Toward Adaptive Interaction – The Effect of Ambient Sounds in an Ultra-Realistic Communication System

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Abstract. Our research focuses on *ambient sounds* as a key to implementing an ambient atmosphere of people, that is, the feeling of another's proximity or presence. Such knowledge is sought for constructing an ultra-realistic communication system with shared reality. This study examines whether people's impressions and behaviors are affected by (a) the existence or (b) non-existence of ambient sounds. A pilot study is conducted by using the ambient sounds of a newspaper's pages being turned and a glass being placed on a table in an adjacent room. No difference in the subjects' surface behavior between the two ambient-sound conditions is observed explicitly. However, the preliminary results suggest that participants feel an ambient atmosphere of people in the next room when the ambient sounds are output. They also suggest that the participants become nervous as they feel the presence of other people. This study demonstrates the importance of investigating the fundamentals of an ambient atmosphere in interaction via an ultra-realistic communication system.

Keywords: Ultra-realistic communication system, Ambient atmosphere, Ambient sound, behavioral evaluation, psychological evaluation.

1 Introduction

Many people have had the experience of visiting the haunted house or fun house at an amusement park. The Haunted Mansion at Disneyland is a typical example of a walk-through ghost house. In these haunted houses, why do people feel so scared of ghosts? Why do people feel that ghosts actually exist around them? Lighting, sounds and objects produce the perceived presence of ghosts in a haunted house. Sounds in particular seem to play an important role in facilitating the perceived presence of ghosts.

The authors have joined the Ultra-realistic Communication System Group of the National Institute of Information and Communication of Japan (NiCT). The purpose of the project is to construct a system for embodied interaction with remote partners by improving the reality of interaction through multi-modality techniques, i.e. using

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3-D video, 3-D audio, olfaction and the tactile sense. As a way to improve the reality of interaction, our research focuses on the effect of ambient atmospheres or existences of people, especially the ambient sounds that people make.

Most conventional systems for supporting communication with remote partners have been developed to provide the physical presence of people [1-3]. Some of these studies have utilized both verbal cues like speech and non-verbal cues like gestures to enhance the presence of remote partners [2, 3]. On the other hand, in face-to-face interaction, people might consciously or subconsciously perceive an ambient atmosphere of partners by listening directly to ambient sounds such as the noises that partners make as a result of interaction between a human body and objects or noises from a human body itself. Ambient sounds seem to play an important role in creating a shared reality among participants. However, little research has focused on the ambient sounds made by people.

This paper examines whether ambient sounds affect both the psychological impressions and behaviors of people, with the aim of demonstrating the effect of ambient sounds on creating a shared reality. A pilot study was conducted with a between-participants design under two different sound conditions: (a) existence and (b) non-existence of ambient sounds. There are many kinds of ambient sounds that people make in everyday life, e.g. footsteps, the rustle of clothing, and breathing. In this pilot study, we examined two types of ambient sounds: a newspaper's pages being turned and a glass being placed on a table. We divided the participants into two groups according to the two sound conditions. They were asked to wait in an experimental room with or without ambient sounds from the next room. Participants answered a personality test and a post-questionnaire about their impressions of the experimental room's atmosphere before and after the experiment, respectively. In addition, their surface behavior was observed during the waiting period. The preliminary results were analyzed, and three factors were examined: (i) the difference in behaviors between the two sounds conditions, (ii) the difference in psychological impressions of the atmosphere between the two conditions, and (iii) the correlation between psychological impressions and the personalities of participants.

2 Related Works

Acoustics

In the research field of acoustics, the focus of studies on ambient sounds has mainly been their induced effect of spatial attention in visually impaired people [4, 5]. These research efforts have studied the relationship between the reflected sound localization and the sense of obstacles held by such people; it was found that they seem to recognize the type of obstacle or their distance from the obstacle by using the reflected sounds that they make themselves. Moreover, by using both acoustics and virtual reality techniques, a spatial navigation system has been developed for the visually impaired. These conventional studies thus examined the relationship between the reflected sounds from an obstacle and the existence of an obstacle. However, little

attention has been given to the relationship between ambient sounds that people make and the presence of people.

Ambient interface
In the research field of ambient interfaces, most conventional studies have tried to adapt the sound presence of people to other media, e.g. the lighting or color of an object including a lamp or a wall. Some studies have regarded ambient sounds as a subtle cue for calling attention to the physical presence of others, such as a hamster or people [6-8]. In these studies, the sound presence of creatures was modified to other kinds of ambient sounds, such as the natural soundscape or the sound of material. The level or the intensity of ambient sounds has been controlled according to the change in the level of the original sound source or the number of people. However, little attention has been given to the direct utilization of the original sound presence of people.

