end of the scale opposite the anchor. Thus, high anchors decrease the judgments of scaled stimuli and low anchors increase them.

A difficulty with the adaptation-level analysis of context effects is that only contrast effects are predicted. On the other

hand, Sherif, Taub, and Hovland (1958) were able to obtain assimilation effects in the judgment of lifted weights when the anchoring stimulus was close to the series stimuli in value. Parducci and Marshall (1962), however, offered an explanation of this phenomenon congruent with adaptation-level theory. Rather than considering the anchor as simply one of the stimuli to be judged and finding the adaptation level as the assimilated effect of independent stimuli as did Sherif et al, the anchor was considered by Parducci and Marshall to be a standard in regard to which each comparison stimulus was evaluated. In the associated model for the production of the adaptation level in this latter case, values for the adaptation level were obtained such that Sherif et al's results were predictable as a contrast effect congruent with adaptation-level theory.

The difficulties in considering assimilation as an adaptation-level effect have been increased by the demonstration that assimilation effects may be obtained in cross-modal judgments. Bevan and Pritchard (1964) obtained a typical contrast effect in the judgment of soft tones when more intense tones were introduced as anchoring stimuli. However, the introduction of lights, previously matched in intensity to the loud tones, produced an assimilation effect in the judgment of the soft tones. They were judged louder in this condition than in a soft tone control condition.

In order to incorporate the assimilation effect into adaptation-level theory, Bevan and Pritchard interpret the anchor effect as a "paradoxical anchor effect." It is reasoned that cross-modal anchors are less potent than anchors within the same modality as the series stimuli. A less potent cross-modal anchor may be equivalent to selecting an anchor of lesser magnitude within the same modality. If the visual anchor is very low in potency, it may be equivalent to a tonal anchor below the series of tones presented for judgment. This would produce a contrast effect and increase the apparent magnitude of the soft series of tones. This is the finding obtained by Bevan and Pritchard.

In order to support the conclusion that the cross-modality assimilation effect is a sensory effect congruent with the

adaptation-level principles of psychophysical judgment, it is necessary to consider certain nonsensory processes that may have been involved in the Bevan and Pritchard study. The first consideration is the greater "attention load" that existed in the tone-light conditions as opposed to the tone-tone conditions. In the former condition, the S had to be prepared to respond to two sets of stimuli occurring in a random order.

The second consideration concerns the role of the S's denotation or labeling of the stimuli on the production of the assimilation effect. Although Bevan and Pritchard found equivalent effects in using a category scale labeled with specific reference to stimulus modality, as they did in using a scale categorized as intensity per se, the use of the relativistic, nonextensive category scaling procedure, regardless of category labeling, may lead to changes in slope and level of the psychophysical function (Krantz & Campbell, 1961; Campbell, Lewis, & Hunt, 1958; Fillenbaum, 1962; Harvey & Campbell, 1963; White, 1963; Melamed, 1966). Furthermore, the possibly greater difficulty of establishing a range of categories to serve as the basis for distributing one's judgments on a common scale, when stimuli are presented from two modalities, may result in a change in the S's strategy or approach to the scaling task as compared to the single modality control condition of the cross-modality paradigm.

The present study was designed to investigate the contribution of the nonsensory factors discussed above to the cross-modality assimilation effect. Thus, the judgment language for all conditions was a maximally extensive, situationally independent number language. In effect, the S was told to use any number she chose to describe the intensive characteristics of the stimulus. Before beginning the task, the S was presented a previously matched tone and light or a tone alone, depending on the condition, that was called "100." This was done to ensure that the S had a sufficient population of numbers to draw from and also to reduce the inherent variability in her selection of numbers. The effect on the formation of the assimilation effect of having the response language extend to both the tone and light series was

