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Cerebral asymmetry in time perception

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Eighteen right-handed male subjects estimated the duration of dot patterns of varying numerosity which were briefly flashed to the left and right visual fields. The mean judged duration of patterns flashed to the left visual field was significantly less than the mean judged duration of patterns flashed to the right visual field. However, the duration of all patterns was underestimated, regardless of visual field. In addition, apparent duration increased linearly when plotted as a function of log duration and increased monotonically when plotted as a function of stimulus numerosity. Overall accuracy was nearly equivalent in both visual fields, but there were interactions between actual durations and visual field and between numerosity and visual field. Thomas and Weaver's (1975) model for time perception is applied to the data, and it is suggested that the left hemisphere relies on a timer to estimate duration, while the right hemisphere relies on a visual information processor to estimate duration.

There have been a number of experiments demonstrating cerebral asymmetry in the normal human brain. The designs of these experiments are premised on the fact that unilateral stimulus presentation leads primarily to stimulation in the contralateral cerebral hemisphere. Typical findings have included the following:

(1) In the visual mode, verbally encoded stimuli are more quickly processed when presented to the right visual field (left hemisphere), while spatially encoded stimuli are more quickly processed and more accurately detected when presented to the left visual field (right hemisphere) (Geffen, Bradshaw, & Wallace, 1971; Kimura & Durnford, 1974; Klatzky & Atkinson, 1971).

(2) In the auditory mode, using dichotic presentation, verbal messages presented to the right ear are more accurately reported than verbal messages presented to the left ear (Kimura, 1961, 1964), while musical sounds presented to the left ear are more quickly monitored and more accurately identified than musical sounds presented to the right ear (Kallman & Corballis, 1975; Kimura, 1964).

(3) The crucial variable may not be the stimulus per se. There is evidence that the left hemisphere processes stimuli linearly and analytically in a linguistic mode, while the right hemisphere processes stimuli holistically and synthetically in an imaginal mode (Bever & Chiarello, 1974; Cohen, 1973; Gordon, 1975; Robinson & Solomon, 1974; Seamon, 1974).

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An essential difference between these two modes of processing appears to be the degree to which a linear conception of time is reflected in thought. In fact, there is evidence that the two hemispheres respond differently to temporal manipulations. Efron's experiments (1963a, b), on judging simultaneity and temporal order of bilaterally presented stimuli (brief electric shocks and light flashes) "suggest that the conscious comparison of time of occurrence of any two sensory stimuli requires the use of the hemisphere which is dominant for language function" (Efron, 1963a, p. 283). More recently, Erwin and Nebes (Note 1) argued that the visual persistence of letter arrays (as measured by the subtractive reaction time technique) involves an interaction between encoding by the left hemisphere and storage by the right hemisphere. In the present experiment, we have studied cerebral asymmetry in time perception, specifically, apparent duration.

The apparent duration of an interval has been shown to vary as a function of the cognitive activity occurring within that interval (Fraisse, 1963; Ornstein, 1969). Most research has focused on manipulating nominal stimulus attributes in order to effect changes in cognitive activity. Mo (1971, 1975) found that increasing the number of dots in briefly flashed dot patterns led to an increase in their apparent duration. Buffardi (1971) reported similar findings in the visual, as well as in the auditory and tactual, modalities. Mo and Michalski (1972) found that increasing the size of a briefly flashed small circle (9 mm) led to an increase in its apparent duration, and Schiffman and Bobko (1974) found that increasing the complexity of a blinking light display (i.e., no blinking, simultaneous blinking, random blinking) had similar effects.

Recently, some investigators have demonstrated a relationship between cognitive activity and apparent

duration by controlling the degree of cognitive activity directly. Avant, Lyman, & Antes (1975) argue that differences in apparent duration may be traced to operations of initial visual processing. Thomas and Weaver (1975) have presented a mathematical model of apparent duration incorporating storage and retrieval, as well as processing variables.

In the present study, we have relied on changes in the nominal stimulus to effect changes in cognitive activity. Thus, dot patterns of varying numerosity and varying brief durations are presented to the left and right visual fields. Cerebral asymmetry in time perception is indicated by laterality differences in duration judgments.

METHOD

Subjects

Twenty-one right-handed males participated in this study; all were fulfilling an introductory psychology course research requirement. The data from three subjects were not analyzed because these subjects failed to follow the instructions properly.

