# Effect of Manipulated Amplitude and Frequency of Human Voice on Dominance and Persuasiveness in Audio Conferences

TZU-YANG WANG, University of Tsukuba, Japan
IKKAKU KAWAGUCHI, University of Tsukuba, Japan
HIDEAKI KUZUOKA, University of Tsukuba, Japan
MAI OTSUKI, University of Tsukuba, Japan

We propose to artificially manipulate participants' vocal cues, amplitude and frequency, in real time to adjust their dominance and persuasiveness during audio conferences. We implemented a prototype system and conducted two experiments. The first experiment investigated the effect of vocal cue manipulation on the perception of dominance. The results showed that participants perceived higher dominance while listening to a voice with a high amplitude and low frequency. The second experiment investigated the effect of vocal cue manipulation on persuasiveness. The results indicated that a person with a low amplitude and low frequency voice had greater persuasiveness in conversations with biased dominance, while there was no statistically significant difference in persuasiveness in conversations with unbiased dominance.

CCS Concepts: • **Human-centered computing** → **Laboratory experiments**; *HCI theory, concepts and models*; Collaborative interaction;

Keywords: CMC; dominance; persuasiveness; vocal cue; audio conference; loudness; pitch; amplitude; frequency

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## 1 INTRODUCTION

Audio conferences are still widely used in business [22, 23]. For such conferences to have the best outcome, every participant should contribute to the discussion equally so that various viewpoints and opinions are well-discussed, leading to the higher conference quality [30]. However, in real-world situations, biased dominance of utterances changes the balance [27]; i.e., participants with assertive personalities tend to acquire more chances to speak, making other participants relatively silent. Therefore, it may be beneficial for participants if an audio conference system was able to adjust each participant's dominance in a discussion and thereby facilitate balanced contributions from participants.

Authors' addresses: Tzu-Yang Wang, University of Tsukuba, Tsukuba, Ibaraki, 305-8577, Japan, st900278@gmail.com; Ikkaku Kawaguchi, University of Tsukuba, Tsukuba, Ibaraki, 305-8577, Japan, ikkaku2165@gmail.com; Hideaki Kuzuoka, University of Tsukuba, Tsukuba, Ibaraki, 305-8577, Japan, kuzuoka@acm.org; Mai Otsuki, University of Tsukuba, Tsukuba, Ibaraki, 305-8577, Japan, otsuki@emp.tsukuba.ac.jp.


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To achieve this goal, we considered two aspects: perception of dominance and persuasiveness. The perception of dominance is how humans perceive a person's ability to control the conversation [44]. By decreasing the perceived dominance, even a relatively reticent individual may not be neglected and have the chance to speak [47]. Persuasiveness is a term to describe the ability how a person can change others' opinions [38]. By increasing persuasiveness, a human can change a decision in a discussion [38]. Both aspects are expected to enhance a participant's impact in an audio conference.

Past research has shown that some nonverbal cues including eye contact and kinesics influence the perception of dominance [31, 52] and persuasiveness [5, 13]. However, since audio conferences do not transmit facial expressions or body movements, most nonverbal cues are not available in them. Hence, it is expected that the importance of the remaining nonverbal cues, i.e., vocal cues, increases. The literature indicates that loudness and pitch are two fundamental vocal cues [11], and amplitude and frequency are objective measures of loudness and pitch, respectively. Here, we propose to manipulate the amplitude and frequency of the voice to change unbalanced situations in audio conferences. As our initial approach to achieving this goal, we investigated how manipulation of vocal cues, i.e. frequency and amplitude, affects the perception of dominance and persuasiveness.

## 2 BACKGROUND

### 2.1 Dominance and Persuasiveness

There are many dimensions with which to describe social interactions; the "vertical dimension" is important for indicating how one person controls another person [21]. The vertical dimension has various aspects such as leadership [48], status [21], dominance [45], and persuasion [46]. Among them, dominance and persuasiveness are two important aspects of conference discussions. An attendee with higher dominance will have higher priority to speak and have more capability to interrupt others [42, 44, 47], while an attendee with persuasiveness can influence others' decision making [38].

The definition of dominance varies depending on the research [46]. In our study, following Schmid Mast's definition [45–47], we defined dominance as the characteristic that someone has the ability to control a conversation. Perception of dominance means the dominance an observer feels from another person. Several studies revealed that many different nonverbal cues affect the perception of dominance, such as facial expression, gaze, interpersonal distance, and posture [21].

Persuasion is a process in which a person attempts to influence or control other people's decision-making, opinion, or behavior [17]. "Persuasiveness" means the ability to persuade. Burgoon et al. indicated that several nonverbal cues such as facial expression, body movements, and eye contact directly influence the source credibility and further affect persuasiveness [5]. Regarding vocal cues, fluency and tone variation were considered to be related to persuasiveness [4, 5]. However, there has been limited research investigating how other vocal cues, such as tempo, pitch, and loudness, affect persuasiveness. Thus, it is worth exploring the relationship between various vocal cues and persuasiveness.

### 2.2 Features of the Human Voice

Vocal cues, also known as vocalic cues, are a class of nonverbal expressions. Among them, we focused on the two fundamental vocal cues, loudness and pitch [11]. Loudness is a term that expresses how humans perceive the power of a voice and it is composed of several physical factors including amplitude. Here, the decibel is a commonly used logarithmic unit describing the power difference between two sounds, and it can be used to quantify amplitude. Pitch is the perceived frequency of sound which is known to be associated with the fundamental frequency (F0) [18],

the lowest frequency produced by any particular sound generator. The pitch of voiced speech is influenced by many factors such as gender and age [25]. Males' F0 is around 120 Hz, while females' F0 is around 210 Hz [54].

Since the amplitude and frequency are objective measurements of loudness and pitch respectively, we will mostly use the terms "amplitude" and "frequency" in the rest of this paper.

