DIFFERENTIAL EFFECTS OF PRACTICE AND SIGNAL INTENSITY ON TEMPORAL DISCRIMINATION OF BRIEF AND LONG INTERVALS

Susanne Brandler and Thomas Rammsayer
Georg Elias Müller Institute for Psychology, Göttingen, Germany

Abstract

Two experiments were performed to investigate differential effects of practice and signal intensity on auditory duration discrimination. In Experiment 1, an adaptive forced choice procedure was used to elucidate the effects of practice. Two base durations of either 50 ms and 1,000 ms were employed. As a measure of performance, the difference limen (DL) was computed. Twenty naive volunteers performed on the same task on 5 consecutive days. Results indicate a significant decrease in DL as a function of testing session for the 1,000-ms but not for the 50-ms base duration. In Experiment 2, 48 volunteers were tested with a duration discrimination task similar to the one of Experiment 1, except that the intervals were presented at different levels of intensity. There were three experimental conditions: In the control condition both intervals to be compared within one trial were presented at the same level of intensity (50 dB). In two conditions intervals within one trial were presented at different intensity, i.e. 50 dB and 75 dB. Either the long interval or the short interval was presented at the higher level of intensity. A significant effect of intensity was demonstrated only for duration discrimination in the range of milliseconds, where performance was less accurate for trials in which the short interval was presented at a higher intensity than the long interval. Results of both experiments provide converging evidence for the existence of dissociable timing mechanisms underlying duration discrimination of intervals in the range of milliseconds and seconds.

To date, there is a growing body of evidence supporting the notion of distinct timing mechanisms underlying duration discrimination in the range of seconds and milliseconds, respectively (e.g., Rammsayer, 1997; Rammsayer & Lima, 1991). While the processing of longer durations is cognitively mediated, temporal processing of very brief durations appears to be beyond cognitive control and based on basic sensory mechanisms. In the present study, two different experimental paradigms were employed to provide additional experimental evidence for the notion of distinct timing mechanisms.

Experiment 1

In Experiment 1, the notion of distinct timing mechanisms was tested by employing a practice paradigm. We proceeded from the assumption that effects of practice should be much more pronounce for higher-order cognitive tasks than for very basic, sensory ones. Thus, according to the view of distinct timing mechanisms, we hypothesized that performance on duration discrimination should be differentially affected depending on the base duration of the stimuli applied. Let us assume that a very basic, sensory mechanism underlies processing of intervals in the range of milliseconds (e.g., Michon, 1985; Rammsayer, 1997; Rammsayer & Lima, 1991), whereas temporal processing of longer intervals involves cognitive processes such as working memory (e.g., Fortin & Breton, 1995; Rammsayer & Lima, 1991). Then the observed effects of extended practice can be expected to be much smaller for intervals in the range of milliseconds than for longer intervals in the range of seconds. Earlier research on practice effects in duration discrimination yielded highly inconsistent results (cf., Brandler & Rammsayer, 1999; Kristofferson, e.g., 1980; Rammsayer, 1994). Therefore, the primary goal of the present experiment was to directly compare the effects of practice in duration discrimination of very brief and longer intervals with a between-subjects design. This procedure was chosen to prevent possible base-duration related carry-over effects.

Method

Participants

Participants were 9 male and 11 female volunteers (mean age: 22.3 ± 3.9 years), who were rewarded for participation by course credits. All of them had normal hearing and were experimentally naive. Participants were randomly assigned to perform a duration discrimination task in either the range of milliseconds or seconds.

Apparatus and stimuli

The presentation of the stimuli and recording of responses was controlled by an IBM-compatible computer. Auditory stimuli were filled intervals consisting of white noise. Stimuli were presented binaurally via headphones at an intensity of 56 dB.

