Noise-Canceling Music: Reducing Noise by Mixing it with Suitable Music

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Abstract. Ambient noise is part of our daily life, and sometimes such noise can be bothersome. To reduce noise exposure, people usually listen to music through headphones and earphones or use noise-canceling devices. However, these measures can block some important information that the users do not want to miss. We propose a method called "*noise-canceling music"* that reduces the subjective sound magnitude of the noise when it is mixed with suitable music. The results of the experimental tests confirm that the perceived sound magnitude of noise decreases when it is mixed with suitable music. However, the method was not effective when perceptions of music were different.

Keywords: Noise, Music, Entertaining, Noise-canceling-music, Discomfort

1 Introduction

We are surrounded by noise in our daily lives. There are many kinds of noise that come from machines (for example, vacuum cleaners, washing machines, police cars, passing trains and aircraft), and noise that comes from people and animals (for example, the sounds of leg shaking, keyboard tapping, mastication, barking dogs, crying children, and electoral campaign loudspeakers), all of which are often annoying.

To protect themselves from noise, people often listen to music at high volume using headphones or earphones. However, this leads to problems such as deterioration of hearing ability and sound leakage. Another way of reducing the exposure to noise is by using hermetically sealed or noise-canceling headphones. However, while these devices can alleviate stress from the ambient noise, using them may cause the wearer to miss important sounds such as train announcements, doorbells, alarms, or the voices of people speaking to us from behind.

We propose a method of protection from the ambient noise by distracting the user's attention from annoying noise instead of covering it up with some other sound. We hypothesize that mixing appropriate music with noise can reduce the negative perception of noise. Specifically, when a particular sound causes negative impressions in a user, our method transforms that impression of the noise to a positive one by playing suitable music and reducing the subjective sound.

We call this method "*noise-canceling music*." In our research, we implement and test a prototype system to check the usefulness of our method through experiments.

2 Related Work

Various studies have reported on measures to environmental noise in our daily lives.

Haiyan et al. [1] proposed a method that creates a masking effect by using natural, relaxing sounds such as the flowing of a river or the chirping of a bird. The masking sound is superimposed on the noise and is limited to natural sounds. Music was not at the center of the discussion in Haiyan et al.'s paper. Also, Karl et al. [2] focused on wind turbine noise in a quiet area and investigated the effect of using natural sound (wind or waves) as masking sounds. The results showed that the perceived loudness of the noise was reduced. In our research, we do not aim to create a masking effect, but our attempt to lower the attention to noise by superimposing another noise over it is similar. If the same effect is confirmed for music, we feel it would be possible to utilize the user's favorite music to cope with noise.

Vawter [3] proposed a method called "a*mbient addition,"* which applies digital signal processing to noise in devices such as headphones and blends it into the music being listened to. Although this approach is similar to ours in that it removes the discomfort from noise without blocking the surrounding information, our goal is also to change noise to a positive impression. This can significantly improve the quality of users' lives.

Various studies have already investigated the effect of music and noise on human perception and behavior.

Alexandra et al. [4] investigated the influence of the background music genre (hip-hop, jazz, classical, and rock) on the taste of food. The results showed that the impressions of the four music genres alter the impression of emotional stimuli in foods such as chocolate. Yamasaki et al. [5] investigated the effects of music on the perception of the environment. The results showed that the evaluation of the environment affected the characteristics of the music, especially in conditions where the perceived characteristics of the music and environment were incongruent. From these reports, it can be expected that an environment of unpleasant noise will be transformed into the opposite impression by mixing music.

Joseph et al. [6] investigated the effect of natural noise on the performance of work, such as study and office work. The result showed that natural noise creates a gentle feeling but suggests that if the volume change is large, it is harmful to the performance of the work. In our method, we expect there to be a positive effect on psychological impressions of various noise levels by manipulating the sound to feel small to the hearer.

3 Noise-Canceling Music

The aim of our work is to reduce the subjective sound magnitude of the noise by mixing the noise with suitable music. We hypothesize that mixing appropriate music with

noise can reduce the perceived magnitude of the sound. The *noise-canceling music* method is based on this hypothesis. Below are some examples of how the method works.

