NOTE

SIMULTANEOUS READING OF BRAILLE WITH THE TWO HANDS: REPLY TO MILLAR (1987)

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In a paper published recently in this journal, Millar (1987) takes issue with previous reports that fluent braille readers can take in text information simultaneously with the two hands. In our own study (Bertelson, Mousty and D'Alimonte, 1985), such parallel intake was shown to occur during two distinct phases of the most typical pattern of two-handed exploration. One is when the two hands explore side-by-side (in the "conjoint mode") a central segment of the line, the length of which varies considerably among readers. The other is when the left hand, having moved to the beginning of the next line, starts scanning that line while the right hand is still reading the end of the previous one, a movement pattern we have proposed to call "simultaneous disjoint exploration".

Millar develops two separate arguments. One is that during conjoint exploration the two reading fingers alternate contacts with the letters and thus do not take in letter information simultaneously. The other argument is that previous reports of simultaneous disjoint exploration have resulted from poor observations of finger movements and are not confirmed with a better method. We take the two points in turn.

(1) Microstructure of Conjoint Exploration

The thesis is that when they scan side by side the median segment of a line, the reading fingers alternate positions on the text, so that when one is "touching a letter" the other is "touching" a space between two letters, or a gap between two words. The proposal is strongly counter-intuitive, as it is difficult to figure out a processing system that would benefit from such staggering of inputs at the periphery. It is thus necessary to examine carefully the evidence presented in its support.

Hand movement data were gathered with an elegant recording method which makes the surface of contact between the finger and the support apparent. In the analysis, for each frame of the video recording, each finger is considered to be either "touching a letter", "touching a space" or "touching a gap". Consequently, each frame can be allocated to one of six categories: both fingers on letters (LL), one on a letter and the other on a space (LS) etc. The individual numbers of frames falling in each of the six categories are tested against the null hypothesis that the six combinations of finger positions are equiprobable. The hypothesis is rejected, and post-hoc tests show that combinations LS (one finger on a letter, the other on a space) and LG (one on a letter and the other in an inter-words gap) are significantly more frequent than both LL and SS. The author concludes that the data are not consistent with the hypothesis that the two hands process letters simultaneously.

Two aspects of the argumentation must be discussed. They concern respectively the coding of finger positions and the statistical analysis.

(a) The criteria for the *categorization of finger locations* are not described in the paper, but Dr Millar (personal communication, 1987) has explained that it is based on the position of the sagittal axis of the area of contact relative to letter boundaries. Contact with

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a letter is supposed to begin when that axis crosses the left column of dots of the letter and to stop when it crosses the right column. Thus, a finger can be considered to "touch a letter" when it actually touches only some of the dots of that letter. On the other hand, it might be considered to "touch a space" when it actually touches some dots of each of the adjacent letters. There is thus no basis for the kind of conclusions that Millar draws from her data, and which imply taking the labels of the categories at their face value.

(b) No justification is given for using *equiprobability* of the six combinations of finger locations as *null hypothesis*, and it is difficult to imagine one. A more reasonable assumption regarding hand activity is that the fingers proceed along the text at constant speed and independently of each other. The time spent by each finger (i.e. its axis) respectively on letters, spaces and gaps would depend on the total space occupied by those items in the particular texts used in the study. To estimate these values, one needs to know the distribution of word lengths. In the absence of such knowledge, one can considered the simpler hypothesis that, whatever the mean time spent in each position by one finger, its momentary position is independent of that of the other finger. This hypothesis predicts that the probability of occurrence of a particular combination of finger positions is the product of the overall probabilities that each finger occupies the particular position.

We have tested the hypothesis using the data in Millar's Table I. Categories S and G have been lumped together into the new category I (for "interval"). For each subject, four proportions can be obtained:

— p(LL) which appears in the Table;
— $p(II) = p(SS) + p(SG)$;
— $p(IL) = p(LI) = \frac{(p(LS) + p(LG))}{2}$

The four values can be entered into a 2×2 contingency table. The independence hypothesis can then be tested using chi^2. Table I shows for each subject the observed number of frames with the two fingers "touching letters", the number expected from the independence hypothesis and the value of chi^2. The hypothesis can be rejected at $p = .05$ in five of the ten subjects. Four are seen in position LL less than predicted, and one *more often* than predicted. For the group as a whole, the expected number of LL frames is 404.3 and the observed one is 351.