### 2.3 Effect of Amplitude and Frequency of Human Voice on Perception of Personality

Many of the interpersonal behavior studies investigated how the amplitude and frequency of the human voice influence perception. Burgoon et al. asked undergraduate students to mark attributes describing a friend as most dominant and least dominant, and the results indicated that loudness[1] was one of the attributes that affected dominance [6]. Collins asked females to rate the attractiveness of recorded male voices, and the results indicated that females considered males with lower F0 to be more attractive [9]. In Tusing et al.'s research, participants judged videos that contained several spoken messages with different mean amplitudes, amplitude variances, mean F0, and F0 variances. The results suggested that two variables of amplitude (mean amplitude and amplitude variance) positively related to the perception of dominance, but mean F0 and F0 variance did not have a significant effect [55]. In all, these results suggest that the amplitude and frequency of the human voice relate to the perception of dominance and persuasiveness.

### 2.4 Effect of Voice Manipulation

Since the amplitude and frequency of the voice are known to affect others' perception of a speaker, we can assume that manipulation of those vocal cues would change such a perception.

Feinberg et al. manipulated the fundamental frequency of males' voices pronouncing vowels and asked female participants to rate their attractiveness. The results suggested that raising the frequency of males' voices decreased the females' perception of attractiveness [15]. A similar result was reported by Collins [9]. Some studies investigated the effect of vocal cue manipulation on perceived dominance. Jones et al. manipulated voice frequency, and they found that voices with lowered pitch[1] were perceived as more dominant [29]. Borkowska et al. manipulated the frequency of female voices; they also found that lowered voices are perceived as more dominant [1]. Note that both Jones et al. [29] and Borkowska et al. [1] used prerecorded human voices pronouncing vowels.

Additionally, Hughes et al. asked participants to intentionally manipulate their voices to portray attractiveness, confidence, dominance, and intelligence. By comparing those voices with their normal voices, they found that the participants changed the fundamental frequency, amplitude, jitter, shimmer, hoarseness, and voice quality [26]. On the basis of these results, we assumed that artificial manipulation of the amplitude and frequency of voices would affect the perception of dominance.

### 2.5 Research Focus of This Study

As we have explained in this section, various studies have investigated the relation between vocal cues and the listener's perception of the speaker's traits. In this study, we are interested in investigating the effect of artificial manipulation of vocal cues, i.e. frequency and amplitude on perceived dominance and persuasiveness during conversation. As for perceived dominance, however, the previous studies either tested only with pronounced vowels [1, 29], self-manipulated human voice [26], or multiple human voices that had different vocal features [55]. No studies have tested artificially manipulated human voices speaking full sentences. Because this study envisions enhancement of audio conferences, it is preferable to use longer speech for our experiments. As for

[1]We use the terms "loudness" and "pitch" consistently with the original literature.

persuasiveness, to the best of our knowledge, no studies have investigated the effect of artificially manipulated vocal cues on (our definition of) persuasiveness.

This paper reports two studies, the first aiming to expose the effects of a speaker's fundamental frequency and amplitude on listener perceptions of dominance (experiment 1), and the second examining the potential of the relative fundamental frequency and amplitude to influence the perception of persuasiveness of a confederate in decision-making tasks (experiment 2). Note that many of the previous studies considered the gender of speakers and listeners as important factors of perception of the speaker's traits. However, as the initial stage of our investigation, we used only male speakers.

## 3 EXPERIMENT 1

### 3.1 Experimental Design

*3.1.1 Hypotheses.* On the basis of the existing studies, a voice with a lower frequency and higher amplitude seems to be perceived as more dominant. Therefore, in the first experiment, we examined following two hypotheses:

- H1: Participants perceive higher dominance while listening to a voice with a lower frequency.
- H2: Participants perceive higher dominance while listening to a voice with a higher amplitude.

*3.1.2 Method.* To test the hypotheses, we conducted an experiment with a 2 (high amplitude vs. low amplitude) x 2 (high frequency vs. low frequency) within-participants design. On the basis of our informal tests, we chose 10 dB as the difference between the high amplitude condition and low amplitude condition to make sure that the sound levels of the voices did not harm the participants. As for the frequency, we chose 40 Hz, about two standard deviations of Japanese male voices [19], as the difference between the high frequency condition and low frequency condition.

We prepared 48 audio tracks (speech in Japanese) recorded by two male adults. They contained 12 different pieces of content relating to environmental protection and social attitudes, such as global warming and garbage recycling. Each piece of content had 4 versions of amplitude-frequency combinations: high amplitude + high frequency, high amplitude + low frequency, low amplitude + high frequency, and low amplitude + low frequency. The audio tracks with high amplitude were 10 dB higher than the audio tracks with low amplitude; the audio tracks with high frequency were 40 Hz higher than the audio tracks with low frequency. The average length of the audio tracks was about 20 seconds.

Instead of asking the participants to rate each audio track individually, we chose Thurstone's paired comparison [53] as the method of this experiment. Participants compared two audio tracks with the same content, but different vocal cues, and selected the version he/she thought more dominant. This method has been used to assess the attractiveness and dominance of voices in previous studies [14, 29]. We expected that the paired comparison could minimize the sequential effect [32] (i.e., the effect that a response to a stimulus is biased by the preceding stimuli). In addition, it is known that linguistic content and message length affect dominance [55]. By asking the participant to compare two audio tracks with the same content, we expected that we could cancel such an effect.

*3.1.3 Procedure.* An experimenter asked a participant to sit at a table equipped with a computer and press the start button of the user interface to start the task when they were ready. The task consisted of 12 trials. In each trial, a pair of audio track versions of one piece of content[2] were selected automatically and the participant saw two play buttons aligned horizontally in a computer

[2]There were six possible combinations for each pair because there were four audio track versions for each piece of content.

