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CROSS-MODALITY EFFECTS OF TV-WATCHING ON OPTIMAL LISTENING LEVEL[1)]

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A series of experiments reported in this paper were conducted to clarify the cross-modal interactions between visual channel and auditory channel by making the subjects to determine optimal loudness level. The conclusions reached from the results obtained with 3 experienced subjects were: (1) Programs rich in information induced higher optimal levels among the subjects, whether visual modality was present or not. (2) Distances to the monitor TVs appears to have inversely affected optimal level (in headphone condition). As this impression was not statistically reliable, it may be more exact to say that difference in distances induced the subjects to make compensatory adjustments with the results that the loudness level at their ears be constant over the varying distances. (3) Presence of visual modality did not affect the loudness level. (4) Our initial expectation that listening through headphones allow louder optimal level was not statistically confirmed. (5) Whether visual modality was present or not, stereophonic listening gave rise to louder optimal level than monaural listening.

(6) Additional experiment with 12 naive subjects confirmed the results with three experienced subjects concerning the size of the monitor TVs. That is, the subjects adjusted the volume at louder level when they watched larger monitor than when they watched smaller one.

Our daily experience suggests that we are under the influence of cross-modality effects, when we adjust the loudness level according to the contents of the program, when we watch TV with louder volume as compared to radio, and the like. The present study experimentally investigated this sort of phenomenon with two-stage approach. First, we have studied as many relevant factors as possible using a few experienced subjects. Secondly, to obtain more generalized results we took up those variables which appeared to have significant effects on this cross-modal phenomenon in the first-stage experiments with increased number of subjects.

Experiment 1

The following four factors were studied to explore this phenomenon as widely as possible (1) Difference in programs, (2) Distance to watch TV, (3) Presence of visual modality (corresponding to the difference that may exists between listening to radio and

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watching TV), (4) Channel of auditory information (whether through headphones or through speakers).

Three kinds of video-recorded programs were used. They were RAKUGO (traditional Japanese storyteller's art), documentary film, and pop-songs show. These programs were selected on the degree of dependency on visual modality, the number of changes in the display, and the richness in auditory channel. Of these programs, pop-songs show seems to have contained information most abundantly and RAKUGO contained least with documentary film falling in between. The aim of this experiment was to test the hypothesis of whether the watcher-listeners should adjust the loudness level in proportion to the amount of information contained in a program.

The distances to watch and listen to TV were 100, 160, and 250 cm. These distances were chosen on the basis of the study done by Rikiishi (1980, in Japanese) which measured most frequently observed TV watching distances among Japanese TV-watching families. It ranged from 100 to 300 cm for those watching the TV set of 22 in. CRT and from 80 to 250 cm for those whose TV set had less than or equal to 14 in. screen. Besides, at these distances two types of monitor TVs (13 in. and 20 in. in size) used in Exp. 2 could be placed to subtend equal visual angles (see Exp. 2 for detailed description). The second purpose of the Exp. 1 was to obtain data on the relationship between the watching distances and the "most comfortable" loudness levels. More precisely, the problems pursued here were: Is the loudness proportional to the distance or does it have inverse relationship or is it constant over the distances at which most Japanese watcher-listners watch TV ?

Factorial combination of these factors (each of which had three levels) made up 9 cells. These were collectively tested in one session. Additional two fctors were the presence of visual modality and the mode of audtiory channel, each of which had two levels. In all it required 4 sessions to cover each combination of the watching distances and the kinds of programs. Thus, total number of the combination of the conditions amounted to 36.

The factor of visual modality presence was introduced here to study the differences that might be found in TV watching and radio listening. Our daily experience suggested the hypothesis that when we watch TV we would increase loudness level to make proportional to the additional visual information. In the former condition the subjects were asked to control the loudness level to become optimal while watching the screen. On the other hand, in the latter condition they were required to do so with the tape-recorded sound stimuli only and without visual displays. The sound was presented by a cassette recorder instead of a radio receiver. The instruction given to the subjects in this latter condition went as follows "Please control the volume controller at hand up to the point at which you think it is most comfortable or optimal to listen to the sound, while watching the tape-recorder." Auditory channel was kept identical to the TV-watching condition (i.e., through a pair of speakers which was placed at each side of the recorder or through headphones).