Procedure

An adaptive psychophysical procedure, the weighted up down-procedure (Kaernbach, 1991), was used for quantification of individual performance on duration discrimination. An experimental session consisted of the presentation of 128 trials. Each trial consisted of the presentation of a standard interval S, with a fixed duration, and a variable comparison interval C. Duration of the standard interval was either 50 ms (reflecting the range of milliseconds) or 1,000 ms (reflecting the range of seconds). The difference x between S and C was varied according to the weigthed up-down method depending on the participant's response to the previous trial. Trials in which S was longer than C (i.e., S — x = C), yielding estimates of the 25th percentil (x.25) of the psychophysical function, and trials in which C was longer than S (i.e., S + x = C), yielding estimates of the 75th percentil (x.75) of the psychophysical function, were employed. The order of presentation of S and C was randomized and balanced within subjects. Participant's task was to decide which of the two intervals presented within one trial was longer and to indicate his or her decision using two designated keys on the computer keyboard ("first interval longer"/"second interval longer"). Visual feedback for correct ("+") and incorrect ("-") answers was provided after each response. As a measure of performance, individual DLs were computed. Each participant completed five testing sessions held at approximately the same time of the day on five consecutive days within one week.

Results

Data were analyzed by one-way analyses of variance (ANOVA) for repeated measurements. To control for the alpha error, within-subjects effects were subjected to a Greenhouse-Geisser correction. A significant decrease in DL for duration discrimination performance in the range of seconds [$F(4,36) = 7.40$, $p < .01$] indicated improved performance as a function of session number (see Figure 1). Post-hoc t test revealed a significant performance increment from the first and second session [$p < .01$] and from the third to the fourth session [$p < .05$]. No statistically significant practice effects could be shown for duration discrimination performance with intervals in the range of milliseconds [$F(4,36) = 1.46$, $p = .25$; see Figure 1]. To directly contrast performance on duration discrimination with intervals in the range of seconds and milliseconds, computed Weber fractions were subjected to a two-way ANOVA with number of testing sessions as five levels of a repeated-measurement factor and base durations as a between-subjects factor. Weber fractions were significantly lower for the significantly lower for the 1,000-ms than for the 50-ms base duration [$F(1,18) = 16.62$, $p < .01$]. Furthermore, there was a significant main effect of session number [$F(4,72) = 5.52$, $p < .01$] reflecting an overall practice effect. The interaction between both factors, however, failed to reach statistical significance [$F(4,36) < 1$, *n.s.*].

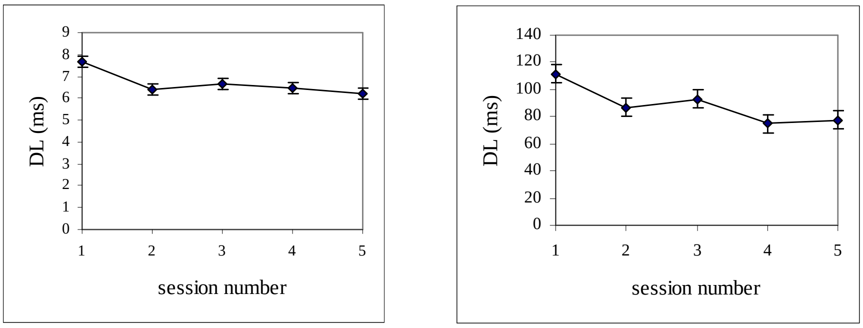

Figure 1. Mean performance (± S.E.M.) on duration discrimination in the range of milliseconds (left panel) and seconds (right panel) as a function of session number.