These results do clearly not support the notion that braille readers systematically alternate exploration of letters by the two reading fingers. There are several possible explanations for the small deviations from independence shown by some of the subjects, which reexamination of the recordings could help to sort out. A rather trivial one is that when the two fingers actually touch each other, as in our data happened quite often during conjoint exploration, their width might in some subjects cause the observed deviations. Another possible source lies in those not very frequent occasions where one finger stops on a character and generally engages in rubbing movements. A tendency to keep the other finger during that time either on a space or on a letter could then introduce a bias in one or the other direction.

(2) Simultaneous Disjoint Exploration

The pattern of two-handed exploration in which the left hand, having completed its return to the next line, starts scanning that line while the right hand is busy scanning the end of the previous line was noticed by unaided viewing of our recordings. It is apparent on several of the actograms which accompany our paper (Bertelson et al., fig. 1, box a; fig. 2, boxes c and d). To quantify the phenomenon, we took four measures for each line transition: a) time at which the left finger leaves the first cell of the new line; b) position of the right finger at that time; c) time at which the right finger leaves the last cell of the previous line; d) position of the left finger at that time. Simultaneous disjoint exploration was considered to have taken place whenever (a) was earlier than (c). This occurred on the majority of line transitions for a majority of the subjects (on at least 15 of 22 transitions in 15 of the 24 subjects). The mean duration was 0.41 sec but there were huge individual differences. Four subjects never showed the pattern and four others did it for less than .25 sec per line. Seven of these eight subjects show a pattern of exploration with a long

TABLE 1

Observed and Expected Number of Frames Showing Both Reading Fingers "Touching Letters" and Values of Chi² (Data recalculated from Millar, 1987, Table I)

S	N	FramesLL		chi²	p
		Observed	Expected		
1	203	24	31.7	3.97	.05
2	305	40	31.2	4.29	.05
3	216	28	33.7	2.10	NS
4	157	14	21.5	5.58	.05
5	331	40	42.9	0.40	NS
6	465	60	68.9	2.46	NS
7	253	18	24.3	3.20	NS
8	497	55	54.1	0.01	NS
9	359	25	35.8	5.13	.05
10	588	47	60.2	5.76	.05
Total	3374	351	404.3		

two-handed segment.

From her description, Millar's analysis of her data was basically identical to ours. Her time RO is the same as our time (c) and her time LN (time at which the left finger touches a new letter on the following line) very close to our time (a). In Table II, she gives "mean times" which are the means of the clock times at which the finger is in the particular position on 11 successive lines of text. This statistic is unusual, but it offers probably a reliable description of hand activity at line changes. The result is that mean LN is higher than mean RO in nine of the ten subjects. Thus, these subjects did apparently not engage in simultaneous disjoint exploration to any substantial extent.

To explain the difference between her results and ours, Millar suggests that our analysis of hand movements at line changes is flawed by being based only on time measures. The imputation is incorrect, for we also used the critical finger positions (b) and (d). Millar suggests also that our count of simultaneous disjoint exploration includes time intervals during which the left hand, after moving off the first cell, later regresses to the beginning of the line. Such regressions actually occur, but in a low proportion of cases. For the 15 subjects who engage frequently in simultaneous exploration, left hand regressions occurred on only 22 of 267 line transitions with simultaneous exploration.

In our opinion, there is no real contradiction between Millar's data and ours. Our results show that many skilled readers, generally those who dissociate the hands a great deal, engage in simultaneous disjoint exploration on most line transitions. They also show that other readers do not produce that movement pattern at all, or do it seldom. These tend to be readers whose reading style involves a large bimanual segment. Millar's subjects resemble those of the latter group: they do not engage in simultaneous exploration, and the data in her Table III show that, with one exception, they tend to explore a large segment in the conjoint mode. So, the differences between the two sets of data might simply reflect differences between the populations sampled in the two studies.

ABSTRACT

Millar (1987) argues that when braille readers scan a passage of text with the two hands side by side, the reading fingers actually alternate contacts with the letters. Reanalysis of her data shows that they provide little support for that claim. On the other hand, unlike a majority of the subjects studied by Bertelson et al. (1985), Millar's subjects do apparently not engage in simultaneous exploration of the end of one line and the beginning of the next one by different fingers. The suggestion offered by Millar that our findings result from an inadequate analysis of the data is rejected. The difference between the two sets of data should for the time being be considered as reflecting genuine differences between the

populations that were sampled in the two studies.

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