As mentioned just now, there were two modes of auditory presentation. Since, in the free acoustic field created by the speakers, sound quality alters a little (even though it may be trivial indeed) due to the room acoustic resonance which may be different from one room to another, the headphones listening condition was added. Furthermore, the possibility was explored that minimal sensation of realistic acoustic field and space that accompanies headphones listening should cause compensatory behavior on the part of the listener by increasing the loudness level. Another factor that may caused relatively increased loudness level in headphones listening is little sound leek, so that one is not necessary to be anxious about the nuisance to the neighborhood.

Three subjects, including the authors served as subjects all of whom had much experience in psychophysical measurements and had made considerable practice. They were asked to adjust the volume controller held in hand by increasing the loundness level up to the point where it was "comfortable" for them to watch TV. When they thought they passed over the optimal level they were allowed to reverse the direction of turning of the cotroller to decrease the volume. The optimal loudness level was defined as the one they thought so under the present experimental conditions. When the subject indicated the end of one measurement, the experimenter who was outside the room stopped both visual and auditory outputs and determined SPL in dB at the *S*'s ear. After registering the obtained value, the experimenter continued presentation at the point just after the interrupted point to obtain another value of the optimal level.

Eleven different attenuation curves were used to control the loudness level in order to prevent the angle of rotation from affecting the determinations. At least 5 measurements were taken at each point of the factorially combined levels of the experimental factors. When the subjects gave too scattered values, additional measurements were obtained and these scattered values were discarded from further analysis. The measurements were randomly done with the restriction that minimum carry-over interference would be brought about from one condition to another. The same scene was repeatedly used as stimuli for each condition. The determination of the optimal loudness level was done with the scenes that contained human voice such as songs and narrations.

The monitor TV of 20 in. screen was used with two speakers, which were separated on each side of the monitor by 90 cm from each other. The size of the experimental room was 1.8m×4.8 m with the hight of 2.4 m and was separated by an accordion curtain from the experimenter's booth. The general arrangement of the experimental room was shown in Fig. 1. The same setting was used in the following Experiments 2–4. The horizontal illuminance was 140 lx at the TV screen and the vertical illuminance was 210 lx. The background noise level was 32 to 40 dBA. The maximum and minimum brightness was 524 and 21 nit, respectively for 20 in. screen. They were 555 and 22 nit for 13 in. screen used in Exp. 2.

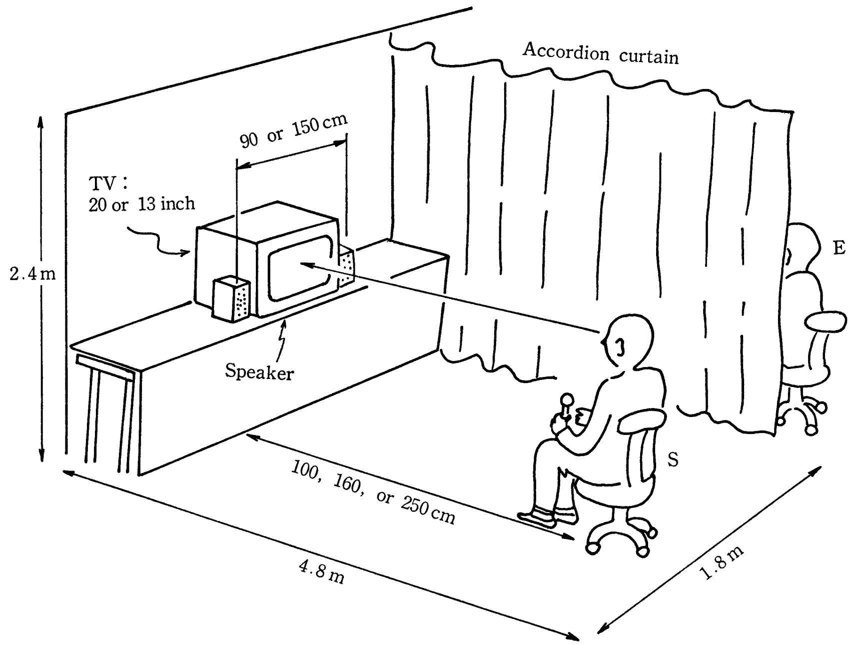

Fig. 1. Illustration of experimental room and conditions.

Results and Discussion:

(1) Determination of the optimal loudness level: According to the introspective reports, there appeared to be a considerable allowance within which the subjects judged the loudness level being optimal for listening. Although they could judge whether a given volume was too loud or too weak. This variance in judgments was reflected in the fact that more than half the measurements required 6 to 8 trials. One cause of the difficulty was the unstable loudness level which typically accompanied these kinds of programs. For example, abrupt increase in loudness level tended to bias judgments to the reverse direction. In spite of these difficulties, the subjects reported that they could maintain relatively stable criterion of optimal listening level over the sessions. As can be seen in Fig. 2, this level ranged approximately from 50 to 60 dB SPL at the peak amplitude.

