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The occurrence of the filled duration illusion: A comparison of the method of adjustment with the method of magnitude estimation ☆

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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 whether and how this phenomenon, sometimes called the filled duration illusion (FDI), occurs for short time intervals (40–520 ms). The investigation was conducted with the method of adjustment (Experiment 1) and the method of magnitude estimation (Experiment 2). When the method of adjustment was used, the FDI did not appear for the majority of the participants, but it appeared clearly for some participants. In the latter case, the amount of the FDI increased as the interval duration lengthened. The FDI was more likely to occur with magnitude estimation than with the method of adjustment. The participants who showed clear FDI with one method did not necessarily show such clear FDI with the other method.

1. Introduction

The perceived duration of a time interval is influenced by what happens during the interval. Long ago, Hall and Jastrow (1886) found that a time interval marked by two short sounds is perceived to be longer when one or more short sounds are inserted within this time interval. This illusion in time perception later became known as the filled duration illusion (FDI), or the illusion of divided time interval (ten Hoopen, Miyauchi, & Nakajima, 2008). Another type of FDI, sometimes called the sustained sound illusion (Repp & Marcus, 2010), is a phenomenon where a continuous sound is perceived to be longer than a physically equal interval defined by two very short sounds or as a silence between two sustained sounds (Wearden, Norton, Martin, & Montford-Bebb, 2007; Zwicker, 1970). In the present article, the FDI refers to this latter type of phenomenon. The temporal distance between the beginning and the end of a continuous sound will be called a *filled interval*, and the temporal distance between two very short sounds an *empty interval*.

Zwicker (1970) found that a filled interval was perceived approximately to be as long as an empty interval in which the physical duration was doubled (see also Fastl & Zwicker, 2007). He employed time intervals ranging from 5 to about 900 ms, and asked participants to adjust the duration of a continuous sound to make it subjectively equal to the silence between two later sounds, or vice versa. Craig (1973) reported that a silent interval between two sustained sounds needs to be 657 ms longer than the first sound—a filled interval—to be perceived as having the same duration. In each stimulus condition, two successive sustained sounds of 100 to 1200 ms were presented with a silent gap in between; the participants adjusted the duration of the gap to make its duration subjectively equal to the duration of the first sound. Wearden et al. (2007) showed that the duration of an empty interval is perceived as only 55–65% of the duration of a physically equal filled interval. They employed durations ranging from 77 to 1183 ms, and participants verbally estimated the duration of each time interval. All studies agreed on the point that there was a clear FDI.

A recent study by Hasuo, Nakajima, and Ueda (2011), however, showed that the FDI does not take place in some cases. They employed very short time intervals ranging from 20 to 180 ms, and presented stimulus patterns consisting of a standard interval and a comparison interval in this order. Participants had to adjust the duration of the comparison to make its duration subjectively equal to that of the

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standard. The standard interval was marked either by a single sound (filled-interval condition), two 20-ms sounds (empty-interval condition), or two 2-ms sounds (control condition), and the comparison interval was always marked by two 2-ms sounds. While the FDI occurred for some participants, an opposite effect occurred for more than half of the participants—they perceived filled intervals to be shorter than empty intervals. A cluster analysis clearly distinguished these groups of participants. These results were surprising not only because they showed that the FDI did not always appear, but also because they showed that such a clear difference between participants could appear in a very simple paradigm. Apparently, there are two different ways of perceiving empty and filled intervals.

The aim of the present article was to examine the robustness of Hasuo et al.'s (2011) findings, and to fill the gap between them and the findings from previous literature on the FDI, for instance by Craig (1973) and Wearden et al. (2007). We focused especially on the range of duration and experimental methods. The main difference between Hasuo et al. (2011) and previous studies was the focus on very brief intervals (20–180 ms). There are studies showing that the processing of short time intervals (<200 ms) may be different from that of longer time intervals (e.g., Czigler, Winkler, Sussmann, Yabe, & Horvath, 2003; Hasuo, Nakajima, Osawa, & Fujishima, 2012; Nakajima, Shimojo, & Sugita, 1980). Therefore, it seemed necessary to investigate the occurrence of the FDI with a different range of duration, including longer ones.

Another concern was about the experimental method. Hasuo et al. (2011) employed the method of adjustment; their participants had to directly compare the durations of two time intervals presented successively. This applies also for the tasks of Zwicker (1970) and Craig (1973). The task of Wearden et al. (2007) was different: the participants made judgments after the presentation of each time interval, without comparing it directly with another time interval. Although Zwicker (1970), Craig (1973), and Wearden et al. (2007) all reported clear FDI, the amount of the illusion differed between these studies. There are many examples in the timing literature showing that using different tasks or stimuli may lead to different findings (Bangert, Reuter-Lorenz, & Seidler, 2011; Gil & Droit-Volet, 2011; Grondin, 1993, 2003; Grondin, Meilleur-Wells, Ouellette, & Macar, 1998; Rammsayer, Buttkus, & Altenmüller, 2012). It is therefore imperative to examine the occurrence of the FDI with different methods, but with similar stimuli so that the effects of different tasks could be compared directly.

