Journal of Experimental Psychology:
Learning, Memory, and Cognition
1992, Vol. 18, No. 2, 284-297

0278-7393/92/$3.00

The Time Course of Braille Word Recognition

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Skilled blind readers read French nouns with the uniqueness point in different locations, presented in unabbreviated braille, and either pronounced each item (Experiment 1) or classified it as to gender (Experiments 1-3). As in previous studies with spoken words, effects of uniqueness point location on recognition reaction time were taken as demonstrating on-line lexical access. For braille words, significant effects were obtained in Experiment 1 in the two tasks. In Experiment 2, blind Ss demonstrated comparable relative uniqueness point effects for gender classification of braille and of spoken words, showing that on-line lexical access is not specific to speech. Experiment 3 showed that the effect of uniqueness point location is limited to the higher frequency words. Finally, mean finger scanning speed did not differ between the pre- and post-uniqueness point regions of the words.

During skilled braille reading, each reading finger[1] scans the line of text from left to right following a smooth pattern that is only occasionally interrupted by regressions to already explored text (Bertelson, Mousty, & D'Alimonte, 1985). Thus, tactile data regarding the letters of each word become available serially in left-to-right order. From the viewpoint of input timing, braille reading is different from visual reading, in which each successive fixation makes a window of text simultaneously available. To a lesser extent, it is also different from listening to speech, in which coarticulation and intonation result in some degree of simultaneous presentation of information relevant to several phonetic segments. Thus, braille reading might well be the most strictly serial mode of language input.[2]

One may ask the following question: Do the processes involved in word recognition take advantage of that serial character of the braille input? A similar question has been considered in recent years for the case of speech. More specifically, it has been proposed that the selection of a lexical interpretation occurs on-line, in step with reception of the phonetic data relevant to each word. The best-known proposal, developed by Marslen-Wilson and Welsh (1978) in the cohort model, was that for each word a short list, or cohort, of possible lexical interpretations was first activated on the basis of some initial acoustic data and that members were subsequently deactivated as soon as they became incompatible with later arriving evidence, until a single candidate remained. The point at which the critical batch of evidence bringing the cohort of lexical candidates down to one was called the *uniqueness point* (UP),[3] and recognition was supposed to occur exactly at that point.

The original cohort model met with several difficulties. First, because membership of the cohort was an all-or-none affair, it predicted that words affected by mispronunciation (e.g., *shigarette*), noise, or misperception could never be identified (McClelland & Elman, 1986; Norris, 1986). On the other hand, it allowed no way of accounting for effects of such variables as usage frequency or expectancy. Finally, the notion that recognition occurred exactly at the UP led to the strong prediction that recognition reaction time (RT) measured from the UP should be invariant across variations in UP location (or, alternatively, that equal differences in temporal position of the UP from word onset should produce equal

This work was supported by the Belgian Ministry of Scientific Policy, Incentive Program for Fundamental Research in Artificial Intelligence, and by the National Fund of Collective Scientific Research (Convention 24531.88). The results have been presented at the Workshop on Word and Sentence Recognition (Zadar, Yugoslavia; September 1989), at the 30th Annual Meeting of the Psychonomic Society (Atlanta, Georgia; November 1989), and at the meeting of the Experimental Psychology Society (London, January 1990).

Graziella D'Alimonte and Anne Deneubourg participated in data collection, and the programs were developed by Edgar Fonck. Thanks are due Ram Frost, Stephen Monsell, Ronald Peereman, Sandy Pollatsek, Juan Segui, Joan Sereno, Philip Smith, and two anonymous reviewers for constructive criticisms. Any remaining obscurities are our responsibility. Particular appreciation is expressed to the subjects without whose competence and collaboration the present line of research could not be pursued.

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[1] The majority of braille readers use exclusively the index fingers to explore the text. Some use only the index of one hand, others the two indexes, following various patterns of cooperation (see Bertelson, Mousty, & D'Alimonte, 1985).

[2] This at least concerns unabbreviated (called *grade one* in the U.S.) braille, in which each letter is represented by the corresponding braille character. In the various abbreviated braille systems (U.S. *grade two*), some letters or letter combinations stand for frequent orthographic clusters. In the present study, unabbreviated braille was used throughout.

[3] A variety of terms have been used in the literature to designate points within words at which a particular information becomes theoretically available: *recognition point, uniqueness point, deviation point* (for pseudowords in a lexical decision task), *nonword point,* and so on. A good generic term would be *critical point.* The present terminological diversity is not too worrisome, for the particular notion implied can generally be gathered from the context.

differences in RT measured from the same onset). Surprisingly few studies have provided the quantitative data necessary to test that prediction, and their results have been mostly unfavorable. The only strong support was provided by a nonword detection experiment reported briefly—and with a minimum of information on procedure—by Marslen-Wilson (1984). A regression coefficient equal to .90 was obtained between RT measured from word onset and the time elapsing between the same onset and the deviation point, or point at which the data became incompatible with any word interpretation. For the same task, Huttenlocher and Goodman (1987) observed a much weaker dependence of RT on UP. They suggested that Marslen-Wilson's results might have been influenced by the fact that some of his nonwords with early deviation point were phonologically illegal. Taft and Hambly (1986), using the traditional lexical-decision task with different responses to words and pseudowords, found that RTs to pseudowords measured from the deviation point varied with such factors as length of continuation past the deviation point or degree of similarity with word neighbors. Finally, in a gender-classification task, in which the subject had to decide whether a spoken French noun was feminine or masculine, and the location of the UP was varied systematically, the effects of these variations on RT were about one third the size of the variations (Radeau, Mousty, & Bertelson, 1989).

