The slowdown across tasks was about the same for both age groups on double target trials (20 and 18 ms), but not on single target trials: Younger adults were 30 ms slower when the single target display also contained a distractor, whereas older adults were 39 ms slower [F(1,10)=2.3, p>0.1]. Brinley plots (Brinley, 1965), in which latencies for older adults on a task are plotted as a function of latencies for younger adults on the same task, were fit by a straight line, for all three tasks in the two conditions. Therefore, our data is not sufficient to reject generalized cognitive slowing models, even if the data strongly suggest that this may be the case.

The presence of a distractor augmented the capacity coefficient values observed for older adults (Figure 1) more than it did for younger adults (Figure 2). None of the younger adults had exhibited significant super-capacity; the lower confidence bound of capacity coefficient function, with and without distractors never exceeded 1. In contrast, four out of six older adults exhibited significant supercapacity for the distractor-present (but not distractor-absent) condition. Notably, for *all* six older adults, the capacity function with distractor exceeded the capacity function without distractor, at least for some time t.

Summary and Conclusions

Elderly Mrs. Johns will make her decision to cross the street more slowly than her grandson. However, she may integrate redundant visual signals as efficiently as her grandson. A busy intersection, entailing distractors in a complex visual scene, will slow down both of them, but the effect of unwanted distractors would be more salient for Mrs. Jones. Further investigation is called for to retrieve the source of these age differences: Reduction in inhibitory processes, generalized cognitive slowing, or information degradation

Acknowledgements

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EFFECTS OF THE SOUND-PRESSURE-LEVEL DIFFERENCE BETWEEN CROSSING GLIDES ON THE OCCURRENCE OF THE GAP TRANSFER ILLUSION

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Abstract

A psychophysical experiment was conducted in order to examine the effect of the sound-pressure-level difference between crossing glides on the occurrence of the gap transfer illusion. The gap transfer illusion is an auditory phenomenon in which a temporal gap in a long glide is perceived as if it were in a short crossing glide that is physically continuous. It turned out that the gap transfer illusion takes place when the short glide is down to 8 dB below the level of the long glide. The results indicate that the subjective continuity of the long glide in the gap transfer illusion is different from the continuity in the continuity illusion, in which the masking potential of the interrupting sound is requisite.

When a long ascending or descending frequency glide with a gap at the temporal middle and a short continuous glide moving in the opposite direction cross at their central positions, observers report that a gap belongs to the short, instead of the long, glide (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, & 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.

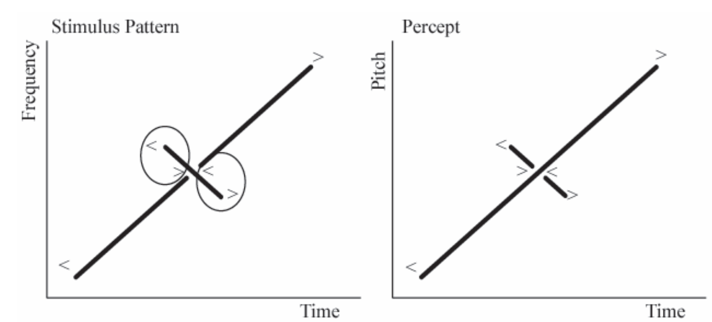

Figure 1. The gap transfer illusion and auditory subevents. The vertical axis shows logarithmic frequency or pitch and the horizontal axis shows time. Circles surround onsets (<) and terminations (>) that are connected with each other in perception.

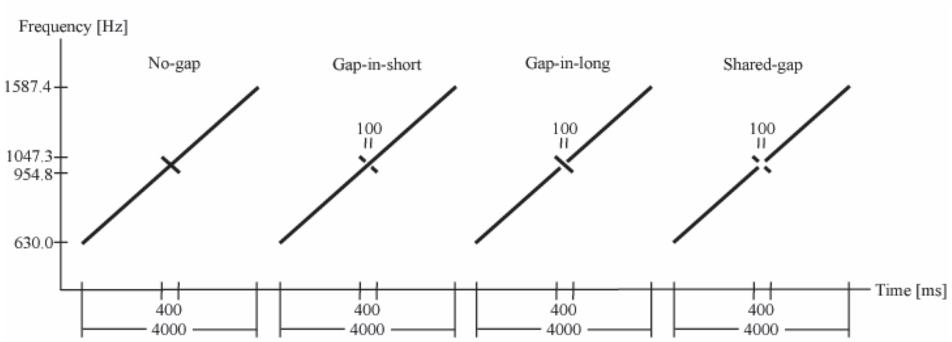

Figure 2. Stimulus patterns. The vertical axis shows logarithmic frequency and the horizontal axis shows time.