Stimuli

The stimuli, which resembled those used by Mo (1971), were 150 white index cards, 12.8 × 20.3 cm in size, each marked with 1, 2, 3, 4, or 5 black dots (Prestype), 2 mm in diameter. Their pattern was determined by randomly assigning them to the cells of a 1.9 × 1.9 cm nine-cell matrix, the center of which was displaced either 2.3 deg (3.2 cm) to the left or 2.3 deg to the right of the fixation point, a 5-mm X in the center of the visual field. (The viewing distance was approximately 78.7 cm.)

In this manner, 75 patterns were generated, 15 patterns for each number of dots. Each pattern appeared once on the left and once on the right, making a total of 150 stimuli.

Apparatus and Design

Each pattern was exposed on a Scientific Prototype Model 800F two-channel tachistoscope at one of five logarithmically increasing durations: 16, 25, 40, 63, or 100 msec. More specifically, for each number of dots, 3 of the 15 patterns (chosen randomly) were exposed at 16 msec in both visual fields, 3 at 25 msec in both visual fields, 3 at 40 msec in both visual fields, etc. The pre- and postexposure fields were identical to the exposure field except for the dots.

Each of the three patterns exposed at the same duration were then separated in order to produce three homogeneous blocks, each containing 50 stimuli. The stimuli in each block included five one-dot patterns, five two-dot patterns, five three-dot patterns, five four-dot patterns, and five five-dot patterns. For each number of dots, one of the five patterns (chosen randomly) was exposed once to the left and once to the right for 16 msec, a second pattern was exposed once to the left and once to the right for 25 msec, a third, for 40 msec, etc. The order of stimuli in each block was randomized and was kept invariant over subjects; however, block order was perfectly counterbalanced such that each of the six possible block orders was presented to three different subjects.

Procedure

Before the experiment began, the subject was shown a sample stimulus (a card with one continuous horizontal line of dots across its center) at each of the five durations in turn. He was then given an answer sheet containing 150 vertical 5-point bipolar scales labeled "shortest" at the top and "longest" at the bottom and otherwise unmarked except for interval boundaries. Before each exposure, the trial number was given by the experimenter, who then asked "Ready?" When the subject responded "OK" (indicating that he was fixating on the X), a stimulus was exposed and the subject indicated its apparent duration by checking the appropriate interval on his answer sheet. The subject wore ear protectors during the experiment so that he would not be distracted by the sound of the tachistoscope-timer as it was being adjusted between trials.

RESULTS

The raw data (duration judgments on a 5-point scale) were summed over the block factor. The experimental design was then 2 (Visual Field) by 5 (Duration) by 5 (Numerosity) with repeated measures across all levels of each factor. All factors except subjects were considered fixed and crossed.

There was a strong main effect of Visual Field. The mean judged duration of patterns presented to the left visual field was 2.68, while the mean judged duration of patterns presented to the right visual field was 2.87, $F(1,17) = 31.22$, $p < .001$. Since a mean judged duration of 3.00 would correspond to the actual mean duration, it appears that the stimuli in both visual fields were underestimated relative to the clock. This was the case, as t tests showed that both 2.68 and 2.87 were significantly different from the theoretical expected mean of 3.00 ($p < .01$).

There was also a significant main effect of Duration, $F(4,68) = 263.00$, $p < .001$. The appropriate data for both visual fields are presented in Figure 1, where mean judged duration is plotted as a function of log duration. The linear functions, derived by the least squares method, fit the data closely. This is consistent with the results of other psychophysical studies using categorical scaling (Engen, 1972, pp. 82-83). The interaction between Visual Field and Duration was not significant, $F(4,68) = 1.70$, $p < .25$.

There was also a significant main effect of numer-

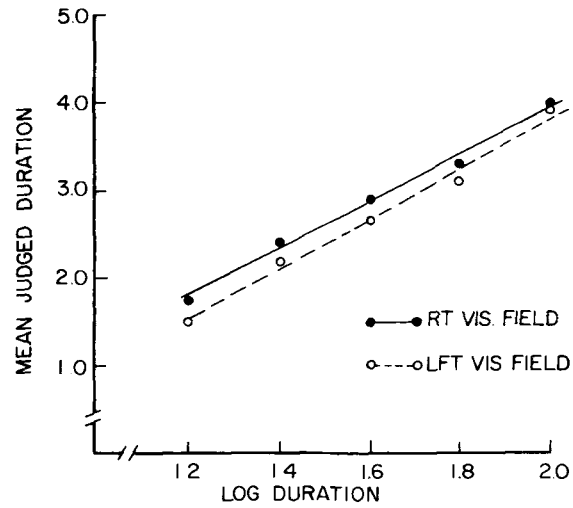

Figure 1. Mean judged duration as a function of log duration.

osity such that as numerosity increased so did apparent duration, $F(4,68) = 60.20$, $p < .001$. This effect is shown in Figure 2 for both visual fields. Only patterns of low numerosity were underestimated relative to the clock. The interaction between Visual Field and Numerosity was not significant, $F < 1.00$.

