PERCEIVING FILLED VS. EMPTY TIME INTERVALS: A COMPARISON OF ADJUSTMENT AND MAGNITUDE ESTIMATION METHODS

Emi Hasuo[*], Yoshitaka Nakajima[**], Erika Tomimatsu[**], Simon Grondin[*], Kazuo Ueda[**]
[*]Université Laval, Québec, Canada
[**]Kyushu University, Fukuoka, Japan
emi.hasuo.1@ulaval.ca

Abstract

A time interval between the onset and the offset of a continuous sound (filled interval) is often perceived to be longer than a time interval between two successive brief sounds (empty interval) of the same physical duration. The present study examined the occurrence of such phenomenon, sometimes called the filled duration illusion, for time intervals of 40-520 ms with the method of adjustment and the method of magnitude estimation. When the method of adjustment was used, the filled duration illusion appeared clearly for a few participants, while it did not appear for the majority of participants. With magnitude estimation, the filled duration illusion was more likely to occur. The amounts of the illusion did not correlate between the two methods, and it was suggested that even for the same participant, the perception of the empty and the filled intervals can be influenced by the experimental methods.

The perception of a time interval can be influenced by the structure of the interval, i.e., the way it is marked (e.g., Grondin, 2010). The interval is said to be *filled* when there is one continuous signal, and its onset and offset mark the beginning and the end of the time interval. The interval is said to be *empty* when it is marked by two successive brief signals and contain no stimulation within the interval. Previous studies showed that a time interval is perceived to be longer when it is filled than when it is empty (e.g., Wearden et al., 2007). Such phenomenon is sometimes called the *filled duration illusion*, and it has been reported repeatedly with various stimulus patterns and experimental tasks (Craig, 1973; Wearden et al., 2007, Zwicker, 1969/70).

However, a recent study by Hasuo et al. (2011) showed that the filled duration illusion does not take place in some cases. When subjective durations of very short time intervals of 20-180 ms were measured using the method of adjustment, the filled duration illusion occurred for some participants, while the filled intervals were perceived to be shorter than empty intervals—an opposite effect occurred—for more than half of the participants. The participants in which the filled duration illusion occurred and those in which it didn't were divided clearly by a cluster analysis. These findings of Hasuo et al. (2011) suggested that even for the same stimulus, the perceived duration could differ clearly between participants.

In the present study, we conducted two experiments to examine the robustness of Hasuo et al.'s (2011) results with longer durations (up to 520 ms) and with a different experimental task. In Experiment 1, the method of adjustment, as in Hasuo et al. (2011), was employed, and in Experient 2, the method of magnitude estimation. The stimuli in both experiments were the same, and some of the participants took part in both experiments, thus the results of the two experiments could be compared.

Experiment 1

The aim of Experiment 1 was to examine the occurrence of the filled duration illusion in a paradigm slightly modified from Hasuo et al. (2011). The experiment consisted of two sub-experiments, Experiment 1A and Experiment 1B.

Method

Participants Thirty-six undergraduate students of Department of Acoustic Design, Kyushu University, participated for course credits. Nineteen participants were assigned to take part in Experiment 1A, and the remaining seventeen to Experiment 1B.

Stimuli All sounds were 1000-Hz pure tones with a rise and a fall time of 10 ms. Empty intervals were marked by the onsets of two 20-ms sounds, and filled intervals were marked by the onset and the offset of a continuous sound (Figure 1). The presentation level of a 20-ms sound was 71 dBA, measured as the level of a continuous tone of the same amplitude, and the total energy of a filled-interval sound was equal to that of two 20-ms sounds together.

Each presentation consisted of a standard and a comparison in this order. The standard began 2.0-2.5 s after the participant clicked the "play" button on the computer screen, and the comparison began 2.5-3.0 s after the standard ended. In Experiment 1A, the comparison was a filled interval, and in Experiment 1B, an empty interval. The standard was the same in Experiment 1A and 1B: both empty and filled intervals were used as the standard.

The standard duration was 40, 100, 160, 280, 400, or 520 ms. Thus, there were 12 experimental conditions (2 [interval types: empty/filled] × 6 [standard durations]), both in Experiment 1A and in Experiment 1B.

Procedure The task for the participants was to adjust the duration of the comparison, by clicking the buttons and sliding bars presented on the computer screen, to make it subjectively equal to that of the standard. The participant could listen to the stimulus pattern and adjust the comparison duration as many times as he/she wanted, and the final comparison duration in each trial was recorded as the *point of subjective equality, PSE*.

For each condition, there were an ascending series and a descending series, and the PSEs from these series were averaged for each participant. Before these trials, 6 practice trials were carried out. The whole experiment, including the practice trials, took about 35 minutes per participant.