Table 1. Number of times that each version was chosen as more dominant than others.

| More dominant \ Less dominant | HA&HF | LA&HF | HA&LF | LA&LF |
|---|---|---|---|---|
| HA&HF | - | 30 | 9 | 18 |
| LA&HF | 2 | - | 3 | 13 |
| HA&LF | 23 | 29 | - | 30 |
| LA&LF | 14 | 19 | 2 | - |

*Note:* HA: High Amplitude; LA: Low Amplitude; HF: High Frequency; LF: Low Frequency

display. Then, he/she was asked to click them to listen to two different versions of the audio tracks with the same content. Following the conventional method of Thurstone's paired comparison [14, 16, 29], the participant was allowed to listen to the two versions repeatedly until he/she was satisfied. Then, the participant compared and judged which audio track was more dominant and answered by clicking the corresponding button. After the selection, the next pair of audio tracks were selected automatically, and two play buttons were presented. The participant was not allowed to adjust the volume during the whole experiment.

The content of the audio tracks in each trial was selected randomly, but it was controlled so that the same content appeared only once in each task (i.e. each participant heard each content only once). To minimize the order effect, a pair of audio track versions were chosen randomly from six possible combinations, but we made sure that each combination appeared twice in each task. It took about 15 minutes for each participant to finish the task.

*3.1.4 Participants.* 17 participants (5 females and 12 males), whose native language was Japanese, were recruited from the University of Tsukuba. The average age was 22 (SD = 1.5). Because one male participant adjusted the volume accidentally, we removed his data from our analysis.

### 3.2 Results

The number of times that one version was chosen as more dominant over the other is shown in Table 1. To analyze the Thurstone paired comparison [53], we used Durbin's test [12] to examine the equivalence of all versions [10, 49].

$$D = \frac{4 \times \sum_{i=1}^{t} (a_i - \overline{a})^2}{nt} = \frac{4 \times 2306}{4 \times 32} = 72.1$$

In this formula, $D$ is a chi-squared score[3], $t$ is the number of versions, $n$ is the number of trials, $a_i$ is the number of times that version $i$ was chosen, and $\overline{a}$ is the average of $a_i$. We found that $D = 72.1$ was larger than $\chi^2_{3,0.05} = 7.82$, which meant that there was a significant difference between versions.

Then, we used the Bradley-Terry model [2] to test the differences between pairs of two versions. Since the positions (left/right) of the play buttons for the two versions in the computer display might be a factor influencing the participant's judgments, we also included the factor "position" in the model. We first chose the "Low amplitude & High Frequency" version as the baseline. In addition, since it was a within-participants design, "individual differences between participants" was considered as a random effect factor and was added to the model. As shown in Table 2, there were significant differences between the baseline version and the other versions. Meanwhile, position did not show a significant effect on judgment. The standard deviation of the "individual differences"

[3]Concordance of each version in the paired comparison distributed as a chi-squared distribution with t-1 degrees of freedom [12, 49].

Table 2. Comparison with baseline version (Low Amplitude & High Frequency)

| | Estimate Score | Standard Error | z-value | Pr(>\|z\|) | |
|---|---|---|---|---|---|
| HA&HF | 1.72 | 0.36 | 4.80 | <.406 | *** |
| HA&LF | 2.88 | 0.45 | 6.50 | <.001 | *** |
| LA&LF | 0.81 | 0.32 | 2.53 | .011 | * |
| Position | 0.19 | 0.22 | 0.83 | .406 | |

*Note:* HA: High Amplitude; LA: Low Amplitude; HF: High Frequency; LF: Low Frequency. The "Low amplitude & High Frequency" version was chosen as the baseline.

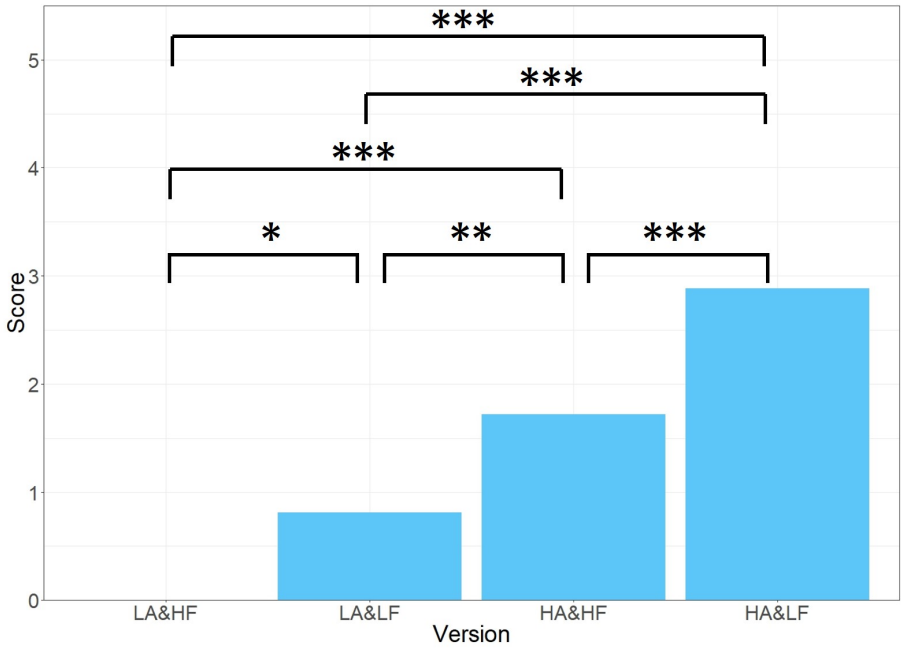


Fig. 1. Effect of amplitude-frequency combination on perception of dominance. The Bradley & Terry [2] model was used to examine the significance of each pair. Significance was found in all pairs.

random effect factor was 0.34. The same analysis was repeated by choosing three other versions as baselines. The results showed that there were significant differences between all pairs (Figure 1).

We further examined whether gender had a significant effect on selection. The results of a Fisher exact test showed no significant effect for all pairs of versions (Table 3).