There were two other significant effects: a Duration by Numerosity interaction, $F(16,272) = 3.29$, $p < .001$, and a Visual Field by Duration by Numerosity interaction, $F(16,272) = 2.20$, $p < .01$. In order to examine these effects, we have plotted the Duration by Numerosity interactions for each visual field separately. These are shown in Figures 3 and 4. It appears that the effect of numerosity as a function of duration is less complicated for stimuli presented to the left visual field than for stimuli presented to the right visual field. In the left visual field, numerosity has an increasing effect on judged duration as actual duration increases. On the other hand, in the right visual field, the effects of numerosity are less orderly and decrease at the longest duration.

A second analysis of variance was computed to determine the effects of the three experimental variables on the accuracy of the duration judgments. We already noted that patterns presented to the right visual field were judged to last longer than patterns presented to the left visual field. If we wish to make inferences regarding hemispheric competence in time perception, we must assess the accuracy of these duration judgments. Differences in mean judged duration do not necessarily reflect differences in accuracy. For this accuracy analysis, the raw data were dichotomous, 0 for an incorrect judgment and 1 for a correct judgment (see Winer, 1971, pp. 303-305).

The main effect of Visual Field was not significant. In the left visual field the proportion of correctly judged stimuli was .41. In the right visual field, the proportion of correctly judged stimuli was .38, $F(1,17) = 2.75$, $p < .25$.

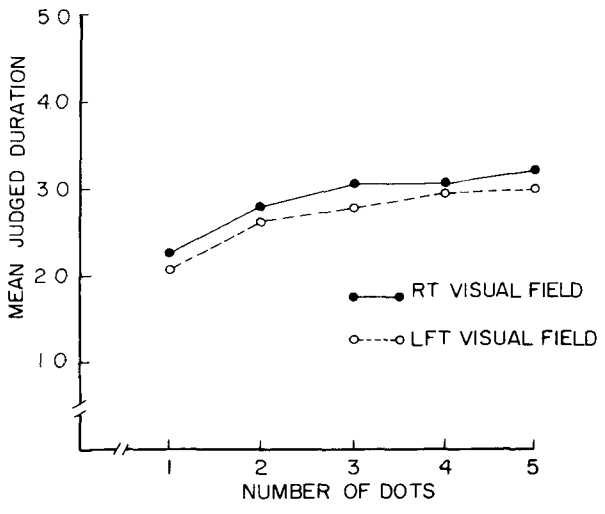

Figure 2. Mean judged duration as a function of numerosity.

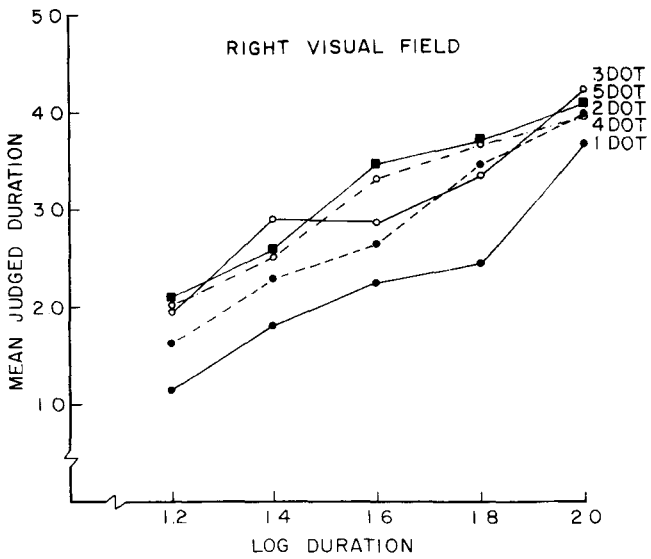

Figure 3. Mean judged duration as a function of log duration and numerosity in the right visual field.

