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Impression of the sound of rain hitting umbrellas

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ABSTRACT

We hear the sound of rain in our daily lives not only on rainy days but also as sound effects to depict scenes. Nevertheless, it has not been clarified what kind of impression the sound gives has not been clarified. Here, we investigated the impression of the sound when rain hits umbrellas. Although many adjective pairs have been proposed to evaluate the sound of musical instruments etc., it was unclear if they were appropriate for evaluating the sound of rain-hitting umbrellas. Therefore, we first interviewed umbrella specialists to collect adjectives that describe the sound of rain hitting umbrellas. Through the interview, we obtained 46 pairs of adjectives to describe the impression given by the sound of umbrellas. We then recorded 30 sets with different umbrellas (including Japanese and western styles) and the magnitude of rain. Finally, we asked 20 participants (21.2 ± 1.0 years, five men and fifteen women) to rate the impressions by hearing the recordings with 46 pairs of adjectives. As a result, four axes of impression evaluation structure were found: "*tactile impressions*," "*physical properties*," "*shape and material*," and *"evoked emotions."* We believe our findings can be applied to product development and entertainment.
Keywords: Rain sound, Soundscape, Umbrella

1. INTRODUCTION

Since ancient times, cultures have enjoyed the sounds generated by water (1). In the literature, there is a famous Japanese haiku by Matsuo Basho, "The sound of water as a frog jumps into an old pond." Traditional Japanese garden styles also utilize water-based sound tools, such as Shishi-odoshi (2) and Suikinkutsu (3). Other countries also have water-based instruments, such as the glass harp, Hydraulophone, and Sea organ. Art and culture have long fostered a relationship between sound and water. The sound and tone of the rain have long been admired. In Japan, many onomatopoeias describe the sound of rain, such as " potsu-potsu," "para-para," "shito-shito," and "za-za." Additionally, a traditional instrument, referred to as the rain stick, is used in rain-making rituals and has presumably originated in Africa, which makes a sound that imitates the sound of rain. We hear the sound of rain in our daily lives, of which a common one is a sound of rain hitting an umbrella.

The sound of rain hitting an umbrella is also used in the artwork. In the Ghibli movie "My Neighbor Totoro (4)," Totoro borrows an umbrella from Satsuki, who loves the sound of rain hitting an umbrella and drops all water from the leaves. There are also artistic works, such as Rain Dance (5) and Re-Rain (6), that use the sound of rain hitting umbrellas. In Japan, there is also the "Taiko-Gasa (7)" umbrella, which is based on the concept of "making rain sound like a taiko drum."

In other words, the sound of rain hitting an umbrella is commonly appreciated.

Although there have been studies on the sound of rain hitting umbrellas (8, 9), only a few emphasize the impression of rainfall as a sound to be appreciated. In this study, we propose an impression evaluation structure for the rainfall hitting an umbrella.

Japanese adjective pairs used to evaluate tone impressions have been proposed by Kitamura and

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Namba and Namba and Kuwano (10). However, these adjective pairs were created only to evaluate sound sources, such as musical instruments, birdsong, and environmental sounds, which are generally considered listening targets. Therefore, we search for new indices that can be applied to the sound of rainfall hitting umbrellas—a sound source that has not been considered a listening target.

This study may have an impact on literature, art, and other fields.

In addition, umbrellas have commonly been designed with a focus on design and functionality. However, a new umbrella design process can emerge based on our results, in which umbrellas are designed from the perspective of sound.

Through discussions with umbrella craftsmen, we learned that they have tacit knowledge of making umbrellas, including what kind of sound they should make based on their in-field experience. However, this knowledge is based on the craftsmen's senses and is not currently documented.

Therefore, in this study, based on interviews with umbrella experts, we selected pairs of evaluation adjectives regarding the sound generated by rain hitting an umbrella and conducted a psychological evaluation using these pairs to explore the impression evaluation axes.

