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Auditory Chronostasis: Hanging on the Telephone

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Summary

The perception of time can be illusory: we have all waited anxiously for important seconds to tick away slowly at the end of a football game and have experienced the truth of the adage "time flies when you're having fun." One illusion of time experience that has recently been investigated, the apparent slowing of the movement of the second hand on the clock when one first looks at it, has been termed "chronostasis," and it has been suggested that the effect is unique to vision and is dependent on eye movements [1–3]. We sought to test whether the effect is really unique to vision or whether it can also be produced with auditory stimuli. Subjects were asked to judge the length of a silent gap between two tones presented through headphones. When the tones were presented to one ear, subjects judged the duration of the gap veridically. When subjects were required to shift concentration from one ear to the other, however, the judgement of time showed that the auditory system is also susceptible to chronostasis. We suggest that this generalization of chronostasis to another sensory system is consistent with theories of time perception that emphasize a single, multimodal clock for duration estimation rather than a mechanism that is dependent on motor acts.

Results and Discussion

Distortions of time perception are a common occurrence in daily life. One example, recently investigated [1], and to which the term "chronostasis" has been given [1, 2], is the apparent delay of the movement of the second hand on a clock face when one first looks at the time: momentarily, it may appear that the clock has stopped. During this experience, a *subjective* second is less than 1000 ms. Yarrow et al. [1] related the existence and size of this illusion to the occurrence and magnitude of saccadic eye movements. They measured subjects' subjective lengthening of duration when required to saccade to a digital counter. Subjects estimated a subjective second to be shorter than 1000 ms by an amount proportional to the length of a saccade. A saccade of 22°, to the counter, for example, yielded a subjective second of 880 ms, whereas a 55° saccade resulted in a subjective second of only 811 ms [1]. It was therefore argued that the perceived slowing of time occurs "because the brain extends the percept of the saccadic target backward in time to just before the onset of the saccade" [1].

There are, however, reasons to believe that this demonstration of chronostasis is a special case of a more generalized phenomenon of time slowing that is not dependent on eye movements and is not restricted to vision. That chronostasis can occur without a change in fixation had been shown by Rose and Summers [3]; subjects presented with four flashes on a screen overestimated the duration of the first flash by approximately 50%. However, Rose and Summers did not observe chronostasis when subjects judged the duration of stimuli in auditory trains and concluded that "the mechanisms activated are peculiar to the visual system" [3].

Another experience in daily life, akin to the stopped clock illusion, prompted us to reinvestigate the assumption that chronostasis is solely a visual phenomenon [1–4]. When making a telephone call and waiting for a reply, one might doodle on a note pad, change TV channels, or continue a conversation with another person. When one's concentration is then returned to the dialing tone, it may appear, briefly, that the line is now dead – the time before the next dialing tone is illusorily lengthened. The illusion can occur in two ways; one can either remove the phone from one's ear and experience the silence when placing it back to the ear, or one can keep the phone at the ear while carrying out the distracting task and experience the illusion when returning to listening. We formalized and quantified this phenomenon by asking subjects to compare durations of unfilled (silent) auditory intervals in conditions analogous to those used to demonstrate visual chronostasis. Our paradigm resembles the second of the examples given above, i.e., subjects concentrate on input to one ear (the non-phone ear) and then return to the phone ear to listen for a response. We chose unfilled intervals because of the previous negative results with trains of tones [3] and because the illusion experienced with the dialing tone occurs between sounds.

Subjects listened to a sequence of four tones presented to the right ear and judged whether the final tone was higher or lower in pitch than the preceding three. The response was made with a key press that signaled the beginning of an unfilled interval that was terminated by an auditory tone and was followed by three further unfilled intervals of 1000 ms (Figure 1). Subjects judged whether the first interval was longer or shorter than the subsequent intervals, and a threshold was determined

