A study on expansion of spatial impression and its image structure

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Abstract: In this research, we investigate the ability of sounds to create "spatial impressions" in the minds of listeners through sketches, interviews, and experimentation. In a previous study, progress was made in clarifying how sound-based spatial impressions were formed by observations of the phase differences between right and left side audio input stimulation. However, in this study, we explore the potential of sound stimulation itself. To estimate this propensity, we conducted three surveys and a series of experiments. The results of our surveys show that spatial impressions do not simply result from differences of input stimulation, but depend on other factors as well.

Key words: Spatial impression, Stereophonic effect, Image structure

1. INTRODUCTION

Sound and music are among the most effective environmental elements for stimulating our emotions or sensations. For example, the sounds of singing birds or ringing temple bells can make us feel comfortable, evoke feelings of fascination, and even create the perception of beauty. Thus, while most sound originates simply as air pressure waves produced by various acoustic mechanisms, its ability to modify our perceptions and/or emotions is any interesting psychophysiological phenomenon that is suitable for advanced study.

Subjects of this nature are often studied by architectural or environmental disciplines where sound and its effects are considered essential elements of the overall environment. In those disciplines, most studies have examined sound phenomena from the viewpoint of "spatial impressions". For example, Damaske and Ando hypothesized that spatial impressions could be explained by using inter aural cross correlation (IACC) as a physical indicator [1]. In their proposal, IACC is explained as the process of examining the differences between right and left side sound signal inputs. One sound stimulation type, which utilizes input into both ears, is called the stereophonic effect. However, in daily life situations, it has become apparent that the ability to discern spatial impressions is not limited to simple stereophonic effects alone.

2. IMAGED EXPANSION OF SPATIAL IMPRESSION

2.1 Practical spatial impressions

Previous studies have shown that the spatial impressions obtained via sound provide one of the more important elements in recent acoustic design [2]. Therefore, numerous researchers have studied the relationship between sound and spatial impressions. In those studies, efforts were made to determine the physical characteristics of acoustic fields by a variety of methods [3]. However, the most important point is the manner by which we perceive and recognize sound as an acoustic effect. Of course, in the practical sense, spatial impressions are generated by physically describable acoustic conditions. However, we believe those factors are insufficient to fully explain this phenomenon. Accordingly, in this paper, we will attempt to verify this hypothesis and more fully explain its psychological structure.

2.2 Shape of audio images and their tendencies

To identify perception tendencies related to a spatial impression, we first conducted a survey that employed both sketching and interviews. For that survey, we prepared 15 sample stereophonic sounds and obtained the participation of 5 test subjects. Each test subject was asked to sit within a quiet room and to listen to the 15 sample sounds using stereophonic headphones "Monitor 8" (Pioneer). The sound samples were recorded by the researchers at the same location and using the same equipment. After listening to each sound, each subject was asked to sketch his or her visual impression of the audio image “shape”. When unable to fully express their image via sketching, they were asked to explain their impressions verbally.

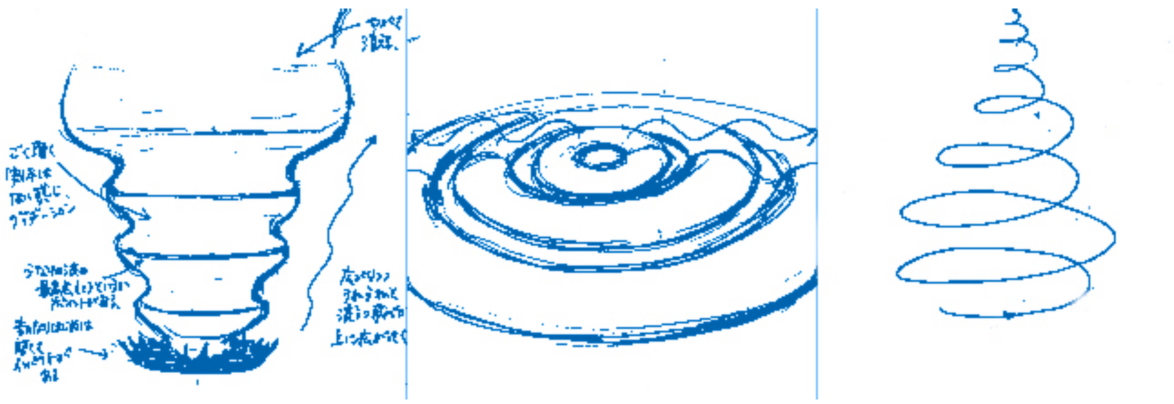

Figure 1: Sample special impression sketches (Sound Sample 6)

In the resulting sketches, we identified several sounds that evoked similar reactions in terms of spatial impression. Figure 1 shows sketches produced by three test subjects after listening to Sound Sample 6. As can be seen in the figure, each test subject sketched curve lines that resembled a vortex or wave, and those curve lines expand outward from a source. Such tendencies were observed in a few other sample sounds as well. Based on these results, it is reasonable to presume that there is a close relationship between sound stimulations and their spatial impressions.