2. MATERIAL & METHOD

To understand the characteristics of the sound of rain hitting an umbrella, we conducted an evaluation experiment in which we presented the sound of rain hitting an umbrella to the participants and asked them to comment on their impressions in response. To collect the experimentally used adjective pairs, we interviewed umbrella experts. Then, the adjective pairs were used in a subjective evaluation experiment.

2.1 Adjective Pairs Used in Impression Evaluation Experiments

Japanese adjective pairs used for tone impression evaluation have been proposed by Kitamura, Namba et al. and Namba, Kuwano et al. However, it is unclear whether these adjective pairs are appropriate for evaluating the sound of the rain hitting an umbrella. Therefore, we interviewed umbrella experts regarding their impressions of the sound of the rain hitting umbrellas and collected adjective pairs to be used in an impression evaluation experiment.

2.1.1 Interviewees to Collect Evaluation Terms

The interviews were conducted with five umbrella specialists who work with umbrellas daily and were interested in the sound of the rain hitting umbrellas. Of these, two were umbrella craftsmen, one was involved in umbrella sales and product development, and one was a public relations representative for an organization related to umbrellas.

Table 1 – Interviewees

ID	Age	Gender	Job	Years of experience
1	48	Male	Western-style umbrella craftsman	25
2	60	Male	Western-style umbrella craftsman	55
3	31	Male	Umbrella sales representative and product development	9
4	58	Male	Umbrella production management	35
5	60	Male	Publicity for organizations related to umbrellas	15

2.1.2 Selecting the Evaluation Adjective Pairs

Semi-structured interviews were conducted to collect adjectives that describe the tone of rainfall hitting an umbrella, based on the following questions. During the interviews, we encouraged the participants to speak freely so that the experimenter would not guide their statements.

The questions asked were as follows, which were asked orally by the experimenter.

- What type of sound do you like?
- What type of rain sound do you want an umbrella to make?
- What type of sound do you want to hear in each situation, such as heavy rain, light rain, and weather rain?

We thought that if we asked the respondents to answer with adjectives, such as "Please answer the adjectives you use to describe the sound of rain hitting your umbrella," they would answer with the adjectives they use most frequently, regardless of whether they actually use them to describe the sound of the rain hitting their umbrellas. Therefore, we asked the respondents to answer about the tone and collected the resulting adjectives.

The interviews were conducted using Zoom, which lasted approximately one hour.

2.2 Impression Evaluation

An experiment was conducted in which participants were asked to listen to the sound produced when the rain hits an umbrella to evaluate their impressions of the resulting sound.

The sounds presented to the participants in the experiment were recordings of rain hitting umbrellas taken during rainfall using a rainfall device at a sports field. The sounds were evaluated using the SD method, based on adjective pairs obtained from the interviews described in Section 2.1, during which the participants rated their impressions of the sounds on a 7-point scale. The details of these experiments are described below.

2.2.1 Material

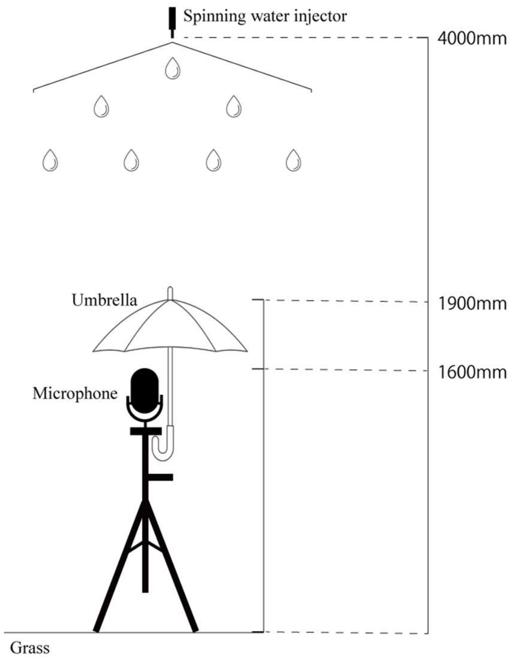

Figure 1 – Experimental equipment

The sound of the rain hitting umbrellas was recorded at a playground. We believe that the impression of the sound image expansiveness of the rain sound hitting an umbrella is also a factor related to the impression of the rain sound. Therefore, in subjective evaluation experiments, it is desirable to present participants with the sound they hear when they hold the umbrella as much as possible. Therefore, in this experiment, a microphone (Voyage Audio Spatial Mic) with a windscreen (Voyage Audio VA-0049) was utilized to record with first-order ambisonics and decoded binaurally using Google Resonance Audio. The recording was taken at a constant recording level and sampling frequency of 48 kHz, 32 bits.