The illusory continuity of the long glide in the gap transfer illusion may be similar to another auditory illusion, the *continuity illusion* (Warren, Obusek & Ackroff, 1972; Warren, 1999), but they should be distinguished from each other. In a typical example of the continuity illusion, a physically discontinuous tone is perceived as continuous when the temporal gap of the discontinuous tone is filled with a sound more intense than the discontinuous tone. The continuity illusion occurs only when the inserted sound is more intense than the discontinuous tone, whereas the gap transfer illusion occurs in a stable manner when the sound pressure levels (SPLs) of the crossing glides are equal. Little is known, however, about the effect of the SPL difference between crossing glides on the occurrence of the gap transfer illusion. Thus, we conducted an experiment to examine this effect.

Method

Six observers, including authors T.K. and S.E., participated. They were acoustic engineering students at Kyushu University or the Kyushu Institute of Design, and had received basic training in music and training in technical listening for acoustic engineers. We checked that all observers had normal hearing by conducting a hearing test.

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 at the same speed in the opposite direction. 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 four “gap” conditions. In the *no-gap* condition, there was no gap. In the *gap-in-short* condition, there was a gap at the temporal middle of the short glide. In the *gap-in-long* condition, there was a gap 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 excluding the fall and the rise time.

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 bits; 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 the mouse in a pane 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.

Before the experiment, the observer listened to all stimulus patterns once in random order. There was no task for the observer, but the observer was instructed to listen to the presented patterns closely.

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 verbally and by 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 percept, 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. Before experimental observations, a training of 8 observations was carried out. Stimulus patterns for the training were employed randomly from all stimulus patterns. The experimental observations of the 168 stimulus patterns were divided into 12 blocks, and thus, each block contained 14 observations. The stimulus patterns were presented in random order. At the beginning of each block, two warm-up observations were carried out, and the warm-up patterns were employed randomly from all stimulus patterns. Breaks were inserted between blocks.

The second 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 for “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 each 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. There were more than 10% responses of “cannot hear” for the short tone in the ascending +9/-9 patterns, the ascending +10/-10 patterns, and the descending +10/-10 patterns. Therefore, we omitted the +9/-9 and the +10/-10 conditions from further analyses.

Figure 3 shows the mean proportions of “continuous” in the gap-in-long patterns. We can find from this figure that the following three percepts appeared: 1) A veridical percept, where the long tone was discontinuous and the short tone was continuous, took place when the long glide was sufficiently more intense than the short glide. 2) The gap transfer illusion took place when the SPL difference between the crossing glides was small. 3) Both the long and the short tone were perceived as continuous when the short glide was sufficiently more intense than the long glide.