### 3.3 Discussion

According to the results, we observed that the "Low Amplitude & Low Frequency" version was perceived as significantly more dominant than the "Low amplitude & High Frequency" version and the "High Amplitude & Low Frequency" version was perceived as significantly more dominant than the "High Amplitude & High Frequency version. Thus, we think H1 (participants perceive higher dominance while listening to a voice with a lower frequency) was supported. This finding is similar to Puts et al.'s result which indicated that a voice with a lower fundamental frequency has higher physical dominance and social dominance [40]. We found that that the "High Amplitude &

Table 3. Effect of gender difference on perception of dominance.

| Pair | Audio 1 | Audio 2 | Males' selection | | Females' selection | | $p$-value |
|---|---|---|---|---|---|---|---|
| | | | Audio 1 | Audio 2 | Audio 1 | Audio 2 | |
| 1 | HA&HF | LA&HF | 22 | 0 | 8 | 2 | .09 |
| 2 | HA&HF | HA&LF | 5 | 17 | 4 | 6 | .41 |
| 3 | HA&HF | LA&LF | 13 | 9 | 5 | 5 | .71 |
| 4 | LA&HF | HA&LF | 2 | 20 | 1 | 9 | 1 |
| 5 | LA&HF | LA&LF | 8 | 14 | 5 | 5 | .7 |
| 6 | HA&LF | LA&LF | 21 | 1 | 9 | 1 | .53 |

*Note:* HA: High Amplitude, LA: Low Amplitude, HF: High Frequency, LF: Low Frequency. No pairs showed a significant difference between male and female choice.

High Frequency" version was perceived as significantly more dominant than the "Low Amplitude & High Frequency" version and the "High Amplitude & Low Frequency" version was perceived as significantly more dominant than the "Low Amplitude & Low Frequency" version. Thus, H2 (participants perceive higher dominance while listening to a voice with a higher amplitude) was supported. These results are also similar to those of past studies [43, 55].

Unlike the previous studies, we 1) manipulated full sentences instead of simple vowels or words and 2) compared artificially manipulated voices of one confederate instead of comparing natural voices. Therefore, our results indicate that, by artificially manipulating a particular person's voice, it is possible to change his/her dominance that listeners perceive.

We did not find any statistical differences regarding gender. This finding is in line with Jones et al.'s research, which indicated that both males and females judged that masculinized voices were more dominant than feminized voices [29]. However, to fully confirm our conclusion, we are aware that it is necessary for us to do an experiment with a female speaker.

In this experiment, we verified that the amplitude and frequency significantly affected the listeners' perception of dominance. Furthermore, the results showed that the listeners' gender did not affect the perceived dominance. Nonetheless, perception of dominance is only the observer's impression. Because it was reported that the perception of dominance affects observers' behaviors including speaking time, number of turn-takings, number of interruptions, and number of times taking the conversational floor [41], we wanted to investigate the question of whether artificial manipulation of vocal cues can affect the result of a group discussion further. Specifically, we were interested in persuasiveness. Although several studies indicated nonverbal cues, such as eye contact [52], affect persuasiveness, few studies have investigated the effect of vocal cues on persuasiveness.

## 4 EXPERIMENT 2

### 4.1 Experimental Design

As we mentioned in the introduction, the purpose of the second experiment was to investigate the effect of artificial manipulation of vocal cues on persuasiveness. In this experiment, we asked the participants to attend two tasks. Because our ultimate goal is to facilitate balanced contributions from all participants in an audio conference, we wanted to determine whether it is possible to adjust the persuasiveness even when the dominance is biased. Therefore, our first task tried to simulate the case where one participant has dominance over the other; i.e., one of the participants played an expert's role and spoke most of the time. We named this task "biased conversation." In another task, we wanted to simulate the case where two participants had similar dominance; i.e. both participants had almost equal chances to speak. We called this task "unbiased conversation."

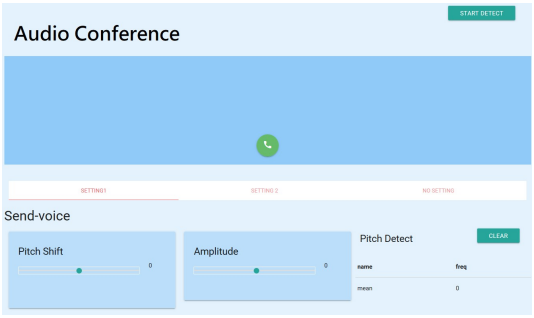


Fig. 2. Screenshot of audio conference system used in Experiment 2.

*4.1.1 Hypothesis.* We assumed that the two different vocal cues, amplitude and frequency, would also influence persuasiveness. Therefore, in light of the results of Experiment 1, our hypotheses for this experiment were as follows:

- H3: A participant is more easily persuaded by a confederate with a higher amplitude voice in both biased conversation and unbiased conversation.
- H4: A participant is more easily persuaded by a confederate with a lower frequency voice in both biased conversation and unbiased conversation.

*4.1.2 Tool.* We developed our own audio conference system that had functions to manipulate the frequency and amplitude of a speaker's voice in real time (Figure 2). As audio transmissions, we used WebRTC (Web Real-Time Communication) [56]. To manipulate the frequency of the voice, we implemented a real-time Fourier transform function with 1024 FFT size. For the voice amplitude manipulation, we used the built-in function to increase and decrease the gain. The average voice transmission latency of our system was less than 0.2 sec.

*4.1.3 Method.* We conducted an experiment with a 2 (high amplitude vs. low amplitude) x 2 (high frequency vs. low frequency) between-participants design. As we did in Experiment 1, the amplitude of the confederate's voice in the high amplitude condition was manipulated to be 10 dB higher than the confederate's voice in the low amplitude condition. Also, the frequency of the confederate's voice in the high frequency condition was manipulated to be 20 Hz higher than his original voice and the frequency of the confederate's voice in the low frequency condition was manipulated to be 20 Hz lower than his original voice.

*4.1.4 Task.* We chose the modified desert survival task to test the effect of two vocal cues on persuasiveness in the biased conversation and the NASA moon survival task to test the effect of two vocal cues on persuasiveness in the unbiased conversation.