- The sound of cicadas is one of the loud noises heard in Japan in summer. When the user feels annoyed by this noise, suitable music evoking images of summer will play (for example, "Summer" composed by Joe Hisaishi) (see Fig. 1).
- The sound of construction is very loud and distracting. When the user feels annoyed by this noise, appropriate music evoking images of people working at a construction site will play (for example, "The star of our planet" by Chijo no Hoshi in Japanese, composed by Miyuki Nakajima).

The sounds surrounding the user should be continuously sensed. If user feels annoyed, suitable music will play automatically, reducing the subjective sound magnitude of the noise psychologically and changing the impression gained from the noise.

The music in our method can be presented in two ways. One is by using smart speakers such as *Google Home* and *Amazon Echo*, which are becoming widespread. The other is by using a wearable acoustic device such as *Xperia Ear Duo [7]*. With smart speakers installed in the environment, it should be possible to reduce the discomfort for all people on the spot by presenting the music selected for a particular kind of noise, but there is also a possibility that for some people that particular music will be undesirable. In contrast, when wearable an acoustic device, the music can be presented according to individual preferences, although it might be inconvenient to wear the device at all times.

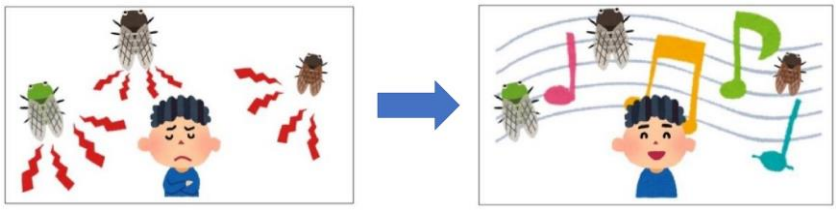

Fig. 1. Concept of proposed method

4 Experiments and Discussion

The *noise-canceling music* which we propose is based on the hypothesis that "mixing appropriate music with noise can reduce the perceived magnitude of the sound." We conducted an experiment to verify whether the noise remains bothersome when it is mixed with appropriate music.

We presented the participants with noise and music at the same time, for 30 seconds. Then, the music playback stopped and only the noise was played. The participants operated the system to reproduce the same sound magnitude of the noise as when it was played with the music. Based on this reproduced volume, we defined the subjective volume evaluation of the noise as the sound volume evaluation value and performed analysis to determine the effect of the proposed method.

To test our hypothesis, we selected noises frequently heard in daily life that were deemed by the authors to be bothersome. We then selected music that was deemed to be suitable for each noise. In addition, we decided on noise and music that could be placed in the same category, and then combined them. Table 1 lists the noise and music used in our experiment and the categories determined to be common for them. The participants tested all of the combinations of noise and music in this table randomly (ten kinds of music and nine kinds of noise). Also, when the category was “silence”, only noise was reproduced. In this case, the participant evaluated the volume of the noise, assuming that the music without sound was playing. After the experiment, we asked all the participants to answer the question: "What do you associate with each example of music?" There were 16 participants (seven male and nine female).

Before analyzing the results, we normalized the evaluation value based on the result of noise in no music (silence) category. Then, we compared the same category with a different category and analyzed the answers to the question to see whether the music associations of the participants were the same as ours or not.

Table 2 summarizes the average volume evaluation values for each combination of noise and music, where the noise is listed in rows and the music is listed in columns. Table 2 shows that the volume of the noise heard together with the music of the same category was evaluated as small in five categories: “summer,” “children,” “bad weather,” “driving sound,” and “construction.”

The average of all volume evaluation values in the same category (e.g. noise category was summer and music category was also summer) was 0.82, and the average in

Table 1. Correspondence table of noise and music.

	Category	Noise	Music/Composer
0	Silence		Silence
1	Summer	Cry of a Cicada	“Summer”/Joe Hisaishi
2	Car	Car Running	“TRUTH”/Masahiro Ando
3	Children	Children's Screeches	“Electrical Parade”/Gershon Kingsley, etc.
4	Bad weather	Strong Wind	“He's a Pirate”/Klaus Badelt
5	Speaking	Crowd	“Moanin’”/Bobby Timmons
6	Machine operation	Air Conditioner Running	“Battaille Décisive”/Shiro Sagisu
7	Construction	Rock drill	“Tijo no Hoshi”/Miyuki Nakajima
8	Sound leakage	Sound Leakage from Earphone	“One More Time”/Thomas Bangalter, etc.
9	Meal	Mastication Sound	“Attack on Titan”/Hiroyuki Sawano

Table 2. Average volume evaluation value.