3 Pilot Study

Our research aim is to construct an ultra-realistic communication system featuring a shared reality. As a method for establishing a shared reality among people at multiple points, we focus on the ambient atmosphere arising from communication partners. In face-to-face communication, people can consciously or subconsciously perceive the ambient atmosphere of communication partners by listening to the ambient sounds that people make as a result of interaction between the human body and objects or from the human body itself. We believe that ambient sounds can play an important role in facilitating a shared reality among participants through an ultra-realistic communication system. As a first step, we conducted a pilot study to examine the effect of ambient sounds on the psychological impressions and behavior of people when they hear such sounds from an adjacent room.

Types of ambient sounds
People make many kinds of ambient sounds, such as footsteps, the rustle of clothing, and breathing. In this pilot study, we selected two kinds of ambient sounds that a human makes while sitting in a chair in the course of everyday life: turning the pages of a newspaper and placing a glass on the table.

Recording of ambient sounds
Figure 1 shows the recording environment for the above two ambient sounds. These sounds were recorded in an anechoic room via a microphone (NEUMANN U87A) and a microphone pre-amplifier (AMEK System 9098) to a DV recorder (SONY DSR-45) (sampling rate 44.1 kHz, 16 bit, monaural). The sound spectrogram of these ambient sounds, especially turning the newspaper's pages, spread out over a wide frequency bandwidth. Ambient sounds are output for five minutes, and they include 15 instances of page turning and 12 instances of placing the glass on the table.

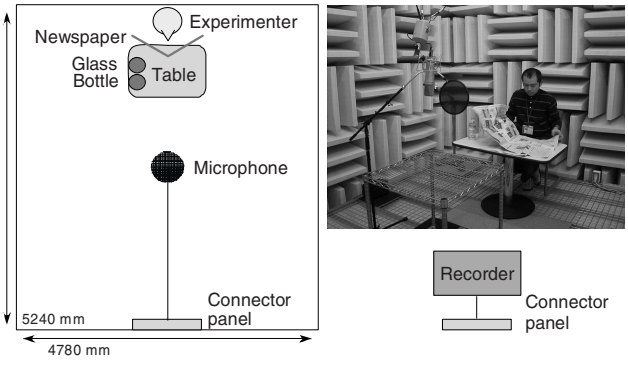

Fig. 1. Recording environment for ambient sounds: wiring diagram and appearance of the anechoic room

Experimental environment

Figure 2 shows the experimental environment for the pilot study. A soundproof room was used as the experimental room. This room was divided into two areas by partitions: a waiting room for the participants and an area used for playing ambient sounds from the speakers. Ambient sounds were played from two speaker sets: high-frequency sounds from JBL Studio Monitor 4410 and low-frequency sounds from BAG END 115 Cabinet via power amplifiers AMCROM D75A and AMCROM D-150A Series II, respectively. The sound source was DV tape and the player was the SONY DSR-45 DV player/recorder. The door of the experimental room was open, but it was difficult for the participants to see the status of the next room across the partitions.

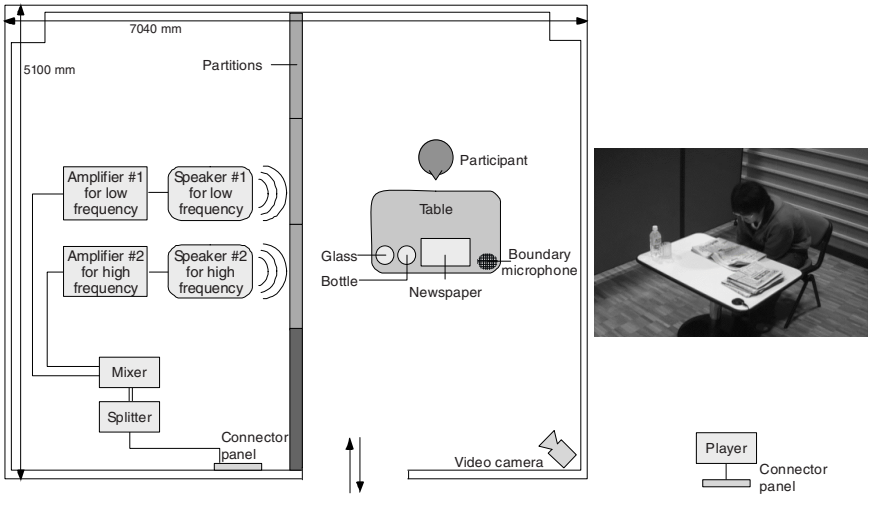

Fig. 2. Experimental environment for the pilot study: wiring diagram and appearance of the experiment

Participants
The participants in the pilot study were 22 people aged from 21 to 36 years old. They were told simply that they would be participating in a study on human tendencies in an ultra-realistic communication system. They were divided into two groups according to the conditions described below.