*Modified Desert Survival Task.* The desert survival task was developed by Lafferty et al., and it has been used in many social experiments [33]. A modified version was designed by Takayama et al. [51]; we employed it as the biased conversational task.

We showed a participant five pairs of items with printed images and asked him/her to choose one item from each pair whichever he/she thought it was more important to survive in the desert. The item pairs were canvas vs. tarp, chocolate vs. 2 liters of water, mirror vs. compass, hand-powered flashlight vs. matches, and knife vs. pistol with 36 bullets.

Then, the participant was informed that he/she was going to interact with a desert survival expert who actually was the confederate. Since assigning a role to individuals can alter a person's

dominance [58] and expertise is an important factor of dominance in conversation [35], we assigned the role "expert" to the confederate to increase the confederate's dominance and simulate the biased conversation.

For each pair, the participant received some advice about the items from the confederate through the audio conference tool and was asked to judge if he/she wanted to change the choice or not. Regarding the advice, since Japanese participants were not familiar with the usage of some items, we added extra explanations to some of the items of Takayama's original version. The following dialog is an example of a typical conversation ("C" denotes the confederate and "P" denotes the participant):

> C: Which item did you choose from the pair, knife or pistol with 36 bullets?
> P: Knife
> C: A knife can be used to cut down trees to build solar still or make simple tent. Besides, it can assist in cutting clothes to make a bandage. But a knife is not as good as a pistol with 36 bullets. With the pistol, we can make a loud noise as a signal to inform the rescue team of our location. Furthermore, since desert animals are fast and dangerous, it is better to use a pistol than knives to hunt them. Now, which one do you want to choose?
> P: Ok, then, I'll change to the pistol with 36 bullets.
> C: Ok, I understand.

To prevent the participant from suspecting that his/her interlocutor was a confederate, the confederate did not disagree with all the choices of the participant. Disagreements happened in four (1, 3, 4, 5) out of five pairs. For each pair, the confederate read both items' descriptions, even when the confederate agreed with the participant in pair 2.

*NASA Moon Survival Task.* The NASA Moon Survival task was developed by Hall et al., and it has been widely used in decision making experiments [20]. We chose it as the unbiased conversational task. A participant was informed that he/she was a member of a space team and was on a spaceship. Their mission was to move to the mother ship on the lighted side of the moon. However, a crash landing happened, and the participant should choose vital items to support his/herself in the effort to reach the mother ship. First, the participant was asked to rank 7 items from 1 (most important) to 7 (least important) according to their order of importance to reach the mother ship. The items were two .45 caliber pistols, 15-meter nylon rope, food, first-aid kit, portable heat unit, parachute silk, and signal flares. The ranking by the participant was considered as his/her "initial ranking." Soon after the participant's initial ranking was defined, the confederate's initial ranking was automatically created by a computer so that the first and seventh items were the same but the rankings of the other five items were different, and also the sum of differences between the participant's initial ranking and the confederate's initial ranking would be 6.

After the initial ranking, the experimenter asked the participant to use the audio conferencing tool to discuss with the confederate and agree on the final ranking. The confederate was given an item list which included the advantages and disadvantages of each item. He was trained to argue with the participant by referring to the item list and his initial ranking. By referring to his initial ranking, he explained the advantages of the second and third ranked items and the disadvantages of the fifth and sixth ranked items. For the fourth item, he explained both the advantages and disadvantages.

*4.1.5 Procedure.* One confederate was recruited to participate in all experiments. The confederate and the participant were in different rooms so that they could not see or hear each other directly. First, the confederate was asked to read an article aloud. While he was reading, the experimenter

Table 4. Subjective Questionnaire

| |
|---|
| Q1: This person usually takes charge of conversations. |
| Q2: This person rarely influences you. |
| Q3: This person never finds out what others think before taking a stand on an issue. |
| Q4: This person often stops to think about what to say in conversations. |
| Q5: I am often influenced by this person. |
| Q6: This person is completely self-confident when interacting with you. |
| Q7: This person often acts nervous in conversations. |
| Q8: This person has a natural talent for winning over others. |
| Q9: This person is very expressive during conversations. |
| Q10: This person is more of a follower than a leader. |
| Q11: This person remains task oriented during conversations. |
| Q12: This person often acts impatient during conversations. |
| Q13: This person is usually successful in persuading you. |

*Note:* Q2, Q4, Q7, Q10, and Q12 were negative questions.

adjusted the frequency and amplitude manipulation levels of the audio conference software on the participant's side to manipulate the output of the confederate's voice to the specific amplitude and frequency according to each experimental condition. The participant and confederate were not notified that the confederate's voice was being manipulated.

After setting up the environment, a participant was invited to the room and was asked to sign a consent form. Then, we asked the participant to do the modified desert survival task (biased conversation) first, and the NASA moon survival task (unbiased conversation) second. There was a 10-minute break between these two tasks.

When we designed this experiment, we were aware of the possibility that the results of the second task could be affected by the participant's familiarity with the confederate and also the dominance of the confederate that the participant perceived during the first task. As we mentioned in the introduction, since our primary goal is to resolve situations with biased dominance, we decided to put higher priority on the biased conversation task and not to counterbalance the order of the two tasks. By making all the participants attend the biased task first, we wanted to minimize the participant's preconception of the confederate and maximize the effect of assigning the confederate the expert's role for the biased task.

After the two tasks, we asked the participants to answer a questionnaire about the second task. The questionnaire (Table 4) was 7-point Likert scale and contained 13 questions which were adapted from Burgoon et al. [6]. The original version consisted of 32 questions, but unsuitable questions for our experiment were removed. Each participant rated their impression of the confederate from 1 (strongly disagree) to 7 (strongly agree). At the end of the experiment, a short unstructured interview was conducted.

*4.1.6 Participants.* 37 participants (14 females and 23 males) and 1 male confederate were recruited from the University of Tsukuba. All of them had normal hearing and their native language was Japanese. The average age was 21.1 years old (SD = 1.86). Each participant received 1,000 yen as compensation at the end of the experiment.

