Sensory Substitution in Perceiving Architectural Surfaces

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요 약

인공건물의 평면특성에 대한 시각을 통한 인지를 청각으로 대체했을 경우의 인지능력을 측정 하였다. 정상적으로 시각(visual)을 이용 하겠으나, 시각 장애자의 경우는 청각(auditory) 또는 촉각(tactile) 또는 두가지 모두를 사용하게 된다.

Psychophysical approach를 사용하여 모의평면에 대한 인지능력을 JND 단위로 측정하였다. 청각적인 신호를 관찰자에게 제공하기 위해 전자장치(electronic ranging device)가 고안되었다. 이 장치는 목표물 까지의 거리를 초음파의 이동시간으로 측정하여 음의 세기(sound level)로 발생시켜 준다. 관찰자는 이 음의 세기를 듣고 거리를 추정하고 물표의 방향은 이 장비를 쥔 손의 방향, 즉, proprioceptive cue를 이용하게 된다. 세가지 task에 대한 실험은 평면의 slantness, 두 평면이 교차하는 모서리의 크기, 두 평면 사이의 공간(aperture size) 등에 대한 인지능력의 측정실험이다.

실험결과를 보면, 관찰자는 시각신호 대신에 청각신호를 사용할 수 있는 능력이 있는 것으로 나타났다. 세가지 task별 JND 측정치는 slant angle 6도, 모서리의 concavity 10도, angular aperture size 3 ~ 5도로 나타났다. 이 결과는 정상인이 시각을 이용한 인지능력과 큰 차이가 없음을 보여주고 있다.

I. BACKGROUND

Human has five principal sensory modes - visual, auditory, tactile, olfactory, and gustatory, though some add the sixth mode of vestibular. As much as 60 percent of senses in a daily life for normal person are visual senses [1]. Problems arised from the use of human sensory modes might be: can the role of a sensory mode be substituted by another mode? or, if yes, is there any difference in performance of function by the substituting sensory mode which might be done by the substituted mode?

This study, therefore, was concerned with the discriminability of human observers in perceiving architectural surfaces when the visual sensory mode was substituted with the auditory mode.

II. EXPERIMENTAL METHODS

Subjects. Eight university students(five males and three females) were volunteered. All subjects were tested their normality of hearing because sound tones would be provided as a cue for the perception of surface features. Prior to measuring their discrimination capability, subjects had a training session on how to use the electronic ranging device and on how to utilize the sound cues to judge the environment surrounding them.

Apparatus. In order to provide subjects sound information, a hand-held electronic ranging device was designed. The device dimensioned 26 x 6 x 15 cm (length x width x height) and weighed about 900 grams. The electronic ranging device was operated by a 12 volt DC battery and had a transducer/receiver set and ranging circuit board cased in a rectangular plastic case.

High-frequency inaudible pulses were transmitted from the transducer at a rate of 56 pulses/sec and the reflected echo signals were received after each transmission. Maximum travelling range of a pulse was set to 7.65m. The output sound level from the loudspeaker was varied with the change of every 3cm (0.1 feet) distance. The rate of sound level change was calibrated at about 7 dBA at every 30cm distance, which was equivalent to 100 dBA at 0.9m (3 feet) and 70 dBA at 2.4m (8 feet) distances to the echoing target.

Target surfaces were artificially assembled with plastic bubbles on insulating boards. Their sizes were 3.4m wide and 1.2m high. These boards were used to simulate a flat wall surface, a corner between two wall surfaces, and an aperture between two surfaces.

Experimental Tasks. The experimental tasks conducted were discriminating three surface features: slantness, concavity, and aperture width.

Slant discrimination tasks were performed to measure the observer's capability of perceiving their orientation with respect to a flat wall surface that was faced with him. Both left- and right-slantness were measured in degrees of slant angle.

Corner discrimination tasks were performed to measure the observer's capability of discriminating the concavity or convexity of a corner that faced with him. Concave corner (protruded away from observer) and convex corner (protruded toward observer) were both tested.

Aperture size discrimination tasks were performed to measure the size differences that could be discriminated by an observer. This task included the increasing size difference and the decreasing size difference from the standard size of 30cm aperture.