To affirm this tentative hypothesis, a second survey was conducted, the method and results of which will be described below.

This survey utilized the same 15 sound samples that were prepared for the first survey, along with another "basic" sample sound. A total of 20 test subjects agreed to participate. In this survey, each participant listened to the sample sounds in a quiet room using the same equipment and under the same conditions as employed in the first survey. After listening to the sound samples, they were then asked to listen to the "basic" sound and compare the strength of the spatial impressions they received from the sound samples with those received from the "basic" sound. During the evaluation phase, sample sounds were evaluated over a value range from -4 to +4, while the "basic" sound was set a 0.

From the results of the two surveys, we then created a table that shows estimated spatial impression values, sketch features, and audio image impressions gleaned from the interview stage (see Table 1). The spatial impression value is average of evaluation scores from the 20 test subjects.

Table 1: Audio image shape and its spatial impression value

Sample No.	*Spatial impression value(ave.)*	*Image of Spatial impression (keywords)*
Sample 1	2.3	Concentrically expansion, Upper swinging
Sample 2	1.5	Concentrically expansion, Upward motion, Sideways motion
Sample 3	0.0	Concentrically expansion, Upward motion
Sample 4	0.4	Elliptically solid, Active sphere
Sample 5	1.5	Concentrically expansion, Upward motion
Sample 6	2.6	Wavelike expansion, Upward motion, Gradual deformation
Sample 7	0.8	Expansion from the center point, cubic enclosed space
Sample 8	-3.1	Downward motion, Random sound straggle
Sample 9	1.4	Upward motion, Sideways swinging
Sample 10	0.0	Concentrically expansion
Sample 11	-2.5	Downward motion
Sample 12	-0.5	Elliptically solid, Gradual deformation, Random sound straggle
Sample 13	-0.9	Upward motion, Random sound straggle
Sample 14	-1.4	Sideways expansion, the form like a donut
Sample 15	-2.0	Elliptically solid, High density of sounds

As can be seen in the table, each audio image shape is expressed by words that include action-related elements, such as "motion" or "struggle", in addition to space-related elements. It is especially noteworthy that words expressing those two elements were accompanied by the word "expansion". In addition, we found the word "expansion" was used to describe a number of other samples, regardless of the value given to those particular samples.

We found that matching spatial impression values and audio image shape impressions tended to indicate upbeat value sounds. For example, Sound Samples 1 and 6, tended to be to be evaluated in terms of images such as "wavelike expansion", "upward motion", and "concentrical expansion". In contrast, sounds with negative scores, such as Sound Samples 8 and 11, tend to be evaluated as images of "downward motion".

These results lead to our hypothesis that the issue of audio image shape unrelated to its intensity of the impression. Most notably, it appears that active variation of the audio image shape is more effective than other elements in influencing the impression intensity. Therefore, we can call this audio image shape process "imaged expansion of spatial impression".

3. EXPERIMENT

From the results of our surveys, we realized it was possible to confirm the existence of a relationship between the intensity of a spatial impression and a perceived image of an expanding spatial impression. In addition, we were able to confirm various tendencies related to spatial impression shape for each of the sound samples. However, such "perceived spatial impressions" are too abstract and conceptualistic to stand on their own merits. Accordingly, it was determined that experimentation was needed to promote clarity.

In our experiment, spatial impressions were analyzed by quantification method type III (QMIII) in order to determine the sound characteristics that are capable of generating spatial impressions. We found that many factors and characteristics provide the structure for such sounds.

Previous research has shown that spatial impressions tend to be produced by the stereophonic effect. However, if those studies were able to fully explain how spatial impressions are created, it would be unnecessary to survey the spatial impression image expansion structures because such impressions could be expressed by physical spatial factors alone, and there would be no relationship between the impression and our minds. Therefore, it was first necessary to clarify whether stereophonic effects alone were responsible for the perceived spatial impressions. To answer this question, a monophonic/stereophonic comparison experiment was performed as shown below.

3.1 Methodology of Quantification Method type III and Cluster analysis

In the first stage of this experiment, we attempted to categorize spatial impressions images using an unstructured interview method and the KJ method. In the interview portion, we asked 4 test subjects to discuss their impressions of the image and spaciousness evoked by a sample sound and then transcribed the discussion. After the interview segment, we attempted to extract images in order to classify them into groups.