Procedure
The pilot study was conducted with the two ambient-sound conditions in a between-participants design. On arriving at the laboratory, each participant was asked to answer the Big Five Personality Test. Participants were brought to the experimental room and instructed to sit down and wait in a chair until the experiment was prepared. Some newspapers, a bottle of water and a glass were put on the table in front of each participant. The experimenter explained why these objects were placed there when the participants asked about them. The participants waited for five minutes. After that, they were asked to answer a post-experimental questionnaire about their impressions of the waiting time. At the end of the experiment, the experimenters also interviewed them. In addition, their behavior was observed during the waiting period with a video camera and a boundary microphone.

Conditions
Two conditions were used for ambient sounds, and the participants were divided into two groups based on these conditions.
EAS: Existence of ambient sounds from two speakers in the next room.
NAS: Non-existence of ambient sounds from the next room.

Measures
(i) Personality evaluation: In a Big Five Personality Test conducted before the experiment, the participants were asked to answer 70 questions about their personality via a computer. The score of each basic personality dimension was calculated from the results of the test. The basic dimensions of personality in a Big Five Personality Test are as follows: E (Extroversion), A (Agreeableness), C (Conscientiousness), N (Emotional stability/Neuroticism), and O (Openness for experience/Intelligence).

(ii) Psychological evaluation: In a psychological evaluation conducted after the experiment, the participants were asked to answer a questionnaire on the following evaluation items. All of these items were evaluated based on a 7-point scale by the participants.

1. Nervousness: Degree of nervous feeling held by the participant during waiting.
2. Space of the experimental room: Degree of feeling the space in the experimental room.
3. Oppressiveness: Degree of oppressive feeling held by participant in the experimental room.
4. Presence of other people: Degree of feeling the presence of other people in the next room held by the participant.
5. Existence of sound: Degree of feeling the existence of sound from the next room held by the participant.
6. Room layout: Degree of belief by the participant that there is another door for other people beyond the partition in the experimental setting.

(iii) Behavior observation: While they waited in the experimental room for five minutes, the participants' behavior was observed by the experimenters and recorded through a video camera and a boundary microphone. In this paper, the experimenter simply analyzed the participant's surface behavior during the first 1 minute according to the following three criteria:

Synchrony:

(a) Whether the participant read the newspaper while listening to the ambient sounds of someone turning newspaper pages.
(b) Whether the participant picked up the glass while listening to the ambient sounds of someone placing a glass on a table.

Awareness:

(c) Whether the participant looked around the experimental room when she/he becomes aware of the ambient sounds from the next room.

Hypothesis

In this pilot study, we assumed the following hypotheses to examine the effects of participants' impressions and behavior in response to the existence of ambient sounds, even when the ambient sounds do not include human speech but simply noises resulting from the interaction between a human body and an object, i.e. a newspaper or a glass.

Psychological evaluation:

- Participants may be aware of ambient sounds when they are assigned to either the EAS group/NAS group.
- Participants may feel the presence of people in the next room when they hear ambient sounds from the next room under either the EAS condition/NAS condition.

Human behavior:

- Participants may change their behavior, such as lifting their face or gazing around the experimental room, when they are aware of ambient sounds under either the EAS condition/NAS condition.
- Participants may pick up a newspaper or a glass when they hear ambient sounds from the next room under either the EAS condition/NAS condition.

4 Results

Behavior observation

Figure 3 shows behavior observation results for both EAS and NAS conditions. NP means the participants who picked up a newspaper and read it. GR means the participants who gazed around the experimental room. WT means the participants who simply waited without gazing around the room while sitting in the chair. No significant difference in people's surface behavior between the two conditions was observed explicitly. The NP participants were 6 for the EAS group and 4 for the NAS group, and the GR participants were 4 for the EAS group and 5 for the NAS group. In

post-experimental interviews, participants explained the reasons for their behavior. Under both conditions, the NP participants answered that they picked up the newspaper just because they found it on the table. In the NAS group, the GR participants answered that they gazed around because they were curious about the structure of the experimental room or the installation of the video camera and microphone. In addition, the GR participants in the EAS group answered that they were also curious about the sounds from the next room. Consequently, these results did not verify our hypotheses of human behavior directly.