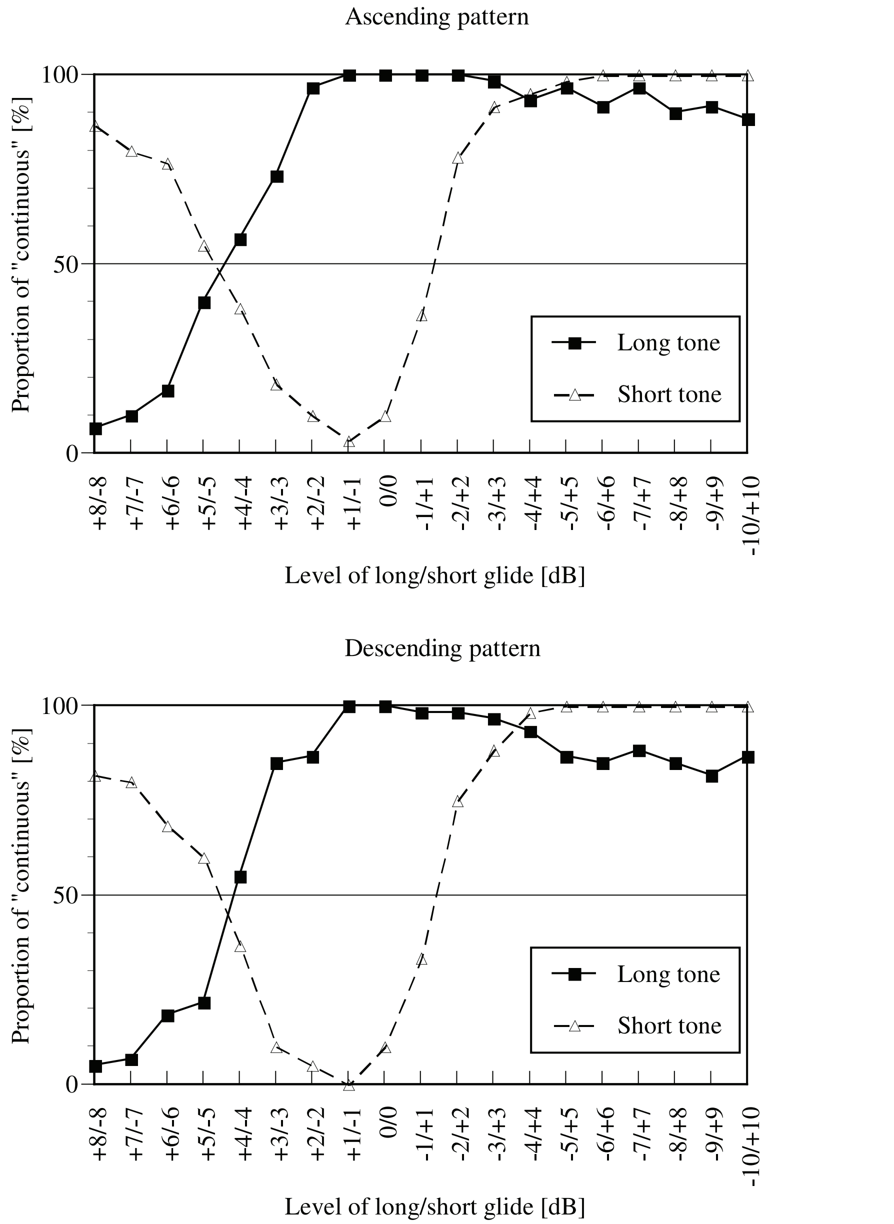

Figure 3. The mean proportions of “continuous” in the gap-in-long patterns. The horizontal axis represents the levels of the long and the short glide. The upper panel represents the ascending patterns and the lower panel represents the descending patterns.

We calculated the proportion of the trials where the observers answered that the long tone was “continuous” and the short tone was “discontinuous” (Figure 4). We define the occurrence range of the gap transfer illusion as the range where this proportion value is above 50%, and we employ the relative level of the short glide to the long glide to describe the range. The gap transfer illusion took place when the relative level of the short glide to the long glide is from -7.7 to +2.6 dB in the ascending pattern, and when the relative level is from -8.0 to +2.7 dB in the descending pattern (The values of the edges of the ranges were calculated with the linear interpolation method.).