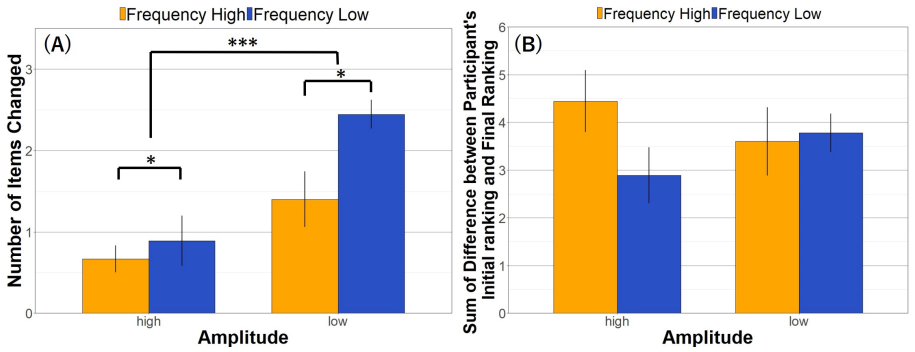


Fig. 3. **(A)**: Effect of amplitude and frequency on number of items changed by participants in modified desert survival task. **(B)**: Effect of amplitude and frequency on changes between participants' initial rankings and final rankings in NASA moon survival task.

## 4.2 Results

*4.2.1 Modified Desert Survival Task.* We used a two-way ANOVA to test how amplitude and frequency affected the number of items that were changed after the participant heard the advice from the confederate (Figure 3 (A)). There were significant effects in both amplitude ($F(1,33)=18.22$, $p<.001$, $\eta^2=0.3$) and frequency ($F(1,33)=5.35$, $p=.027$, $\eta^2=0.09$). There was no interaction between frequency and amplitude ($F(1,33)=2.39$, $p=.131$, $\eta^2=0.04$).

Further, we included gender as a factor and used a three-way ANOVA to analyze the effect of gender difference. The results showed that there were significant effects of amplitude ($F(1,29)=16.6$, $p<.001$) and frequency ($F(1,29)=4.87$, $p=.04$), but the effect of gender was not significant ($F(1,29) = 0.61$, $p=.44$). No interaction was found between factors.

*4.2.2 NASA Moon Survival Task.* We used a two-way ANOVA to test how amplitude and frequency affected the changes of participants' rankings after the participants reached consensus with the confederate (Figure 3 (B)). As a result, neither amplitude ($F(1,33)=0$, $p=1$, $\eta^2<0.001$) nor frequency ($F(1,33)=1.2$, $p=.281$, $\eta^2=0.03$) had a significant effect. Additionally, there was no interaction between frequency and amplitude ($F(1,33)=2.02$, $p=.16$, $\eta^2=0.05$).

*4.2.3 Questionnaire.* As we mentioned before, the questionnaire results only reflected the participants' impression about the NASA moon survival task. We used a two-way ANOVA to examine the effect of amplitude and frequency on each question (Figure 4). Concerning frequency, we found that Q7 ($F(1,33)=5.99$, $p=.02$) revealed a significant effect which meant that the confederate was considered to be acting nervously in high frequency condition. Concerning amplitude, Q5 ($F(1,33)=7.03$, $p=.01$) and Q13 ($F(1,33)=5.93$, $p=.02$) revealed significant effects which meant that participants tended to be influenced by the confederate.

We also conducted an exploratory factor analysis to construct sub scales from the questionnaire (Table 5). We chose 2 as the number of factors based on the results of the Very Simple Structure (VSS). We used the maximum likelihood method as the factor extraction method. Concerning the factor rotation method, we followed the procedure suggested by Tabachnick and Fidell [50] and first used the promax rotation as the factor rotation method. We found that the correlation between the two factors was 0.31, which was lower than the criterion ±0.32 [50]. Thus, we concluded that the matrix was orthogonal and changed the factor rotation method to the varimax rotation. The results of a Kaiser-Meyer Olkin test suggested that the sampling adequacy was acceptable