(2) Effects of the kinds of programs: Figure 2 shows each subject's overall mean result with the kinds of program plotted as abscissa. It may be seen that the optimal loudness level increased from RAKUGO to documentary film and to pop-songs show in this order. This trend was found to hold at three distances, irrespective of whether visual display was on or off and either through speakers or headphones. And it was found to be statistically significant at 5% level. This effect of programs seems to reflect the trend that the optimal loudness level depended on the value of or richness in information contained in a program. This also holds even if the subjects were deprived of visual modality as when listening to radio.

(3) Difference in distance: Separate analyses of each combination of auditory channel (speakers or headphones) condition and display condition suggested (as shown in Figs. 3–6) that relatively little changes in loudness level occurred under any of

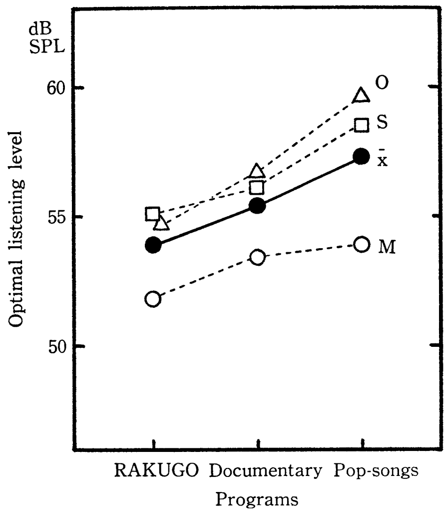

Fig. 2. Optimal listening levels for 3 TV programs adjusted by 3 *S*s.

the conditions. Although it appears that increased distance was compensated by the increment of source volume keeping the loudness level at the listner's position approximately the same over all the distances (see Figs. 3, 4 for the effects of visual display when the subjects heard sounds through speakers). That is, the subjects adjusted the loudness level to become approximately the same whether they were watching TV at 100 cm or at 250 cm, although at the latter distance the source volume increased by approximately 2.5 dB. Presence of visual modality did not affect this tendency. On wearing headphones, as there were no confounding effects of distances interfered, the presense of visual modality appears to have some effects on the loudness level (as can be seen in Fig. 5–6). This impression was not, however, statistically confirmed. Therefore, the trend of increased loudness with decreased distance, as is shown in Fig. 6 was not statistically reliable, either.

The overall effect of the watching distances may appear to work to keep the effective loudness at a constant level or slightly to increase it as one approaches to the sound source.

(4) Effects of the presence of visual modality: Accompaniment of visual display does not seem to have had consistent effects on the loudness determinations from one subject to another. For example, the subject M chose louder point of listening as being optimal when he both listen to and watched TV than when he only listened to the recorded voice if sound was presented through speakers. On the other hand, the reverse was true for the remaining two subjects.

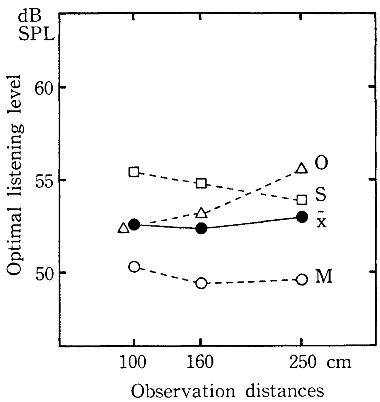

Fig. 3.

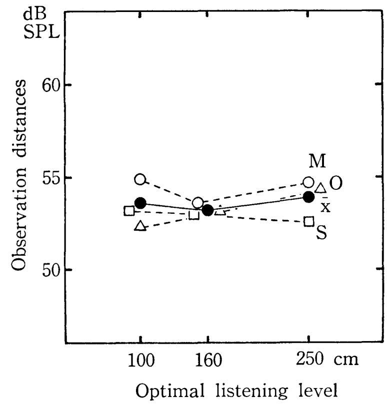

Fig. 4.

Fig. 3. Optimal listening levels as a function of observation-distances in free-field condition without picture.

Fig. 4. Optimal listening levels as a function of observation-distances in free-field condition with picture.

