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RELATIVE SENSITIVITY TO FILLED VS. EMPTY INTERVALS DEPENDS ON METHODS: EVIDENCE FROM DEVELOPMENTAL DATA

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Abstract

Two experiments involving child participants were conducted to test the relative effect of nontemporal factors and age on duration discrimination. In Experiment 1, a method similar to the time test of the Seashore Measures of Musical Talents, which involves a forced-choice presentation of intervals and a 800-ms standard, was employed. Results showed that the discrimination is better with filled intervals (a continuous signal) than with empty intervals (a silent period between two brief signals). As well, discrimination gradually improved with age, from 9 years old to adulthood, and this was generally true with intervals presented both in the visual and in the auditory modes, with either filled or empty intervals. Experiment 2 showed that children, as reported in previous studies with adults, have better discrimination with empty than with filled intervals in conditions where a 250-ms standard, visual signals, and an adaptive procedure are employed. There was an apparent contradiction of the two experiments regarding the structure --filled vs. empty-- of the interval. The filled vs. empty difference may depend on the method (Seashore-like vs. adaptive), on the range of duration, or on the combination of both factors.

Time perception is often argued to depend on the output of an internal clock (see Grondin, 2001). This clock is most often described as composed of a pacemaker and an accumulator. The pacemaker emits pulses at some rate that are counted by the accumulator. The number of pulses accumulated over an interval of time depends on the rate of emission by the pacemaker, and is under the control of a switch (e.g. Church, 1984) triggered by the signals marking the beginning and end of the timing activity. It is the number of pulses that represents duration, and variations in temporal performance are assumed to depend mainly on the variability of this pulse accumulation process. When analyzing the variability of timing performances, it is important to determine what part of variance is due to the clock, and what part is nontemporal. The experiments presented below are focused on nontemporal factors, to examine how they influence time judgments.

The experimental task most employed in time psychophysics is probably duration discrimination. In such a task, a participant is asked to judge the relative duration of two or more time intervals. Discriminating a filled interval (marked by a continuous signal) instead of an empty interval influences performance. The literature shows that performance difference between these two types of intervals probably depends on the range of durations under investigation and on the method employed. For instance, with an adaptive procedure (i.e., a procedure where both a standard and a comparison interval are presented on each trial, and where the level of difficulty of the discrimination is adjusted after each trial with an appropriate change of the comparison interval), Grondin (1993) reported no difference between filled and empty auditory intervals for both the 50- and the 250-ms ranges of duration. However, in the visual modality, discrimination was better with empty than with filled intervals, for these two ranges of duration (see also Plourde, Gamache & Grondin, 2008). Moreover, with a single stimulus method of presentation of the intervals (i.e., one response after each presentation of an interval), empty intervals were better discriminated than filled intervals in both ranges of duration, and with both sensory modalities (visual and auditory; see also Grondin, Meilleur-

Wells, Ouellette & Macar, 1998). Thus, the method of presentation of stimuli seems critical in determining the direction of the filled vs. empty effect (for a review, see Grondin, 2003).

Rammsayer and Lima (1991) proposed that empty intervals entail misassignment of the pacemaker`s pulses to the counter because of errors in the switching process. With filled intervals, the switch is closed at the onset of a signal, which allows pulse accumulation, and opened at the offset of the signal, which stops pulse accumulation. With empty intervals, each signal serving as marker consists of two events, an onset and an offset. This should result in a more complex switch mode that is more prone to errors.

Developmental perspective

The data available on duration discrimination by children have been collected mostly with filled auditory intervals (but see Fitzgibbons & Gordon-Salant, 1994). For instance, one of the six items of the Seashore Measures of Musical Talents (SMMT), the time test, concerns duration discrimination, and the intervals to be discriminated are filled and presented in the auditory modality (Seashore, Lewis, & Saetveit, 1960). Performance is seen to improve with age. More recently, Droit-Volet, Meck and Penney (2006) used auditory and visual filled intervals and showed an effect of age on performance for both type of signals, and observed a greater auditory-visual difference in perceived duration for children, which they attributed to reduced attentional capacities. However, developmental literature provides little information on the relation between filled and empty intervals as a function of age and the interaction between the structure of an interval and its sensory mode.

