# FILLED DURATION LENGTHENING TAKES PLACE IN A SOUND PRECEDED BY A MORE INTENSE SOUND

**Tsuyoshi Kuroda and Simon Grondin**
École de psychologie, Université Laval, Québec (QC), G1V 0A6, Canada

## 1. INTRODUCTION

The *time-stretching illusion* is an auditory illusion where a sine tone is perceived as longer when it is preceded by a more intense noise (Figure 1). This illusion was reported by Carlyon et al. (2009) and Sasaki et al. (2010), and the latter authors assumed that the illusion is caused by the fact that the onset of the sine tone is masked by the preceding noise. This onset is restored in perception, but it is interpreted to be buried in the noise. Thus, the sine tone's duration is overestimated.

Sasaki et al. (2010) demonstrated the occurrence of the time-stretching illusion, however, with only one condition where the sine tone was preceded by the noise. The present experiment employing the method of constant stimuli examined whether or not the sine tone would be overestimated when it was *followed* by the noise.

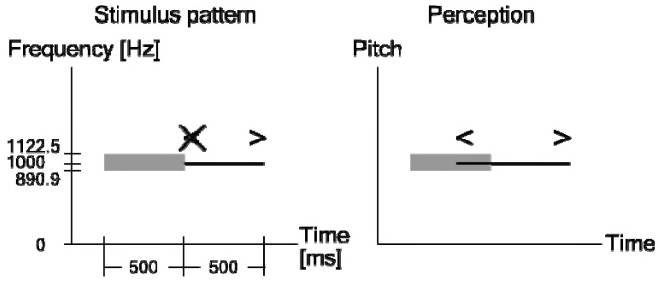


**Figure 1. The time-stretching illusion: "<" represents the tone's onset and ">" the tone's offset.**

## 2. METHOD

### 2.1. Participants

Eight Laval University students and employees volunteered to participate. The participants all reported they had normal hearing. They received $60 CAN for their participation.

### 2.2. Apparatus and stimuli

Digital signals of stimuli were sampled at 44100 Hz and quantized to 16 bits. The stimuli were delivered from headphones (Sennheiser HD 477) connected to a computer (IBM Netvista).

The *standard* tone and the *comparison* tone were presented successively in each trial. They were sinusoidal tones of 1000 Hz at 58 dBA. The standard tone was fixed at 500 ms, and the comparison tone was varied from 360 to 640 ms in steps of 40 ms.

The standard tone was adjoined temporally by a 500-ms 1/3-octave band noise with a center frequency of 1000 Hz in four ways (Figure 2). (1) In the noise-preceding condition, which is the typical pattern causing the time-stretching illusion, the noise was placed just before the standard tone. (2) In the noise-following condition, the noise was placed just after the standard tone. (3) In the noise-on-both-side condition, the noise was placed on both sides of the standard tone. (4) In the control condition, no noise adjoined the standard tone. The noise was 6 dB higher than the standard tone. The comparison tone was always without any noises.

The amplitude of each sound rose and decayed during 10 ms at the beginning and the end, and a half part of a cosine window was applied to the envelope of these transitions.

The standard pattern and the comparison tone were presented in two types of order: The standard pattern preceded the comparison tone in the standard-comparison type, and vice versa in the comparison-standard type. A silent interval, which was varied from 2000 to 3000 ms randomly, was placed before the beginning of stimulus presentation and was inserted between the standard pattern and the comparison tone.

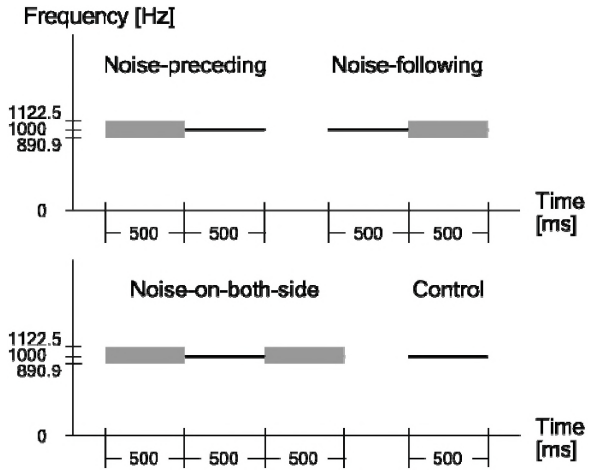


**Figure 2. Standard patterns**

### 2.3 Procedure

The task was performed by clicking on panes on a computer display. The participants listened to the stimulus pair by clicking on the "play" pane. The participants were allowed to listen to the stimulus pair only once in each trial except when listening was disturbed for some specific reason (e.g., a sleep or a cough)—in such a case, the participants listened to the pair again by clicking on the "replay" pane.