There was a significant main effect of Duration, $F(4,68) = 7.75$, $p < .001$. The breifer the duration of the flash, the greater the proportion of correct judgments. This is consistent with our finding that the duration of stimuli in both visual fields was underestimated. On the average, subjects gave more short estimates than long estimates, leading to an increase in the number of correct judgments for the shorter durations.

There was also a significant Visual Field by Duration interaction, $F(4,68) = 5.52$, $p < .001$. It is represented in Figure 5, which shows that briefly flashed stimuli are more accurately judged when they are presented to the left visual field, while the effect is reversed for longer stimuli. This is consistent with our finding that left visual field stimuli were underestimated more than right visual field stimuli. On the average, subjects gave more short estimates for left visual field stimuli than for right visual field stimuli, reflecting greater left visual field accuracy at brief durations and greater right visual field accuracy at long durations.

There was a significant effect of Numerosity, such that as numerosity increased so did accuracy of judgment, $F(4,68) = 2.66$, $p < .05$. However, this effect is complicated by a Visual Field by Numerosity interaction, $F(4,68) = 2.55$, $p < .05$, which is shown in Figure 6. Accuracy increases as a function of numerosity only for stimuli presented to the left visual field. Accuracy is less dependent on numerosity for stimuli presented to the right visual field.

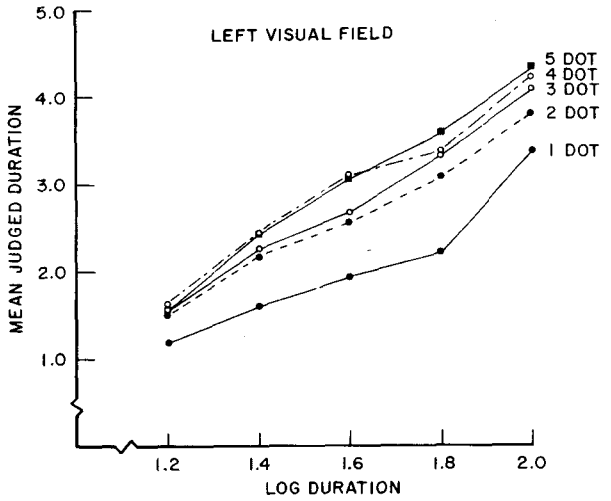

Figure 4. Mean judged duration as a function of log duration and numerosity in the left visual field.

Moreover, with patterns of low numerosity, right visual field stimuli are more accurately estimated, while this effect is reversed for patterns of high numerosity. We will discuss these data in the following section.

Finally, there was a significant Duration by Numerosity interaction, $F(16,272) = 8.08$, $p < .001$. This interaction could be predicted on the basis of the significant main effects of actual duration and numerosity on mean judged duration. At short durations, stimuli of low numerosity were judged correctly more often than stimuli of high numerosity. At long durations, stimuli of high numerosity were judged correctly more often than stimuli of low numerosity.

DISCUSSION

The mean judged duration of patterns presented to the left visual field was significantly less than the mean judged duration of patterns presented to the right visual field. However, there was a systematic tendency to underestimate the duration of all patterns, regardless of visual field. In addition, apparent duration increased linearly when plotted as a function of log duration in both visual fields (see Figure 1) and, consistent with previous findings, was a positive function of numerosity of both visual fields (see Figure 2).

These findings indicate that there is cerebral asymmetry in time perception, although the precise nature of this asymmetry is not clear. Kimura (1966) and Kinsbourne (1970) have argued that such perceptual asymmetries may be attributed to functional differences between the two hemispheres. One hemisphere is viewed as more competent, the other less competent, for a particular task. For Kimura, perceptual asymmetries result from transcallosal degradation of information as it is passed from the less competent to the more competent hemisphere. On the other hand, Kinsbourne attributes perceptual asymmetries to pre- and/or poststimulus shifts in attention. That is, perceptual asymmetries result from gazing and head-turning, which occur contralateral to the active, or more competent, hemisphere.

These theories, based as they are on the notion of relative competency, do not successfully explain our data. If one hemisphere is more competent regarding time perception, accuracy in judging duration should be higher for the contralateral visual field. Yet we found that neither field showed greater accuracy; for both visual fields, overall accuracy was nearly equivalent. Thus, we believe an alternative explanation of our data is appropriate.