Alternative theoretical conceptions have been proposed, which preserve the notion of on-line selection, but dispense with the all-or-none assumption. In his new cohort, Marslen-Wilson (1987) proposed that the selection process—instead of discarding candidates that do not entirely fit the acoustic evidence—simply modulates their activation and that a choice is made when the activation of one candidate exceeds that of any competitor by some threshold value. An activation model can clearly account for frequency effects and for the recognition of mispronounced or misperceived items. Although Marslen-Wilson did not consider the issue, an activation model presumably makes less efficient use of the data than the all-or-none cohort, making some processing of post-UP data necessary. A similar view was developed by Taft and Hambly (1986), who proposed that a first phase of data-driven activation is followed by a phase of faster top-down verification based on the post-UP data. The new cohort model, not surprisingly, has many features in common with the TRACE model of McClelland and Elman (1986), which was explicitly motivated by the shortcomings of the original cohort. More recently, Norris (1990) described a rather different type of on-line model, in which the whole evidence accumulated since word onset is reevaluated against lexical possibilities on the arrival of each new batch of data.

A basic assumption of the present study was that one can address the general issue of the on-line character of the lexical selection processes without committing oneself to one detailed model of these processes, such as those just mentioned. The issue is to choose between two views of the way lexical access proceeds when the input is temporally distributed. Following the off-line, or accumulation, view, any decisions regarding the choice of a lexical interpretation are delayed until all the data relevant to each word have been collected. On the contrary, for the on-line view, some decisions are started before the whole evidence has become available, on the basis of early partial perceptual data. There are facts that support the on-line view without constraining much the choice between alternative models of on-line processing. Examples are the findings that word recognition responses sometimes occur before the whole word has been delivered (Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978; Radeau et al., 1989) or that pronunciation errors are detected more efficiently late in a word than in the early part (Cole, 1973). Similarly, the on-line view is supported by the results showing effects of UP location on the occurrence of phoneme restoration (Samuel, 1987) or on RT to words in such tasks as lexical-decision (Taft & Hambly, 1986), phoneme-detection (Frauenfelder, Segui, & Dijkstra, 1990), gender-classification (Radeau et al., 1989), and shadowing (Radeau & Morais, 1990), irrespective of the size of the effect. The size on the other hand is, as discussed earlier, relevant to the choice of a particular model. Another class of arguments that might support the on-line view are the recent claims that spoken primes that share their beginning with a word probe would be more effective than those that share a later fragment (Marslen-Wilson & Zwitserlood, 1989; Zwitserlood, 1989).

The main objective of the present study was to examine whether the kind of evidence that supports the on-line view for speech could be obtained also for braille word recognition by blind readers. An answer to that question could help put the results obtained with speech in a wider perspective. On-line processing may be contingent not only on the serial character of the speech signal, but also on some specialized inherited features of the speech processing machinery. In that case, it would not occur in braille reading, which shares with listening the serial character of the input, but is, like visual reading, an artificial skill, acquired relatively late in life through effortful learning.

As a criterion of on-line processing, we chose the effect of UP location on the speed of recognition of isolated words. Two word recognition tasks were used. The main one, which was used in all three experiments, was the gender-classification task. It consisted of deciding whether a French noun was feminine or masculine. In an earlier study with spoken words (Radeau et al., 1989), the task allowed the demonstration of reliable effects of UP location on RT measured from word onset. One problem with that task was to know whether it really required recognition of the word. For many French words, the ending provides relatively reliable information regarding gender (Desrochers, Paivio, & Desrochers, 1989) and gender classification could thus conceivably be performed, at least on some trials, through a procedure based on the sole examination of the ending. In our previous study (Radeau et al., 1989), subjects were asked to judge the gender of pseudowords built by attaching the ending of each of the nouns in our materials to a nonsense radical, and the reliability of the obtained judgments was .79. This finding thus confirmed the partial reliability of word endings, but it also meant that systematically deciding solely on their basis would have led to about 20% incorrect responses, a value much in excess of the 3% to 4% that was typically obtained across the different experiments. On the other hand, because the procedure involves waiting until the end of each word, response

latency would not have been affected by the location of the UP. As a matter of fact, no correlation was found between mean gender decision RTs to the different words and the predictive values of their endings, as estimated from the judgments of pseudoword gender. This result seemed to rule out any substantial recourse to the word-ending strategy. It was concluded that gender classification is probably carried out most of the time by a sequential lexical strategy. It was proposed, on the other hand, that the strategy is not as efficient as the one considered in the original cohort model, because the RT difference between words with late and early UP was only about one third the difference in the temporal location of the UP.

