Perceptual Organization within Temporal Displacement

Michele Sinico

***Abstract*—**The psychological present has an actual extension. When a sequence of instantaneous stimuli falls in this short interval of time, observers perceive a compresence of events in succession and the temporal order depends on the qualitative relationships between the perceptual properties of the events. Two experiments were carried out to study the influence of perceptual grouping, with and without temporal displacement, on the duration of auditory sequences. The psychophysical method of adjustment was adopted. The first experiment investigated the effect of temporal displacement of a white noise on sequence duration. The second experiment investigated the effect of temporal displacement, along the pitch dimension, on temporal shortening of sequence. The results suggest that the temporal order of sounds, in the case of temporal displacement, is organized along the pitch dimension.

***Keywords*—**Time perception, perceptual present, temporal displacement, gestalt laws of perceptual organization.

I. Introduction

THE psychological present is not punctual, as in physical measurement, but has an actual extension. Some experimental studies on the temporal organization within the psychological present represent robust evidence that a series of sounds, which are therefore in a sequence on a physical time gradient, does not necessarily correspond to a succession of events that takes up perceptual time [1]-[5]. In a classical study, Rubin [7] used three stimuli in sequence: a hammer blow, a pause of 294 ms, a bell ring, a pause of 36 ms, and a hammer blow. The sequence of the three stimuli brought about a negative displacement of the second hammer blow: the two hammer blows were heard first before the bell ring. Another example is the following auditory sequence [3]: a pure sound of 440 Hz (100 ms); a white noise (35 ms); a pure sound of 392 Hz (100 ms). The white noise is positively displaced: it is heard by the observers after the succession of the two sounds.

From a phenomenal perspective [4], [5], the judgment of the temporal order depends on the perceptual structure, which is the result of the qualitative relationships of the perceptual properties of auditory events. If a succession of events falls within a brief interval of time (about 200 ms), then they are not perceived individually, each in its own isolated temporal position, but as a structural whole. The perception of the stimuli is unitary (perceptual compresence), but it groups the similar elements, in accordance with the Wertheimer laws of organization [8], [9], so as to change the order and delay the heterogeneous elements.

As for the relationships among the perceptual properties of auditory events, there is a considerable amount of research regarding the influences of non-temporal variables (i.e. frequency, intensity, timbre, etc.) on temporal properties (i.e. order, simultaneity, duration) of auditory events [10], [11]. The judgment of simultaneity cannot be accounted for only in terms of temporal contemporaneity between stimuli at the physical level. Different bichords' intervals are perceived with different degrees of simultaneity [6], [12]. Furthermore, judged duration is influenced by the way in which the temporal interval is marked [10]. Perception of duration is also influenced by non-temporal stimulus magnitude [13].

The aim of the present study was to investigate the influence of the perceptual grouping of auditory events, within the temporal displacement, on the duration of sequences.

II. General Method

A. Participants

The participants were 10 students (eight men and two women) from the University of Padua, ranging in age from 22 years to 36 years, with declared normal hearing. Three were musicians (either trained or students at conservatoire) and seven were not.

B. Apparatus and Stimuli

The signals were synthesized by the Sound Edit 16 (2.0.7 version) for Macintosh software. Stimuli were generated by a PowerBook G3 computer, amplified by a Technics SU-V560 power amplifier and presented on Sennheiser HD 570 headphones at a comfortable listening level. The stimulus presentation and recordings of the responses of the participants were controlled by the SuperLab 1.5.9 for Macintosh software. A recording test by means of a high fidelity recorder was carried out to verify any signal distortions or temporal irregularities. No distortions, nor irregularities of the original signals were observed.

All the sounds (G of 392 Hz; A of 440 Hz; A flat of 415.3 Hz) were generated by triangular waves. In Experiment 1 (see Fig. 1), the stimuli were three different sequences:

1. A of 100 ms; white noise of 35 ms; G of 100 ms.
2. A of 100 ms; pause of 35 ms; G of 100 ms.
3. A of 100 ms; G of 100 ms, white noise of 35 ms.

In Experiment 2 (see Fig. 2), the stimuli were three different sequences:

4. A flat of 35 ms; A of 100 ms; G of 100 ms.

The last two sequences were composed of two overlapping sequences:

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5.i. A of 100 ms; G of 100 ms.
5.ii. pause of 165 ms; A flat of 35 ms.
6.i. A of 100 ms; G of 100 ms.
6.ii. pause of 82.5 ms; A flat of 35 ms.

The sequences included onset and offset ramps which were linear changes in amplitude: a 6 ms offset ramp up to 60 dB and then an immediate decline in amplitude during a 6 ms offset ramp.

The duration of the sequences was measured by the duration between the onset of the two sounds, which is defined as SOA-*within* (*stimulus onset asynchrony-within*) [14].

