Notes and Comment

A new temporal illusion or the TOE once again?

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Recently, Nakajima, ten Hoopen, and van der Wilk (1991) and Nakajima, ten Hoopen, Hilkhuyzen, and Sasaki (1992) described what they believed to be a new illusion of auditory time perception. They reported that the perceived duration of a temporal interval was influenced by an immediately preceding or succeeding temporal interval. The influence of a neighboring temporal interval on perceived duration is not a new illusion, however, but is another demonstration of the time-order error.

Recently, Nakajima, ten Hoopen, and van der Wilk (1991) and Nakajima, ten Hoopen, Hilkhuyzen, and Sasaki (1992) described what they believed to be "a new illusion of auditory time perception" (Nakajima et al., 1992, p. 504). This "new illusion" refers to data indicating that the perceived duration of a temporal interval was influenced by an immediately preceding or succeeding temporal interval. In fact, the influence of a neighboring temporal interval on perceived duration is not a new illusion, but is another demonstration of the well-known time-order error.

The time-order error (TOE) refers to the influence of the order of presentation on the comparison of successively presented stimuli. Such presentation-order effects have been observed in many types of comparisons, such as those involving brightness, heaviness, loudness, and duration (see Hellström, 1985). The TOE in the comparison of temporal intervals was extensively investigated in Woodrow's laboratory many years ago (see, e.g., Stott, 1935; Woodrow, 1935, 1951; Woodrow & Stott, 1936). The duration TOE has continued to intrigue and puzzle time researchers (e.g., Allan, 1977, 1984; Hellström, 1977, 1979, 1985; Jamieson, 1977; Jamieson & Petrusic,

1975a, 1975b, 1975c, 1976, 1978; Petrusic, 1984; Schab & Crowder, 1988).

Various psychophysical methods (e.g., forced choice, reproduction) have been used in investigations of the duration TOE. In a duration TOE experiment with the forced-choice procedure, two temporal intervals are presented sequentially on each trial: the longer interval followed by the shorter (S_{LS}) or the shorter followed by the longer (S_{SL}). The subject's task is to indicate the relative durations of the two intervals: long followed by short (R_{LS}) or short followed by long (R_{SL}). The TOE is the signed difference between two conditional probabilities: $TOE = P(R_{LS} | S_{LS}) - P(R_{SL} | S_{SL})$. A positive TOE indicates overestimation of the first interval and/or underestimation of the second; a negative TOE indicates underestimation of the first interval and/or overestimation of the second.

Allan (1979) summarized the empirical findings regarding the duration TOE. The TOE has been observed with a variety of temporal intervals, such as filled and empty intervals marked by auditory and visual events. The TOE is not observed, however, when trial feedback is provided. The TOE tends to be positive for brief temporal intervals and negative for longer intervals. The size of the TOE, whether positive or negative, decreases as the delay between the two sequential intervals is increased.

Nakajima et al. (1992; Nakajima et al., 1991) used empty auditory intervals and the method of adjustment in their experiments. On each trial, a standard interval (St) was presented. Five seconds after the onset of St , a comparison interval (C) was presented. The subject adjusted the duration of C to match the perceived duration of St . In the experimental conditions, a neighboring temporal interval (N) either preceded or followed St ; in the control condition, St was presented alone. The three types of trials are presented schematically in Figure 1A for N shorter than St and in Figure 1B for N longer than St . N_F denotes trials on which the neighboring interval precedes the standard, N_P denotes trials on which the neighboring interval follows the standard, and noN denotes control trials. In Figure 1A, N_P trials are S_{SL} trials and N_F trials are S_{LS} trials; in Figure 1B, N_P trials are S_{LS} trials and N_F trials are S_{SL} trials. The temporal illusion is the perceived duration of St (i.e., the adjusted value of C) in an experimental condition relative to the control condition.

Nakajima et al. (1991) varied St from 120 to 720 msec and found that perceived duration of the shortest values of St , 120 msec and 240 msec, was influenced by N . Specifically, a preceding N shortened the perceived duration of St and a succeeding N lengthened the perceived duration of St . The underestimation of St occurred only when

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Figure 1. The three types of trials in the experiments reported by Nakajima et al. (1992; Nakajima et al., 1991). On each trial, the subject adjusted the duration of the comparison interval (C) to match the perceived duration of the standard interval (St). N_P denotes trials on which the neighboring interval (N) precedes St, N_F denotes trials on which N follows St, and Cont denotes control trials on which N was not presented. In Figure 1A, N is shorter than St; in Figure 1B, N is longer than St.

the preceding N was shorter than St (N_P trials in Figure 1A), and the overestimation of St occurred only when the succeeding N was longer than St (N_F trials in Figure 1B). That is, perceived duration of St was influenced when a shorter interval was followed by a longer interval (S_{SL}): St was underestimated when it occurred second and it was overestimated when it occurred first. This is the positive TOE.

