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# Intermodal transfer in temporal discrimination

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This study determined if training for accuracy in temporal discrimination would transfer across sensory modalities. A fractionation method was used in which subjects bisected the durations of acoustic and visual signals at three standard intervals (6, 12, and 18 sec). Absolute error was the performance index. Half of the subjects were trained with acoustic stimuli and then tested in vision; the remainder were trained in vision and tested in audition. Similar negatively accelerated acquisition functions were noted for both modalities. Positive intermodal transfer, characterized by symmetry across modalities, was obtained at all standard durations. The results were considered to provide support for the notion that a common mechanism underlies temporal discriminations in different sensory systems.

Several investigations have demonstrated that the accuracy of temporal discriminations can be improved by controlled practice or practice with correction (Aiken, 1965; Bakan, Nangle, & Denny, 1959; Robinson, 1963; Schoeffler & Poole, 1967; Taber, Homme, & Csanyi, 1961). Implicit in these studies is the assumption that such improvement is mediated by some centrally determined information processing mechanism and, consequently, the role of peripheral sensory factors in this form of perceptual learning has not been examined. Yet, the sensory modality used for stimulus delivery is a salient factor in the processing of temporal information, particularly in regard to audio-visual forms of input.

Audition has been found to be superior to vision in terms of the accuracy of temporal judgment (Goodfellow, 1934; Tanner, Patton, & Atkinson, 1965) as well as in the organization of temporal patterns (Garner & Gottwald, 1968). Acoustic intervals also tend to be judged as longer than visual intervals (Behar & Bevan, 1961; Goldstone & Goldfarb, 1966) and similar variations in stimulus parameters do not necessarily produce identical changes in the perception of time in the auditory and visual modes (Behar & Bevan, 1961; Goldstone & Goldfarb, 1963; White & Lichtenstein, 1963). These sensory differences are difficult to explain, but they are pervasive. Accordingly, one aspect of this investigation was to explore the influence of the sensory modality of signals on the modification of temporal discriminations with practice.

Intermodal transfer—the degree to which perceptual skills acquired through one sense modality will influence performance in another modality— is a critical topic in perceptual learning (Gibson, 1969). This issue has particular relevance for temporal perception in light of a review of the ontogenesis of timing behavior by Goldstone and Goldfarb (1966). They have suggested that audition may be dominant over vision in learning temporal discriminations and that intermodal transfer of timing skills may be greater from audition to vision than in the opposite direction. These investigators described the results of an experiment involving categorical judgments of the durations of intervals ranging from 0.15 to 1.95 sec, which provides some support for their position. For both children and adults, an initial experience with auditory stimuli reduced the variable error of later visual judgments. In contrast, an encounter with visual stimuli had no effect on the variable error of subsequent auditory judgments.

To date, Goldstone & Goldfarb's (1966) report constitutes the single experimental effort to explore intermodal transfer in the discrimination of unitary stimulus durations. A second aspect of the present study was to extend this line of investigation using a different spectrum of intervals and a different psychophysical technique.

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## METHOD

### Subjects

Sixty men served as subjects. They ranged in age from 18 to 27 with a mean of 22 years. All subjects were from psychology classes at the University of Cincinnati; none had served previously in an experiment involving temporal discrimination.

### Experimental Design

Three standard intervals (6, 12, and 18 sec) were used in combination with the two sensory modalities (audition and vision). The experimental session was divided into three phases; pretraining, training, and transfer. Ten subjects were assigned at random to each of six experimental groups defined by the sensory modality and standard interval used in each phase. These groups are outlined in Table 1.

Groups AV-6, AV-12, and AV-18 experienced pretraining and training trials with acoustic signals and were tested during the

**Table 1**
**Sensory Modalities and Standard Intervals Employed During the Pretraining, Training, and Transfer Phases for All Groups**

| Group | Standard Interval (Sec) | Pre-training Mode | Training Mode | Transfer Mode |
|---|---|---|---|---|
| AV-6 | 6 | Audition | Audition | Vision |
| AV-12 | 12 | Audition | Audition | Vision |
| AV-18 | 18 | Audition | Audition | Vision |
| VA-6 | 6 | Vision | Vision | Audition |
| VA-12 | 12 | Vision | Vision | Audition |
| VA-18 | 18 | Vision | Vision | Audition |

transfer phase with visual stimuli. Groups VA-6, VA-12, and VA-18 experienced visual signals during the pretraining and training phases and were tested with acoustic stimuli during transfer. For each group, the standard interval remained constant throughout all phases of the session.

