EFFECTS OF RELATIVE SOUND PRESSURE LEVELS OF CROSSING GLIDE COMPONENTS ON THE OCCURENCE OF THE GAP TRANSFER ILLUSION

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Abstract

When a long ascending frequency glide with a gap in the temporal middle and a short continuous descending glide cross each other at the temporal midpoint of both glides, observers often report that the gap is perceived in the short, instead of in the long, glide (Nakajima et al., 2000). We examined the effect of the sound-pressure-level difference between crossing glides on the occurrence of this illusion, which we call the gap transfer illusion. A psychophysical experiment revealed that 1) the gap transfer illusion takes place only when the sound-pressure-level difference between the crossing glides is small, and that 2) both the long and the short glide are likely to be perceived as continuous when the short glide is sufficiently more intense than the long glide.

When a long ascending or descending frequency glide with a gap at the temporal middle and a short continuous glide moving in opposite directions cross at their central positions, observers report that the gap, despite its physical position, belongs to the short glide (see Figure 1). This phenomenon is called the *gap transfer illusion*, and is explained with *auditory subevents* such as onsets and terminations (Nakajima, Sasaki, Kanafuka, Miyamoto, Remijn, and ten Hoopen, 2000). When the gap transfer illusion takes place, onsets and terminations are detected at the temporal edges of the glides (Figure 1). The principle of proximity, one of the *Gestalt* principles, is applicable to these auditory subevents; an onset and a termination that are close to each other in frequency and time are likely to be connected perceptually to form an auditory event. In the stimulus pattern indicated in Figure 1, the onset and the termination preceding the gap are close to each other, and thus they are connected with each other. The onset and the termination succeeding the gap are connected as well. The residual onset and termination form a long continuous tone. Thus, the gap transfer illusion has been explained.

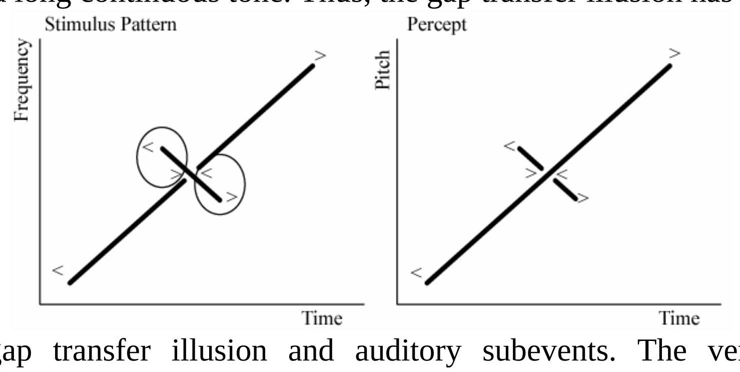

Figure 1. The gap transfer illusion and auditory subevents. The vertical axis shows logarithmic frequency or pitch and the horizontal axis shows time. Circles surround onsets (<) and terminations (>) that are close to each other (see the text for details).

Nakajima et al. (2000) hypothesized that an onset and a termination that are close to each other in time and frequency should be connected to each other even when they belong to *different sounds* physically. However, it seemed improbable that this kind of illusion should take place between *any* different sounds; what would happen if there is a clear cue indicating that there are two sounds that are quite different in their nature? As a first step, we manipulated the sound pressure levels (SPLs) of the glides and examined whether the gap transfer illusion should take place even when the crossing glides have different SPLs.

Method

Four males including authors T.K. and S.E., participated. They were acoustic engineering students at the Kyushu University or the Kyushu Institute of Design and had normal hearing. They had received basic training in music and training in technical listening for acoustic engineers.

One-hundred-sixty-eight stimulus patterns consisting of a long and a short single-component glide were generated (Figure 2). The long glide was 4000 ms and ascended or descended in logarithmic frequency at a constant speed of 1/3 oct/s. The short glide was 400 ms and moved in opposite directions. These glides crossed each other at 1000 Hz in the same phase. We call the stimulus patterns in which the long glide ascended *ascending patterns* and the stimulus patterns in which the long glide descended *descending patterns*. The rise and fall times of both glides were 20 ms and with cosine-shaped ramps.

There were following four “gap” conditions: In the *no-gap* condition, there was no gap. In the *gap-in-short* condition, a gap was at the temporal middle of the short glide. In the *gap-in-long* condition, a gap was at the temporal middle of the long glide. In the *shared-gap* condition, a gap was shared by both glides at their temporal middles. The duration of the gap was always 100 ms.

The level of the long/short glide was varied from +10/-10 to -10/+10 dB in steps of -1/+1 dB. Thus, there were 21 “level” conditions, and 0 dB was calibrated to 75 dB SPL.

