Temporal order: The effect of single versus repeated presentations, practice, and verbal feedback¹

ROY W. GENDEL² AND IRA J. HIRSH
CENTRAL INSTITUTE FOR THE DEAF

Whereas Hirsh and Sherrick (1961) found that experienced Os could judge correctly the temporal order of a sound and a light presented repeatedly when the interval separating them was 20 msec, Hirsh and Fraisse (1964) found that naive Os required about 60 msec for the same accuracy of performance with single presentations of the same pair. This experiment examined the effects of single vs repeated presentations, practice, and verbal feedback on performance in the judgment of temporal order. The results indicate that performance under repeated presentation is significantly better than under single presentation, that learning effects are most pronounced during the first 4 of 16 sessions, and that the effects of feedback appear to depend on the precise wording given the S on how he is to perform.

Hirsh and Sherrick (1961) reported that an interval of about 20 msec between the onsets of a sound and of a light is necessary for Ss to report temporal order with 75% accuracy. On the other hand, Hirsh and Fraisse (1964), also pairing sound and light, reported a 60-msec interval for 75% accuracy.

Whereas Hirsh and Sherrick presented the stimuli repeatedly until S reported his judgment, Hirsh and Fraisse gave only a single presentation of the pair per response. Furthermore, while Hirsh and Sherrick used experienced Ss, Hirsh and Fraisse used naive Ss. Although it is known that repeated presentations of stimuli can enhance performance in psychophysical experiments (Schreitmüller, 1952; Swets, Shipley, McCay, & Green, 1959), it is not clear (1) how much enhancement repeated presentations will provide when training effects are equalized, and (2) to what degree performance can be improved with practice under conditions of single and repeated presentations of stimuli.

The main purposes of this experiment are (1) to compare single with repeated presentation for performance in judging temporal order, and (2) to examine the effect of practice on performance. In addition, a third purpose is to study the effect of verbal feedback on performance, especially under the more difficult condition of single presentation of stimuli.

METHOD

Apparatus

Stimuli and test environment were essentially those described by Hirsh and Fraisse. The interval between onset of click and light was controlled by two Tektronix Type 161 pulse generators, triggered by a Tektronix Type 162 waveform generator. The waveform generator was externally triggered.

A tuned circuit, consisting of a 12-H inductor in parallel with a 0.01-microfarad capacitor and a variable resistor, was excited by a 0.1-msec positive pulse from one pulse generator to produce a damped sinusoid of 400 Hz with a decay time of 40 msec. The tonal transient was amplified, attenuated, and presented through a loudspeaker to Ss at 50-dB sensation level (SL).

A 0.2-msec positive pulse from the second pulse generator served to activate a Sylvania R-1131C glow-modulator tube that illuminated a 0.7-cm diam circle on a ground Plexiglas screen. The intensity of the light was predetermined from average intermodality brightness-loudness matches made by several Os to the 50-dB SL damped sinusoid previously described.

The Ss were tested individually while sitting in a dimly lit room facing the loudspeaker and the light source, both of which were at eye level. The loudspeaker was placed directly behind the light source and was 50 cm from S's ears.

In conditions where Ss received single presentations of the stimulus pair, a 1-in.-diam, green warning light, situated next to the light source, on S's left, momentarily flashed 1 sec prior to the onset of the stimuli.

Experimental Design

Four conditions were used. In Condition 1, single presentations of each of the stimuli were given and Ss were told after each judgment that they were "correct" or "wrong" (feedback). In Condition 2, single presentations were given but without feedback. In Condition 3, repeated presentations of stimuli were given, and feedback was given after the response. In Condition 4, repeated presentations were given but without feedback.

In each experimental session, Ss were

given 20 trials each of click leading light by 60 msec, click leading light by 20 msec, light leading click by 60 msec, and light leading click by 20 msec. In addition, Ss in the single-presentation conditions received 20 presentations of click leading light by 100 msec and of light leading click by 100 msec. Within a session, the order of presentation of stimulus pairs was random. Ss in each condition were tested for 16 sessions.

Subjects and Procedure

Each of 16 students with normal hearing and vision and no prior experience in the experimental task was quasirandomly assigned to one of four groups (two men and two women in each).

All 16 Ss were told that their task was to judge whether the click or the light started first. In addition, Ss in the feedback conditions were told that E would report if their judgment was correct or wrong. E's report was based on the physical temporal order.

