Demonstrations of time-shrinking

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Introduction

When three successive sound bursts mark two empty durations, the perception of the second duration can be affected by the first duration (Figure 1) (Nakajima, Ten Hoopen, and Van der Wilk, 1991). That is, the second duration can be underestimated when it exceeds the first duration physically. This effect appears clearly only when the first duration is as short as or shorter than 300 ms. Previous studies showed that the underestimation was largest when the standard duration, S, to be judged exceeded the preceding duration, P, by 60-100 ms. The stability of this illusory phenomenon has been confirmed (e.g., Ten Hoopen, Hilkuysen, Nakajima, Yamauchi, and Sasaki, 1993; Suetomi and Nakajima, 1998; Nakajima et al., 2000). A recent study showed a similar illusion in the visual modality (Arao, Suetomi, and Nakajima, 2000).

\[\text{"Stimulus Pattern"}\]

\[\text{"PSE of S"}\]

\[\text{Control Condition}\]

\[\text{Tone Burst} \quad \text{S} \quad \text{Time}\]

\[\text{Preceding-neighbor Condition}\]

\[\text{P} \quad \text{S} \quad \text{Time}\]

\[\text{Under-estimation}\]

\[\leftrightarrow\]

\text{Figure 1. Time-shrinking. Underestimation of S appears when S and P (\text{S}) neighbor each other. Negative overestimation means underestimation.}

Nakajima, Ten Hoopen, Hilkuysen, and Sasaki (1992) named this illusory phenomenon "time-shrinking," and interpreted it as a sort of perceptual assimilation between P and S. However, time-shrinking does not seem a typical example of assimilation. First, this kind of context has a substantial effect only on the perception of S, but not on the perception of P. Second, the effect is clear only when S exceeds P physically. We would like to present three auditory demonstrations showing the nature of this illusion.
Figure 2. Stimulus patterns of Demonstration 1. All the empty durations are marked by 10 ms pure tone bursts of 1000 Hz including a rise time of 2 ms and a fall time of 5 ms.

Demonstration 1: A Typical Example of Time-shrinking.

The present demonstration is based on the study of Nakajima et al. (1991). A fixed empty duration of 240 ms is immediately preceded by another empty duration of 80-320 ms (Figure 2). In the first presentation, the preceding duration is 320 ms, and it is decreased in steps of 20 ms in the following presentations. The second duration is perceived as if it were shortened when the preceding duration reaches about 180 ms (in the eighth presentation). This is a typical example of time-shrinking.

Demonstration 2: A Discontinuous Change of Time Perception Caused by a Sudden Release from time-shrinking.

In the study of Nakajima et al. (1992), an informal listening test was conducted. A series of temporal patterns was presented, and each pattern consisted of two neighboring durations P and S in this order, where P = 50 ms and S was varied from 50 ms to 160 ms in steps of 10 ms. When S was up to ~90 ms, the listeners perceived the two neighboring durations as almost equal. When S was lengthened further, the perceptual difference between P and S became clear rapidly. A following psychophysical experiment revealed that the point of subjective equality (PSE) of S was approximately 60 ms in the pattern (P, S) = (50, 100) [ms], while the control value was almost equal to the point of objective equality (=100 ms). This
means that the second duration was underestimated by ~40 ms. This result suggested that P and S could be perceived as almost equal even when S was longer than P by 50 ms.

<table>
<thead>
<tr>
<th>First series [ms]</th>
<th>Second series</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 160</td>
<td>12 160</td>
</tr>
<tr>
<td>2 150</td>
<td>13 170</td>
</tr>
<tr>
<td>3 140</td>
<td>14 180</td>
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<td>15 190</td>
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<td>5 120</td>
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<td>6 110</td>
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<td>9 80</td>
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<td>10 70</td>
<td>21 250</td>
</tr>
<tr>
<td>11 60</td>
<td>22 260</td>
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</tbody>
</table>

Figure 3. Stimulus patterns of Demonstration 2. All the empty durations are marked by 10 ms pure tone bursts of 1000 Hz including a rise time of 2 ms and a fall time of 5 ms.

The present demonstration consists of two series of temporal patterns (Figure 3). In the first presentation of the first series, three sound markers define two empty durations of 160 ms each. The first duration is decreased in steps of 10 ms, while the second duration is increased in steps of 10 ms. The total duration is fixed at 320 ms. When the difference between the first and the second duration is up to 80 ms (in the fifth pattern), the underestimation of the second duration takes place, and the two neighboring durations are perceived as very similar to each other. This is also an example of time-shrinking. When the physical difference between these durations is increased further, time-shrinking disappears suddenly, and a clear difference between the neighboring durations is perceived.

This kind of sudden perceptual change does not take place when the temporal order between the two durations is reversed as in the second series, where time-shrinking cannot take place.

Demonstration 3: Time-shrinking in Patterns Consisting of Three Empty Time Intervals

We were interested in how Gestalt principles work in this kind of situation, and employed stimulus patterns consisting of three neighboring durations (Suetomi, Nakajima, Sasaki, and Ten Hoopen, 1998). When three empty durations $P_1$, $P_2$, and S neighbored each other in this order (Figure 4), $P_2$ seemed to have a dominant influence upon the perception of S. The underestimation of S was conspicuous when $S = P_2 + 80$ [ms]. This corresponded to the results of our previous experiments, where the single
neighbor, P, caused the largest underestimation when $60 \leq (S - P) \leq 100$ [ms] (e.g., Ten Hoopen et al., 1993; Nakajima et al., 2000).