The other task was word pronunciation. It was applied, only in Experiment 1, mainly to check on the generality of any effects obtained with gender classification. One reason for choosing it, however, was that it has led to much theoretical elaboration in the various versions of the dual-route conception (see Paap & Noel, 1991; Patterson & Coltheart, 1987, for recent formulations) or of their alternatives (Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). Consideration of the case of braille word recognition poses the question of how the various hypothetical processes would work with a temporally distributed input. For instance the dual-route conception assumes that besides the lexical-addressing process, which can retrieve the whole phonological specification of the printed word in the mental lexicon, the system can also assemble a phonological representation through piecemeal conversion of subword orthographic fragments into phonetic fragments. Normally, only the addressing process should be affected by the state of the lexical neighborhood and show for instance the influence of the UP. The assembly operations should proceed in the same way whether the word fragment it is dealing with is anterior or posterior to the UP. Thus, in the case of braille, the observation of effects of UP location could provide a new demonstration of lexical processing.

Another objective of the study was to examine the pattern of scanning speed across words. If the effect of UP location was observed at the level of RT, then one was led to assume a change in processing load correlated with the fact of reaching that point. This change might then be reflected at the level of scanning speed. The question was asked in exploratory fashion mainly, for little is known so far about the control of braille exploration movements. The evidence now available suggests, however, that scanning speed is affected little by local changes in text difficulty (Bertelson et al., 1985; Bertelson & Mousty, 1990). The question of scanning speed was examined post hoc in Experiment 1 and more systematically in Experiment 3.

Experiment 1: Gender Classification and Pronunciation of Braille Words

Braille words were presented on a computerized braille display. Subjects read them with their preferred hand and named their gender, in one condition, or pronounced them, in the other. In both conditions, half the words had an early UP and half had a late UP.

The measurement of the UP involves several decisions, regarding both the size of the vocabulary to be taken into account and the extent to which that reference vocabulary should be adapted to the specific demands of each particular experimental task. For gender classification, for instance, only nouns can be used. One can calculate substantive UPs solely on the basis of the population of substantives, or nouns, in the base. Substantive UPs were used in the preceding study (Radeau et al., 1989). Another consideration is that there are words for which an ideal classification device could decide ahead of both lexical or substantive UPs, because all remaining candidates are of the same gender (e.g., in French, *préjudice* and *préjugé* both allow a masculine decision from the *j* on). One could thus consider using gender UPs. Whatever the task, the most difficult problem, however, concerns morphological complexity: Should the reference base contain inflected word forms or only base forms? All these problems could in principle be solved empirically by examining which particular recognition point produces the best predictions. But until such data become available, more or less arbitrary choices must be made. In the present study, UPs were calculated using a lexical database, BRULEX, developed in this laboratory (Content, Mousty, & Radeau, 1990). BRULEX contains the approximately 30,000 words of the Micro Robert dictionary (Robert, 1986). Thus, only base forms were taken into account. Moreover, lexical UPs, taking into account all the words in the database, were used in Experiments 1 and 3, whereas substantive UPs were used again in Experiment 2, for reasons to be explained later. Finally, the problem of possible gender calculation ahead of the lexical UP was, as in the preceding study, avoided through the (admittedly disputable) procedure of using only nouns that had at least one neighbor of the other gender immediately before the UP.

Method

Subjects. Twelve skilled blind braille readers, 6 women and 6 men, agreed to participate in one session each. Their ages ranged from 22 to 75 years. Actually, 6 were above 50: 75, 74, 73, 66, 62, and 52, respectively. Such skewing of the age distribution toward the higher values might well be typical of the population of braille readers. Its implications concerning comparisons with results obtained with younger subjects are examined in the *Results* section.

Materials. Two sets of 84 French nouns (Appendix A) were selected from BRULEX, which contains their frequency of usage as appearing in the data for the second half of the 20th century in the *Trésor de la langue française* (1971).

Each set of nouns contained 42 items with early lexical UP and 42 with late UP. The mean UP was 3.95 letters (range = 2–5) in the early UP subsets and 8.95 (range = 7–11) in the late UP subsets. Each subset contained nouns of the two genders in equal numbers. Mean word length was constant at 9.3 letters (range = 8–11) in all subsets. Mean usage frequency was 2.85 occurrences per million, across the subsets. In each set of 84 nouns, UP location and gender occurred in random order. Two additional sets of 42 nouns, again half feminine and half masculine—with lengths in the same range as the experimental nouns and UPs in medial position—were used for practice trials.

Apparatus. A braille active line (EHG BT40), controlled by an Apple IIe microcomputer, was used to display the braille words. The active line has 40 positions on each of which any braille configuration

can be produced by protruding plastic styluses. Subjects, who sat in front of the active line, spoke their responses into a microphone, which activated a voice key.

The position of the reading finger was recorded using a system developed at Université libre de Bruxelles specially for the study of braille reading (Noblet, Ridelaire, & Sylin, 1985). A solid-state video camera (Hitachi KP-12OU) is positioned above the active line. A diode attached to the nail of the reading finger produces a 1-ms flash every 40 ms. The location of each flash is coded into numerical X–Y coordinate values that are stored in the computer. At the beginning of each session, the location measuring system is calibrated by having the subjects position their fingers twice on each of two reference positions.