Since rain falls equally on the ground, sounds are also generated when it falls on objects other than the umbrella. Therefore, to record only the sound of the rainfall hitting the umbrellas, recordings were made on a grassy area away from the surrounding buildings and trees so that the sound of the rainfall hitting the ground is less likely to occur.

The rainfall device was set at a height of 4 m. The umbrella was fixed at 190 cm, and the microphone was fixed at 160 cm. The height of the umbrella and microphone was determined based on the average height Japanese male holding the umbrella and the position of his ears.

Figure 2 shows example of the umbrellas used during the experiments. We used nine types of commercially available umbrellas (Japanese umbrella (large, D), Japanese umbrella (small), Western-style umbrella (8 bones, A), Western-style umbrella (24 bones), Western-style umbrella (double), vinyl umbrella, vinyl umbrella (bird cage type, C), folding umbrella (polystyrene), and folding umbrella (polyethylene, B)). The Japanese umbrellas were opened at two different positions for a total of 10 different conditions.

Three different rainfall patterns were applied using the heavy rain, standard, and diffusion nozzles of the rainfall device.

Thirty sound patterns were used as samples, varying the type of umbrella and rainfall strength.

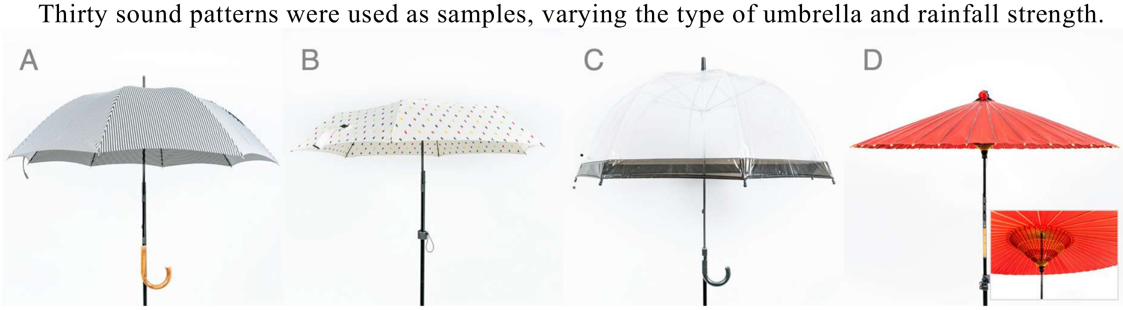

Figure 2 – Example of umbrellas used in the experiment

2.2.2 Sound Selection

Table 2 – Acoustic features of sound source

No.	Sharpness [acum]	Roughness [asper]	Normalized A-weighted root-mean-squared value [dB]	Spectral centroid [Hz]
0	1.71	0.21	0.0	3,024
1	1.84	0.34	10.9	3,721
2	1.66	0.33	9.5	3,100
3	1.94	0.21	3.5	4,064
4	1.72	0.25	1.6	3,404
5	1.80	0.22	8.8	3,973
6	2.08	0.28	11.6	4,648
7	1.87	0.26	2.3	3,914
8	1.65	0.22	0.0	2,774
9	1.75	0.30	8.7	3,174
10	1.76	0.24	10.9	3,305
11	1.93	0.27	2.3	4,009
12	1.76	0.18	1.6	3,465
13	1.59	0.31	6.8	3,080
14	1.88	0.30	10.7	3,898
15	1.57	0.19	9.0	2,728
16	1.70	0.29	9.2	3,211
17	1.53	0.31	7.4	2,573
18	1.82	0.29	9.5	3,690
19	1.97	0.21	11.4	4,145
20	1.91	0.27	9.5	4,238
21	1.83	0.37	10.4	3,648
22	2.14	0.19	12.1	4,710
23	1.81	0.23	0.3	3,505
24	1.75	0.23	-0.1	3,494
25	1.77	0.23	2.2	3,456
26	1.59	0.33	8.0	3,032
27	2.05	0.24	10.7	4,757
28	1.97	0.29	9.8	4,404
29	1.60	0.33	7.8	3,011