Discussion

The finding of significant effects of practice on duration discrimination performance with intervals in the range of seconds was the expected outcome given the assumption that processing of temporal information in this time domain is highly cognitive in nature. The practice effects were most pronounced from the first to the second testing session, but significant improvement was still observed for subsequent testing sessions. Similarly, the hypothesized lack of practice effects on duration discrimination with very brief intervals was confirmed. This outcome may support the notion of a very basic, sensory timing mechanism beyond cognitive control and, therefore, less sensitive to extended practice. Thus, at first sight, this differential pattern of results appears to be consistent with the assumption of distinct timing mechanisms underlying duration discrimination of brief and long intervals. A cautionary note, however, is that when directly contrasting both duration discrimination tasks, the two-way ANOVA failed to reveal a significant interaction between session number and base duration - a finding that argues against the existence of two qualitatively different timing mechanisms. The statistical interaction might had failed to become siginificant since with both base durations, discrimination performance tended to improve from the first and the second testing session. This improvement due to short-term practice in both experimental conditions may be explained in terms of unspecific effects not related to the underlying timing mechanisms. Such unspecific effect may reflect participants' adjustment to the experimental setting and more general aspects of the experimental task such as comprehension of the instructions. While after the second session duration discrimination performance in the range of milliseconds remained virtually practice-invariant, further improvement was observed with intervals in the range of seconds. An explanation could be that during the later testing sessions, additional strategies could successfully be applied for duration discrimination with longer but not with brief intervals. These strategies could be directly related to cognitive processing of temporal information or include explicit counting (cf., Grondin, Meilleur-Wells, & Lachance, 1999). Given the assumption that processing of very brief intervals is not cognitively mediated, no such strategies would be available for durations in the range of milliseconds.

Experiment 2

In Experiment 2, the influence of signal energy on auditory duration discrimination was investigated . If duration discrimination performance were solely based on temporal information, as implied by most internal clock conceptions (e.g., Allan, 1979; Creelman, 1962; Rammsayer, 1994), performance on duration discrimination should be the same for trials with filled intervals presented at equal intensity as well as for trials in which the intervals differ in intensity. However, because duration has to be marked by energy signals, it is conceivable that subjects' discrimination between two different durations may be based on some characteristics of the stimuli other than their duration. To be more specific, with filled auditory intervals such as tones, total stimulus energy is proportional to duration and, especially for brief stimuli, loudness is a strong function of duration (e.g., Small, Brandt, & Cox, 1962). Therefore, discrimination between two auditory intervals in the range of milliseconds may be one of stimulus energy rather than duration discrimination. Therefore, if non-temporal, energy-dependent cues, also available in the stimuli, were used as additional information for temporal discriminations, duration discrimination performance would be expected to improve when temporal and non-temporal stimulus information is congruent as compared to a control condition with all intervals presented at the same level of intensity. Whereas, on the other hand, duration discrimination performance should decrease, compared to a control condition, when temporal and non-temporal stimulus information, within one trial, is incongruent (Rammsayer, 1994). "Congruent" refers to the condition that the longer interval within a given trial is presented at a higher level of intensity than the shorter interval. If duration discrimination benefits from energy-dependent cues, that is, intervals are judged to be longer because they sounded louder, higher performance, should be expected for trials in which the longer interval was presented at a higher level of intensity than the shorter interval. Similarly, temporal and non-temporal stimulus information is called "incongruent", if the longer interval within a given trial is presented at a lower level of intensity than the shorter interval. In this case, poorest performance should be observed since temporal and non-temporal information are incompatible with each other. If duration discrimination of intervals in the range of seconds and milliseconds is differentially affected by experimentally induced changes in intensity within a trial, this would provide further evidence for the notion of distinct timing mechanisms underlying temporal processing of long and brief intervals.

Method

Participants

Participants were 19 male and 29 female volunteers (mean age: 24.7 ± 4.6 years), who were rewarded for participation by course credit. All of them had had normal hearing and were experimentally naive. Participants were randomly assigned to one of the two experimental tasks, i.e. duration discrimination of intervals in the range of seconds and milliseconds, respectively.

Apparatus and stimuli

The experimental set-up was the same as in Experiment 1. The auditory stimuli were filled intervals consisting of sine waves with a frequency of 775 Hz. Two levels of stimulus intensity ("low" = 50 dB and "high" = 75 dB) were employed in the present experiment.

Procedure

As in Experiment 1, the adaptive weighted up-down method was used. Durations of S were 50 ms and 1,000 ms, respectively. Again, participants' task was to decide which of two consecutively presented auditory intervals was longer in duration. The experimental task consisted of five practice trials followed by 180 experimental trials. In the control condition, all standard and comparison intervals were presented at the low level of intensity. Within a given trial of the congruent condition, the long interval was presented at the high level of intensity and the short interval was presented at low level intensity, whereas in the incongruent condition, the short interval was presented at the high and the long interval at the low level of intensity. There were 60 trials of each of three experimental conditions. Trials from all three conditions were presented in random order. As in Experiment 1, visual feedback was provided after each response.