Nakajima et al. (1992) focused on short values of St, 40 msec to 280 msec, and evaluated the influence of a preceding N that was usually shorter than St (N_P trials in Figure 1A)—that is, S_{SL} patterns. They found that a preceding N shortened the perceived duration of the shorter values of St ($St \leq 160$) and lengthened the perceived duration of the longer values of St. That is, the TOE was positive for the shorter values of St, and the TOE was negative for the longer values of St, the classic TOE pattern.

The positive TOE was larger and more consistent than the negative TOE. Nakajima et al. (1992) attempted to account for this asymmetry by claiming (but not referencing) that such asymmetry was consistent with auditory masking results. In fact, asymmetry is not the case for temporal masking. Kallman and colleagues (Kallman, Hir-

tle, & Davidson, 1986; Kallman & Morris, 1984), for example, compared forward and backward masking of tonal duration. They found that “forward- and backward-masking effects were virtually equivalent” (Kallman et al., 1986, p. 45).

Nakajima et al. (1992) observed a negative TOE for an St value yielding a positive TOE in Nakajima et al. (1991)—namely, 240 msec. This type of inconsistency is not new in the TOE literature. While a positive TOE is generally observed with brief intervals and a negative TOE with longer intervals, there is considerable variability, both between and within studies, in the temporal interval resulting in a zero TOE, the “indifference interval” (see Allan, 1979). Jamieson and Petrusic (1975a) showed that the sign of the TOE is determined not only by the duration values being compared, but also by the other duration values being presented in the session.

Nakajima et al. (1992) suggested an “assimilation hypothesis” (p. 506) to account for the influence of N on the perceived duration of St. In the Nakajima et al. (1992) experiment, N was always 50 msec. For the shorter values of St, therefore, N and St were similar, and “when several similar objects are situated close to each other, they can be perceived as even more similar” (Nakajima et al., 1992, p. 506). For the longer values of St, N and St were dissimilar, and “when two objects are considerably different from each other, the assimilation does not take place, but contrast between them appears instead” (Nakajima et al., 1992, p. 506). Assimilation and contrast are at the center of the adaptation-weighting model of the TOE proposed and developed a number of years ago by Hellström (e.g., 1977, 1979, 1985). The Hellström (1985) model is the most comprehensive and integrative account of the TOE. The qualitative assimilation hypothesis proposed by Nakajima et al. (1992) is consistent with, and can be subsumed by the quantitative Hellström (1985) model. The Hellström model (1985) has been shown to account for the major TOE results in the literature. In contrast, Nakajima et al. (1992) acknowledge that their assimilation hypothesis does not fully describe even their own results.

Nakajima et al. (1992; Nakajima et al., 1991) have not discovered a new illusion, and their assimilation hypothesis can be subsumed by a more comprehensive model proposed a number of years ago. There are, however, novel aspects to the data reported by Nakajima et al. (1992; Nakajima et al., 1991). The forced-choice method has been the modal psychophysical procedure in investigations of the duration TOE. Nakajima et al. (1992; Nakajima et al., 1991) demonstrated the TOE with the method of adjustment. Also, they produced the TOE by using a somewhat different stimulus configuration. In their studies, the two empty intervals were adjacent; the marker of the end of the first interval was also the marker for the beginning of the second interval. Usually, the two empty intervals in duration TOE studies are separated by a short interstimulus interval.¹ Most important, Nakajima et al. (1992; Nakajima et al., 1991) tracked the TOE

over a large range of St and N values. Nakajima et al. (1992) found that when a 50-msec N preceded very short values of St ($St < 100$ msec), the perceived duration of the various St values were very similar. They argued that this result is an example of categorical perception, and that such categorization of the time dimension might be important in understanding speech and music perception.

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NOTE

1. Carbotte (1973) and Carbotte and Kristofferson (1973) also used adjacent empty auditory intervals in their duration discrimination experiments. They provided trial feedback, however, and the TOE is not observed when feedback is available (see Allan, 1979).

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