The sounds used in the experiment were selected based on the following criteria:

1. the sound of rain hitting an umbrella recorded in Section 2.2.3 was selected after three experimenters conducted in a quiet room after thoroughly listening to and comparing the sound sources using headphones.
2. No environmental sounds other than rainfall hitting the umbrella, such as the sound of a running car, were included.
3. There was no change in the amount of rainfall hitting the umbrella or in the size of the raindrops.
4. No change in the sound of raindrops hitting the umbrellas owing to changes in wind volume, etc. was observed.
5. The experimenter, who was not the same as the person who experimented, agreed with the above.
6. If a change in rainfall is detected, it is treated as a different stimulus sound.

Thirty sound types, one for each condition, were selected. The acoustic features of the sound sources presented are shown in Table 2. The normalized A-weighted root-mean-squared value was normalized with a value of No. 0.

The volume of each sound was not changed with respect to what was originally recorded, and the sound was cut off after 10 s. Although a longer cut-off interval would be ideal, it is necessary to cut off at a fixed interval because it is affected by rainfall, wind changes, and extraneous noise. In addition, the time length should be the same for all stimuli. For these reasons, the experimenter checked the recorded data for all conditions and decided on the longest possible cut-off time to maintain specific stability.

2.2.3 The Evaluation Experiment Participants

An experiment to evaluate impressions of rainfall sounds hitting umbrellas was conducted with 5 male and 15 female participants with an average age of 21 years (±1.0) with no hearing problems. The median number of years of musical experience was 11.5 years with a standard deviation of 5.634. The median years of experience with professional music education were five years with a standard deviation of 5.883. The median time spent listening to music was 105 min/day with a standard deviation of 58.585. Sixteen respondents were aware of environmental sounds in their daily lives. Fourteen respondents indicated that they perceived melody or rhythm in the environmental sounds and voices in their daily lives.

2.2.4 Sound Presentation Method

Subjects were presented with 15 randomly selected samples from the 30 samples and asked to evaluate them.

During this experiment, since it was difficult to conduct real-life experiments owing to the Covid-19 pandemic, we evaluated the impression of the sound when played through the headphones/earphones provided by each subject. Since the experiment was a subjective evaluation based on comparing the sounds generated by rain hitting umbrellas, the influence of the headphones/earphones was expected to be minimal. The participants were instructed to experiment in as quiet a room as possible with the equipment they use daily.

The volume was adjusted by the participants themselves so that they could hear the reading at the volume of everyday speech. Since it was unclear whether existing metrics, such as equivalent noise levels, were appropriate for adjusting the volume between the rainfall sound and voice, the sound level was adjusted subjectively to what the experimenters themselves heard and judged to be the average volume of the rainfall sound hitting each umbrella. The order of the adjective pairs used in the SD method was randomly presented to each subject, who rated them using a 7-point scale.

3. Results and Discussion

3.1 Evaluated Adjective Pairs

Four native Japanese-speaking experimenters conducted discussions and removed adjectives with overlapping meanings from the evaluated adjective pairs obtained from the interviews. The results are shown in Table 4.

Some commonly used adjectives for tone evaluation, such as "pleasant - unpleasant," "metallic - moist," and "unsatisfactory - powerful," were detected, as well as others that are not commonly used, such as "sparse - dense," "sunny - cloudy," "turbulent - ordered," "glossy - matte," "childlike - mature," and "flaky - watery."