First, those groups were divided into "spatial impression" and "other impression" groups. These groups were used to evaluate QMIII case data as "spatial impression", and category data as "other factors". Case data and category data matches were identified using the interview/discussion transcripts. In the next step, cluster analysis was performed on the same data. In that analysis, we employed Euclidian distance of raw data as the calculation.

3.2 Methodology of Monophonic/Stereophonic Comparison Experiment

In this stage of the experiment, we prepared a "singing bowl" as a sample sound to stimulate the subjects. In this process, each subject was asked to listen to two types of recorded sound_stimulation under the same conditions as described in our earlier surveys. After the listening session, they were asked describe their spatial impressions of the two samples, just as was done in the previously discussed survey. The collected data was then subjected to variance analysis.

4. RESULTS

4.1 Result of QMIII and Cluster analysis

We can get three axes by QMIII. The following table (Table 2) shows the characteristic values of these three axes. In addition, we could obtain a cluster tree and try to separate them into five groups (Table 3).

Table 2: Characteristic values of three axes analyzed by QMIII

Axis	*Characteristic value*	*Contribution ratio*	*Cumulative contribution ratio*	*coefficient of correlation*
1	0.53	18%	18%	0.73
2	0.39	13%	31%	0.62
3	0.37	12%	43%	0.60

Table 3: Matching of the cluster groups and samples

Cluster1	*Cluster2*	*Cluster3*	*Cluster4*	*Cluster5*
Sound loudness	Damping	Low density	Frequency	Variable
Beat	Clear	Imbarance	Clear shape	Non-uniform variation
Stereophonic image	Roundlike	Bleary shape		
Monophonic image	Uniform variation			
Thick	Expansion from the center point			
High density				
Materiallike image of the sound				
Spreaded				
Affinity				
Fuzzy				

4.2 Results of Monophonic/Stereophonic Comparison Experiment

The results of the variance analysis are shown Table 4.

Table 4: Matching of the cluster groups and samples

	Square sum	*Freedom degree*	*Mean square*	*f value*	*p value*
Detail	36	19	1.9		
Factor	1.6	1	1.6	2.45	0.13
Error	12.4	19	0.65		

5. DISCUSSION

From results of these experiments and surveys, we can construe the three axes as shown in figure 3. Therefore, we can recognize that the phase difference between sound stimulation provided to both sides is just one of the factors that generate spatial impressions and that spatial impressions have more complex structures than could be explained by the results of previous studies. In addition, were able to show that there is no significant difference in the spatial impressions imparted by stereophonic and monophonic environments. This indicates the possibility that spatial impressions do not depend on the stereophonic effect.

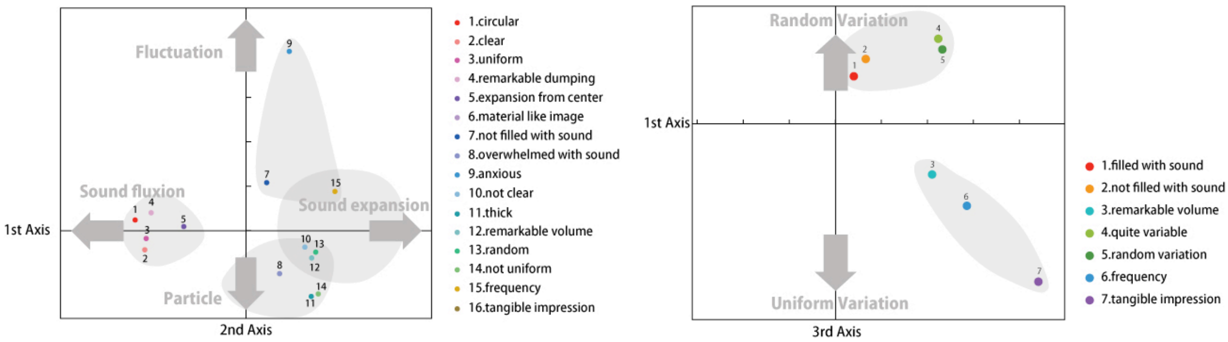

Figure3. Three axes and their construe

6. CONCLUSION

We first hypothesized that stereophonic sound is not necessary to evoke spatial impressions from listeners, which was supported by an example, and proposed the existence of an imaged spatial impression. To explore imaged spatial impressions, we then analyzed spatial impression structures via QMIII and the KJ-method. Finally, we showed the plausibility of our hypothesis. However, our presumption remains unproven at this point because of the experimentation environment and insufficient data. Therefore, we intend to continue with this study in order to obtain further data and create an integrated experimentation environment.

7. REFERENCE

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