![Figure 4](image)

*Figure 4.* Stimulus patterns used in Suetomi et al.'s (1998) study. S: Standard duration. C: Comparison duration. P: Preceding duration in the single-neighbor condition. P1: First preceding duration in the two-neighbor condition. P2: Second preceding duration in the two-neighbor condition. The subject's task was to match C to S subjectively.

![Figure 5](image)

*Figure 5.* The overestimations of S as a function of P1 in the patterns of P1 / 120 / 200 [ms] (top panel) and in the patterns of P1 / 200 / 280 [ms] (bottom panel) in Suetomi et al.'s (1998) Experiment 2. Each point indicates the median of 30 PSEs from 5 subjects. The left-hand panels depict the overestimations of S in the single-neighbor condition (120 / 200 and 200 / 280 [ms]), and the right-hand panels the overestimations in the two-neighbor condition.

The physical difference between P2 and S seemed suitable to cause underestimation of S when $60 \leq (S - P_2) \leq 100$ [ms]. If P2 and S were
presented as a pattern without P₁, time-shrinking should be caused clearly by P₂. However the first duration P₁ seemed to modify the effect of P₂ upon the perception of S. When the relationship between P₂ and S was fixed at S = P₂ + 80 [ms] and the duration of P₁ was varied in 40 ms steps, we found a complicated but systematic influence of P₁ (Figure 5). It seemed important to consider the whole relationship between the three neighboring durations in order to understand the effect of P₁.

1. When P₁ < P₂ (when 40 ≤ P₁ ≤ 80 [ms] in the patterns P₁ / 120 / 200 [ms], and when 40 ≤ P₁ ≤ 160 [ms] in the patterns P₁ / 200 / 280 [ms] in Figure 5), S was not underestimated. Our explanation is that the principle of proximity worked between the first two markers (Povel and Okkerman, 1981; Handel, 1992; Ross and Houtsma, 1994), and that the shortest duration P₁ stood out perceptually as a clear "figure". This made P₂ perceived as a part of the "ground", and the percept of P₂ was obscured. This means that P₂ could not cause underestimation of S.

2. When P₁ = P₂ (when P₁ = 120 [ms] in the patterns P₁ / 120 / 200 [ms], and when P₁ = 200 [ms] in the patterns P₁ / 200 / 280 [ms] in Figure 5), S was underestimated clearly. Our explanation is that the principle of proximity worked between the two markers of P₁ and between those of P₂. There was no reason for P₂ to be perceived as a part of the ground. Probably, a sort of similarity principle worked between P₁ and P₂ connecting the first two durations as a single figure, possibly involving S. Thus, P₂ was clearly perceived as a figure or a part of a figure, and it could cause time-shrinking. This kind of principle working in isochronous neighboring durations might be called the principle of temporal regularity (e.g., Povel, 1984; Handel, 1989; Yee, Holleran, and Jones, 1994).

3. When P₁ > P₂, S was underestimated clearly in most cases (when P₁ ≤ 160 [ms] in the patterns P₁ / 120 / 200 [ms], and when P₁ ≤ 240 [ms] in the patterns P₁ / 200 / 280 [ms] in Figure 5). Because P₂ was the shortest duration in this case, the proximity between the second and the third marker facilitated the perceptual organization of P₂ as a figure, and P₂ could cause time-shrinking easily.

4. When P₁ ≡ S (when P₁ = 200 [ms] in the patterns P₁ / 120 / 200 [ms], and when P₁ = 280 [ms] in the patterns P₁ / 200 / 280 [ms] in Figure 5), S was not underestimated at all. Our explanation is that the principle of similarity worked between P₁ and S. This made these separate durations stand out together as a group of figures. The second duration P₂ was perceived as a part of the ground, and lost its influence on the perception of S.
Figure 6. Stimulus patterns of Demonstration 3. All the empty durations are marked by 10 ms pure tone bursts of 1000 Hz including a rise time of 2 ms and a fall time of 5 ms.

The present demonstration is based on these results (Figure 6). In the first presentation (the control condition), an isolated empty duration C of 200 ms serves as the comparison. It is perceived as equal, or almost equal, to the standard duration, S. In the second presentation (the single-neighbor condition), P = 120 ms and S = 200 ms neighbor each other. Now, S is shorter than C subjectively because S is underestimated. In all the following presentations (the two-neighbor condition), three empty durations P₁, P₂, and S neighbor each other in this order. The physical values of P₂ and S are fixed at 120 and 200 ms, respectively, and P₁ is varied from 40 to 400 ms in steps of 40 ms. The standard duration S is perceived as shorter than C when P₁ is 120 ms (in the fifth presentation), 280 ms (in the ninth presentation), or above (after the ninth presentation). This corresponds to our experimental results described above. That is, S is underestimated when P₁ ≥ P₂, but except when P₁ ≡ S.

The present demonstrations show how time-shrinking appears in different contexts. This illusion may affect the perception of various rhythm patterns in our daily life.

References