Results

Figures 2a and 2e show the mean PSEs of all participants in Experiments 1A and 1B. In both cases, the PSEs of the filled intervals (closed circles) were not so large compared to those of the empty intervals (open squares), i.e. the filled duration illusion did not appear. The standard deviations between participants (shown with error bars) were larger for empty intervals in Experiment 1A (Figure 2a), and for filled intervals in Experiment 1B (Figure 2e). This could

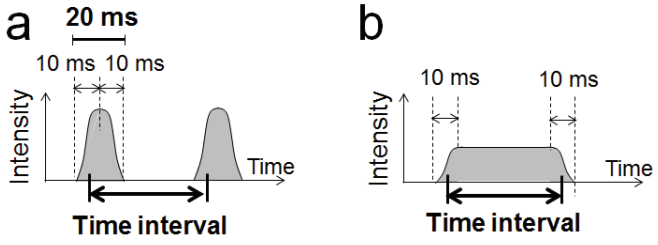

Figure 1. Illustration of the empty (a) and the filled (b) intervals. Note that the temporal midpoints (or beginnings depending on how we describe the patterns) of the rise/fall time were considered as the beginning and the end of a time interval.

have been due to the difficulty to compare the durations of an empty interval and a filled interval directly, which was necessary in these conditions.

To look more closely into these large variabilities, we conducted a hierarchical cluster analysis for standard durations of 100-520 ms[1], as in Hasuo et al. (2011), using the amount of overestimation of the empty intervals [(empty PSE) – (filled PSE)] for Experiment 1A and of the filled intervals [(filled PSE) – (empty PSE)] for Experiment 1B. Note that the filled-interval condition served as the control for Experiment 1A, and the empty-interval condition for Experiment 1B, since the comparison stimulus was the same as the standard. Clusters were determined by the Ward method, which analyzed the squared Euclidean distance between points.

Results of the cluster analysis showed that participants could be divided clearly into two groups (Figures 2d and 2h). We calculated the mean PSEs for Cluster 1 (16 out of 19 participants in Experiment 1A; 13 out of 17 participants in 1B) and Cluster 2 (3 out of 19 participants in Experiment 1A; 4 out of 17 participants in 1B) separately, and plotted them against standard duration (Figures 2b, 2c, 2f, 2g). For participants in Cluster 1, the mean PSEs did not differ much between the filled and the empty intervals (Figures 2b and 2f), whereas participants in Cluster 2 under/overestimated the empty/filled intervals, especially as the standard duration became longer (Figures 2c and 2g).

Summarizing Experiment 1, the filled duration illusion did not take place for many participants (Figures 2b and 2f), however, it took place clearly for a few participants (Figures 2c and 2g). This was in line with Hasuo et al. (2011). Extending the range of duration up to 520 ms did not seem to have much impact on the results.

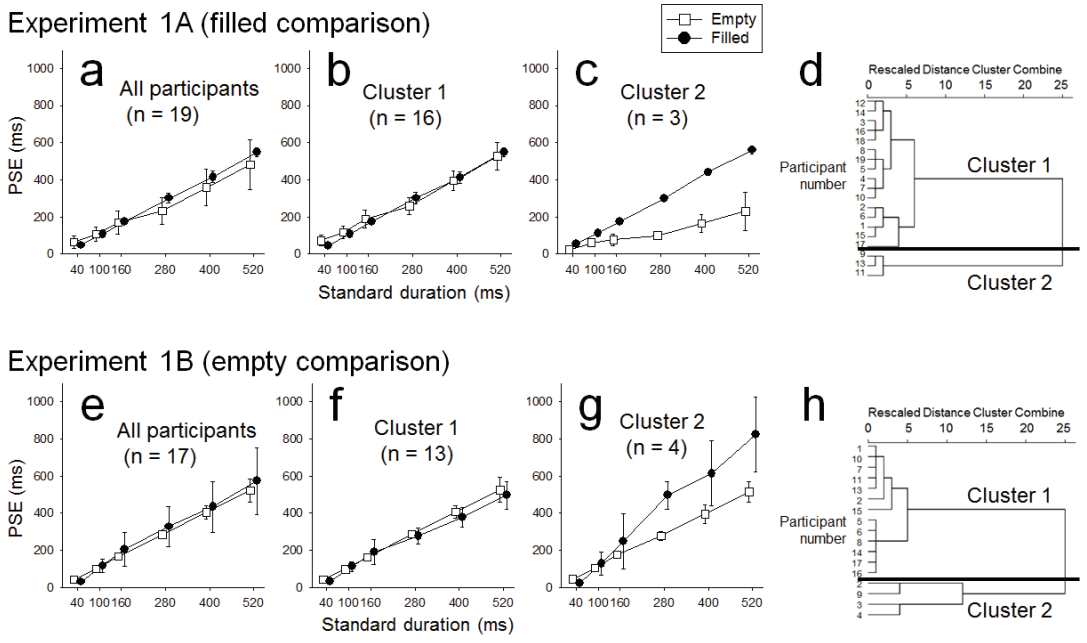

Figure 2. Results of Experiments 1A (a-d) and 1B (e-h): mean PSEs of all participants (a, e), Cluster 1 participants (b, f), and Cluster 2 participants (c, g). Clusters were divided according to the dendrograms (d, h) established by the hierarchical cluster analyses. Error bars represent the standard deviation between participants.