Participants responded through the use of a computer keyboard. The matching stimulus was a sound of 440 Hz, which could range from 35 ms to 435 ms. To avoid response bias, the duration of the matching stimulus of each trial was not fixed but randomly varied (35 ms or 435 ms) and was randomly presented after and before the target stimuli as well.

C. Procedure

The experiment took place in an isolated room. The only source of sound in the room was headphones. The participants sat in front of the screen in an experimental room and received oral instructions. Using the method of adjustment, observers had to match the duration of the acoustical sequence of tones. The matching stimulus was presented after the target stimulus. Observers had to adjust the matching stimulus by setting it to the same duration as the acoustical sequence of tones.

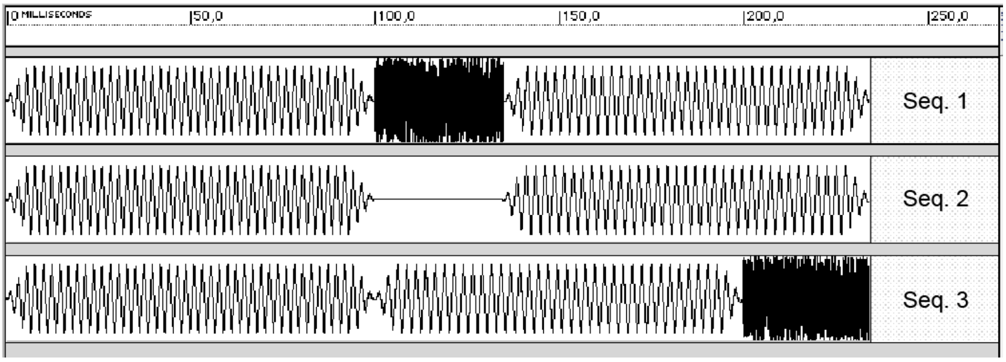

Fig. 1 Stimuli used in Experiment 1

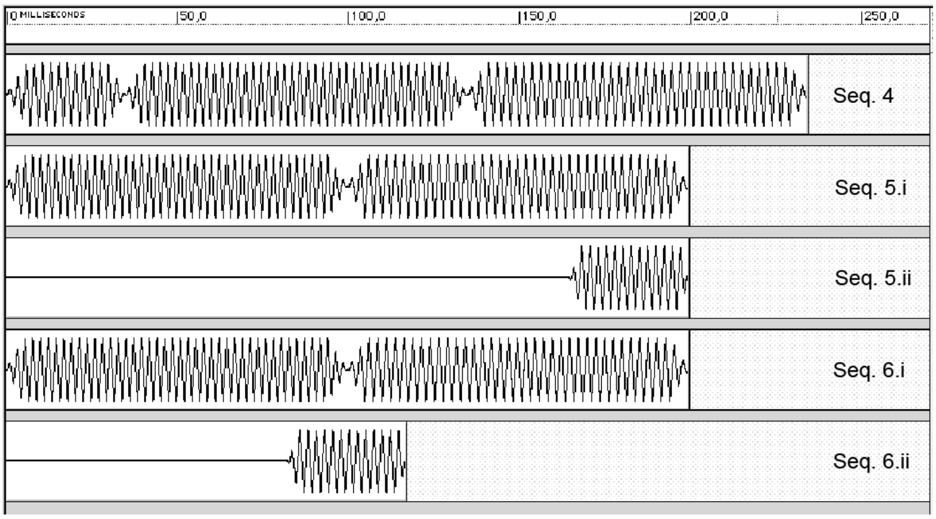

Fig. 2 Stimuli used in Experiment 2

The following instructions were given: “Please, adjust the duration of the sound until it looks identical to the duration of the acoustical sequence of tones. Use one key to gradually increase the duration of the matching stimulus, and the other key to decrease it. When you are satisfied with the adjustment, press the third key to continue.” The final settings were recorded for later analysis offline.

All the participants were interviewed after the completion of the experiment. There were four repetitions of the three stimulus sequences and the Point of Subjective Equality (PES) corresponded to the average of the four values. The resulting 12 trials were presented to each participant in an individually randomized order.

D. Data Analysis

An analysis of variance within-participants was carried out on the average values of PES in order to determine how the estimation of the sequences duration depended on the perceptual organization within the temporal displacement. A post-hoc *t* test was used for pairwise comparisons.

III. Experiment 1

This experiment was conducted in order to investigate whether the perceptual grouping of similar sounds, within a temporal displacement (sequence 1), influences the estimation of the sequences duration, in comparison to two control sequences (sequence 2 and sequence 3).

A. Results and Discussion

Results are shown in Fig. 3. ANOVA showed a significant effect of the factor, Sequence (1, 2, 3): $F(2, 18) = 38.16$, $p < 0.001$. A post-hoc comparison showed that sequence 1 differed significantly from both sequence 2 ($p< 0.05$) and sequence 3 ($p< 0.001$), and also that sequence 2 differed significantly from sequence 3 ($p< 0.001$).