Table 3 – Removed adjective pairs and the reasons

Removed adjective pairs	Reason
angular - rounded	overlap with "round - square."
harsh - mellow	overlap with "round - square."
grainy - smooth	overlap with "tight - loose."
sharp - blunt	overlap with "tight - loose."
muted - resonant	overlap with "muffled - clear."
cheerful - gloomy	overlap with "light - dark."
cute - deep	"cute" is a polysemous word, the meaning assumed by each subject is likely to differ when evaluating.

Table 4 – Evaluated Adjective Pairs

English (Translated)	Japanese
loud - soft	大きい - 小さい
round - square	丸い - 四角い
shallow - deep	浅い - 深い
light - heavy	軽い - 重い
noisy - quiet	うるさい - 静かな
smooth - rough	なめらかな - ざらざらした
light - dark	明るい - 暗い
high - low	高い - 低い
clear - murky	澄んだ - 濁った
thick - thin	厚い - 薄い
soft - hard	やわらかい - かたい
strong - weak	強い - 弱い
unsatisfactory - powerful	物足りない - 迫力のある
thin - thick	細い - 太い
beautiful - dirty	きれいな - 汚い
delicate - bold	繊細な - 豪快な
rough - quiet	荒れた - 静まった
dry - wet	乾いた - 湿った
sharp - dull	鋭い - 鈍い
warm - cold	暖かみのある - 冷たい
metallic - moist	金属性の - 深みのある
intense - mild	激しい - 大人しい
noisy - quiet	騒々しい - 穏やかな
refreshing - depressing	爽快な - 憂鬱な
refreshing - annoying	さわやかな - 鬱陶しい
muffled - clear	こもった - 抜けのよい
sunny - cloudy	晴れた - 曇った
fuzzy - distinct	あいまいな - はっきりした
turbulent - ordered	乱れた - 整った
distorted - straight	歪んだ - まっすぐな
rich - thin	豊かな - やせた
wide - narrow	広い - 狭い
fun - boring	楽しい - つまらない
pleasant - unpleasant	快い - 不快な
glossy - matte	光沢のある - マットな
simple - complex	単純な - 複雑な
secure - anxious	安心な - 不安な
open - closed	開いた - 閉じた
sunken - bouncy	沈んだ - 弾んだ
happy - sad	嬉しい - 悲しい
sparse - dense	疎な - 密な
angry - pleased	怒った - 喜んだ
tight - loose	芯のある - 締まりのない
cohesive - disjointed	まとまりのある - ばらばらな
childlike - mature	子供っぽい - 大人っぽい
flaky - watery	ぱらぱらした - べしょべしょした