[1]We excluded the 40-ms condition from analysis because, when the standard was 40 ms, there were a few participants who tried to make the comparison shorter than the shortest duration technically possible (i.e., 10 ms in Experiment 1A, and 20 ms in Experiment 1B). The 40-ms condition was excluded from the analysis of Experiment 2 also, because the main purpose of this analysis was to compare the results with those of Experiment 1.

Experiment 2

The aim of Experiment 2 was to examine the occurrence of the filled duration illusion with the same stimuli as in Experiment 1 but with a different method, i.e., magnitude estimation.

Method

Participants Seventy-six undergraduate students of Department of Acoustic Design, Kyushu University, participated for course credits. Thirty-six had participated in Experiment 1.

Stimuli The empty and the filled intervals were the same as in Experiment 1 (Figure 1). At the beginning of each trial, the type (i.e. filled or empty) of the interval to be presented was indicated on the computer screen, and 2 seconds later, the time interval was presented once. Following the time interval, there was a silent period where nothing happened for 6 seconds, and then the next trial began automatically with the indication of the interval type for the next interval.

The interval duration was 40, 100, 160, 280, 400, or 520 ms. Thus, there were 12 experimental conditions (2 [interval types: filled/empty] × 6 [interval durations]).

Procedure The task for the participants was to listen to the time interval and verbally respond during the following silence the value that corresponded to the perceived duration of the interval. The participant could respond in any range of values he/she liked (including decimals and fractions) as long as they were positive numbers.

The 12 stimuli were presented in random order, and there were 4 repetitions. For each participant, the response value for each condition was obtained by calculating the geometric mean of the last 2 repetitions. Before these trials, participants listened to all 12 stimuli once, presented also in random order, without making responses. The whole experiment, including the listening-only trials, took about 8 minutes per participant.

Results

Figure 3a shows the geometric mean of the responses obtained from 76 participants plotted against the interval duration. The values of the responses for the filled intervals were larger than those for empty intervals (i.e., the filled duration illusion appeared), and this difference increased as the interval duration became longer.

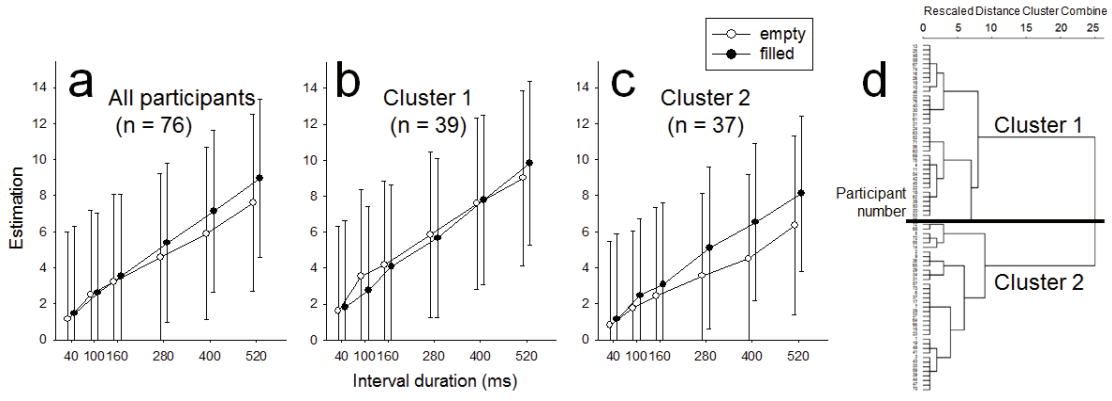

Figure 3. Results of Experiment 2: geometric mean magnitude estimations (responses) of all participants (a), Cluster 1 participants (b), and Cluster 2 participants (c). Clusters were divided according to the dendrogram (d) established by the hierarchical cluster analysis. Error bars represent the geometric standard deviation between participants. Note that the large variability is due to the huge difference in the range of response values chosen by each participant, and the error bars are shown just for the comparison between empty and filled intervals.

As in Experiment 1, we conducted a hierarchical cluster analysis using the log-transformed values of the amounts of overestimation of the filled interval [(filled geometric mean response) / (empty geometric mean response)] for interval durations of 100-520 ms[1]. Results showed that participants could be divided clearly into two groups (Figure 3d). Participants classified in Cluster 1 (39 out of 76 participants) did not show much difference between the filled and the empty intervals (Figure 3b), whereas participants in Cluster 2 (37 out of 76 participants) under/overestimated the empty/filled intervals, especially as the standard duration became longer (Figure 3c).