### Apparatus and Procedure

Acoustic stimulation was the output of a Grason-Stadler white-noise generator fed to subjects binaurally via headphones. The visual stimulus consisted of a circular spot of orange-colored light, 5 mm in diam, centered on a 7.62 x 7.62 cm white screen which, in turn, was centered on a 30.48 x 30.48 cm flat-black panel. The brightness of the light was 10 fL. The visual display was mounted on a table, slightly below eye level, approximately 71 cm from the seated subject.

Temporal judgments were secured by means of a fractionation procedure in which subjects were required to bisect the standard interval presented to them. The bisection task was chosen as one which would be relatively unfamiliar to the subjects and which would minimize the need to resort to conceptualized time units in making temporal discriminations. The subject initiated each trial by pressing a push-button switch mounted in the panel housing the visual display. Immediately thereafter, an auditory or visual signal was presented for the appropriate standard duration. Two seconds after the termination of the standard interval, the signal automatically reappeared; the subject then terminated the signal, by pressing a second push-button switch on the visual display panel, when he felt that half of the duration of the standard had been reached. The value of the subject's bisection response was read to the nearest .01 sec from a Standard Electric Model S-1 timer which was activated automatically at the start of the bisection portion of the trial and deactivated by the subject's response. All timing sequences were controlled by a bank of Hunter (Model 111-C) decade interval timers.

Each subject was run individually in a small, windowless room. Ambient illumination was provided by a single 25-W bulb mounted in a wall fixture in front of, and above, the subject. The bulb was shaded so that its light was indirect. The control equipment and the experimenter were located in an adjacent room; voice communication was maintained through an intercom.

At the start of each session, the subject was required to match the loudness of the acoustic stimulus to the brightness of the circular spot of light by means of a cross-modal matching procedure (Stevens, 1960). Afterwards, he received four blocks of five pretraining trials, six blocks of five training trials, and four blocks of five transfer trials with the sensory-modality/standard-duration combination appropriate for his experimental group. The intertrial interval within each block of trials was 15 sec. Subjects were permitted a 20-sec rest between every two blocks of trials and whenever else they requested it. Feedback or corrective information regarding performance efficiency was provided during the training phase and only during this phase. Feedback was given by verbal report in terms of whether the subject's bisection response was too short or too long to the nearest .01 sec. Experimental sessions lasted for approximately 1 h and 30 min.

The subjects were required to surrender their watches at the start of the session and they were instructed to try not to count or tap or attend to respiration or heart rate during any trial. They were also informed that perfect accuracy on any trial was unlikely but that they should strive to keep errors as small as possible. A prize of $15 was offered for the best performance in each experimental group.

## RESULTS

Means of median bisection scores were computed from the data of each subject for each block of trials during the three phases of the experiment. Inspection of these scores revealed that the magnitude of bisection was greater than that required for perfect accuracy (one half the standard interval) at all stimulus durations. While the disparity between the absolute value of bisection and perfect accuracy increased with increments in the duration of the standard, there were no consistent trends in the direction of this difference over the range of 6-18 sec. Consequently, since response accuracy was the primary concern in this investigation, absolute error (the difference between one-half the standard interval and the bisection response disregarding algebraic sign) was used as the index of performance.

For each subject, the median absolute error of bisection was computed for each block of trials during the three phases of the experiment. Table 2 presents the means of median absolute errors and their corresponding standard deviations for each treatment combination during each phase of the study.

### Pretraining

In order to provide a clearer view of trends in the data, means of median absolute errors during the pretraining and training phases are plotted in Figure 1 as a function of blocks of trials. Sensory modality is the parameter. The data for the three standard intervals are presented separately in each panel.