3.2 Understanding the Impression Structure Using Factor Analysis

Table 5 – Results of factor analysis

	MR1	MR2	MR3	MR4	h2	u2
beautiful - dirty	0.805	0.476	-0.007	-0.048	0.693	0.307
noisy - quiet	-0.763	0.127	0.272	0.064	0.813	0.187
turbulent - ordered	-0.752	-0.351	0.029	0.178	0.521	0.479
secure - anxious	0.737	0.188	0.121	0.162	0.561	0.439
pleasant - unpleasant	0.715	0.228	0.066	0.241	0.632	0.368
rough - quiet	-0.703	0.140	0.381	0.087	0.826	0.174
noisy - quiet	-0.680	0.139	0.379	0.090	0.784	0.216
intense - mild	-0.667	0.209	0.377	0.031	0.816	0.184
smooth - rough	0.654	0.011	-0.039	0.051	0.461	0.539
delicate - bold	0.603	-0.079	-0.445	-0.161	0.696	0.304
childlike - mature	-0.590	-0.108	-0.050	0.440	0.380	0.620
soft - hard	0.540	-0.406	-0.105	0.164	0.596	0.404
metallic - moist	-0.497	0.345	-0.254	0.031	0.451	0.549
refreshing - annoying	0.492	0.221	-0.024	0.372	0.547	0.453
warm - cold	0.489	-0.202	0.174	0.244	0.339	0.661
cohesive - disjointed	0.463	-0.008	0.303	-0.068	0.226	0.774
angry - pleased	-0.453	0.005	0.174	-0.305	0.471	0.529
round - square	0.450	-0.401	0.048	0.218	0.432	0.568
sharp - dull	-0.266	0.677	-0.076	-0.042	0.586	0.414
distorted - straight	-0.179	-0.662	-0.098	-0.018	0.415	0.585
fuzzy - distinct	0.238	-0.610	-0.293	-0.044	0.581	0.419
tight - loose	0.035	0.592	0.458	-0.117	0.461	0.539
muffled - clear	0.115	-0.521	0.136	-0.211	0.486	0.514
clear - murky	0.449	0.521	-0.015	0.207	0.563	0.437
flaky - watery	0.119	0.509	-0.299	-0.120	0.332	0.668
sunken - bouncy	0.063	-0.477	-0.035	-0.324	0.464	0.536
high - low	0.043	0.471	-0.195	0.156	0.395	0.605
dry - wet	-0.210	0.426	-0.295	0.127	0.421	0.579
glossy - matte	-0.151	0.422	-0.176	0.163	0.356	0.644
simple - complex	0.111	0.386	-0.034	0.063	0.181	0.819
thin - thick	0.176	0.195	-0.747	-0.078	0.682	0.318
rich - thin	0.164	-0.122	0.685	0.198	0.405	0.595
thick - thin	-0.039	-0.139	0.670	-0.016	0.519	0.481
light - heavy	0.142	0.174	-0.630	0.128	0.624	0.376
loud - soft	-0.421	0.054	0.621	0.153	0.671	0.329
shallow - deep	-0.112	0.242	-0.603	0.059	0.479	0.521
unsatisfactory - powerful	0.399	-0.230	-0.595	-0.088	0.693	0.307
strong - weak	-0.486	0.221	0.594	0.071	0.805	0.195
sparse - dense	0.087	0.018	-0.433	0.159	0.303	0.697
happy - sad	0.060	0.031	0.071	0.700	0.496	0.504
fun - boring	0.041	0.055	0.214	0.640	0.395	0.605
light - dark	-0.014	0.217	-0.106	0.608	0.590	0.410
sunny - cloudy	0.117	0.188	-0.178	0.437	0.432	0.568
refreshing - depressing	0.185	0.353	0.068	0.419	0.439	0.561
open - closed	-0.128	0.221	-0.034	0.289	0.208	0.792

Table 6 – Factor contribution

	MR1	MR2	MR3	MR4
SS loadings	8.910	5.452	5.649	3.219
Proportion Var	0.198	0.121	0.126	0.072
Cumulative Var	0.198	0.319	0.445	0.516

Factor analysis was conducted on the results of an impression evaluation experiment to understand the impression structure of the sound of rain hitting an umbrella. The results are shown in Table 5. MR is the factor, h2 is communality, u2 is uniqueness. The analysis was conducted using the psych package in R with the maximum likelihood method and Promax rotation. Table 6 shows sums of squares of loadings(SS loadings), contribution ratio(Proportion Var), and cumulative contribution ratio(Cumulative Var) for each factor. The "wide - narrow" category was excluded from the factor analysis because its commonality value was low (0.0504), and we assessed that it could not be explained by the factors found in the analysis. Then, another factor analysis was conducted. Factor names were examined by associating the adjective pairs with factor loadings of 0.400 or higher on that axis, and 0.200 or lower on the other axes. The results indicated that the first factor was *tactile impressions*, including "secure - anxious," "pleasant - unpleasant," and "smooth - rough." The second factor was *physical properties*, including "distorted - straight," "muffled - clear," and "high - low." The third factor was interpreted as *shape and material*, including "thin - thick," "thick - thin," and "light - heavy." Finally, the fourth factor was *evoked emotions*, including "happy - sad," "fun - boring," and "light - dark."

3.3 Discussion

Since the interviewees stated that "children enjoy rainy days," we thought that the adjective "childlike - mature" may have been used to describe the tone because of this image.

In addition, since the target sound was rain, a sound associated with the weather, "sunny - cloudy," may have been used to describe the tone.