For the purposes of the present experiment, the following values were registered for each trial: (a) time at which the reading finger was first seen on the first letter of the word, (b) time at which it was first seen on the UP character, (c) time at which it left the last character of the word, and (d) time at which the response triggered the voice key. The recording was controlled by a program that had been written mainly for measuring time to UP and RT. For each trial, all recording was terminated by the response, so that the time at which the end of the word was reached was sometimes lost. As appears in the *Results* section, the consequences proved serious only for the measurement of scanning speed.

Procedure. Subjects each worked for 42 practice trials and 84 experimental trials on each of two tasks. Different sets of words were presented for the two tasks. A trial began with a warning tone inviting the subjects to position the reading finger on the first cell of the line. The word itself always began on the fourth cell. The subjects started moving from the resting position when it suited them, but they were asked to respond as soon as possible after having started to scan the word. In the gender-classification task, the response consisted of saying either "féminin" or "masculin" into the microphone. In the pronunciation task, the response was to say the word aloud. The allocation of the sets of words to the two tasks and the order of administration were counterbalanced across subjects. No feedback was provided at any stage.

Results

Table 1 shows for each task and each group of items (early vs. late UP) the mean RT measured from word onset (i.e., the time at which the finger is first seen on the first letter of the word), the mean scanning time from word onset to UP, and the mean percentage errors. For the calculation of mean RTs and of mean times to UP, we discarded trials on which (a) the response was wrong, (b) the RT deviated from the mean RT of the subject for the task by more than two standard deviations, (c) a regression occurred, or (d) the necessary data were not all available. Missing data resulted from equipment failures, experimenter mistakes, or actual interruptions of scanning ahead of the UP. The recording program unfortunately did not register regressions (c) separately from trials made unusable by missing data (d), so that only a total count for the two categories was available. For the present experiment, it represented 9.05% of the total number of trials, while errors represented 6.69% and out-of-range RTs 4.75% of that total. The question of the incidence of regressions is examined again in Experiment 3, in which separate recordings of the different categories of trials were achieved.

Before analyzing the RT data, we checked that there were no systematic differences linked to the age of the subjects. Two groups were formed with the 6 subjects aged 52–75, and the 6 aged 22–42, respectively. Mean RTs per task and UP location tended to be shorter in the older group. In an analysis of variance (ANOVA) of mean individual RTs, the main effect of age was nonsignificant, $F_1(1, 10) = 2.35$, $MS_e = 2{,}612{,}873$, $p = .16$, and so were all the interactions involving that factor ($Fs < 1$, for all three interactions). Therefore, we pooled the data from all the present subjects for the further analyses. A more important implication of the finding is that the age of braille readers does not necessarily compromise comparisons of their performances with those of the younger subjects typically used in work with other tasks.

The significance of effects observed on RTs was assessed through two ANOVAs: one based on mean RTs per subject, UP location (early vs. late), and task and the other based on mean RTs per item in each task. The main effect of UP location was significant in the two analyses, by subjects, $F_1(1, 11) = 28.2$, $MS_e = 15{,}418$, $p < .001$, and by items, $F_2(1, 166) = 9.98$, $MS_e = 164{,}135$, $p < .005$. Words with early UP were responded to faster than those with a late UP. The effect of task was also significant in both analyses, $F_1(1, 11) = 80.4$, $MS_e = 46{,}621$, $p < .001$, and $F_2(1, 166) = 41.75$, $MS_e = 618{,}134$, $p < .001$. Pronunciation was faster than gender classification (by about 20%). The interaction between UP location and task was significant neither by subjects, $F_1(1, 11) = 2.21$, $MS_e = 11{,}232$, $p = .14$, nor by items, $F_2(1, 166) = 1.20$, $MS_e = 618{,}134$. $p = .28$. Thus, the difference between the effects of UP location observed in the two tasks (208 ms for gender classification against 117 ms for pronunciation) was nonsignificant. Given the potential theoretical importance of a difference between the two tasks in the size of the effect of UP location, the data were analyzed separately for each task. For gender classification, the effect of UP location was significant both by subjects, $F_1(1, 11) = 17.1$, $MS_e = 15{,}278$, $p < .001$, and by items, $F_2(1, 166) = 4.98$, $MS_e = 409{,}995$, $p < .05$. For pronunciation, it was significant by subjects, $F_1(1, 11) = 7.31$, $MS_e = 11{,}372$, $p < .025$, but not by items, $F_2(1, 166) < 1$. The possibility of a difference in the size of the UP location effect between the two tasks is thus not completely ruled out by the present results.

Mean time necessary to reach the UP, which for each task was of course longer for words with late UP than for those with early UP, was slightly longer for the pronunciation task than for gender classification. By ANOVA, the latter difference was however significant neither by subjects, $F_1(1, 11) = 2.20$, $MS_e = 16{,}341$, $p = .17$, nor by items, $F_2(1, 166) = 1.38$, $MS_e = 540{,}984$, $p = .25$. None of the results obtained at the level of RT should thus be considered as a consequence of a systematic difference between the two tasks in pre-UP speed of scanning.