Table 1
Experimental Design

Stimuli	Tone-Light I ($T_s + L_b$)	Tone-Light II ($T_s + L_b$)	Tone Control ($T_s - \text{Dark}$)
A. Cross-Modality Assimilation Effect			
High Intensity	128, 53, 19.5 74 F ₁ L (Lights)	128, 53, 19.5 7.4 F ₁ L (Lights)	Only low tones presented Room dark
Low Intensity	41, 36, 31, 26 dB (Tones)	41, 36, 31, 26 dB (Tones)	41, 36, 31, 26 dB (Tones)
	Tone Experimental I ($T_s + T_1$)	Tone Experimental II ($T_s + T_1$)	Tone Control ($T_s - \text{Light}$)
B. Within Modality Contrast Effect			
High Intensity	86, 81, 76, 71 dB	86, 81, 76, 71 dB	Only low tones presented Room light
Low Intensity	41, 36, 31, 26 dB	41, 36, 31, 26 dB	41, 36, 31, 26 dB

investigated by comparing the obtained judgments of the soft tones, when judged along with a series of bright light anchors, to the judgments of the tones obtained when the lights were presented but not judged. In order to determine the uniqueness of the judgment functions derived from cross-modality judgments, two tone-tone groups were used in which the stimulus structure and judgment procedures paralleled those in the two tone-light experimental groups.

METHOD

Table 1 presents the experimental design and the values of the stimuli. Essentially, there were two parallel experiments. In the within-modality contrast-effect experiment, there were three groups. The first group was a control group (T_s -light), in which the Ss were presented four soft tones (T_s) of 1,000 Hz for judgment of intensity. The word "light" indicates that the judgments were made with the lights on in the experimental room, as they were for all conditions in the first experiment. There were 24 presentations of each stimulus. An experimental group, designated ($T_s + T_1$), was presented both the soft-tone set and a set of four loud tones (T_1). There were 12 trials for each of these stimuli. Finally, there was a second experimental group, designated ($T_s + \bar{T}_1$), who were presented exactly the same stimuli as in the first experimental group, but who judged only the soft-tone set. The bar above the T_1 is used to indicate the fact that the loud tones were not judged. The loud tones were responded to in the manner of a simple reaction time task. An "X" on the response sheet indicated to the S that a loud tone would occur and that she was to press the response button as quickly as she could to its onset and keep it depressed as long as the tone was on.

The second experiment, the cross-modality assimilation effect paradigm, involved a comparison of three

groups directly comparable to those of the contrast effect experiment. Thus, there were a control group who received the soft-tone set and two experimental groups who received both the soft tones and a series of bright lights (L_b) that had previously been matched in intensity to the loud tones. The matched light values presented in Table 1 were selected on the basis of a pilot study involving 12 Ss, in which a modified method of limits was used to obtain matches between the light intensities and the four loud tones of the loud-tone set and an additional 56-dB standard. In the first experimental group ($T_s + L_b$), the Ss judged both the bright lights and the soft tones in intensity. In the second experimental group ($T_s + \bar{L}_b$), only the soft tones were judged, whereas the lights were responded to in the reaction time task. All judgments were made in the darkened experimental room in this condition. The instructions for all groups were of equal length, as were the preexperimental dark adaptation intervals.

The judgment task for both experiments involved an absolute and extensive response language that resembles magnitude estimation, except for the lack of reference to ratios of sensation. In this method, the S is essentially told to use any number she wishes to describe the intensity of the tone or of the light. The S is given a standard tone (56 dB) or both a tone and a light (1.75 fL) before the presentation of the comparison stimuli, which are said to represent "100" on a common scale of intensity.

A total of 90 female Ss participated in the experiment and were given experimental credit for the introductory psychology course. Fifteen Ss were assigned to each condition for both experiments.

RESULTS

In the following data analysis, all comparisons involve a mixed design consisting of one between factor, groups,

with repeated measurements over two variables, the 12 trials and the four tones of the soft-tone set. All significance levels applied to within S are conservative estimates based on the Geisser-Greenhouse correction procedure (Myers, 1966, p. 162). Conservative tests were used due to the likelihood of heterogeneity of covariance associated with the comparisons involving tones. Since the within-S factor, "tones," was significant beyond the .001 level for all comparisons throughout the entire experiment, it will not be reported below.