An analysis of variance of the pretraining scores revealed that accuracy of bisection depended upon the standard interval, $F(2,54) = 10.98$, $p < .001$. It is evident in Table 2 and in the figure that the magnitude of absolute error in judgment during the pretraining phase increased with increments in the intervals to be bisected. Response accuracy did not change systematically across blocks of trials, $F(3,162) = 1.45$, $p > .05$, and there were no significant differences between sensory modalities ($F < 1$). All of the interactions in the analysis also lacked significance ($F < 1$ in each case).[1]

### Training

In order to assess the effects of training with corrective information, comparisons were made among the final block of pretraining trials and the six blocks of training trials for auditory and visual judgments at each standard interval. The data of the

**Table 2**
**Means and Standard Deviations of Absolute Errors for Auditory and Visual Judgments at Three Standard Intervals for Each Block of Trials During the Pretraining, Training, and Transfer Phases**

| | | | Blocks of Trials | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| Phase | Interval (sec) | Mode | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Pre-training | 6 | Audition | .52 | .28 | .45 | .27 | .40 | .30 | .48 | .25 | | | | |
| | | Vision | .75 | .45 | .77 | .46 | .57 | .40 | .56 | .26 | | | | |
| | 12 | Audition | 1.13 | .73 | 1.10 | .81 | .91 | .70 | .94 | .68 | | | | |
| | | Vision | .76 | .30 | .76 | .47 | .70 | .40 | .64 | .35 | | | | |
| | 18 | Audition | 1.76 | 1.28 | 1.94 | 2.07 | 1.77 | 1.51 | 2.17 | 2.15 | | | | |
| | | Vision | 1.39 | 1.14 | 1.99 | 1.44 | 1.42 | 1.04 | 1.47 | .83 | | | | |
| Training | 6 | Audition | .36 | .28 | .32 | .15 | .31 | .17 | .21 | .09 | .27 | .18 | .27 | .14 |
| | | Vision | .30 | .15 | .34 | .20 | .32 | .13 | .33 | .15 | .33 | .24 | .30 | .12 |
| | 12 | Audition | .61 | .35 | .46 | .31 | .66 | .32 | .58 | .46 | .48 | .37 | .42 | .24 |
| | | Vision | .73 | .30 | .43 | .13 | .48 | .30 | .41 | .23 | .39 | .18 | .39 | .22 |
| | 18 | Audition | 1.06 | 1.14 | .68 | .41 | .84 | .46 | .61 | .52 | .55 | .38 | .69 | .35 |
| | | Vision | .95 | .50 | .99 | .61 | 1.04 | .88 | .85 | .70 | .53 | .27 | .61 | .29 |
| Transfer | 6 | Audition | .21 | .16 | .35 | .14 | .38 | .15 | .39 | .18 | | | | |
| | | Vision | .35 | .22 | .35 | .21 | .37 | .14 | .33 | .19 | | | | |
| | 12 | Audition | .68 | .59 | .56 | .40 | .59 | .32 | .47 | .33 | | | | |
| | | Vision | .87 | .51 | .56 | .32 | .58 | .57 | .57 | .30 | | | | |
| | 18 | Audition | 1.24 | 1.10 | .98 | .80 | .84 | .65 | .98 | .47 | | | | |
| | | Vision | 1.09 | 1.15 | .89 | 1.05 | 1.09 | .78 | .75 | .45 | | | | |