Procedure. Each subject was assigned to discrimination tasks in random order. In each task, nine stimulus levels were randomly presented with total of 25 trials for each stimulus level. The subject was asked whether the presented surface left-slanted or right-slanted in slant discrimination task, concave or convex in corner discrimination task, or wider or narrower in aperture size discrimination task.

III. RESULTS AND DISCUSSIONS

From the 25 measurements for each stimulus level in each task, the percentage of "yes" responses were calculated to form a psychometric function. Typical psychometric function shows an S-curve which resembles a cumulative normal distribution function [2]. A just-noticeable-difference (JND) can be estimated by a curve-fitting this S-curve.

In this study, JND was defined as the stimulus level corresponding to the level that the observers correctly responded 75% of times as other studies did [3].

Fig.1 shows the psychometric function in slant discrimination tasks. The psychometric function depicts the average yes-responses of the 8 subjects measured against stimulus levels (slant angle). Most observers responded 10% of time that the flat surface was perceived as slanted to the left (or right) when the slant angle was 12 degrees. Negative slant angle means a surface which is physically slanted in opposite direction, that is, it was slanted to the left when right slanted surface was tested. For the slant angle of -4 degrees, none of the observers responded that the surface was perceived as slanted to the left (or right).

Since only two choices, a yes or a no, in a response existed, the chance level was 50% and, therefore, the JND was estimated from the slant angle that corresponded to the 75% of yes-reponses. The estimated JNDs of left slant angle is 4.8 degrees and that of right slant angle 6.6 degrees. This degree of resolution is similar to that of visual discrimination which showed in some experiments[4, 5] a 2.2 to 6.1 degrees depending on the size and texture of the surface.

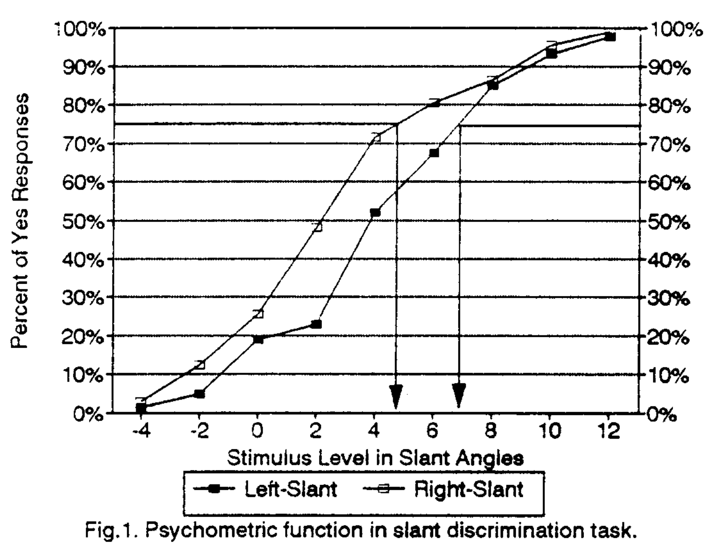

Fig.1. Psychometric function in slant discrimination task.

In order to know the orientation of an observer in an empty room, certain requirements on discriminating surface feature should be placed. That is, one must have a precision better than 45 degrees to appreciate one's orientation to a wall. The experimental results in the present study document that the use of sound information as a distance cue can provide observers with valuable information as visual information can do.

Fig.2 shows the average percentage of yes-responses of 8 subjects in corner discrimination task. For a corner angle of 24 degrees, all of the subjects responded the surface was perceived as a corner, either it was convex or concave. For the flat surface, a corner angle of 0 degrees, most of time for most of subjects were responded that it was not a corner. For the same reason as in the slant discrimination task, the corner angles corresponding to the 75% of yes-responses was estimated as JNDs. The JNDs in concave corner discrimination task was estimated as about 10 degrees and that in convex corner as 8.5 degrees.

If an observer wishes to know whether the surface in front of him is a corner, it is reasoned that he must have a JND smaller than 45 degrees at each side of the corner. Any capability worse than this would not be useful in a rectangular room. The estimated JNDs much smaller than this requirement document that the sound cues from the electronic ranging device may also be a useful measure to provide a cue on corner feature in a building structure. Unfortunately, any literatures on visual perception of a corner were not found by the authors, which did not give a chance to compare the results.