Within-Modality Contrast Effect

The analysis of the within-modality contrast effect involves a comparison of the two experimental groups, ($T_s + T_1$) and ($T_s + \bar{T}_1$), who were presented both the loud- and soft-tone series, and a control group, (T_s -light), who were presented only the soft tones. A contrast effect exists in the judgments of the two experimental groups to the extent that the soft-tone series is judged softer than in the control condition. The average judgments of the four soft tones for the three groups are shown in Fig. 1. Each data point is an average of the 12 trials for each tone. It is clear from Fig. 1 that the concurrent presentation of the loud- and soft-tone series produced a large downward shift in the judged loudness of the soft-tone series in both experimental groups even though, in the case of Group ($T_s + \bar{T}_1$), the loud tones were not judged. The analysis of the group main effect was significant [$F(2,42) = 7.01, p < .01$] as was the Groups by Tones interaction [$F(6,126) = 10.26, p < .01$]. This latter finding is evidenced in Fig. 1 by the increases in the contrast effect that accompany increases in the intensity of the soft tone judged. Thus the contrast effect was largest for those soft tones nearest the loud series in intensity.

A subsequent analysis of the group differences in the judgment of the soft tones was performed using Fisher's least significant difference (LSD) test. In using this test, T tests are performed on pairs of means subsequent to a significant between-groups main effect in the analysis of variance. The judgments of the control group (T_s -light) were significantly larger than the ($T_s + T_1$) group [$T(42 \text{ df}) = 3.92, p < .01$] and the ($T_s + \bar{T}_1$) group [$T(42 \text{ df}) = 3.96, p < .01$]. The difference between the experimental groups was not significant [$T(42 \text{ df}) = .05$]. In fact, there were no significant differences between these two groups at any stimulus level.

Cross-Modality Assimilation Effect

This analysis involves a comparison of

Fig. 1. The lines connecting the circles depict the effect of concurrent loud (T_l) tones on the loudness judgments of a set of soft (T_s) tones. Three groups are represented: A group that judged both loud and soft tones ($T_s + T_l$); a group that was presented the same test series but judged only the soft tones ($T_s + \bar{T}_l$); and a control group that was presented only soft tones under the same illuminating conditions as the other groups (T_s -light). The lines connecting the black dots represent the effect of concurrent bright lights (L_b) on the loudness judgments of the soft-tone set. Again, three groups are represented: A group that judged both the lights and soft tones ($T_s + L_b$); a group presented both sets of stimuli but who judged only the soft tones ($T_s + \bar{L}_b$); and a control group which was presented only soft tones under the same conditions as the other two tone-light groups (T_s -dark).

the two experimental groups ($T_s + L_b$) and ($T_s + \bar{L}_b$) and the control group (T_s -dark). Evidence for the assimilation effect would consist of an increase in the judged loudness of the soft tones when presented within the series of lights and tones in the experimental groups.

It is evident from Fig. 1 that the loudness ratings of the ($T_s + L_b$) group are considerably above the level of the other two groups in this experiment. An analysis of the differences between all these groups in their judgments of the soft tones revealed a significant group effect [$F(2,42) = 7.73, p < .01$] and a significant Groups by Tones interaction [$F(6,126) = 4.89, p < .025$]. This latter finding reflects the increased assimilation

effect for the higher-intensity tones within the soft-tone set. Thus, as was the case in the contrast-effect analysis, the assimilation effect was greatest for those stimuli closest in value to the high-intensity set of stimuli.

A pairwise comparison of the group differences, using the Fisher LSD test, indicated that the soft tones were judged significantly louder in the ($T_s + L_b$) group than in either the control condition [$T(42 \text{ df}) = 3.64, p < .01$] or the ($T_s + \bar{L}_b$) condition [$T(42 \text{ df}) = 2.78, p < .01$]. The ($T_s + \bar{L}_b$) experimental group and the (T_s -dark) control condition were not significantly different in their judgments of the soft tones [$T(42 \text{ df}) = .83$]. A further analysis between these two groups at each stimulus level failed to find any significant differences.