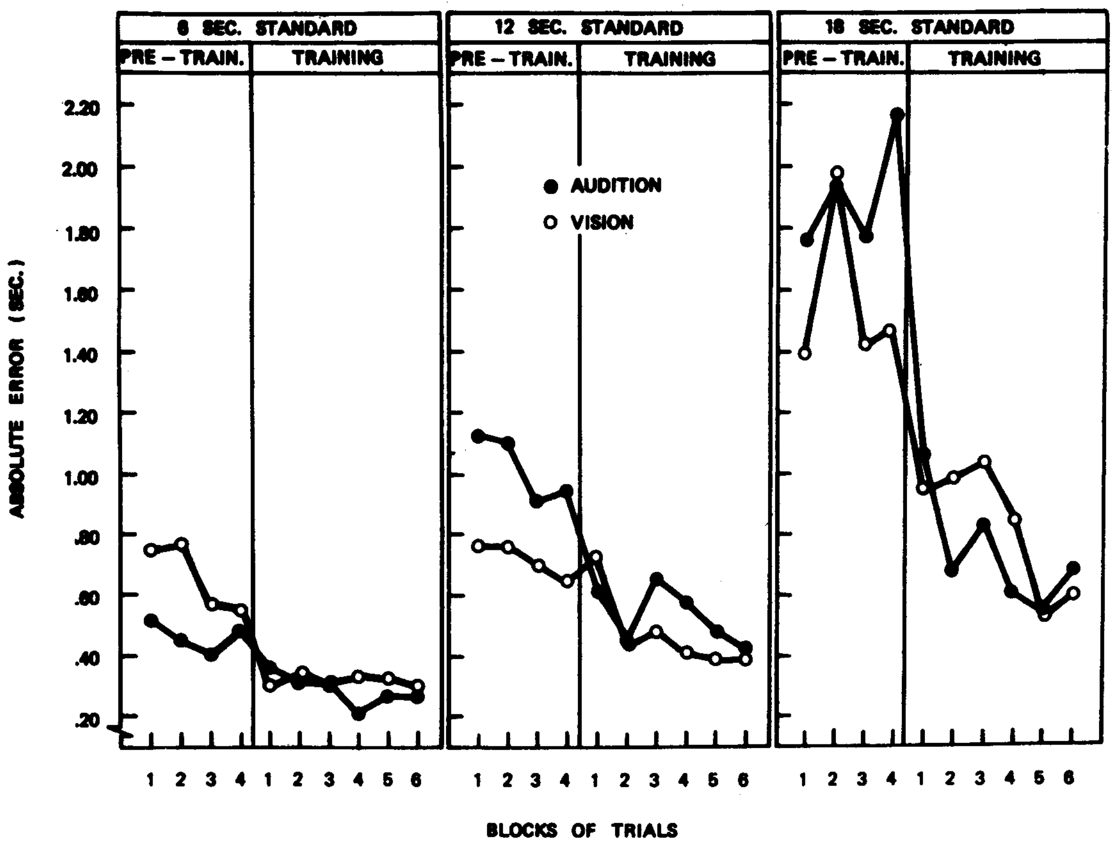


Figure 1. Absolute errors for auditory and visual judgments during pretraining and training. Data are plotted as a function of blocks of trials at three standard intervals.

three factors (blocks of trials, modes, and intervals) were subjected to an analysis of variance. Significant differences were found between blocks of trials, $F(6,324) = 13.05$, $p < .001$, and between intervals, $F(2,54) = 19.18$, $p < .001$, and there was a significant Blocks by Intervals interaction, $F(12,324) = 3.43$, $p < .001$. No significant differences were noted between sensory modalities ($F < 1$), and all interactions involving modality also lacked significance ($p > .05$ in each case). Figure 1 reveals that for both audition and vision, accuracy of bisection tended to improve at all intervals with the greatest absolute amount of improvement occurring at the two longer durations. At each interval, the rate of improvement in accuracy was negatively accelerated; the greatest gains occurred early in practice.

**Transfer**

Intermodal transfer effects were evaluated by comparing response accuracy during the pretraining and transfer phases of the study. Preliminary inspection of the transfer scores revealed that accuracy remained unchanged across the four blocks of transfer trials for all combinations of modality and interval. This lack of systematic change over blocks was similar to that noted during pretraining. Consequently, the data for both phases were collapsed across blocks for the individual subjects. Pretraining-transfer comparisons were based upon each subject's median absolute error scores for the entire pretraining and transfer phases.

Transfer from audition to vision was assessed by comparing the pretraining scores of groups VA-6, VA-12, and VA-18 with the transfer data of groups AV-6, AV-12, and AV-18, respectively. Means of median absolute errors for the pretraining and transfer phases with visual signals are presented in the right panel of Figure 2. The data are plotted as a function of standard interval.