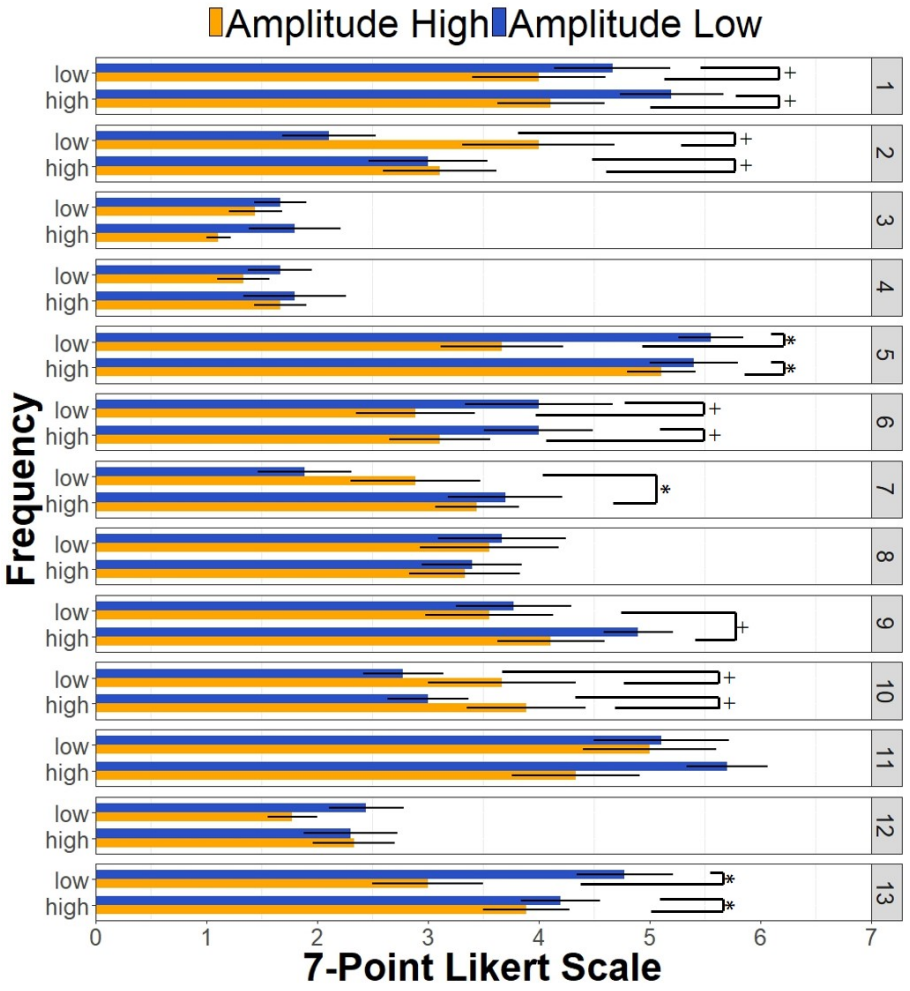


Fig. 4. Results of questionnaire.

(KMO=.71). Q4 and Q12, whose loadings were less than 0.30, were excluded. The first factor was defined as "Impression of Confederate", which contained 7 items (Cronbach's alpha=.83). Regarding the second factor, Q3, which lowered the reliability, was removed after examining the results of Cronbach's alpha. The second factor was defined as "Conversation Control", which contained 3 items (Cronbach's alpha=.7). We used a two-way ANOVA to examine the effect of amplitude and frequency on the two factors. The results showed that amplitude had a significant effect on "Conversational Control" ($F(1,33)=5.55$, $p=.025$, $\eta^2=0.14$).

### 4.3 Discussion

In the second experiment, we asked the participants to do two tasks, the modified desert survival task and the NASA moon survival task. We found that the results of the two tasks were quite different.

Table 5. Factor analysis for questionnaire

| Question | Factor 1 | Factor 2 |
|---|---|---|
| Q1 | 0.60 | 0.18 |
| Q2 | 0.41 | 0.86 |
| Q3 | 0.28 | -0.49 |
| Q5 | 0.58 | 0.62 |
| Q6 | 0.81 | -0.01 |
| Q7 | 0.40 | -0.08 |
| Q8 | 0.73 | 0.16 |
| Q9 | 0.56 | 0.19 |
| Q10 | 0.65 | 0.34 |
| Q11 | 0.08 | 0.34 |
| Q13 | 0.75 | 0.20 |
| Proportion Variance | 0.33 | 0.16 |
| Cumulative Variance | 0.33 | 0.48 |

*Note:* Q2, Q7, and Q10 have been reverse-scored. Q4 and Q12, whose loadings were less than 0.30, were excluded.

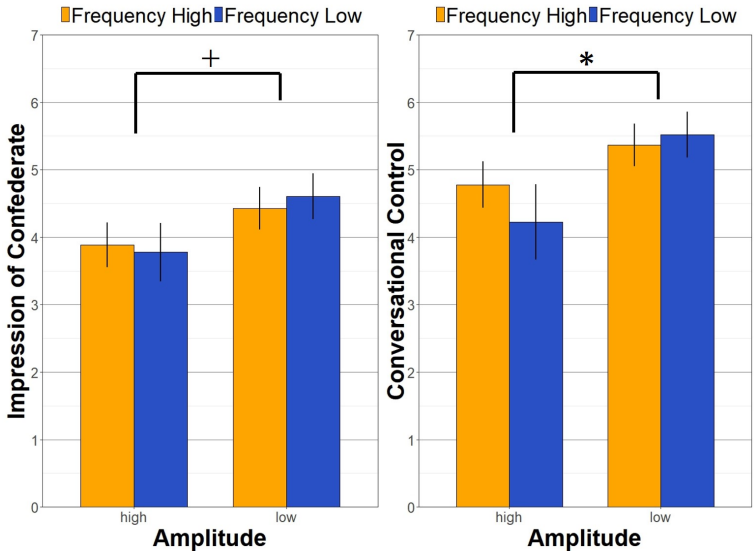


Fig. 5. Effect of amplitude and frequency on impression of confederate and conversational control.

*4.3.1 Biased Conversation.* In the modified desert survival task, the confederate had strong dominance and expressed his opinions unilaterally. The results of this task partially supported H4; participants were more easily persuaded by a confederate with a lower frequency voice. As for H3, however, the results were opposite from what we expected; participants were more easily persuaded by a confederate with a lower amplitude voice. One participant mentioned that the confederate was giving him too much pressure in the conversation. Carli et al. suggested that too much dominance or too little dominance has a detrimental effect on the speaker's persuasiveness [7]. Therefore, it is possible that the confederate's voice in the high amplitude condition might have

provided too much dominance to the participants and weakened the confederate's persuasiveness. However, further study is necessary to determine the actual reason.

*4.3.2 Unbiased Conversation.* In the NASA moon survival task, the participant and the confederate exchanged opinions on an equal basis. Although the results of the questionnaire showed that there was a significant difference in "Conversational Control", the two independent variables (amplitude and frequency) showed no significant effect on the changes of the participants' rankings. Thus, we think that the results support neither H3 nor H4. One of the reasons for this result is the carry-over effect from the first task, as we mentioned earlier. However, the previous studies suggest some other reasons. For example, Chidambaram et al. showed that vocal cues had a weak effect on persuasiveness in survival tasks [8]. According to the elaboration likelihood model of persuasion [37], humans focus more on the literal meaning of a received message rather than "peripheral attitude cues" when they are motivated and "the ability to process the message" he/she received. According to Petty et al. [37], "repetition" and "message comprehensibility" are two of the major factors for the "ability to process a message". In our NASA moon survival task, the confederate sometimes explained the advantages and disadvantages of an item repeatedly during the discussion. In the following example, the confederate explained the disadvantage of the "first-aid kit" repeatedly in the conversation:

> Group 31 (C: confederate, P: participant)
> C: The last item is the "first-aid kit". Since ***no one is hurt*** at the moment, I considered the possibility of getting hurt during the transfer. Because there are no dangerous animals on the moon, there are ***few chances to get hurt***. Thus, I decided to rank it sixth. This is my opinion. Do you have any ideas?