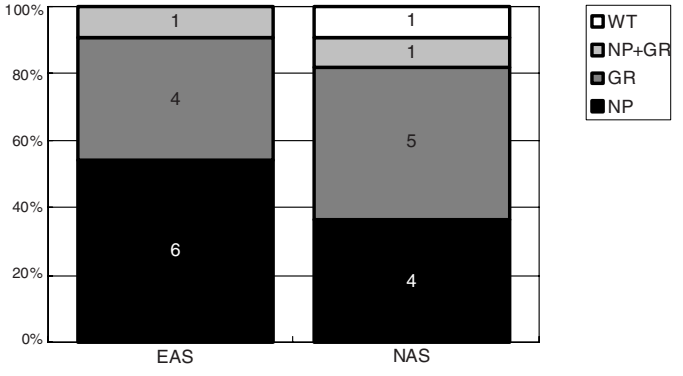

Fig. 3. Behavior observation results under two conditions: EAS and NAS

Psychological evaluation

Analysis 1: Comparisons between EAS and NAS groups

Figure 4 shows the results of comparing the psychological evaluations of the EAS and NAS groups. There were significant differences in both evaluation items 4 (Presence of other people) ($p = .0001$) and 5 (Existence of sounds) ($p < .0001$) by using the Mann-Whitney U test. On the other hand, there were no significant differences in 1 (Nervousness) ($p = .9171$), 2 (Space of experimental room) ($p = .1222$), 3 (Oppressiveness of room) ($p = .8869$), and 6 (Room layout) ($p = .3326$). In the post-questionnaire, participants who scored 5 points or more on question D were asked how many people were in the next room. All of these participants answered just one. This result shows that the participants under the EAS condition were aware of ambient sound from the next room and felt the presence of other people there. These results support our hypothesis.

Analysis 2: Correlations among items

EAS group: There is a positive correlation between 4 (Presence of other people) and 5 (Existence of sounds from the next room) ($\rho = .780$, $p = .0031$). This result supports our hypothesis.

NAS group: There is a positive correlation between 1 (Nervousness) and 5 (Existence of sounds from the next room) ($\rho = .788$, $p = .0025$). This result suggests that the participants in the NAS group may be sensitive to sounds around them, including noise from the air conditioner during the waiting period.

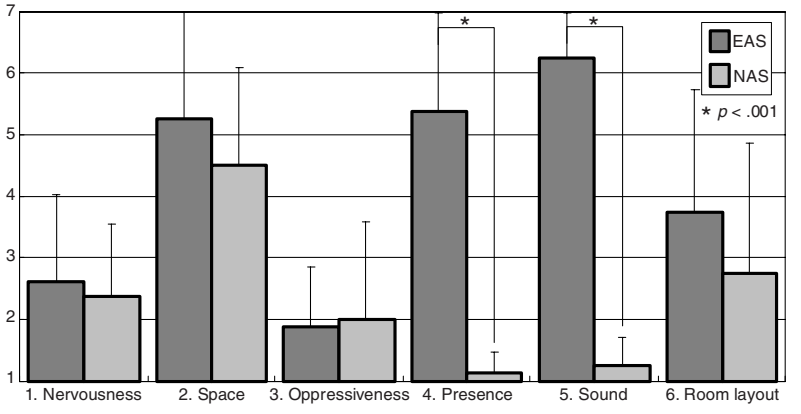

Fig. 4. Psychological impressions between EAS and NAS groups

Analysis 3: Factor analysis

EAS group: Factors were extracted by the unweighted least squares method, and the promax rotation was adopted. Two factors were extracted by considering the decay of the eigenvalues (Table 1). The inter-factor correlation between two factors is weak, with a value of only .084. This suggests that these factors are independent.

NAS group: No factor was extracted.

These results suggest that the participants in the EAS group became more nervous as they felt the presence of other people in the next room by listening to the ambient sounds. In addition, the oppressive feeling of the participants in the EAS group is associated with the room layout of the experimental room. These results supported our hypothesis.