An analysis of variance of these data indicated that positive transfer from audition to vision was obtained; absolute errors during the transfer phase were significantly smaller than during the pretraining phase, $F(1,54) = 5.12$, $p < .05$. As in the other analyses, standard interval was a significant source of variation, $F(2,54) = 10.09$, $p < .001$. However, there was no significant Phase by Interval interaction, $F(2,54) = 1.09$, $p > .05$.

Visual-to-auditory transfer was assessed by comparing the pretraining scores of groups AV-6, AV-12, and AV-18 with the transfer scores of groups VA-6, VA-12, and VA-18, respectively. Means of median absolute errors for the pretraining and transfer phases with acoustic signals are plotted as a function of standard interval in the left panel of Figure 2. An analysis of variance of these data indicated that positive transfer was also obtained in the visual to auditory direction. The magnitude of absolute errors during the transfer phase was significantly smaller than during the pretraining phase, $F(1,54) = 6.24$, $p < .025$. Once again, response accuracy was significantly related to standard interval, $F(2,54) = 9.76$, $p < .001$. The figure shows a tendency for the difference between the pretraining and transfer phases with acoustic signals to increase with increments in the duration of the standard interval. However, the Phase by Interval interaction also failed to reach significance in this case, $F(2,54) = 1.29$, $p > .05$.[2]

Directional differences in intermodal transfer can be probed by comparing the data for audio-visual *transfer* in the right panel of Figure 2 with the data for visual-auditory *transfer* in the left panel. It is evident that during the transfer phase response accuracy was practically identical for the two modalities at each standard interval. Since the modes did not differ significantly prior to, or during training, the continued similarity in the accuracy of auditory and visual judgments during the posttraining phase of the study indicates that transfer effects were symmetrical across sensory modalities.

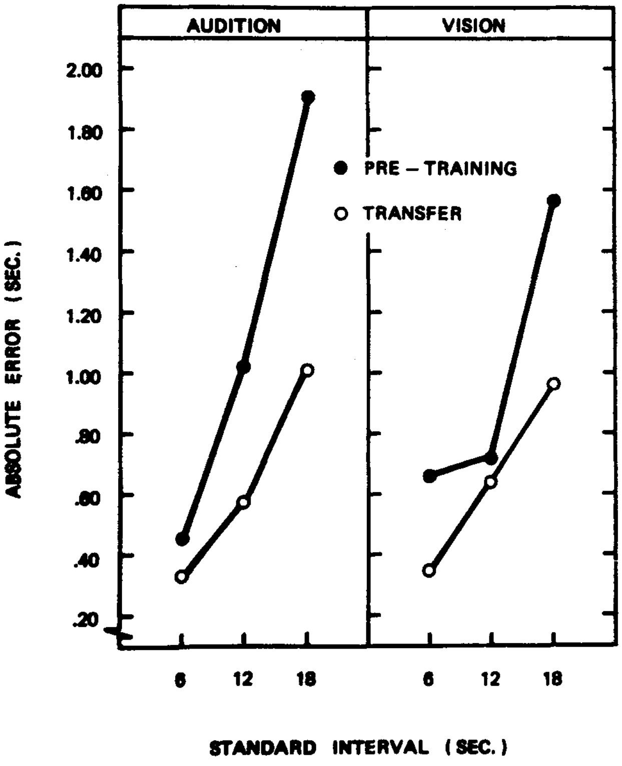


**Figure 2. Transfer of training across modalities. Absolute errors during the pretraining and transfer phases are plotted as a function of standard interval for the auditory and visual modes. Note that, for each mode, transfer data reflect performance after training in the opposite mode.**

## DISCUSSION

The results are generally consistent with those of prior investigations with respect to the effects of training on improvement in the accuracy of temporal discriminations. The negatively accelerated learning functions found here, and the fact that the degree of improvement was directly related to stimulus duration, are in accord with the results obtained by Aiken (1965), Bakan, Nangle, and Denny (1959), and Robinson (1963). Moreover, the fact that early practice was more productive than later stages in the acquisition of timing skill is consistent with the outcome of several other perceptual learning tasks (Gibson, 1969). Above all, the finding that these results were similar for judgments of auditory and visual stimuli indicates that they are general in nature and not dependent upon the particular sensory system used for stimulation.