Summarizing, the filled duration illusion appeared clearly for some participants while it did not for other participants. This was similar to Experiment 1, but the filled duration illusion seemed more likely to appear with the method of magnitude estimation than with the method of adjustment (compare Figures 2 and 3).

General Discussion

The two experiments showed that, even for the same stimuli, the filled duration illusion can occur for some participants while it doesn't occur for others. This was consistent with Hasuo et al. (2011). To examine whether the participants who showed clear filled duration illusion in the method of adjustment task (Experiment 1) also showed clear illusion in the magnitude estimation task (Experiment 2), we focused on the 36 participants who participated in both Experiments 1 and 2, and calculated the amount of filled duration illusion for each of those participants for each experiment, by dividing the response for the filled intervals by the response for the empty interval (i.e., [(filled PSE) / (empty PSE)] for Experiment 1, and [(filled geometric mean response) / (empty geometric mean response)] for Experiment 2). Then, we averaged the amounts of filled duration illusion for the 100-520-ms intervals for each participant.

Figure 4 is the scatter plot showing the amount of filled duration illusion in Experiment 2 as a function of the amount of filled duration illusion in Experiment 1. It seemed that the participants who showed clear filled duration illusion in Experiment 1 did not always show large filled duration illusion in Experiment 2, and vise versa. Pearson's correlation coefficient (for 100-520-ms intervals) was low and non-significant (filled comparison, r = .206, p = .396; empty comparison, r = .249, p = .336)

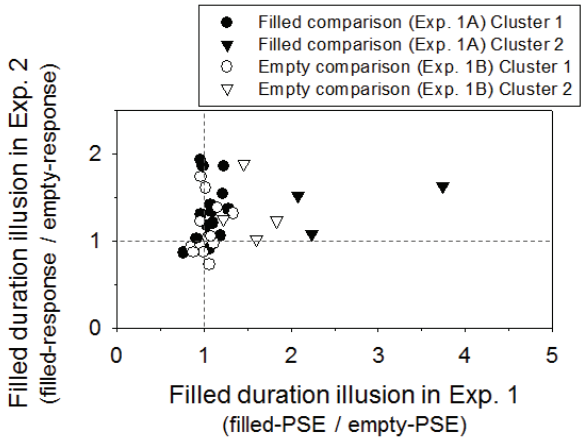

Figure 4. Scatter plot of the amount of filled duration illusion in Experiment 1 vs. Experiment 2 for the 36 participants who participated in both experiments. Larger values correspond to greater amount of filled duration illusion, and values smaller than 1 mean that the empty intervals were subjectively longer than the filled intervals (i.e., an opposite effect).

One interesting aspect about the results was that the participants were always divided clearly into two groups (Figures 2d, 2h, 3d), and that clear filled duration illusion appeared in one group whereas neither over- nor underestimation of the filled intervals appeared in the other. For participants with clear filled duration illusion, the amount of illusion increased as the interval lengthened (Figures 2c, 2g, 3c). This kind of filled duration illusion can be explained by assuming that the existence of a sound during a filled interval made the internal pacemaker run faster, which lead to the impression of time passing more quickly, consequently leading to an overestimation of filled intervals compared to empty intervals (Wearden et al., 2007). For participants without filled duration illusion (Figures 2b, 2f, 3b), such kind of pacemaker acceleration may not have occurred much; the subjective durations of the empty and the filled intervals were close to each other irrespective of the duration in their case. It could be possible that these participants were very accurate in perceiving the timing of sound onsets and offsets, thus the filled duration illusion did not appear (Repp & Marcus, 2010).

It was a new finding that there are two different modes for perceiving empty and filled intervals (one would cause filled duration illusion and the other would not), and that which mode the listener uses can be influenced by experimental methods. The filled duration illusion being less likely to occur for the method of adjustment task could be related to the fact that participants were able to listen to the stimulus pattern many times. This may have promoted the participant's attitude to attend more carefully to the onset and offset. For the magnitude estimation task, having the participant make a judgment right after presenting the stimulus only once could have made the participants base their judgments more on the impression of the duration, not precisely on the onset and offset timing. This explanation warrants further investigation.

In summary, the well-established filled duration illusion appeared clearly for some listeners, but did not appear for others. When the subjective durations were measured with the method of magnitude estimation, the illusion was more likely to occur; it occurred for a considerable number of participants who did not exhibit it in the method of adjustment task. The experimental method can influence the occurrence of the filled duration illusion, and the absence of the illusion in some cases and the occurrence in others may be related to the location of the listener's attention.

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