Furthermore, because the participants were allowed to discuss each item, we can assume that the participants had more time to comprehend the confederate's message compared with the case of the modified desert survival task. In fact, the average discussion time for the first task and the second task were 581 sec and 783 sec, respectively. Therefore, it is possible that, in the NASA moon survival task, "repetition" and longer comprehension time increased the comprehensibility of the message received from the confederate and caused the participant to judge the message by its literal meaning instead of the confederate's nonverbal cues.

## 5 GENERAL DISCUSSION

### 5.1 Findings

The two experiments revealed that amplitude and frequency affected the listener's perceived dominance. Furthermore, they also affected the speakers' persuasiveness in the conversation with biased dominance. These results indicate that, when dominance is biased in conversation, it is possible that a machine can artificially manipulate a speaker's vocal cues to adjust the participants' levels of dominance appropriately.

### 5.2 Limitations

In our experiments, we recruited both male and female as listeners and found that there was no significant difference between genders. However, our limitation was that we used only males as our speakers in both experiments. Past research has shown that the amplitude and frequency of both genders' voices had a similar effect on perceived dominance [7, 29]. Meanwhile, Maner et al. reported that males' signs of dominance drew observers' attention more than females' signs of dominance [36]. Furthermore, Borkowska et al. found that females rated females' voices as more dominant than males did when the voices were in the lower frequency range and that females rated

females' voices as less dominant than males did when the voices were in the higher frequency range [1]. This means that to clarify the gender difference, it is necessary to investigate the effect of vocal cue manipulation on perceived dominance and persuasiveness with both male and female speakers.

Another limitation is that, in our experiments, the confederate and the participants were from one culture, that of Japan. In terms of dominance, Mast et al. showed that some nonverbal cues affected dominance similarly between cultures, but some affected dominance differently [46]. Meanwhile, many studies reported that loud and low voices are associated with dominance, and soft and high voices are associated with submissiveness [1, 39, 40, 55]. Borkowska et al. suggested the relationship between fundamental frequency and dominance is universal [1], and Hoeschele et al. believed it is represented by an evolutionary mechanism [24]. These studies suggest that many cultures share the same tendency. However, Bridge et al. showed a cultural bias in dominance judgment; i.e., participants judged their own cultural group as being more dominant than other cultural groups [3]. Furthermore, since the mean and variance of the fundamental frequency vary between languages [54], it is possible that the effect of vocal frequency manipulation also varies between languages.

As for persuasiveness, it was proved that linguistic cues[4] strongly contribute to persuasiveness [5, 45]. Therefore, more studies should be conducted to clarify cultural differences in terms of dominance and persuasiveness.

Finally, in experiment 2, we have to admit that the second task (unbiased conversation) might be affected by the carry-over effect from the first task (biased conversation). We definitely need to conduct further experiments with unbiased conversation cases.

### 5.3 Future work

The results of this study raised some issues that require further investigations.

First, we found that a low voice amplitude provided the speaker with higher persuasiveness, which contradicted with our hypotheses. We suspect that overpowered dominance might have a negative effect on persuasiveness. However, to determine the effect of vocal cues on persuasiveness more clearly, it will be necessary to conduct a similar experiment with more fine-grained amplitude and frequency manipulations.

Second, the interaction effects between linguistic cues and nonverbal cues have not been discussed. The second experiment featured two survival tasks. In order to reduce the effect of linguistic cues, all of the conversational content was well-controlled. However, linguistic cues and nonverbal cues might influence each other during persuasion [46]. To apply this method in real-world settings, more research is needed on how amplitude and frequency manipulation interact with various linguistic cues and further affect persuasiveness.

Third, we hope to apply our method to practical applications. One sort of application may be audio conferences that involve both native speakers and non-native speakers. It has been pointed out that, in such situations, native speakers participate more actively [59]. To alleviate this problem, Yamashita et al. proposed to introduce a time delay only to the native speakers' audio transmission to improve the non-native speaker's comprehensibility and also their chances to speak [57]. The results of this paper indicate another method to level the contributions of native and non-native speakers.

A further issue that we should consider is that how a system can automatically adjust dominance. Here, it is necessary to detect more/less dominant participants in a group discussion in real time. Rienks et al. used a support vector machine to detect dominance in a meeting. The results showed that with the two features, the numbers of turns in a meeting and the numbers of times a person

[4]Short phrases (e.g. "first", "I believe", etc.) that are used to emphasize certain information or draw attention [34].

took the floor, the detection system could correctly classify a person's dominance status into three levels (high, normal and low) with 75% accuracy [41]. Jayagopi et al. examined the effectiveness of different cues on detecting the most and least dominant people in a group conversation; the results indicated that audio cues performed better at detecting the most and least dominant person than visual cues did. Moreover, the speaking length and total speaking turns without short utterances were two features that performed very well in dominance detection [28]. Although these studies focused on face-to-face conversations, they provide insights into detecting dominance in audio conferences. In our future work, we should develop a dominance detection function for audio conferences and integrate it with the vocal cue manipulation function. With these two functions, we can expect that the system will be able to alleviate the biased dominance problem in the group discussions automatically and facilitate balanced discussions.

## 6 CONCLUSION

Biased dominance of utterances has a detrimental effect on conversations. We proposed a way of manipulating vocal cues to balance dominance of utterances in audio conferences. Two studies were conducted to determine how the amplitude and frequency of human voices affect listeners' perceived dominance and persuasiveness. The first study showed that both amplitude and frequency influenced the perceived dominance. The second study showed that, in conversations with biased dominance, persuasiveness could be adjusted by manipulating the amplitude and frequency. Taken together, these findings suggest the possibility that real-time manipulation of vocal amplitude and frequency can lead to balanced contributions from participants in audio conferences.

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