Thomas and Weaver (1975) presented a mathematical model of time and perception which assumes that the perceived duration of a brief visual stimulus is a function of two processors, a timer and a visual-information processor. Attention is shared between these processors such that, as visual information increases, more attention is given to the visual-information processor. As visual information decreases, more attention is given to the timer. Perceived duration is assumed to be a weighted average of the output of both processors. (It is a *weighted* average, because as one processor captures more attention, the other processor becomes less reliable.)

In applying Thomas and Weaver's model to our data, we assume that the hemispheric distinction serves as an automatic control over the distribution of attention to the timer and the visual information processor, such that, when the stimulus is presented to the left (right) visual field, judgment of duration is based on the output of the visual-information processor (timer). This assumption is consistent with previous data indicating that the left hemisphere

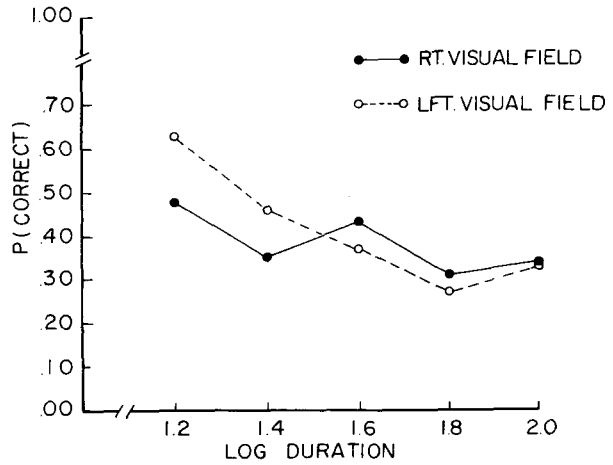

Figure 5. Accuracy of judged duration as a function of log duration and visual field.

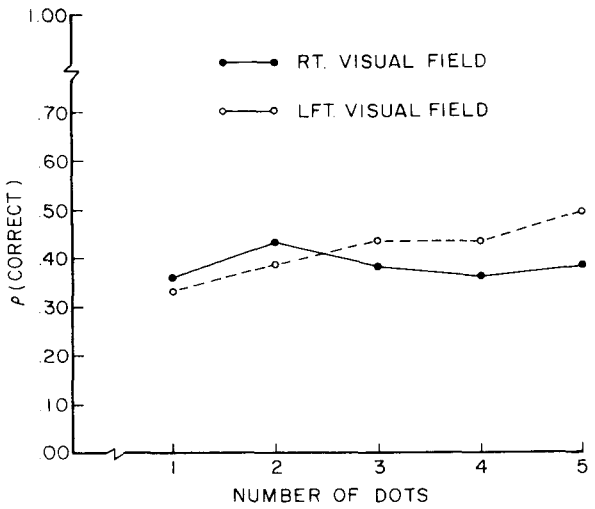

Figure 6. Accuracy of judged duration as a function of numerosity and visual field.

processes within a linear mode, while the right hemisphere processes within a perceptual mode. Examining our data, Figures 3 and 4 do suggest that the right hemisphere is less variably and more systematically affected by changes in visual information, i.e., numerosity.

We can now use Thomas and Weaver's model to interpret Figures 5 and 6. Figure 5 can be considered to represent accuracy as a function of increased attention to the timer, with attention to the visual-information processor held constant. (We assume, with Thomas and Weaver, that at these brief durations the time to process visual information is greater than and independent of duration.) Accuracy is higher in the left visual field at shorter durations because relative attention to the visual information processor is greatest when duration is decreased. The general decline in accuracy as a function of duration probably reflects a systematic tendency for the timer to underestimate all durations (Thomas and Weaver observed a similar tendency.)

Figure 6 can be considered to represent accuracy as a function of increased attention to the visual-information processor, with attention to the timer held constant. Accuracy is higher in the right visual field with low numerosity because relative attention to the timer is greatest when visual information is reduced. Accuracy is higher in the left visual field with increased numerosity because relative attention to the visual-information processor is greatest when visual information is increased.

Regarding the localization of the timer and the visual-information processor, two possibilities are suggested: Both processors may be functions of both hemispheres, the timer being more accurate in the left hemisphere and the visual information processor being more accurate in the right hemisphere. Alternatively, the timer may be localized in the left hemisphere and the visual information processor localized in the right hemisphere. The situation is further complicated by Efron's (1963a, b) findings, which imply that the left hemisphere is necessary for judgments of temporal order. Our data are consistent with any of these possibilities, and more research is clearly appropriate.

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