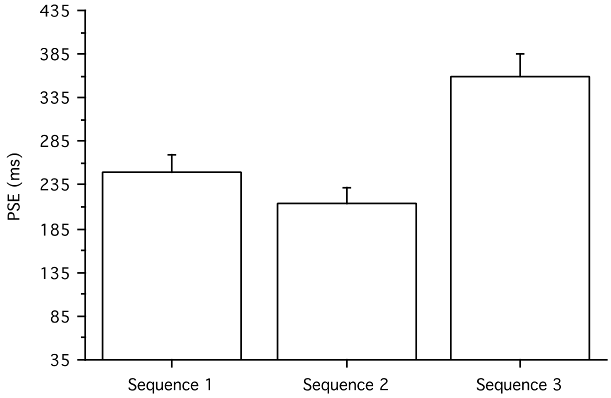

Fig. 3 Results of Experiment 1. The average values of PES as a function of the three sequences (1, 2, 3). The errors bars represent standard errors

In considering relative estimations, despite the fact that the overall duration of the three sequences was the same, sequence 2 was perceived as being shorter than sequence 1 and sequence 3. It is well known that the number of stimulus elements presented within a given interval of time influenced its perceived duration [15]-[17]. Secondly, sequence 1 was perceived as being shorter than sequence 3. As reported by the participants, the temporal displacement was always perceived in sequence 1. This result suggests an effect of temporal displacement, when there is grouping of similar sounds and the postposition of the heterogeneous element (white noise), on sequence duration. This can be explained by the fact that in sequence 1, the white noise is segregated along the pitch dimension, whereas in sequence 3, the noise is segregated in succession [6].

IV. Experiment 2

In studies of temporal dislocation, several authors [1], [4], [5] have described noise displacement along the pitch dimension. In this respect, a second experiment was conducted in order to investigate the influence of temporal displacement, along the pitch dimension (sequence 5 and sequence 6), on temporal shortening of sequences.

A. Results and Discussion

Fig. 4 shows the results of Experiment 2. ANOVA showed that the main effect for Sequence (4, 5, 6) was significant ($F(2, 18) = 28.27$, $p< 0.001$). Post hoc comparison revealed significant differences between sequence 4 and sequence 5 ($p< 0.001$), sequence 5 and sequence 6 ($p< 0.02$), sequence 4 and sequence 6 ($p< 0.001$).

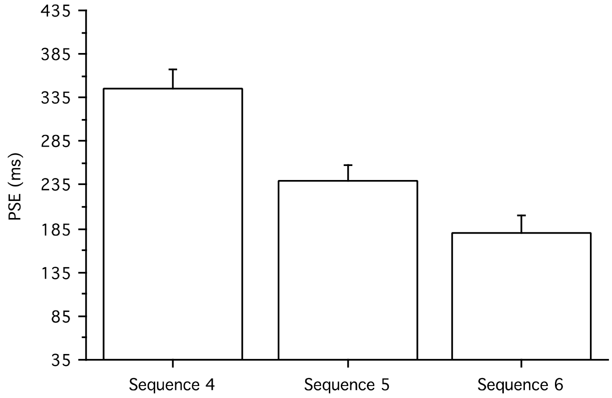

Fig. 4 Results of Experiment 2. The average values of PES as a function of the three sequences (4, 5, 6). The errors bars represent standard errors

As predicted, the results confirm the hypothesis that the observers did not overestimate the perceptual duration of sequences 5 and 6, in which the temporal displacement of tone A flat on a different pitch line was given, compared to sequence 4, in which the tone A flat is physically positioned before the pair of tones A and G. This result is entirely consistent with those obtained in previous experiments [15]-[17]. In fact, sequence 4, without temporal displacement, is relatively perceived to last longer also due to the greater number of elements on the same pitch line [6].

The difference in the estimate between sequences 5 and 6 is a consequence of a different tendency towards dislocation. In sequence 5, the tone A flat is positively displaced at the end of the pair of tones A and G. In sequence 6, the tone A flat is displaced on a different pitch line with an effect of *acciaccatura*.

V. Conclusions

The major goal of the present study was to examine the influence of perceptual grouping, with temporal displacement, on the duration of auditory sequences.

By considering the results obtained with Experiment 1 and Experiment 2, it can be concluded that the perceptual organization of auditory sequences with temporal dislocation (sequence 1, sequence 5, sequence 6) influences perceptual duration. Nevertheless, the findings suggest that the influence on the duration is due to the qualitative relationships between the properties of the events, in accordance with the Gestalt laws of perceptual organization [8], [9]. In particular, when the heterogeneous elements are displaced on the pitch dimension (sequence 1 as well as sequence 6) the judged duration tends to be shorter.

In conclusion, the present findings indicate the opportunity of applying a bidimensional model for understanding the temporal organization of the perceptual present.

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