The present study

Firstly, the present study examines the role of nontemporal factors on duration discrimination. It compares performances under filled and empty conditions, and different ranges of duration. Secondly, the study addresses the question whether the effect of these nontemporal factors is the same for child and for adult participants. There are reasons to expect differences between children and adults regarding the filled vs. empty comparison. Children's estimation of time is known to be very sensitive to attentional fluctuations (Zakay, 1992). The switch process is indeed critically influenced by attentional mechanisms (Droit-Volet et al., 2006). Consequently, children might face more problems than adults with empty intervals, given the importance of the switch process in Rammsayer and Lima (1991)`s misassignment hypothesis.

Experiment 1

Method

Participants. Seventy-two volunteer children participated in the experiment, with their parents' agreement. The participants were assigned to one of 3 groups, on the basis of their age: 9-, 11- and 13-years old (mean = 108, 132, and 155 months, respectively). In addition, there were 24 volunteer adults from 18 to 48 years old.

Apparatus and stimuli. The duration discrimination tasks were controlled by a Zenith PC computer. The auditory stimuli were 1-kHz complex tones generated by the computer and were presented in a free-field manner. The visual stimuli were produced by a circular red light-emitting diode (LED: Radio-Shack #276-088) placed about 1.5 m in front of the participant. A box with push-buttons was used by the participants. The filled intervals were defined by a continuous stimulation, either auditory or visual. The empty intervals were the silent duration between two 20-ms stimuli. The time test of the SMMT (Seashore, Lewis, & Saetveit, 1960) was also used.

Procedure. A forced-choice procedure is employed. A standard duration of 800 ms and a comparison interval were presented in variable order on each trial. The participant had to indicate if the second interval was shorter or longer than the first one. There were four marker-type conditions labelled Ve, Vf, Ae, and Af: 2 sensory modalities (Visual or Auditory) and two types of intervals (Empty or Filled). Their order of presentation was balanced between participants. Each condition included 5 blocks of 10 trials. For Blocks 1 to 5, the duration of the comparison intervals were, respectively, 550, 650, 675, 700, and 725 ms. There was a 1-s interval between the two intervals and a 2.5-s interval between trials. In the time test of the SMMT, the intervals to be discriminated were filled and presented in the auditory modality. There were five blocks with comparison intervals varying from 500 to 775 ms, and a 800-ms standard. Before testing, each child was trained to discriminate intervals of 500 ms and 700 ms with each marker-type condition for 10 trials.

Results and discussion

The dependent variable was the proportion of correct responses. Results for each condition, excluding the SMMT, are reported in Figure 1. Those results generally show higher means for auditory intervals than for visual ones and higher means for filled than for empty ones. However, for the filled vs. empty comparison, there was no difference in the visual modality with adults and 13 years old. Finally, the performance generally tended to improve with age.

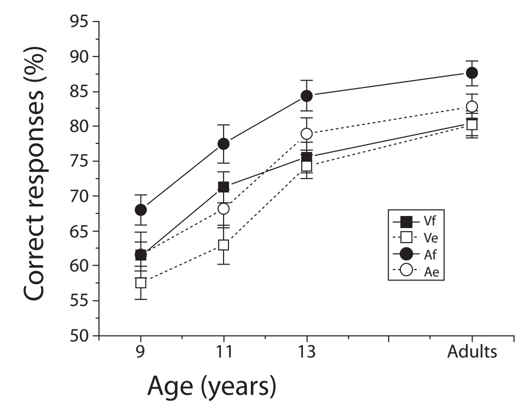

Figure 1. Percentage of correct responses (with standard error) for each age group under each marker-type condition in Experiment 1. V: Visual; A: Auditory; f: Filled; e: Empty

An ANOVA according to a 2 (filled vs. empty) x 2 (auditory vs. visual) x 4 (age) factorial design revealed that the visual vs. auditory difference was significant, $F(1,92)= 57.10$, $p < .01$, as well as the empty vs. filled difference, $F(1,92) = 33.31$, $p < .01$, and the age effect, $F(3,92) = 25.34$, $p <. 01$. A Tukey test revealed that the mean for the 9-year olds was significantly lower ($p<.05$) than the mean for the 13-year old and adult groups. The other comparisons by pairs were not significant.

Of all interactions, only the modality by filled/empty effect was significant, $F(1,92) = 4.71$, $p < .05$. A Tukey test revealed that only the differences between the Af conditions and the other three conditions were significant.

For the time test of the SMMT, the mean results were 61.92%, 69.5%, and 77% for, respectively, the 9-, 11-, and 13-year-old groups. These results are consistent with the norms for the SMMT (Seashore & al.,1960). The age effect is about the same here as in the tests reported above; however, it is lower than in the Af condition. A 3 (age) X 2 (Af vs. time item of SMMT) ANOVA revealed a significant age effect, $F(2,69) = 19.60$, $p < .01$, and a significant method effect, $F(1,69) = 24.59$, $p < .01$. The interaction is not significant. A Tukey test revealed that the mean for the 9-year olds was significantly lower ($p < .05$) than the mean for the 13-year-old group.