Numbers of errors were also analyzed by subjects and by items. The effect of task was significant neither by subjects, $F_1(1, 11) = 2.59$, $MS_e = 4.24$, $p = .14$, nor by items, $F_2(1, 166) = 3.78$, $MS_e = 0.42$, $p = .06$. The effect of UP location was also nonsignificant in both analyses, $F_1(1, 11)$ and $F_2(1, 166) < 1$, as was the Task × UP Location interaction, $F_1(1, 11) = 1.51$, $MS_e = 3.97$, $p = .24$, $F_2(1, 166) = 2.06$, $MS_e = 0.42$, $p = .15$. The latter results are important, for they mean that the effects of UP location observed at the level of RTs are not produced by a speed–accuracy trade-off.

Table 1
Experiment 1: Gender Classification and Pronunciation of Braille Words: Mean Time to Uniqueness Point (UP), Mean Reaction Time (RT) From Word Onset, and Percentage Errors

Measure	Gender classification: Early	Late	Difference[a]	Pronunciation: Early	Late	Difference[a]
Time to UP	878	2,063	1,185	921	2,130	1,209
RT	2,854	3,063	209	2,336	2,453	117
Percentage errors	8.13	7.94	−0.19	4.76	5.95	1.19

Note. All times are in milliseconds.
[a] The difference between items with early and late UP.

The preceding analyses were based on the dichotomization of the material into the two categories: early versus late UP. With this procedure, no account is taken of the probable effect on RT of the variation, between items within each category, of the time taken to reach the UP. A more detailed analysis can be obtained by measuring the correlation between RT and time necessary to reach the UP. The approach was used in our earlier study with spoken words (Radeau et al., 1989), in which regression coefficients of RT on time of occurrence of the UP phoneme were computed. In the case of braille, however, the time at which the UP is reached, which depends on individual scanning speed, is itself a dependent variable. Consequently, regression coefficients would have allowed no inference (Hays, 1969), and correlation coefficients were used instead. Product-moment *r*s between RT and time to UP for individual words were computed separately for each subject and each task. Coefficients ranging from .18 to .52 (m = .37) for gender classification and from 0 to .57 (m = .33) for pronunciation were obtained. The hypothesis of zero mean correlation can be rejected by simple sign-tests (12 of 12, p = .00025, for gender classification and 11 of 11, p = .0005, for pronunciation). In a two-variable (subjects and tasks) ANOVA, the effect of task was nonsignificant, $F(1, 11) < 1$. The results of the correlation analysis thus confirm through a different procedure first the dependence of RT on time necessary to reach the UP and also the similarity of the effects in the two tasks.

The question was asked in the Introduction whether scanning speed was affected by the fact of reaching the UP. The recordings in principle allowed computation of overall scanning speed for the pre- and post-UP regions of the words, at least for early UP words, for in many late UP items, the post-UP region was too short to allow a reasonable measurement. However, the computation was not possible for those trials on which—partially as a result of the recording problem mentioned in the *Method* section—the time at which the end of the word was reached was not registered. Mean scanning times per cell for each task and each word region (pre- or post-UP) were nevertheless calculated for each subject on the basis of the usable trials. They were slightly shorter for pre-UP than for post-UP regions: 215 against 238 ms per cell in gender classification and 230 against 255 ms in pronunciation. In an ANOVA by subjects, the effect of region failed to reach significance, $F(1, 11) = 4.68$, $MS_e = 1,383$, $p = .06$, and the UP Location × Task interaction was nonsignificant, $F(1, 11) < 1$. There seemed to be no point in running an analysis by items, given the high variability caused by missing data at the level of means calculated on a maximum of six individual values each. Thus, the present data suggest that scanning pattern is affected little by UP location.

Discussion

In both tasks, response latency was affected by the location of the UP. The effect was demonstrated at two levels. First, mean RT to words with late UP was slower than to words with early UP. Second, there were consistently positive correlations between time to reach the UP and RT. The faster responses to early UP words were not accompanied by an increase in error rate and thus cannot be attributed to a speed–accuracy trade-off. These results support the notion that in braille reading, lexical selection occurs on-line to at least some extent. One can of course ask whether the efficiency of on-line processing is comparable for braille words and for spoken words. That question is considered in Experiment 2.

The effect of UP location was present even in the pronunciation task. As explained in the Introduction, in the framework of the classical dual-route conception, this finding would imply that braille word pronunciation is based at least partially on addressed whole-word phonological information. For the pronunciation of printed material, arguments for the use of lexical information have traditionally been based on the effects of lexicality and of usage frequency on naming RT (Forster & Chambers, 1973; Frost, Katz, & Bentin, 1987). In the cases of braille and of spoken words, effects of UP location can be used to the same purpose. An interesting question for future research is whether effects of UP location appear in exactly the same conditions as those of frequency and of lexicality.

Although the mean effect of UP location appeared to be greater in gender classification than in pronunciation, the interaction between task and UP location was significant neither by subjects nor by items, and correlations between mean time to UP per item and RT also did not differ between the tasks. The only aspect of the results supporting the notion of a smaller effect of UP location in pronunciation is that the effect was significant by subjects only for pronunciation, whereas it was significant both by subjects and by items for gender classification. Further experiments are needed to explore possible differences between extent of on-line processing in the two tasks.