One of the principal questions of this experiment concerned intermodal transfer between the auditory and visual systems. The results indicated that positive transfer is possible not only from audition to vision, but in the opposite direction as well. Moreover, intersensory transfer was symmetrical across modalities. These findings are contrary to those reported by Goldstone and Goldfarb (1966), who noted significant transfer only in the audio-visual direction. Although a complete explanation of the disparity between this and the earlier investigation is not immediately available, it is worth noting that different psychophysical methods (category scaling vs. fractionation judgments) and different stimulus durations (0.15 to 1.95 sec vs. 6-18 sec) were employed in these studies. Such differences should certainly be considered in weighing the outcome of the two investigations, since temporal discriminations have been shown repeatedly to be sensitive to variations in psychophysical technique and to the spectrum of intervals employed (Carlson & Feinberg, 1968; Doob, 1971; Stutz, Warm, & Woods, 1974; Warm, Smith, & Caldwell, 1967).

The present results have important implications for current theories of temporal discrimination. These positions stress the mediational role of a central neural pacemaker (Adam, 1971) or a central event counter (Allan & Kristofferson, 1974; Creelman, 1962; Ornstein, 1970; Treisman, 1963) and make the crucial assumption that temporal discriminations are based *only* upon the temporal information in the stimulus pattern (Allan & Kristofferson, 1974). Such an assumption is intuitively appealing, since duration is a prothetic stimulus attribute (Stevens, 1960) common to the auditory and visual modes. However, attributive commonality does not necessarily imply that a unitary mechanism is operative in mediating discriminations in two modalities. Stimulus intensity is also a prothetic attribute common to audition and vision, and data are accumulating to indicate that intensity discrimination is signal-specific and dependent upon the sensory system involved (Eijkman & Vendrik, 1965; Künnapas, Hallsten, & Söderberg, 1973). The lack of mutual consistency in judgments of auditory and visual durations noted earlier implies that a similar situation may be the case in relation to temporal discriminations.

The assumption of a common blender of temporal information requires the stipulation of conditions under which sensory invariance will occur. Some evidence for such invariance comes from studies demonstrating significant correlations between duration judgments in audition and vision (Eijkman & Vendrik, 1965; Loeb, Behar, & Warm, 1966). The positive and symmetrical intermodal transfer found in this study constitutes still another empirically determined invariance condition and lends further credence to the notion that a common mechanism underlies temporal discriminations in different sensory systems.

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## NOTES

1. In the present investigation, as in many temporal discrimination experiments where intervals are studied over a large range, response variability was directly related to stimulus duration. Therefore, the assumption of homogeneity of variance was not met in this analysis or in the remaining analyses of variance performed on the data. However, no attempt was made to transform the data for two reasons. As indicated by Edwards (1968) and by Myers (1972), the analysis of variance is relatively insensitive to violations of the assumption of homogeneity of variance when the number of observations in each cell of the analysis is equal, as is the case in all of the analyses in the present study. Furthermore, the magnitude of the differences in absolute error scores between intervals was quite large—absolute errors at 18 sec were approximately twice as great as at 6 sec.

It should be noted that nonparametric analyses support the conclusions reached on the basis of the analysis of variance with regard to the absence of a significant difference among blocks of trials and among sensory modes during the pretraining phase of the study. Friedman two-way analyses of variance for differences between blocks of trials at each interval failed to reach significance ($p > .05$ in each case) and Mann-Whitney U tests for differences between modes at each interval also lacked significance ($p > .05$ in each case).

2. Another way of looking at the data in regard to transfer is to compare the scores for each mode in the last block of training trials, in Figure 1 to the transfer scores in Figure 2. At the 6-sec interval, the training and transfer scores are almost identical. By contrast, at the 12- and 18-sec intervals, transfer scores were somewhat larger than the last block of training scores. This suggests that transfer was more complete at the 6-sec than at the two longer intervals. Such a result might be due to the greater degree of error in bisection inherent in performance at the two longer standard durations.

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