The difference between the Af condition and the time item of the SMMT is quite important (6-8%), even if the tasks are essentially the same. The Pearson correlation between the performances, although reasonably high (.52) and significant ($p < .001$) when all age groups are taken into account is non significant for the 9- (.35), 11- (.26), and 13- (.40) year-old groups. However, there are some methodological differences, such as the type of sound used (440 Hz in the SMMT, and 1000 Hz in Af). The last five trials were a little more difficult with the SMMT. Also, the participants responded with a pencil in the SMMT, but with a simple key press for the Af condition. If more time was consumed to respond with the pencil, then less preparation time was available for the next trial. Those data might question the reliability and validity of the time test of the SMMT.

Experiment 2

Method

Participants. Forty-four volunteers participated in this experiment with their parents' agreement. They were assigned to one of four groups: 9-, 11-, 13-, and 15- years old.

Apparatus and stimuli. The material was the same as in Experiment 1 except that a small light was placed beside each response button to provide feedback after each trial.

Procedure. The main changes in the method, in comparison with Experiment 1, was the utilization of 1) a 250 ms standard duration, 2) a 1.7-s visual feedback (with the next trial starting 2-s after), and 3) a forced-choice adaptive procedure. With this procedure, after each correct response, the duration of the comparison interval was made more similar to that of the standard interval by a factor of X, and, after each wrong response, the duration of the comparison interval was made more different by a factor of 3X. This technique provides an estimate of the difference threshold at which participants are correct on 75% of the trials. Each threshold estimate was based on a run of 50 trials composed of three blocks of 10, 20, and 20 trials. The duration of the first comparison interval was 500 ms and the step sizes for Blocks 1, 2, and 3 were set at 30, 10, and 3 ms. The adjustment procedure was constrained so that the duration of the comparison interval could not be smaller than or equal to the duration of the standard interval. There were two sequences of 50 trials to estimate the threshold in each of two marker-type conditions: Vf and Ve. In each group, 5 participants were tested in one given condition first and 6 participants in the other condition first. Before the first sequence, each participant had 10 training trials in each condition.

Results and Discussion

The dependent variable of interest is the difference threshold, which was estimated by subtracting the value of the standard (250 ms) from the average of the comparison intervals in the last 10 trials. The lower the threshold, the better the performance.

The average result for each age group in each marker-type condition is presented in Figure 2. The results tended to improve with age. Moreover, contrary to Experiment 1, the performance seemed to be better in Ve than in Vf. Interindividual differences were important.

To test the statistical significance of the differences between groups, we used a 2 x 4 ANOVA with repeated measures. The analysis revealed that the age effect was significant,

$F(3,40) = 3.51$, $p < .05$. The empty vs. filled conditions were also significantly different, $F(1,40) = 14.34$, $p < .01$. The interaction was not significant ($p > .05$). Although the differences for the 9- to 13-years old were not significant in the present experiment, it is noteworthy that for these groups, the trend was similar to the one observed in Experiment 1. It is also interesting to note that in the Ve condition, the difference threshold of the 13- and 15-years old was about the same, and is comparable to what was observed with adults (57 ms: Grondin, 1993). Indeed, in the Vf condition, the performance is even slightly better for the 15-years old than for adults (87 ms: Grondin, 1993).

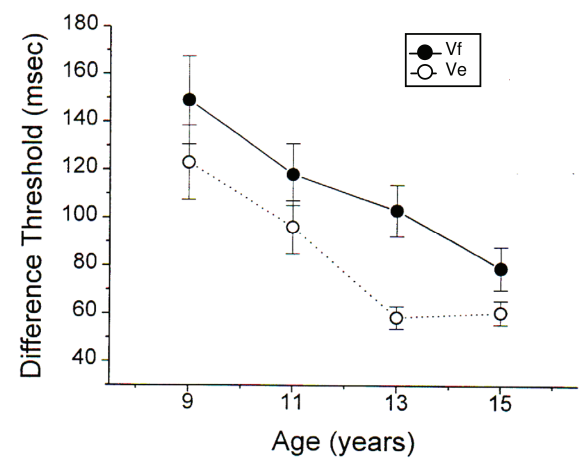

Figure 2. Difference threshold (with standard error) for each age group under each marker-type condition in Experiment 2. V: Visual; f: Filled; e: Empty

Contrary to Experiment 1, the empty intervals yielded a better performance than the filled intervals. This is consistent with the results of Grondin (1993) where the procedure was the same as in Experiment 2. For both children and adults, this marker-type difference depends on the method.