Additional Comparisons

An analysis of variance between the judgments of the (T_s -light) and (T_s -dark) conditions, for Trials 1-12, failed to find any overall group differences [$F(1,28) = .13$] or a significant Group by Tone interaction [$F(3,84) = .26$]. Furthermore, there were no overall or differential effects involving trials. Thus the two control groups were quite comparable in their loudness judgments.

DISCUSSION

In the present experiment, a significant assimilation effect was obtained with a more extensive judgment language than was used by Bevan and Pritchard (1964). Thus, the assimilation effect is not a simple effect of the restrictiveness of the category judgment language. Nor did specific sensory fatigue or arousal effects seem important in the formation of the assimilation effects. The assimilation effect was not an artifact of a depressed performance of fatigued Ss in the (T_s -dark) control condition. The judgments of the (T_s -dark) group were not different in level, form, or changes, over trials from the judgments of the (T_s -light) group. It is unlikely that the bright lights served as an "arousal" factor for the facilitation of auditory sensitivity. The bright lights were only effective in producing the assimilation effect when they were judged. The mere exposure of the S to the lights was ineffective in changing their judgments of soft tones.

It is interesting to note that the dependence of the assimilation effect upon the experimental group's usage of the response language was a unique effect and did not occur in the within-modality contrast-effect paradigm. Thus, comparable contrast effects were obtained in the ($T_s + T_l$) and ($T_s + \bar{T}_l$) groups. This unique

dependence of the cross-modality assimilation effect on the use of judgment language is contradictory to a sensory and, thus, to an adaptation-level-theory interpretation of its dynamics. Furthermore, the form of the assimilation effect argues against Bevan and Pritchard's interpretation of it as a "paradoxical contrast effect" where the lights serve as weak anchors below the tonal series. In the present study, the assimilation effect was greatest for those tones closest to the lights in intensity (41 and 36 dB), while it was not significant for the softest tone. The Ss seemed to be extending their judgments of the soft tones upwards towards the range of judgments used for the bright lights. On the other hand, the form of the contrast effect in the tone-tone conditions was what would be expected with the introduction of the loud tones. The soft tones closest to the loud tones in intensity showed the greatest downward shift in judgments in comparison to the soft control group.

The cross-modality assimilation effect may be viewed as a strategy adoption on the part of the S for resolving the difficulty involved in judging two qualitatively different modalities on one judgment scale. In the assimilation-effect paradigm, where both soft tones and bright lights are presented, the 26- and to some extent the 31-dB tones, the softest presented, and the 128- and to some extent the 53-fL lights, the brightest presented, serve as natural end anchors in the S's production of her psychological range of stimuli for judgment on the common scale of intensity. However, the 41- and 36-dB tones and the 19.5- and 7.4-fL lights no longer serve as end points for the psychological scale of intensity. The S must now make judgments across both modalities using a single common scale. This produces an added dimension to the judgment task that does not exist in the within-modality contrast effect paradigm. The S must first attempt to relate the concept of intensity, the scaling dimension, to both brightness and loudness. The S must essentially do her own cross-modality match between the two dimensions.

One strategy that the S may adopt in resolving this unique feature of the cross-modal judgment task would be to use a simple compromise in the formation of the psychological midpoint of the scale of intensity. The midpoint would be raised in regard to the tones and lowered in regard to the lights. Thus the 41-dB tone would be judged greater in intensity when presented along with bright lights than in the control group. Similarly, the 7.4-fL light would be judged less intense than when presented with the lights alone. The change would be somewhat less for the

36-dB tone and 19.5-fL light. The fact that the assimilation effect was greatest for the 41-dB tone and that the assimilation effect only occurred when both modalities were judged may indicate the adoption of this strategy by the Ss. It may indicate that the Ss were primarily attempting to produce a common scale in the cross-modal judgment task. There is, of course, no evidence obtainable from this study to support the notion that the lower range of the light stimuli were being judged in a manner consonant with the compromise hypothesis. The absence of a light-judgment-alone group makes for an inability to detect changes in the judgment of the 7.4-fL light that would be predicted for the (T_s+L_b) group, given the compromise hypothesis.