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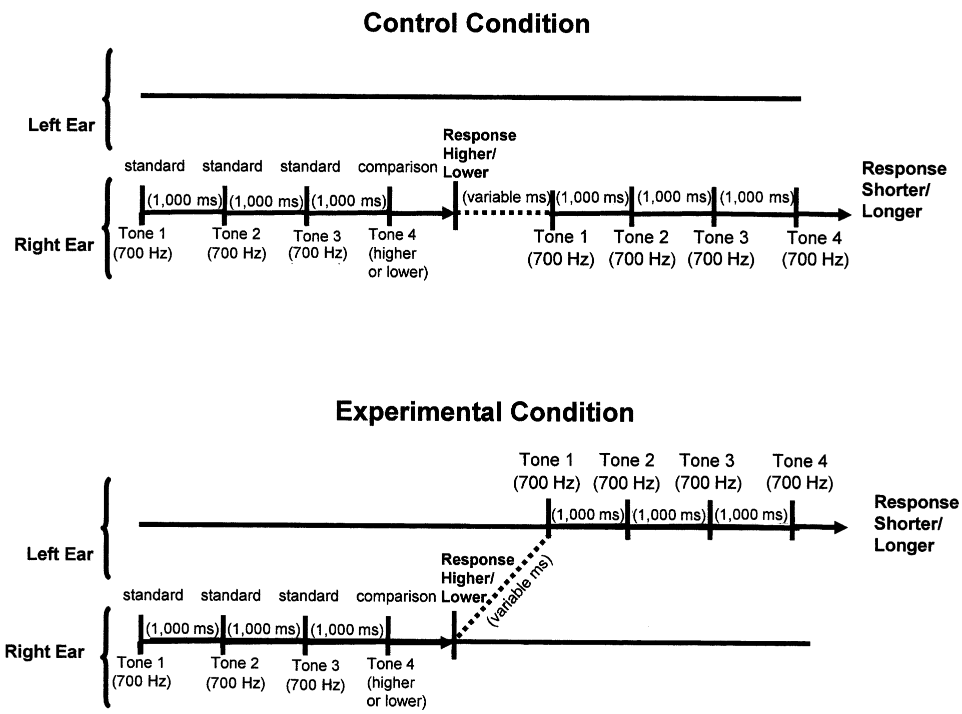

Figure 1. The Sequence of Stimuli Used in the Time Perception Task

Subjects were presented with a sequence of tones played to the right ear through headphones. Three standard tones (700 Hz, for 50 ms) were separated by 1000 ms, and the subjects indicated whether a fourth comparison tone was higher or lower than the standards. The response was made with a button press, which initiated the first interval of the time perception task. The termination of this interval was signaled by a 700 Hz tone with a duration of 50 ms and was followed by three further tones, each separated by 1000 ms, to mark the comparison intervals. Subjects judged whether the first interval was longer or shorter than the succeeding three. The first interval was determined by a modified binary search algorithm [4]. In the control condition, the pitch and time tasks were both presented to the right ear, and, in the experimental condition, the time task was presented in the left ear.

by using a modified binary search procedure [5]. The stimuli in the duration judgement task were presented either to the same (right) ear as the pitch task or to the left ear. Based on the real world experience of the dead telephone, we anticipated that, to obtain auditory chronostasis, it may be necessary to require subjects to shift task demands from the right ear to the left.

Auditory chronostasis was obtained when the duration judgements required changing one's concentration from the right ear (pitch discrimination) to the left to estimate duration (Figure 2). A subjective second was 955 ms when no ear change was required and 825 ms when it was. This result establishes chronostasis as a phenomenon that is neither limited to the visual domain