In the repeated-presentation conditions, stimuli were presented once per second until S reported his judgment. (The actual number of presentations varied from as few as 2-3 for some Ss to as many as 20-30 for others. No consistent relation between number of presentations and accuracy of performance was evident.)

RESULTS

The previous results of Hirsh and Fraisse were compared with the median per cent of "click first" responses on the 1st test day from the Ss with single presentations (Condition 2). A line of best fit (visual) was drawn through the median points of the group data, and the interpolated intervals for 75% and 25% "click first" responses were averaged to give the estimate of threshold of temporal order. The obtained value of 56 msec agrees well with the value of 60 msec reported by Hirsh and Fraisse.

To check the previous results of Hirsh and Sherrick, a similar analysis was done on the data obtained on the 16th day from the Ss with repeated presentations (Condition 4). The obtained value of 14 msec is not too far from the value of 20 msec reported by Hirsh and Sherrick.

Fig. 1. Example of data plots used to estimate thresholds of temporal order for one S.

the data were collapsed into two groups: single- and repeated-presentation conditions. (No differences in performance were found between feedback and no-feedback conditions).

Significant differences in performance were found ($p < .05$) between Sessions 1-4 and Sessions 5-8 but not between subsequent sessions. Therefore, practice is only initially a significant factor determining the limen for temporal order.

Effects of Feedback on Performance

Figure 2 suggests, in addition, that feedback is not a significant variable affecting performance in judging temporal order under either single- or repeated-presentation modes of stimulus delivery. This was not especially surprising for the group that received repeated presentations of stimuli and therefore could perceive as many samples as they wished before responding. However, from conversations with Ss receiving single presentations with feedback (Condition 1), it was evident that some of them suspected beforehand that on some trials they would be told that their judgements were "wrong." Nevertheless, they felt that their perception of the stimulus was subjectively correct. Apparently, for these Ss, the point of subjective simultaneity of presentation of stimuli did not coincide with physical simultaneity of presentation.

To determine whether feedback could be used to teach Ss to perceive correctly the conditions of physical simultaneity, Condition 1 (single presentation with feedback) was replicated with four different Ss. These Ss were told to be "correct," that is, to attempt to label the stimuli according to the physical order of presentation. This instruction is very different from that given the group described above, who were told they could ignore the feedback if they desired.

The results of this experiment are shown in Fig. 3, where the median scores in each set of sessions are plotted and connected by lines. The figure shows that the point of subjective simultaneity is displaced approximately 25 msec from the point of objective simultaneity for Sessions 1-4. In contrast, the points of subjective and objective simultaneity are approximately equal for Sessions 13-16.

These data show that feedback, in the form of knowledge of results, can modify performance in the judgment of temporal order. What is not clear, however, is the exact nature of this influence. For

Effect of Single vs Repeated Presentation

The data within each series of 4 successive test days were averaged for each S. These data were then plotted to obtain individual thresholds (75% correct) of temporal order. A line of best fit was drawn through each set of data, and the time intervals for 75% and 25% "click first" were averaged to estimate threshold of temporal order. An example of these plots for one S arbitrarily selected from the

single-presentation feedback group (Condition 1) is shown in Fig. 1. Sessions 1-4 represent the data for the first 4 days, and Sessions 13-16 represent the data for the last 4 days. The slopes steepen as the training proceeds (vide infra).

The comparison of single with repeated presentation for performance in judging temporal order is shown in Fig. 2. The median threshold value of the four Ss in each experimental condition in each successive series of four sessions is plotted.

Figure 2 shows that thresholds for repeated presentations of stimuli are initially approximately 20 msec smaller than for single presentations. After training, the difference is reduced to approximately 10 msec. These results agree with those of other studies, in which other types of stimuli were employed, suggesting that number of presentations is a significant factor in determining performance level for judging temporal order.

Effect of Practice on Performance

Figure 2 suggests that Ss in all four experimental conditions show a higher performance level (smaller threshold) on Sessions 5-16 than for Sessions 1-4. To determine whether or not improvement in performance (e.g., as illustrated in Fig. 1) was statistically significant, the Wilcoxon Matched-Pair Signed-Ranks Test was employed (Siegel, 1956). For this analysis,

Fig. 2. Threshold for perception of temporal order as a function of test session.