Table 1. Factors in EAS group loading after promax rotation

	Factor I	Factor II
4. Presence	0.847	0.076
5. Sound	0.803	-0.196
2. Space	0.585	0.365
1. Nervousness	0.568	-0.166
6. Room layout	-0.004	0.813
3. Oppressivenss	0.122	-0.725

Correlation between personality of participants and psychological evaluation

EAS group: There is a positive correlation between C (Conscientiousness) and 3 (Oppressiveness) (ρ = .643, p = .0309). In addition, there is a negative correlation between N (Emotional stability/Neuroticism) and 1 (Nervousness) (ρ = -.665, p = .0233).

NAS group: *There was no correlation.*

We found two correlations between personality of participants and psychological evaluation in the EAS group but no correlation in the NAS group. These results

suggest that ambient sounds provide an interpersonal effect, since the Big Five Personality Test includes interpersonal factors.

5 Discussion

The above results partly support our hypotheses. No difference in participants' surface behavior between the two ambient-sound groups, EAS and NAS, was observed explicitly. On the other hand, the participants in the EAS group were aware of ambient sounds from the next room and felt the presence of other people there, even when ambient sounds did not include human speech but simply the sounds of turning the pages of a newspaper or placing a glass on a table. In addition, the above results suggest that the participants in the EAS group felt nervous as they felt the presence of other people in the next room.

The main reason for this is the difficulty of selecting the appropriate surface behavior for behavior observation. In this pilot study, we selected two kinds of surface behaviors, synchrony and awareness. For synchrony behavior, we did not induce such behavior from the participants, since we did not succeed in making the participants recognize the correct sound source. We set newspapers, a glass and a bottle of water on the table, since we expected that the participants would synchronize their behavior to the contents of ambient sounds. Almost none of the participants in the EAS group recognized the contents of the ambient sounds of turning a newspaper's pages and placing a glass on the table, although they were aware of the existence of sounds. In the post-questionnaire, they answered that these sounds came from turning A4-sized papers over or touching a plastic bag, not from a newspaper. They also assumed the sounds of operating equipment, i.e. a computer mouse, rather than from a glass. This also involves the technical problem of recording and playing ambient sounds with a wide frequency range. In addition, people are apt to pick up a newspaper to "kill time," regardless of the existence or non-existence of ambient sounds. For awareness behavior, we did not identify the participants' behavior of gazing around the room as a result of awareness. The participants in both EAS and NAS groups gazed around the experimental room. In the post-experiment interview, the participants in the NAS group explained that they did this because they were interested in the structure of the room and equipment such as the video camera and microphone. On the other hand, the participants in the EAS group answered that they gazed around because the sounds from the next room had caught their attention.

These preliminary results have theoretical and practical implications. The key theoretical implication is that ambient sounds have the possibility of inducing the presence of other people; this is even true for sounds that do not include human speech or any noise from the nose/throat but that instead consist of noises people make as a result of interaction between the human body and an object. This could lead to examination of other kinds of ambient, implicit factors as fundamental determinants of feeling the presence of other people.

As a practical implication, this pilot study shows a new direction in a design concept for a system that supports communication with remote partners, i.e. an ultra-realistic communication system. Moreover, it was found that even ambient sounds offer the possibility of facilitating a shared reality among participants by inducing the presence of other people.

6 Conclusions

In this paper, we focused on the effects of the ambient sounds of a newspaper's pages being turned and a glass being placed on a table. These effects were investigated as a fundamental aspect of facilitating a shared reality among participants through an ultra-realistic communication system. We examined how ambient sounds affect psychological impressions and behaviors of people through a pilot study. We analyzed the experimental data through behavior observation, psychological evaluation, and a personality test. This pilot study was conducted with a between-participants design, by dividing the participants into two groups: EAS (existence of ambient sounds) and NAS (non-existence of ambient sounds). From the pilot study, we obtained the following results:

- Participants in the EAS group were aware of ambient sounds from the next room and felt the presence of other people there.
- Participants in the EAS group became nervous as they felt the presence of other people in the next room.
- No difference in the participants' surface behavior between the two groups was observed explicitly.

We confirmed that ambient sounds affect human impressions of the presence of other people, even though the ambient sounds consist of only noises resulting from an interaction between the human body and objects, i.e. a newspaper or a glass.

This work represents a first step toward examining the relationship between ambient sounds and the shared reality among participants achieved through an ultra-realistic communication system. Perhaps there are many other ambient and implicit factors that can provide more effective fundamentals. We will investigate such candidates in our future research.

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