Results

Data were analyzed separately for each experimental task by one-way ANOVAs with experimental conditions as three levels of a repeated-measurements factor. To control for the alpha error, within-subjects effects were subjected to a Greenhouse-Geisser correction.

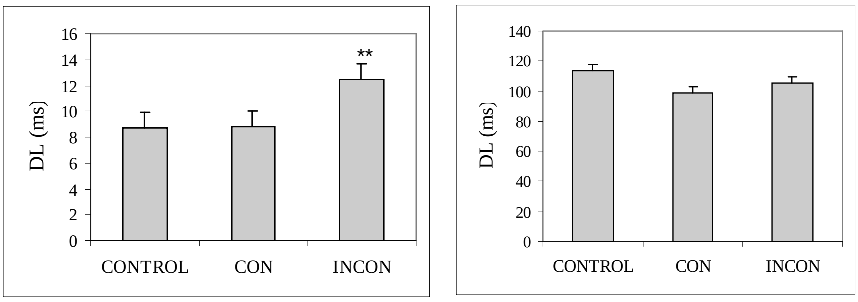

Figure 2. Mean DLs as a measure of performance on duration discrimination in the range of milliseconds (left panel) and seconds (right panel) as a function of experimental condition (CON: congruent, INCON: incongruent).

There was a significant effect of experimental condition on duration discrimination of intervals in the range of milliseconds ($F(2,46) = 8.28$, $p < 01.$). Post-hoc *t* tests indicated a significant performance decrement for the incongruent condition compared to the control and congruent conditions [$p < .01$ for both comparisons] while the latter two conditions did not differ significantly (see Figure 2). No effect of experimental condition on duration discrimination performance could be shown for longer intervals in the range of seconds [$F(2,46) = 1.23$, *n.s.*]. To directly contrast performance on duration discrimination with intervals in the range of seconds and milliseconds, computed Weber fractions were subjected to a two-way ANOVA with experimental conditions as three levels of a repeated-measurement factor and base durations as a between-subjects factor. A statistically significant main effect of experimental condition [$F(2,92) = 6.87$, $p < .01$] revealed lower Weber fractions for duration discrimination of intervals in the second than in the millisecond range. Also the main effect of experimental condition reached statistical significance [$F(1,46) = 56.02$, $p < .001$]. Finally there was a highly significant interaction between both factors [$F(2,92) = 7.34$, $p < .001$]. Post-hoc analyses showed that DL_INCON was significantly exceeding DL_CONTROL as well as DL_CON in the milliseconds condition, whereas no such effect occured in the seconds condition.

Discussion

The lack of intensity effects on duration discrimination in the range of seconds suggests that temporal processing of longer durations is more likely based on cognitive than on sensory mechanisms. Although the mechanisms that have caused the deteriorating effect observed with incongruent stimulus information in the range of milliseconds are still unclear, they seem to be highly specific for sensory-based temporal information processing. At first sight, the impaired performance for the incongruent intensity condition appears to be consistent with the notion of sensory intergration, i.e. the contribution of non-temporal, energy-dependent cues to duration discrimination. However, no facilitating effect was observed in the congruent condition. This latter finding strongly argues against the general notion of energy-dependent cues to be effective in duration discrimination. If energy-dependent cues were involved in temporal information processing of brief intervals, as suggested by the sensory integration hypothesis, performance under the congruent condition should have been superior to performance under the control condition. Nevertheless, the differential pattern of the intensity effects on duration discrimination performance in the range of seconds and milliseconds, provided some converging evidence for dissociable timing mechanisms.

General Discussion

Although our findings were partly ambiguous, results of both experiments provide some indirect evidence for the notion of two dissociable timing mechanisms involved in temporal discrimination of intervals in the range of seconds and milliseconds.

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