Noise \ Music	Summer	Car	Children	Weather	Speaking	Driving	Construction	Leakage	Eating
Summer	0.81	0.89	1.00	1.10	0.82	0.84	0.83	0.97	0.86
Car	1.04	0.85	0.94	0.94	0.76	0.82	0.91	0.92	0.94
Children	0.90	1.05	0.82	1.31	1.24	1.38	1.04	0.97	1.11
Weather	0.88	0.77	0.92	0.72	0.95	0.89	0.81	0.86	0.80
Speaking	0.90	0.90	0.81	0.83	0.91	0.97	0.91	0.95	1.00
Driving	0.82	0.91	0.99	0.93	0.92	0.81	0.82	0.85	0.81
Construction	0.94	0.96	0.97	0.89	0.88	0.91	0.87	0.92	0.91
Leakage	0.97	0.86	0.96	0.95	0.81	0.88	0.99	0.91	0.82
Eating	0.95	0.84	0.74	0.62	1.03	0.79	0.84	0.68	0.76

a different category (e.g. noise category was summer and music category was speaking) was 0.94. Fig. 2 shows a comparison of the volume evaluation average with the averages of the same and different categories. Also, the left diagram shows the cases where the associations of the participants were the same as ours, and the right diagram shows the cases where the associations were different from ours. These results reveal that the sound volume evaluation value of the same category was significantly lower, regardless of whether the music associations were the same as, or different to ours ($p < 0.05$).

The results of the experiment demonstrate that our method can reduce the subjective sound magnitude of the noise by presenting music suitable for the noise, thus confirming our hypothesis. Moreover, even if associations from the music were different to ours, our method worked effectively with the music selected by us. The results show that even if the images evoked by the music do not match the noise, the tone and the atmosphere of the music blend with the images of the participants, so the noise can be well integrated.

However, in the "Children" category in Table.2, the sound volume is rated very high when presenting the music of another category. This may mean that presenting music unsuitable for the noise makes the noise feel louder, which confirms the importance of presenting music appropriate for the noise. We believe that the effectiveness of our method will increase greatly if we present music that will evoke the same images in as many people as possible.

In the future, we will investigate different kinds of music appropriate for reducing the perceived volume of other types of noise. If wearable acoustic devices like the *Xperia Ear Duo* become more common, it will be possible to present to the user the music he or she likes without having to seal the ears.

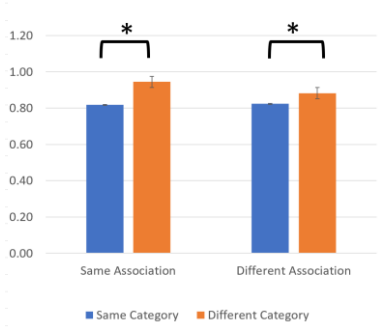

Fig. 2. The difference of the sound volume evaluation.

5 Conclusion and Future Work

In this paper, we proposed a method called "*noise-canceling music*" which protects users from everyday noises by mixing the noise with appropriate music. We conduct-

ed experiments combining multiple kinds of noise and music and discovered that the noise tended to be evaluated as less obtrusive when it evoked the same images as the music.

In our experiments, all participants were Japanese, so we used music familiar to Japanese people. However, even in areas other than Japan, the method is expected to have similar effects because it focuses on matching the images evoked by music and noise. Music can be selected according to the specific region and culture.

There are still many aspects of the proposed method that have not been clarified yet. For example, it is not clear whether the effect depends on the context of the music, the frequency, or something else altogether. We intend to clarify these points by conducting more experiments in the future.

In our research, we focused on matching the noise and the music, but the method in which the impression of noise is transformed can also be considered. Sounds in movies, dramas, and animations are often artificial: for example, the sound of a wave is made by shaking red beans in a box, and the footsteps of a horse can be made using a box, a bowl, and wood. In other words, by manipulating the noise to make it seem like something else, it is possible to eliminate the negative influence of the noise. The possibility of this impression transformation will be explored in our future work.

In addition, we also plan to implement a system which can sense the noise surrounding the user and select and play from the user's music archive a type of music suitable for the noise. We plan to assess the usefulness of our system in daily life.

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