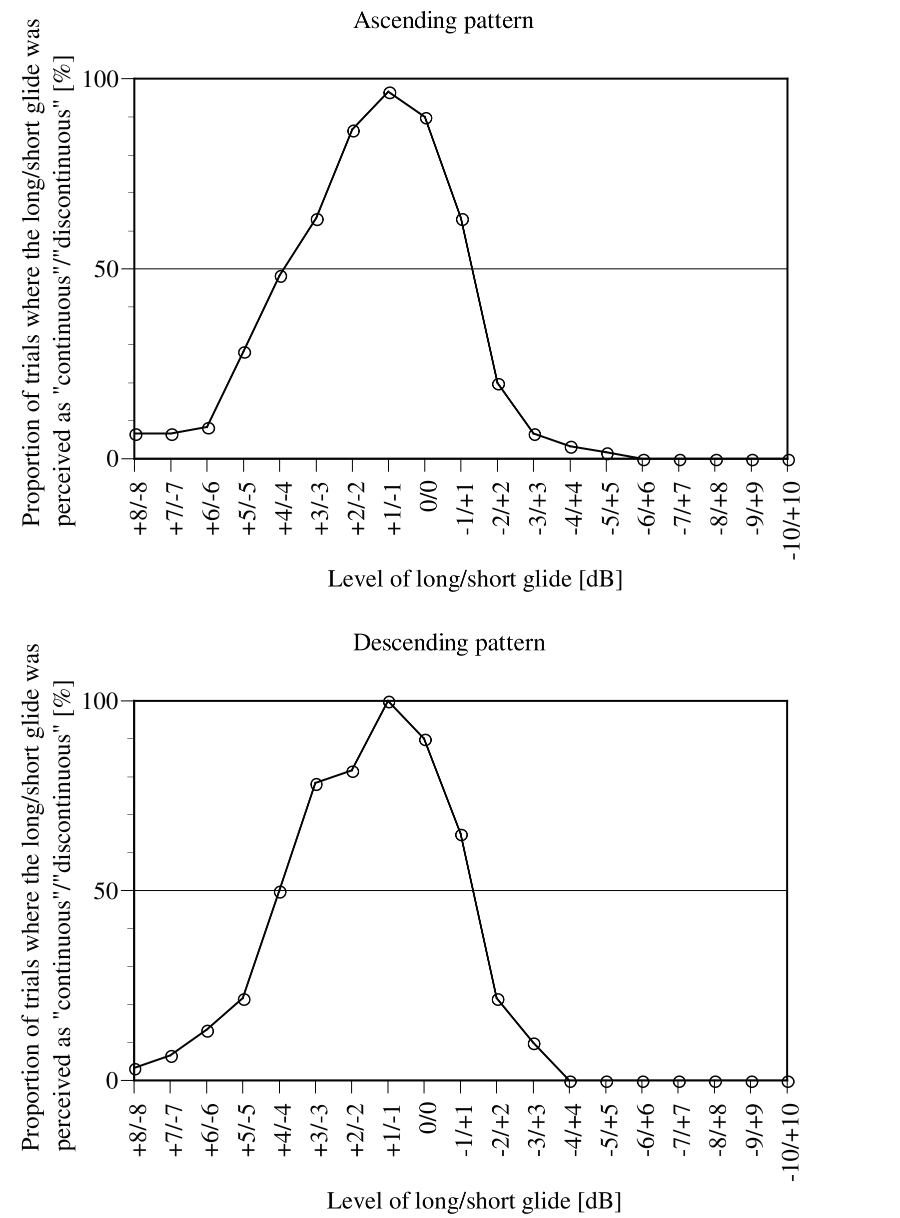

Figure 4. The mean proportions of the trials where the observer answered that the long tone was “continuous” and the short tone was “discontinuous” in the gap-in-long patterns. The horizontal axis represents the levels of the long and the short glide. The upper panel represents the ascending patterns and the lower panel represents the descending patterns.

It turned out that the gap transfer illusion takes place even when the short glide is down to 8 dB below the level of the long glide. This supports our claim that the illusory continuity of the long glide in the gap transfer illusion is different from the continuity illusion in its typical form. It is required for the occurrence of the continuity illusion that the inserted tone be intense enough to be a potential masker of the discontinuous tone (Warren et al., 1999). It is difficult to assume that the long glide can be masked with the short glide less intense than the long glide.

Our results may imply a high ability of auditory completion. The gap transfer illusion took place when a discontinuous long glide crossed with a less intense continuous short glide, but there should be a lack of sound energy, up to 8 dB, to fill in the gap of the long glide even if the sound energy of the short glide is allocated to the long glide. We should perceive discontinuity for the temporal dip, but the gap transfer illusion took place in such a stimulus condition, and the long glide was perceived as continuous. Auditory system behaves as if it could generate new energy to fill in the gap.

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DIFFERENCES BETWEEN "EARLY" AND "LATE" PROCESSING OF STIMULUS DIMENSIONS IN PERCEPTION? THE ROLE OF CONTEXT INVARIANCE

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Abstract

When a pair of dimensions is tested for perceptual interaction, the outcome can depend on the task at hand. In particular, inconsistencies are found when the same dimensions are tested in detection and in 'higher-level' judgments. The so-called Redundant Signals Design in detection and Functional Measurement in judgment are discussed for illustration. It is shown that the notion of context invariance is critical for a theoretical resolution.

Rectangles have been a popular tool to assess perceptual interaction with height and width as natural input dimensions. Their components, pairs of vertical and horizontal line segments approximating an L-shape, have similarly been used to probe separability or independence in perception. In fact, the vertical and horizontal position of a single dot placed within a rectangle (Garner & Felfoldy, 1970) can also serve to address the presence and nature of the interaction between the two dimensions. The gamut of tasks used varied from detection (Kadouri-Labin, 2008; Townsend, Hu, & Ashby, 1981) to identification (Monahan & Lockhead, 1977; Weintraub, 1971) to speeded classification (MacMillan & Ornstein, 1998) to judgments of similarity (Schonemann, Dorcey, & Kienapple, 1985) to judgments of area (Algom, Wolf, & Bergman, 1985; Anderson & Cuneo, 1978; Wilkening & Lange, 1989). Notably, the results varied across tasks (and, to a much lesser extent, within tasks), sometimes in a qualitative way. Detection and estimation of area can provide one illustration. For detection, horizontal and vertical line segments were often found to interact, whereas height and width were often found additive in judgments of the area of the respective rectangles (with children). The inconsistency is typical of many other dimensions. My goal in this article is to pinpoint one possible source for the inconsistency. I refer to a critical assumption that has been recognized in detection, but that has not been fully recognized in the more "cognitive" tasks of integration such as estimation of area. The assumption is known as context invariance (Townsend & Wenger, 2005) or context independence (Colonius, 1990).

Detection and Context Invariance

In a simple detection design, the Redundant Targets Paradigm (RTP), a horizontal line (signal A), a vertical line (signal B), both (A&B), or none is presented on a trial and the observer indicates the presence of any signal as fast as possible (espousing a minimum time stopping rule). It has often been observed that reaction times are stochastically faster on the redundant signals (A&B) trials than on the single signal (A, B) trials, the Redundant Targets Effect (RTE). The RTE, in turn, figures prominently in attempts to characterize the architecture of the system processing the signals. The assumption of context invariance is critical for the success of these attempts: We assume that the rate of processing along the vertical (horizontal) line channel is invariant across single- and redundant-targets presentations. In other words, we assume that the vertical line is processed in the same way regardless of whether the horizontal line is also presented on that trial; the same holds for the processing of