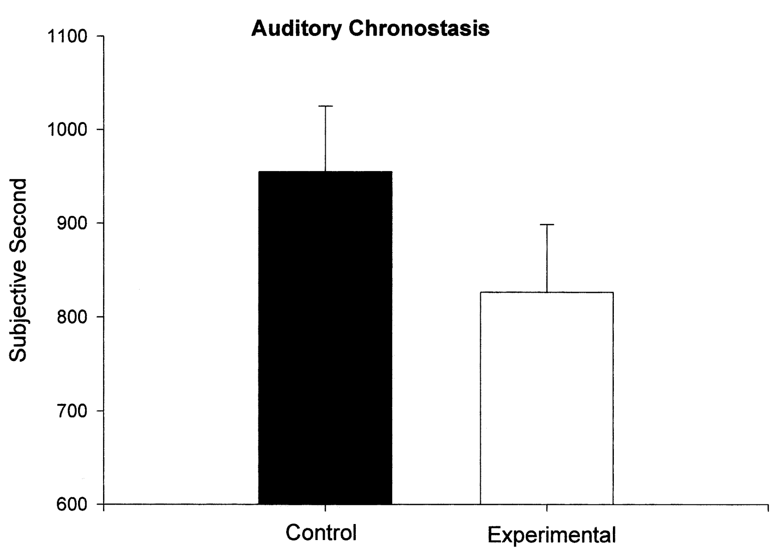

Figure 2. Auditory Chronostasis

When subjects judge an interval in the left ear following a pitch discrimination in the right ear, the duration of a subjective second is reduced from 955 to 825 ms (Wilcoxon signed ranks test, $Z = 2.585$, $p < 0.01$). A total of 16 subjects (8 male, 8 female; mean age = 27) participated in this study.

nor dependent on corrective mechanisms elicited by saccades. Both the variability between individual subjects and the overall magnitude of the effect are similar to the observations of Yarrow et al. [1], suggesting that a common timing mechanism may underlie chronostasis.

In the Yarrow et al. study, the subjects actively executed a movement to induce chronostasis, and, in our experiment, the subjects signaled the onset of the unfilled duration by a key press. It could be argued, therefore, that the mechanisms of chronostasis may depend on making a manual response. However, as Rose and Summers demonstrated, a chronostasis effect can be obtained without any eye movements. Another feature common to Yarrow et al.'s experiment and the current study is that subjects were required to move processing capacity from one spatial location to another. Again, however, this factor alone cannot explain the data, because spatial shifts have been shown to be either insufficient [1] or unnecessary [3] for chronostasis to occur.

In the light of evidence that chronostasis is not unique to vision, not dependent on eye movements or other motor responses, and not dependent on changes in the spatial location of events, we suggest an explanation rooted in the large behavioral literature on time perception. Psychological models of time perception rely on an internal pacemaker and an accumulator that accrues "ticks" of the clock [6, 7]. According to these models, new events or increased task demands cause an increase in arousal that speeds up the rate at which ticks accumulate. The onset of *any* new discrimination may transiently increase internal clock speed and result in a perceived slowing of external time events. On this account, chronostasis will not occur if the initial arousal is too little or subsequently damped. For example, in a train of new stimuli, the first stimulus is the one that is most likely to be overestimated in duration [1, 3], due to the transient, heightened level of arousal and concomitant increase in clock speed. If there is a delay between the arousing stimulus and the temporal discrimination task, the clock may be able to return to a slower rate and thus preclude chronostasis. Indeed, a gradual slowing of the clock, and resultant lengthening of temporal experience, is seen to occur as the number of trials increases [8]. The two previous studies differ in that Yarrow et al. also reported an absence of chronostasis if the clock was constantly fixated, whereas Rose and Summers presented their stimuli at fixation. This difference may be accounted for by the abrupt, and therefore more arousing, stimulus presentation used in the latter study. The failure of auditory stimuli to elicit an illusion in the Rose and Summers study is likely to be a consequence of judging sound durations rather than intervals. Sounds are likely to be judged as lasting longer than lights [9], and the overestimation of the first sound may mask the transient effect of arousal. However, to demonstrate complete symmetry of chronostasis in audition and vision, it remains to be shown that intervals can be illusorily lengthened in the absence of a spatial change.

Conclusions

This extension of chronostasis into the auditory domain suggests that the illusion is a feature of new task demands irrespective of the sensory channel of input; therefore, this finding brings the phenomenon into the remit of current theories of time perception [6, 7] and the increasing evidence of common timing mechanisms that underlie perception and action ([10, 11]; S. Jackson, personal communication). The demands of making an eye movement or a hand movement may contribute to chronostasis to the extent that they are nonspecific alerting events but do not of themselves explain the phenomenon. Similarly, moving one's concentration from one location in space to another may add to the alerting nature of beginning to analyze new events.

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