Regarding scanning speed, the present data revealed no difference related to UP location. They, however, allowed only computation of mean scanning speed for the whole pre- and post-UP regions of each word, and these computations were strongly affected by the occurrence of missing data. More detailed analyses are necessary to reach a conclusion regarding possible changes in exploration behavior correlated with evolution of the cohort of possible interpretations. These analyses are carried out in Experiment 3.

Experiment 2: Gender Classification With Braille Versus Spoken Words

The preceding experiment has shown that recognition RT is affected by the location of the UP in braille words. This result supports the notion of on-line lexical access in braille word recognition. In the present experiment, we shall try to go beyond that conclusion and examine whether on-line processing is as efficient in braille reading as in listening.

That kind of comparison meets, however, with several difficulties. First, the units available to measure the location of the UP are not the same in the two modalities: There is for instance no one-to-one mapping between phonemes and letters. A common measure can be provided by the time at which the UP is reached, but a second type of difficulty then results from the differences in input timing between the two modalities. For braille, the input rate depends on individual scanning speed, which varies from reader to reader, whereas the speed of delivery of spoken data is the same for all subjects. On the other hand, the scanning speed of even the most fluent braille readers is much slower than normal speech delivery. As a consequence, the absolute difference in RT to two groups of words with early and late UP, respectively, is not a good criterion for comparing on-line processing in the two modalities. The ratio of the RT difference to the difference between the mean times at which the UP is reached offers a better basis. This ratio, which we call *relative gain,* can be considered as providing a measure of the efficiency of on-line processing.

The effect of UP location observed in Experiment 1 for gender classification translates into a relative gain of .17 (a mean 208-ms gain in RT for a 1,185-ms difference in time to UP). In our previous study of gender classification of spoken words (Radeau et al., 1989), in two conditions with mixed order of presentation of the two categories of UPs, mean relative gains were .37 (Condition 2) and .31 (Condition 3.1). These comparisons suggested that UP effects might be somewhat stronger for speech than for braille. They were, however, not completely convincing, because the source of difference we were interested in, that between braille and spoken-word recognition, was confounded with differences in subject populations (blind vs. sighted) and in materials (different sets of words). In Experiment 2, the same subjects, blind readers of braille, performed gender classification of the same word sets, presented auditorily in one condition and in braille in the other. In our earlier study of gender classification of spoken words (Radeau et al., 1989), one condition involved two successive presentations of the material (identical to the present one). Although mean RT was, as one would expect, shorter for the second presentation, the effect of UP location was unaffected by repetition. The finding seemed to authorize the use of repeated presentation in the present experiment.

Method

Subjects. Ten of the 12 subjects tested in Experiment 1, 5 women and 5 men, aged 22 to 74 years, participated in one session each.

Materials. The materials consisted of the two sets of 34 trisyllabic nouns already used in the previous study with spoken words (Radeau et al., 1989; the material is listed in that article). Half the words of each set were feminine and half were masculine. The UP (substantive UP) fell on the average on the 3.85th phoneme (range = 3–5) for the early UP set and on the 6.28th phoneme (range = 5–8) for the late UP set. None of the items had a gender UP earlier than the substantive UP. The two sets were matched as to phoneme length (7.00 on the average in the early UP set and 7.08 in the late UP set) and usage frequency (respective means of 6.82 occurrences per million, range = 0.2–46.6; and 9.22, range = 0–61.4). The two sets were comparable as to orthographic form also: Mean letter length was 8.94 (range = 7–12) in the early UP set and 9.00 (range = 8–11) in the late UP set. The average (substantive) UP was on the 4.26th letter in the early set and on the 7.53rd in the late set. The words of the two sets were presented in mixed order in the two conditions.

For the auditory condition, the words were pronounced by a male native speaker of French. They were recorded on one track of the tape, and a 50-ms pulse, inaudible to the subject, was positioned on the other track, near the beginning of each word. The temporal location of word onset, UP, and word offset relative to the pulse were measured on spectrograms. Details of these procedures are given in Radeau et al. (1989). The interval between word onset and UP was on the average 398 ms (range = 243–553) in the early UP set and 757 ms (range = 467–1,169) in the late UP set.

In the study by Radeau et al. (1989), for which the material had originally been prepared, substantive UPs were used instead of the lexical UPs used in Experiment 1. In the braille condition of the present experiment, the location of the UP had to be specified in the program, to allow the automatic registration of the time at which that point was reached by the reading finger. It was thus not possible to reanalyze the data on the basis of lexical UPs. The problem, however, is not too serious, for in the Radeau et al. study, in which the two types of UPs were available, they produced virtually the same profiles of results. As a matter of fact, the two UPs were found to correlate at .82.

Apparatus. For the braille condition, the experimental situation was the same as in Experiment 1. For the auditory condition, it was the same as in our previous study with spoken words, except for the substitution of a vocal response for the keypressing response. Words were delivered through Beyer DT 202 headphones from a Revox A77 tape recorder connected to an Apple IIe computer. The pulse on the second track of the tape triggered a clock card.