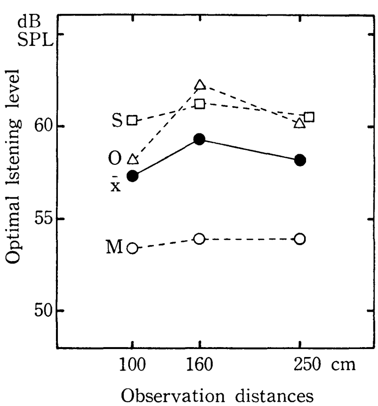

Fig. 5.

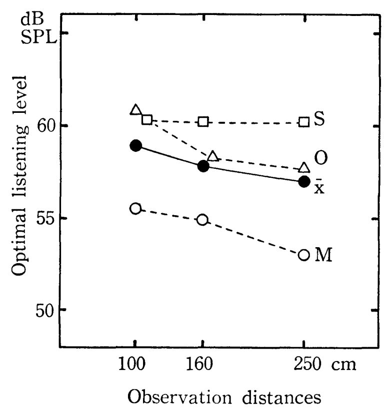

Fig. 6.

Fig. 5. Optimal listening levels as a function of observation-distances in headphone condition without picture.

Fig. 6. Optimal listening levels as a function of observation-distances in headphone condition with picture.

(5) Headphones vs. speakers: As can be seen in Fig. 7, all of the subjects tended to hear with louder volume when they did so through the headphones than through the speakers. Although this effect of sound presentation means was not statistically significant. Were it real, then it might be ascribed to the compensation of the impoverished impression of the acoustic field or space. Another possible explanation is the lack of potential nuisance to the neighborhood which usually accompanies TV watching or radio listening with speakers. This point deserves further study.

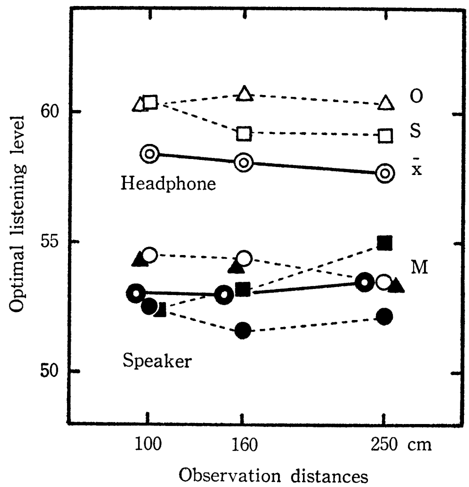

Fig. 7. Results of optimal listening level adjustmens in free-field and headphone conditions.

EXPERINENT 2

Exp. 2 was conducted to obtain data on the effects of the difference in the size of the screens. Two monitor TVs were used here. One of them had the 20 in. CRT (SONY, SR2 which was the one used in Exp. 1) and the other had 13 in. CRT (SONY, KV-13A5). Display quality was adjusted to be approximately the same between the two monitors. The watching distances were chosen to be equal to those used in Exp. 1. These distances were selected so that at the distance of 100 cm, 13 in. monitor subtended the same visual angle as subtended by 20 in. monitor at 160 cm (i.e., 10.85°) and the distance 160 cm of 13 in. monitor corresponded to the distance 250 cm of 20 in. monitor in terms of visual angle (which was 6.89°). The program used in this experiment was RAKUGO, which contained least frequent change in the angle or size of the displayed scenes. Sound material was presented through speakers. Procedure to determine optimal loudness level was similar to the one used in Exp. 1.

Three subjects who served as subject in Exp. 1 participated in this experiment also. Each of them gave two measurements for each condition, mean result of which were shown in Fig. 8.

First, the effects of distances on the optimal level of volume was found to be similar in trend to that was mentioned in Exp. 1. That is, at shorter distances the subjects tended to increase the volume. As this trend is not very conspicuous, it may be said that the subjects adjusted the volume to have equivalent loudness at their ears irrespective of the listening distances.