All the stimulus patterns were generated digitally (16 bit; a sampling frequency of 44100 Hz) and controlled by a computer (Frontier KZFM71/N) with an audio card (E-MU, 0404). The stimulus patterns were presented via a digital-to-analog (D/A) converter (Fostex VC-8); an active low-pass filter at 15000 Hz (NF DV8FL); a digital graphic equalizer (Roland RDQ-2031); an amplifier (Stax SRM-212); and headphones (Stax SR-202). The stimulus patterns were presented in a soundproof booth to one ear of the observer. The levels were measured with a sound level meter (Node 2072), and an artificial ear (Brüel & Kjær 4153).

The observer started each presentation by clicking on a button on the display connected to the computer outside the booth. There was always a silent interval of 1.5 s between the click and the onset of the presented pattern.

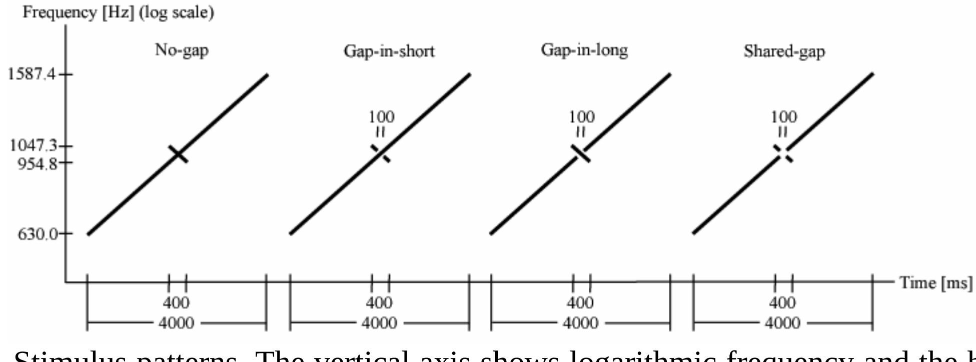

Figure 2. Stimulus patterns. The vertical axis shows logarithmic frequency and the horizontal axis shows time. (see the text for details).

Before each experimental trial, the observer listened to all stimulus patterns once by clicking on a button on the display.

There were two tasks for the observer. First, the observer performed a *phenomenological* task. The observer was allowed to listen to each pattern as many times as he/she wanted. The observer described his/her percept in writing and drawing with a pencil on a blank sheet of paper, using the vertical axis for pitch and the horizontal axis for time. The observer handed this sheet to the experimenter when he/she finished the pattern. If there was more than one type of percepts, the observer described all types and indicated the order of dominance if possible. For the descriptions that included ambiguous or contradictory parts, the experimenter asked for more clarification. A training of 8 observations was carried out. Stimulus patterns for the training were employed randomly from all stimulus patterns. An experimental trial contained four blocks. At the beginning of each block, two warm-up observations were carried out. The stimulus patterns were presented in random order and, the warm-up patterns were employed randomly from all stimulus patterns. Thus, a block contained 16 observations, and breaks were inserted between blocks.

The next task was *psychophysical*. The observer listened to each stimulus pattern once, and judged whether the long tone and the short tone were “continuous” or “discontinuous” by clicking buttons. There were also buttons “unsure” and “cannot hear.” The observer pressed the “unsure” button when he/she was unsure whether the tone was continuous or discontinuous, but the observer was instructed not to use this button except when definitely necessary. The observer pressed the “cannot hear” button when the long or the short tone was too faint to be detected clearly. When the observer failed in listening to a presented pattern for some specific reason (e.g., a tentative sleep or a cough), he/she could press a “replay” button. When the observer could not perceive the presented pattern as a pattern of a long and a short tone, he/she was asked to report his/her percept phenomenologically. All stimulus patterns were presented once randomly in each block, and each observer went through 11 blocks. The observer was instructed that the first block was for training and he/she could repeat the training block if he/she wished (in reality, no training was repeated). Breaks were placed in the middle and at the end of each block, and two warm-up observations were carried out after the breaks. The warm-up patterns were employed randomly from all stimulus patterns.

Results and Discussion

All observers perceived a long tone and a short tone for all stimulus patterns in the phenomenological task.

We analyzed the psychophysical data in the following way: The responses of “cannot hear” were omitted from further analyses. The +10/-10 condition was omitted because there were more than 20% responses of “cannot hear” for the short tone. Half of the responses of “unsure” were allocated to the responses of “continuous,” and the rest were allocated to the responses of “discontinuous.” Figure 3 shows the mean proportions of “continuous” in the gap-in-long patterns.

The occurrence range of the gap transfer illusion is defined as the range in which, for both ascending and descending patterns, the long tone received more than 50 % “continuous” responses and the short tone received less than 50% “continuous” responses. The gap transfer illusion took place when the levels of the crossing glides were from +4/-4 to -1/+1 dB. Different percepts occurred outside this range. When the long glide was sufficiently more intense than the short glide, a veridical percept took place—the long tone was discontinuous and the short tone was continuous. When the short glide was sufficiently more intense than the long glide, both the long and the short tone were perceived as continuous.