Procedure. Subjects each worked for 32 practice trials and two blocks of 34 experimental trials in each of the two conditions. The same words were presented in the two conditions, in two different random orders. The order of the conditions was counterbalanced across subjects.

In the braille condition, the procedure was identical to that of gender classification of Experiment 1. In the speech condition, the words were delivered at a constant rate of about one every 6 s, and subjects spoke their decision ("feminin" or "masculin") as soon as possible into the microphone. No feedback was provided.

Results

The criteria for the exclusion of trials from the analyses were the same as in Experiment 1. Percentage out of range

RTs were 5.00 for braille and 7.34 for speech. For braille, unusable trials (regressions plus recording failures) amounted to 3.52%, a value much lower than in Experiment 1 (in which it was 7.73% for gender classification).

Mean RTs per modality and UP location are given in Table 2. In each modality, RTs to words with early UP are shorter than those to words with late UP. The difference was tested for each modality both by subjects, using a two-variable (UP location and subject) ANOVA, and by items, using a single variable (UP location and item) design. The effect of UP location is significant in both analyses, for both braille, $F_1(1, 9) = 9.57$, $MS_e = 6{,}980$, $p < .025$, $F_2(1, 66) = 4.85$, $MS_e = 47{,}116$, $p < .05$, and speech, $F_1(1, 9) = 47.7$, $MS_e = 971.1$, $p < .001$, $F_2(1, 66) = 5.16$, $MS_e = 25{,}783$, $p < .05$.

Numbers of errors were also analyzed separately for the two modalities, following the two designs used for RTs. The main effect of UP location was nonsignificant, both by subjects and by items, for braille, $F_1(1, 9)$ and $F_2(1, 66) < 1$, and for speech, $F_1(1, 9) = 3.27$, $MS_e = 0.24$, $p = .11$, $F_2(1, 166) < 1$. Thus, none of the effects observed at the level of RTs could have been due to speed–accuracy trade-off. RT was thus affected by UP location in both the present modalities, as could be predicted for speech from the previous study and for braille from Experiment 1.

The times from word onset to UP, which appear also in Table 2, confirm that the speed of braille scanning is slower than the rate of delivery of speech. Mean braille scanning speed was as a matter of fact less than half the rate of speech delivery. Thus, as explained in the Introduction, the differences between the absolute RT values obtained for early versus late UP words cannot be used for intermodality comparisons. Hence, no overall ANOVA was performed on mean RTs.

For comparing effects of UP location obtained in the two modalities, relative gain measures were used. The means of individual relative gains are .16 for braille and .18 for speech. By ANOVA applied to individual relative gains for speech and braille, respectively, the effect of modality was nonsignificant, $F(1, 9) < 1$.

As in Experiment 1, product-moment correlations between RT and time to UP were calculated for each subject and each modality. Values ranging from .15 to .52 ($M = .29$) were obtained for spoken words and values ranging from .12 to .61 ($M = .35$) were obtained for braille words. Thus, the hypothesis of zero correlation can be rejected for both modalities at $p = .00025$ by simple sign-tests. The coefficients were submitted to a two-variable ANOVA (subjects and modality). The effect of modality was nonsignificant, $F(1, 9) = 1.17$, $MS_e = 0.015$, $p = .31$.

Discussion

When it is assessed on the same blind subjects, the efficiency of on-line processing, measured by the relative gain ratio, is as great for braille as for spoken words. The conclusion is supported also by the results of the correlation analysis, which also revealed no difference between the two modalities.

The mean relative gain value obtained for spoken words in the present experiment (.18) was smaller than those (.37 and .31) obtained with the same words and the same task in the previous study (Radeau et al., 1989). The discrepancy must be linked to some difference between the populations of subjects tested in the two studies. The critical factor is not linked to age: Mean relative gain for spoken words is .17 for the 6 subjects younger than 50 and .19 for the 4 older ones. (Interestingly, the difference is much larger for braille words, .09 against .27, suggesting the existence of a superiority specific to braille of our older subjects on their younger colleagues.) The most likely explanation for the generally lower relative gains observed in the blind subjects is presumably to be found in the different amounts of linguistic experience of the blind and the sighted.

Experiment 3: Gender Classification of Braille Words, Effects of Uniqueness Point Location, and Frequency of Occurrence on RT and Scanning Speed

The exploration carried out in Experiment 1 suggested that scanning speed was not strongly affected by the fact of reaching the UP. However, the recordings were affected by missing data and, on the other hand, they allowed only computation of mean scanning speed across the whole pre-UP and the whole post-UP region of each word, respectively. In the present experiment, the location of the reading finger was registered for every cycle of the video system, allowing the detailed analysis of finger progression across each word. To make it possible to average scanning speed over items, words of two letter lengths only (seven and nine) were used, and for each length, the UP was situated either exactly on the middle or exactly on the final letter.