The words "turbulent - ordered" and "sparse - dense" are thought to be related to the rain patterns, while "glossy - matte" and "flaky - watery" are thought to be related to the water repellency of the umbrella's surface.

The low values for "wide - narrow" depicted in the factor analysis results may be because an umbrella is a tool that separates and creates personal space. Therefore, the umbrella image may have been defined by this tool.

The first factor, "secure - anxious," "pleasant - unpleasant," "smooth - rough," and "warm - cold," were highly contributing adjective pairs, which we named *tactile impressions* because we interpreted these as sensations obtained through the sense of touch.

The second factor was named *physical properties* because many factors related to the physical properties of objects, such as sharpness, distortion, lumpiness, bounce, height, and luster, were detected in this category.

The third factor was named *shape and material* because of the high contribution of adjective pairs related to the shape and material of the object, such as the thickness, thickness, and roughness/density.

The fourth factor was named *evoked emotions* because of the large number of adjective pairs related to emotions evoked when listening to the rainfall sound, such as happy, pleasant, and exhilarating.

Compared to the three factors of timbre proposed so far, namely the metallic, power, and aesthetic factors, the emotional and physical factors are included in the fourth factor, which is different from the metallic factor.

Elements of conventional factors are found in each factor, for example, in the first factor, "beautiful - dirty" and "pleasant - unpleasant," which are often interpreted as adjective pairs of the aesthetic factor, "metallic - moist," which is often interpreted as adjective pairs of the metallic factor, and “powerful,” which is often interpreted as adjective pairs of the influential factor. The factors include “noisy - quiet,” and “intense - mild,” which cut across the factors that have been proposed. The factors that constitute the timbre may differ for sounds that have not been considered as listening targets, such as the sound of the rain hitting an umbrella.

4. LIMITATIONS

The experiment was conducted with 30 samples, gathered with ten variations of umbrellas and three variations of rain; however, neither the rain nor umbrella variations were comprehensive.

The listening experiment could not be conducted in person owing to the Covid-19 pandemic, and the experimental environment and equipment used in the experiment could not be regulated. We believe that differences in the environment and equipment may have caused differences in the sounds heard by each subject. In the case of low-quality headphones, it can prevent listeners from hearing some subtle differences between sounds. Although the sound sources were presented as binaural sounds, we could not verify whether they adequately simulated the actual environment.

In addition, there were significant individual differences in the degree to which each subject perceived the rainfall sound. Many of the participants in this experiment were highly interested in environmental sounds; accordingly, their rain sound resolution was considered high. It is also possible that some people have opposing impressions of certain sounds. Therefore, the reproducibility between subjects remains an issue. In any case, it is necessary to increase the number of participants and verify these individual differences.

5. FUTURE RESEARCH DIRECTION

The impression structure revealed in this study may be useful when designing umbrellas that produce rain sounds to give desired impressions. It may also help select and generate rain sounds to provide the desired impression in a movie, animation, or game scene. In this study, the adjectives were collected from five umbrella experts. We aimed to collect adjectives not only from umbrella experts but also from sound experts, such as musicians, and word experts, such as poets and writers. There may be differences in the adjectives collected depending on the experts' specialty. In addition, although we experimented with Japanese, we would like to experiment with other languages to examine whether adjectives are invariant across cultures.

6. CONCLUSIONS

In this study, we collected evaluation adjective pairs describing the sound of rainfall hitting umbrellas and experimented to evaluate the impression of the same, which yielded the following results. Unique evaluative adjective pairs describing the sound of rainfall hitting umbrellas were found, such as "sparse - dense," "sunny - cloudy," and "turbulent - ordered," which are not often used as evaluative adjective pairs for tone. The impressions of the sound of rainfall hitting umbrellas can be expressed by a four-factor structure comprising *tactile impressions*, *physical properties*, *shape and material*, and *evoked emotions*. Thus, the results of this study provide insight into the impression structure of the sound of rainfall hitting umbrellas. These findings may be useful when designing umbrella products to reflect the "sound of rain hitting the umbrella" as a product value. The findings may also help select and create sound effects for movies, animations, and video games.

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