We conducted two perceptual experiments with intervals lasting from 40 to 520 ms. In Experiment 1, we measured the subjective durations of the time intervals with the method of adjustment, a method similar to that used by Hasuo et al. (2011). In Experiment 2, the stimuli were the same as in Experiment 1, but the method of magnitude estimation was used. Results of Experiment 1 will indicate whether the results of Hasuo et al. (2011) are limited or not to very short durations, and comparing the results of Experiments 1 and 2 will allow us to assess the effects of the experimental methods.

2. Experiment 1: method of adjustment

While the comparison intervals were always empty intervals (marked by 2-ms clicks) in Hasuo et al. (2011), the present experiment treated the empty and the filled intervals equally by utilizing both filled intervals and empty intervals as comparison. The upper limit of the duration range was prolonged from 180 ms (Hasuo et al., 2011) to 520 ms. The longest duration, 520 ms, was well over the 200-ms time window for temporal processing (e.g., Czigler et al., 2003), and also long enough to have overlap with previous studies (e.g., Craig, 1973; Wearden et al., 2007).

Experiment 1 consisted of two sub-experiments, 1A and 1B. In Experiment 1A, the comparison interval was a filled time interval ("filled comparison"), whereas in Experiment 1B, it was an empty time interval ("empty comparison") (Fig. 1c). Other aspects of the experiments were the same in these two sub-experiments.

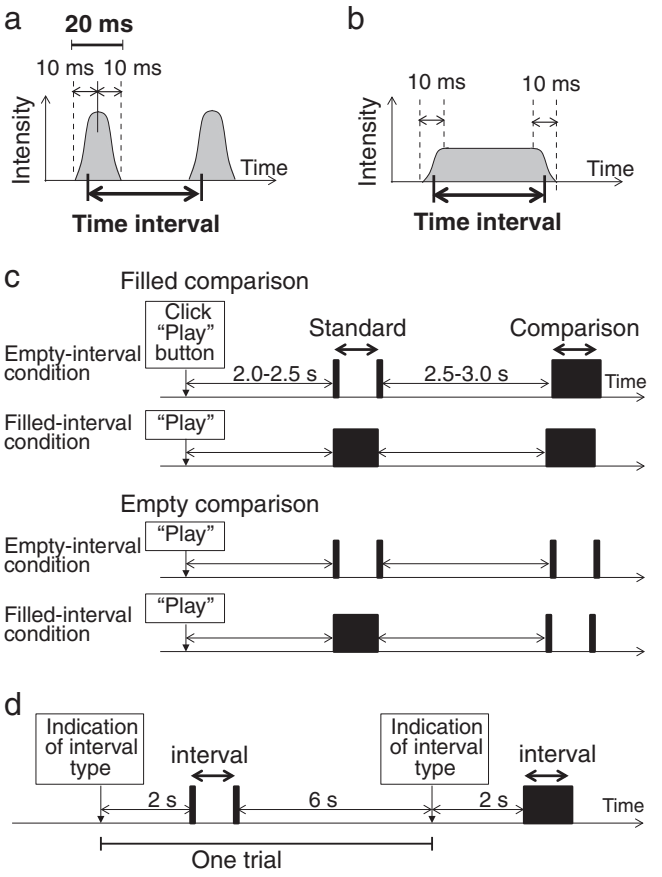

Fig. 1. Illustration of the stimuli and the stimulus patterns. The top two panels show the details of the sounds that marked the empty (a) and the filled (b) time intervals. Note that the temporal midpoints (or beginnings depending on how we describe the patterns) of the rise/fall time were considered as the beginning and the end of a time interval, as in Hasuo et al. (2011). The middle panel (c) shows the stimulus presentation charts for the method of adjustment task (Experiment 1), and the bottom panel (d) shows the stimulus presentation chart for the magnitude estimation task (Experiment 2).

2.1. Method

2.1.1. Participants

Thirty-seven undergraduate students of Department of Acoustic Design, Kyushu University, participated for course credits. All had received training in technical listening for future acoustic engineers (Iwamiya, Nakajima, Ueda, Kawahara, & Takada, 2003). This training was done in a class once a week for one or two semesters, and it focused mainly on developing ability to discriminate timbres and intensity levels of sounds. None had participated in Hasuo et al. (2011). Nineteen participants were assigned to take part in Experiment 1A, and the remaining seventeen[2] to Experiment 1B.

2.1.2. Stimuli and apparatus

Each presentation consisted of a standard and a comparison in this order (Fig. 1c). 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. The durations of these silences were randomized for each presentation in order to prevent the participants

[2] The data of one additional participant were collected, but were excluded from analysis, because the minimum threshold of hearing was high for this participant. The exclusion was just for safety, and this participant's PSEs were not qualitatively different from the other participants' PSEs.