Fig.3 shows the psychometric function formed from the aperture size discrimination task. The aperture sizes in abscissa represent the difference in width of a stimulus from the standard size of 30 inch wide. The linear aperture size of 12 inches was the size difference that most subject perceived 100% of time it was wider or narrower than the standard size.

The estimated JNDs are 3.2 and 5.1 degrees in angular subtense, converted from linear size, for narrower and wider apertures, respectively. In travelling a building with no visual cues, knowing whether or not a door is passable could be a challenging problem. It may be reasonable to assume that a JND smaller than the passage clearance, i.e., the difference between the standard door width of 30 inches [6] and one's shoulder width of about 19 inches [7], be required. Results of the present study show that the observer's discriminability exceeded the above minimal requirements.

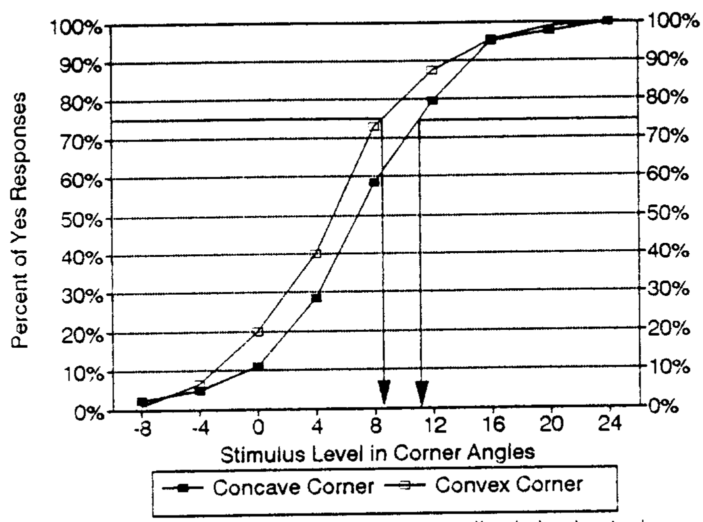

Fig.2. Psychometric function in corner discrimination task.

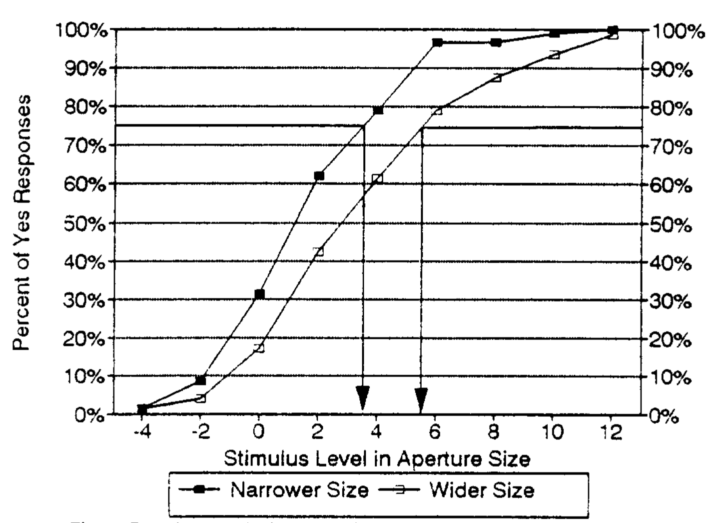

Fig.3. Psychometric function in aperture size discrimination task.

IV. CONCLUSIONS

The main objective of this study was to examine how well the observers could discriminate surface features when visual cues were substituted with auditory cues to provide an information about distance to an object. The results were consistent with the hypothesis that the blindfolded subjects can recover a certain amount of spatial information about the interior architectural surfaces.

Though a number of travel aids for the blind has been developed, more than 90 different products as of 1977 [8], they were not tested if any information on surface feature could be provided. They might have failed to integrate auditory cues of the distance with proprioceptive cues of the direction, or to provide an adequate substitution for the visual sensation, or to design them with sufficient resolution for providing meaningful information.

ACKNOWLEDGEMENTS

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