Fig. 3. The effect of feedback and training on the point of subjective simultaneity in judging temporal order. The cross in the center of the graph indicates the point of objective simultaneity.

made after single presentations of stimuli.) They argue that the difference between their results and Hirsh's (1959) is due to the relatively greater experience Ss have had discriminating the onsets of formants. Similarly, it could be argued that Ss have had relatively more experience discriminating the order of two sounds than discriminating combinations of sound and light.

In conclusion, we suggest that number of presentations of stimuli is a significant factor affecting performance in judging the temporal order of light and sound. It remains a possibility that training beyond the extent given in this experiment can minimize its significance. Finally, it appears that Ss can be taught by verbal feedback to judge temporal order in conformity to standards set by the E.

DISCUSSION

Whereas single vs repeated presentation was found to have a significant effect in judging the temporal order of light and sound, even after training, a recent study by Homick, Elfner, and Bothe (1969) indicates that, after extensive training, Ss can judge accurately the temporal order of two sounds as well with single presentations of stimuli (threshold = 14 msec) as Hirsh (1959) reported for repeated presentation (threshold = 17 msec).

One explanation of the discrepancy of results between the present experiment and the results of Homick et al is that although bimodal (visual-auditory) and unimodal (auditory-auditory) perceptions of temporal order can be made equally well under optimum sampling conditions, under more difficult conditions, unimodal performance is superior (Fraisse, 1963, pp. 109-110).

A second explanation is that Ss in the single-presentation condition of this experiment were actually on a learning plateau and, with further practice, might have shown performance comparable to that found for the condition of repeated presentations. Support for this contention is found in data published by Liberman et al (1961), who found that differences of only 12 msec between the onset of first and second speech formants could be accurately discriminated. (Judgments were

Table 1

Individual Points of Subjective Simultaneity. Each Value is the Average PSS for Sessions 13-16 of an Individual Subject.

Condition	Point of Subjective Simultaneity			
I	+50*	+12	0	-31
IA	+5	+3	-4	-9
III	+6	+6	-6	-6

I = single presentation, feedback ignored if desired

IA = single presentation, feedback with instruction: "be correct"

III = repeated presentations, feedback ignored if desired

* Values indicate time in msec by which click precedes light

example, Table 1 shows that the point of subjective simultaneity can be brought into line with the point of objective simultaneity when single presentations are followed by feedback and the S is instructed to be "correct" (Condition 1A). Under Condition 1, where the S could ignore the feedback, such homogenizing of performance did not result. But under Condition 3, where repeated presentations were used and the S was free to ignore feedback, results more like those of Condition 1A were obtained. Thus, there appears to be some dependence of the influence of feedback not only on instructions to S concerning the use of feedback, but also on method of stimulus presentation, whether single or multiple.

REFERENCES

- FRAISSE, P. *The psychology of time*. New York: Harper & Row, 1963.
- HIRSH, I. J. Auditory perception of temporal order. *Journal of the Acoustical Society of America*, 1959, 31, 757-767.
- HIRSH, I. J., & SHERRICK, C. E. Perceived order in different sense modalities. *Journal of Experimental Psychology*, 1961, 62, 423-432.
- HIRSH, I. J., & FRAISSE, P. Simultaneité et succession de stimuli, heterogenes. *L'Annee Psychologique*, 1964, 64-19.
- HOMICK, J. L., ELFNER, L. F., & BOTHE, G. G. Auditory temporal masking and the perception of order. *Journal of the Acoustical Society of America*, 1969, 45, 712-718.
- LIBERMAN, A. M., HARRIS, K. S., KINNEY, J., & LANE, H. L. The discrimination of relative onset time of the components of certain speech and non-speech patterns. *Journal of Experimental Psychology*, 1961, 61, 379-388.
- SCHREITMUELLER, R. F. Effect of repeated presentations on the detection of signals in noise. Unpublished MS thesis, Massachusetts Institute of Technology, 1952.
- SIEGEL, S. *Nonparametric statistics for the behavioral sciences*. New York: McGraw-Hill, 1956.
- SWETS, J. A., SHIPLEY, E. F., McCAY, M. J., & GREEN, D. A. Multiple observations of signals in noise. *Journal of the Acoustical Society of America*, 1959, 31, 514-521.

NOTES

1. This research was supported by Program Project Grant 03856 from the National Institute of Neurological Diseases and Stroke to Central Institute for the Deaf.

2. Address: Central Institute for the Deaf, St. Louis, Missouri 63110.

(Accepted for publication June 4, 1969.)