The participants judged whether the second sine tone was "shorter" or "longer" than the first sine tone. The participants could answer that the two tones were "equal" in duration, and they could also answer that they perceived the two tones as different but were "unsure" whether the second tone was shorter or longer. The participants were instructed not to use the last two alternatives except when definitely necessary.

There were six sessions: three sessions for the standard-comparison order and three sessions for the comparison-standard order. These two sets of sessions were carried out in counterbalanced order. Each session consisted of four blocks corresponding to four standard configurations, which were carried out in counterbalanced order. Each block consisted of 80 trials for ten repetitions of 8 steps of comparison duration, which were arranged in random order. Breaks of a few minutes were inserted between the blocks. A warm up of two trials was carried out at the beginning of each block, for which the stimulus pairs were selected randomly. The participants finished each session in about an hour.

## 3. RESULTS

The probability that the comparison was perceived as longer was calculated for each comparison duration to make 8-point psychometric functions for each configuration and for each order. Each point was based on 30 responses, and the alternative responses of "equal" and "unsure" were split between the "shorter" and the "longer" responses. A cumulative normal distribution was fitted to the resulting curves. Because two participants showed poor goodness of fit ($R^2$ values of less than .30) in some conditions, they were replaced with new participants. As a result, the $R^2$ value was above .90 in 59 cases out of 64 (8 participants × 2 orders × 4 configurations), and was between .90 and .70 in 5 cases.

From each curve, the point of subjective equality (PSE) was calculated for determining the perceived duration of the standard tone (Figure 3). A repeated-measure ANOVA according to a 2 order × 4 configuration design revealed that the configuration effect was significant, $F(3, 21) = 4.659$, $p = .012$, $\eta_p^2 = .400$, the interaction was marginally significant, $F(3, 21) = 2.856$, $p = .062$, $\eta_p^2 = .290$, and the order effect was not significant, $F(1, 7) = .286$, $p = .610$, $\eta_p^2 = .039$.

## 4. DISCUSSION

It turned out that a sine tone was perceived as longer when it was adjoined by a more intense noise. This overestimation was the largest when the sine tone was preceded by the noise, which is the typical case of the time-stretching illusion. Less overestimation was observed when the sine tone was followed by the noise. In this case, the offset of the sine tone is supposed to be masked by the noise. The classical studies of auditory masking have indicated, however, that there is limited evidence supporting the backward masking (i.e., the peripheral masking of the preceding sound by the following sound; see Moore, 2003). If the masking of the tone's offset is similar to the classical backward masking in their mechanism, it is not difficult to assume that the masking of the tone's offset has weaker effect on the tone's perceived duration than the masking of the tone's onset.

It is interesting to note that the overestimation was not so high when the noise was placed on both sides of the sine tone. In this case, the preceding noise should have caused the same overestimation as in the time-stretching illusion. Rather, the observed overestimation was similar to that in the situation where the noise was placed only after the sine tone. In order to explain this effect, it may be required to assume another mechanism, which is not related to the masking of tone's onset and offset. When the noise is placed on both sides of the sine tone, this configuration may shrink the perceived duration of the sine tone, and cancel the overestimation by the masking of the tone's onset. If so, it should be valuable to conduct an experiment where the noises on both sides are weaker than the sine tone. In this situation, the onset and the offset of the sine tone should not be masked, and only the effect of configuration can be examined.

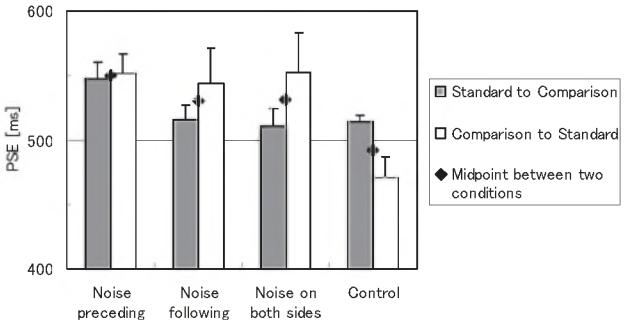


**Figure 3. The estimated point of subjective equality**

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