It is interesting to note that in further evaluating certain conditions used by Bevan and Pritchard in exploring the cross-modal assimilation effect, data were obtained that are consistent with the present evaluation of the assimilation effect. Bevan and Pritchard not only used an experimental group who were presented bright lights of matched intensity to a set of loud tones but also two additional groups who received the soft tones plus either lights moderately more intense than the matched light group or extremely brighter. They were able to convert the assimilation effect into a contrast effect by considerably increasing the intensity of the lights over the initial matched levels. This is consistent with their interpretation of the assimilation effect as a paradoxical contrast effect in which lights are considered equivalent to weak tonal anchors. As the intensity of the lights is increased, the lights should become equivalent to more intense "tonal" anchors and thus an apparent assimilation effect can be converted into a clear contrast effect. Two features of the data are clearly inconsistent with this interpretation. As the lights were increased in apparent brightness, the range of judgments of the concomitantly presented soft tones expanded. In fact, when the lights were extremely bright, the range of judgments for the soft tones was almost identical to that of the soft controls although the judgments were significantly lower (3.6 scale units for the experimental group and 3.8 units for the controls). A constriction in the range of judgments, as was found in the present study, most frequently occurs with the contrast effect. Secondly, this contrast effect with the conjoint presentation of the extremely bright lights and soft tones was uniform for the softest and loudest tones of the soft-tone series: approximately 1.1 scale

units of the lowest tone and 1.3 for the loudest. The anchoring effect is typically much greater for those stimuli closest to the anchors in intensity (loud or bright lights) as was found in the present study.

These two features of Bevan and Pritchard's data are consistent with the interpretation that the cross-modality assimilation effect specifically represents a resolution of the difficulty involved in judging two sensory modalities on a common scale. The "compromise" hypothesis was evolved for the data of the present study to explain the S's tendency to extend their range of judgments of the soft tones upwards toward the range used for the bright lights when the two modalities are judged conjointly. Similarly, in Bevan and Pritchard's results, the correlated expansions of the range of judgments of the soft tones as the intensity of the bright light anchors increases and the uniform nature of the contrast effect obtained may indicate the terminal point for the application of an equivalent process by their Ss. Thus, as the lights are made extremely more intense in comparison to the intensity of the tones, the necessity for evaluating and comparing both stimulus modalities in determining the psychological midpoint of the scale of judgment disappears. Essentially, the scale may be split into two clearly distinct parts, the upper of which serves for the judgment of the lights, the weakest of which is clearly bright, and the lower division for the judgments of the soft tones. The fact that the contrast effect occurs at all could be due to a redistribution of the verbal referents for the soft tones as compared to those judgments made by the control Ss (Stevens, 1958). Thus none of the soft tones are moderately intense in comparison to the brightness of the lights and the judgments of the entire set of soft tones would have to shift downwards in the experimental group.

There is evidence³ that Ss in the contrast effect paradigm, whether using a category or number response language, are redefining the verbal or numerical referents for the soft tones when they are presented along with loud tones. This in itself could be sufficient in producing both the form and level of the contrast effect. Two sources of evidence in opposition to a sensory interpretation of the contrast effect were found. First, the effect reaches its maximum within two trials after the initial presentation of soft and loud tones and is extremely constant from that point. It seems unrelated to the frequency of category usage as would be expected from Parducci (1965). Secondly, there is no

evidence of a concurrent differential decrement in threshold when loud tones rather than soft are presented to the ear. The threshold increases slightly (nonsignificantly) in both cases. Thus the deflated judgments of the loudness of the soft tones would not seem to be produced by some simple sensory reflex such as the middle ear reflex.

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NOTES

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