General Discussion

The present experiments were conducted to examine the effects of age and nontemporal factors, such as the modality of presentation of an interval or the structure of presentation, on temporal discrimination. In Experiment 1, filled auditory intervals are clearly better discriminated than empty auditory intervals with the Seashore-like method, for both children and adults. They probably use similar duration discrimination mechanisms, and are influenced by similar nontemporal variables. However, the effect of these variables might differ in magnitude according to the age group.

In Experiment 1, discrimination was better with filled than with empty intervals but this effect was reversed in Experiment 2. One potential explanation of this inconsistent pattern might be the fact that different participants were tested in Experiments 1 and 2. However, in our view, there are two main sources of error to consider. First, with the Seashore-like method, not only is the period (inter-stimuli interval - ISI) between both to-be-discriminated intervals short, but the response period is also limited, which does not allow much preparation time for the next trial. It is known that temporal discrimination requires extra processing time after the presentation of an interval to-be discriminated (Nakajima, 1987) and that the preparation is critical or duration discrimination (Grondin & Rammsayer, 2003). This might account for some inconsistency, but does not explain why discrimination is better with filled intervals in Experiment 1.

The second critical factor is the fact that in both methods, there is a succession of signals marking two intervals to-be discriminated, and one extra interval, i.e., the ISI. Confusion in processing a series of time intervals is probably increased if the intervals to-be discriminated are close in duration to the value of the ISI (Rammsayer & Lima (1991)`s misassignment hypothesis). There is no such problem with filled intervals but in Experiment 1, the risk of confusion with empty intervals is very high. Thus, any potential advantage of empty intervals is probably masked by confusion

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A PERCEPTUAL-COGNITIVE DIVIDING MODEL FOR THE INTEGRATION OF VELOCITY AND TRAVELED DISTANCE OF A MOVING TARGET BY LOCALIZATION RESPONSES

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Abstract

Differently from phenomenological responses, Representational Momentum (RM) offers a continuous response measure in the field of dynamic representations and naïve physics. This property is taken here as a basis for the use of Information Integration Theory in a field where one-dimensional approaches are the rule and integration results are entirely lacking. The present work establishes a psychological multiplying/dividing model in a data pool obtained from a full factorial design Velocity (4) × Traveled Distance (3) with forward displacement error of the last seen position of the target as the measured response. Besides compliance with standard criteria (Anderson, 1982; Weiss, 2006), the model was tested for additional algebraically derived predictions concerning the relations of the intercept c_0 to interval and ratio-scale functional measures of the stimuli (Anderson, 1982; Masin, 2004). Implications of the findings are discussed, with an emphasis on estimation of c_0, which opens the way to the functional measurement of both stimulus dimensions on a common ratio-scale.

When a moving target that suddenly disappears is presented to subjects who are required to locate its vanishing point, an error in the direction of motion is typically found. Originally reported by Freyd & Finke (1984), this error was coined Representational Momentum, calling upon a "mental analogue" of physical momentum. Partly in agreement with the proposed analogy, RM was shown to increase with the target's velocity for both implied (Freyd & Finke, 1985) and smooth motion presentations (Hubbard et al., 2001; Hubbard & Ruppel, 2002), although no effect upon RM was apparent for the target's mass (Hubbard, 2005). In an attempt to merge the existing evidence, Hubbard surmised that RM expresses a second order-isomorphism between mental representations and environmental invariants applying to the dynamics and kinematics of physical objects. Support for this view was provided from several displacement effects consistent, for instance, with the internalization of principles of friction, centripetal force, or gravity (Hubbard, 2005).

One important feature of RM is that, being a continuous variable, it makes it possible to address the issue of the integration of its contributing factors. Although many such determinants have been studied in isolation, they have seldom been considered in acting jointly. Anderson's Information Integration Theory (IIT: Anderson, 1981; 1982; 1996) is taken here as an appropriate framework for the study of RM multidetermination. Specifically, the present work focuses on the integration of the target's velocity and travelled distance by RM magnitude. In line with IIT methodology, all variables were fully crossed in factorial integration tasks, requiring a localisation response. As a supplementary between-subjects factor, two kinds of localisation response, either indirectly through a mouse cursor, or directly through a pointer, were used.