The size of the monitors was found to have significant cross-modality effect ($p < .05$) on the optimal loudness level. Furthermore, absolute distances were also found to be a relevant variable. The two monitor screens that had different sizes but were

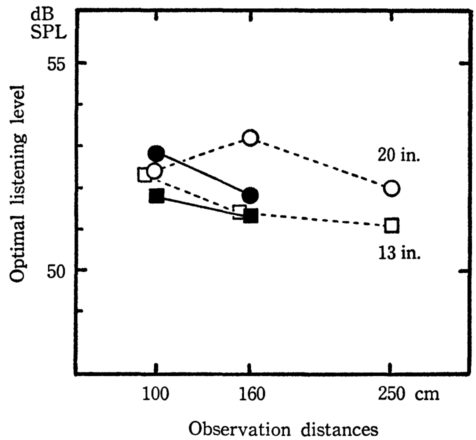

Fig. 8. **Effects of TV-size on optimal listening level in free-field condition.**

placed to have a corresponding visual angle did not give rise to equivalent loudness levels. Therefore, the subjects did not respond to the two TV monitors with matched visual angle as being equal in their effects on volume adjustments.

Experiment 3

In order to explore the generality of the results concerning the screen size as reported in the previous section, additional experiment was conducted in which 12 subjects participated to determine optimal loudness levels with three monitor TVs that had different screen size of 8 in. (SONY, PVM–76L), 13 in. (SONY, KV–13A5), and 18 in. (SONY, CVM-1850). As the smallest monitor was monochromatic, all the displays were presented without chromatic information. Brightness of the monitor screens was 378 nit for 8 in. TV, 609 nit for 13 in., 538 nit for 18 in. at the bright spot respectively. It was 12 nit, 20 nit, and 17 nit at the dark spot in the order of the smallest to the largest. The order of the testing with these monitor TVs were counterbalanced among the subjects. The video material used here was a scene from RAKUGO. The watching distance was at 100 cm. The procedure to determine optimal volume was similar to the one described in Exp. 2.

As shown in Fig. 9, the factor of screen size had significant effect on the determination of optimal loudness level as confirmed by ANOVA ($p<.01$). That is, the optimal level became louder as the size of the screen was increased from 8 in. to 18 in.

Experiment 4

In this experiment, the effects of stereophonic and monaural listening conditions were explored in connection with the effects of the presence of visual modality.

The monitor TV with 20 in. screen was used here. When visual modality was to

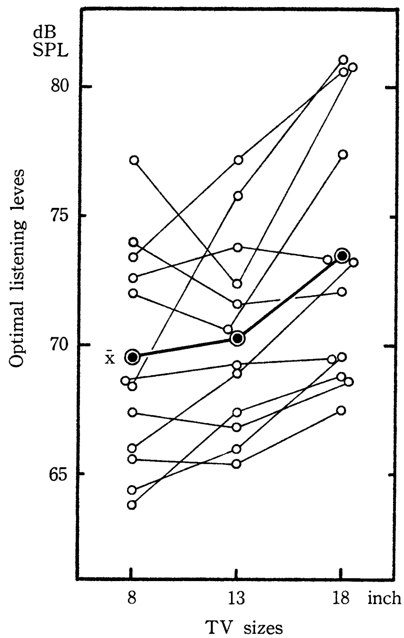

Fig. 9.

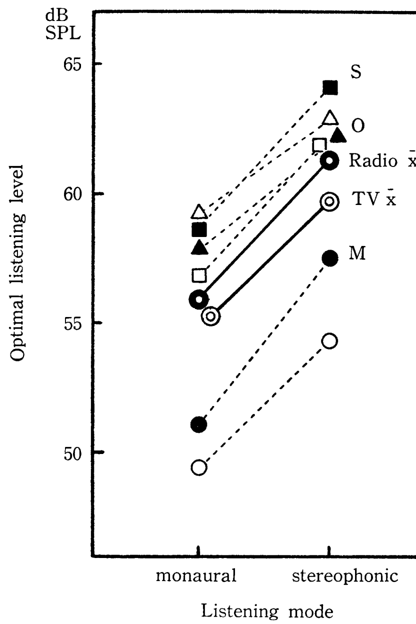

Fig. 10.

Fig. 9. Effects of 3 TV-sizes on optimal listening level for 12 *S*s.
Fig. 10. Results of level adjustments for 3 *S*s in monaural and stereo listening conditions with and without picture.

be omitted, a cassette recorder replaced the monitor TV. One alteration from Exp. 1 was listening distance (i.e., the distance between subject and the speakers), which was 150 cm in this experiment. A scene from pop-songs show was used as video material, which was watched at the distance of 160 cm.

Each subject's optimal loudness levels were plotted in Fig. 10. It may be seen that when visual modality is omitted optimal loudness level appears to have increased. This effect of visual modality was not, however, statistically reliable as it was not in Exp. 1. On the other hand, stereophonic listening apparantly made the subjects set volume louder than monaural listening.

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