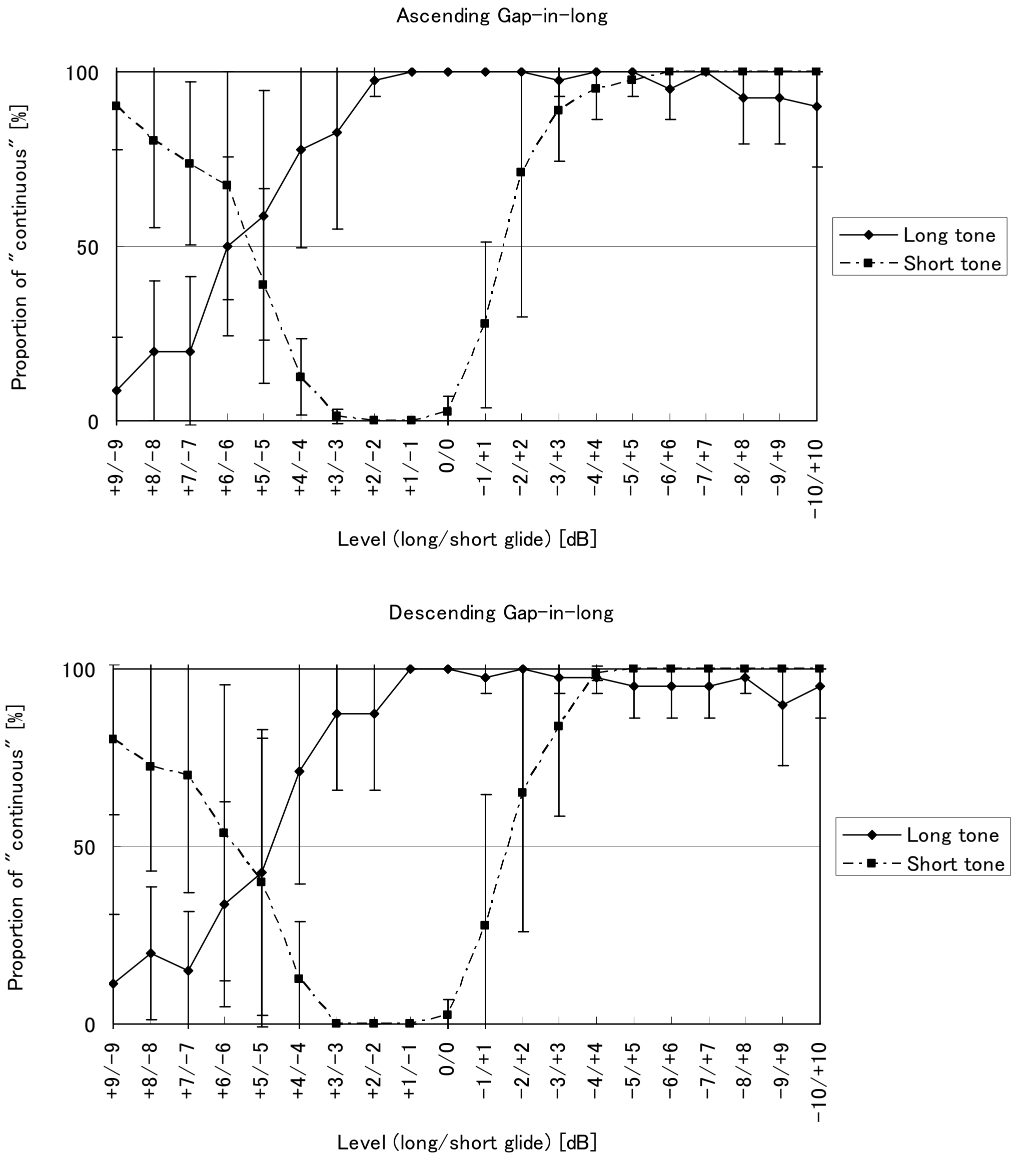

Figure 3. The mean proportions of "continuous" in the gap-in-long patterns. Intersubject standard errors are indicated (N = 4). The horizontal axis represents the levels of the long and the short glide. The upper panel represents the ascending patterns and the lower panel represents the descending patterns.

Acknowledgments

The research was supported by grants to Y. Nakajima from the Japan Society for the Promotion of Science (14101001 in the fiscal years 2002-2006 and 19103003 in the fiscal years 2007-2011) and The "Center of Excellence (COE)" program of Japanese government, entitled "Design of Artificial Environments on the Basis of Human Sensibility."

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