Although the design of the experiment was strongly constrained by the requirements of the scanning-speed study, it offered the opportunity to check on the results obtained

Table 2
Experiment 2: Gender Classification of Braille and Spoken Words: Mean Time to Uniqueness Point (UP), Mean Reaction Time (RT) From Word Onset, and Percentage Errors

Measure	Braille word			Spoken word		
	Early	Late	Difference[a]	Early	Late	Difference[a]
Time to UP	888	1,592	704	397	759	362
RT	2,562	2,677	115	1,210	1,275	65
Percentage errors	4.12	4.41	0.29	3.53	2.65	−0.88

Note. All times are in milliseconds.
[a] The difference between items with early and late UP.

previously at the level of RT and to extend them. One useful extension appeared to be a manipulation of usage frequency. Frequency is one of the most extensively studied factors in research on written-word recognition. Although the site of the effect has been the object of much recent controversy (Balota & Chumbley, 1985; Grainger, 1990; Monsell, Doyle, & Haggard, 1989), its robustness is in no doubt. The evidence is much less abundant for other modalities. Only a few years ago, Bradley and Forster (1987) suggested that frequency effects might be smaller, if not nonexistent, for spoken words. Effects of frequency on word decisions in lexical decision with speech have, however, been reported by Taft and Hambly (1986) and more recently by Connine, Mullennix, Shernoff, and Yelen (1990) and by Marslen-Wilson (1990). It was thus felt worthwhile to examine the effects of usage frequency on braille word recognition.

Method

Subjects. Eight skilled blind braille readers, 3 women and 5 men, aged 22 to 73 years, participated in one session each.

Materials. Four sets of 36 nouns each (Appendix B), resulting from the combination of two lengths (seven or nine letters) and two locations of lexical UP, medial (UP on the fourth letter in seven-letter words and on the fifth letter in nine-letter words) and final (last letter), were selected from BRULEX. Half the nouns in each set were feminine and half were masculine. Half the items were of low-usage frequency (M = 0.70 occurrences per million; range = 0–1.48) and half of higher usage frequency (M = 15.9 occurrences, range = 3.5–74.3). An additional set of 18 nouns, eight letters long, with medial or final UP, were used for practice.

Apparatus. Two additions were made to the equipment. First, a toggle switch, which could be moved toward or away from the body, was provided for responding. The switch could be positioned for use with either hand. On the other hand, the computer (Apple II GS) now registered the horizontal location of each successive flash in the diode, making a cycle-by-cycle reconstruction of the movement of the finger possible for each individual trial. Recording went on for 2 s after the response, thus eliminating the danger that relevant events would go unrecorded.

Procedure. The procedure for each trial was the same as for gender classification of braille words in Experiment 1, except for the substitution of a manual response on the toggle switch with the nonreading hand for the vocal response. Each subject worked first on the 18 practice items and then on the four sets of experimental items. Each set was presented as two successive blocks of 18 items. The order of presentation of the sets was counterbalanced across subjects.

Results

The criteria for discarding trials were the same as in the other two experiments. However, it was now possible to measure separately the incidence of the different causes of elimination. The relevant figures appear in Table 3. The important point is that the percentage of trials on which the passage of the UP is missing, possibly because scanning was interrupted, is very low (<1%). On the other hand, the total incidence of discarded trials is practically identical for medial and final UP words. Differences at that level could thus not have been at the origin of effects observed in RTs.

Mean RTs are shown in Table 4. Effects of UP location are apparent, but they are stronger for high-frequency than for low-frequency words. These data were submitted to two ANOVAs: one based on mean RTs per subject, UP location, length, and frequency and the other on mean RTs per item across subjects. The main effect of frequency was significant by subjects, $F_1(1, 7) = 29.6$, $MS_e = 19{,}719$, $p < .001$, and by items, $F_2(1, 136) = 20.4$, $MS_e = 53{,}112$, $p < .001$. The effect of length was also significant in both analyses, $F_1(1, 7) = 10.1$, $MS_e = 78{,}791$, $p < .025$, $F_2(1, 136) = 23.0$, $MS_e = 53{,}112$, $p < .001$. The effect of UP location was significant by items, $F_2(1, 136) = 4.89$, $MS_e = 53{,}112$, $p < .05$, and marginally so by subjects, $F_1(1, 7) = 5.46$, $MS_e = 15{,}304$, $p < .06$. The interaction between UP location and frequency was significant by subjects, $F_1(1, 7) = 9.55$, $MS_e = 3{,}372$, $p < .025$, but not by items, $F_2(1, 136) < 1$. In separate analyses, the effect of UP location was significant both by subjects, $F_1(1, 7) = 11.0$, $MS_e = 9{,}975$, $p < .025$, and by items, $F_2(1, 68) = 3.97$, $MS_e = 48{,}449$, $p < .05$, for high-frequency words but nonsignificant neither by subjects, $F_1(1, 7) < 1$, nor by items, $F_2(1, 68) = 1.37$, $MS_e = 57{,}775$, $p = .25$, for low-frequency ones.

Mean percentage errors were analyzed following the same two designs as RTs. None of the three main effects, length, $F_1(1, 7) = 4.33$, $MS_e = 1.17$, $p = .08$, $F_2(1, 136) = 2.67$, $MS_e = 0.84$, $p = .11$; frequency, $F_1(1, 7)$ and $F_2(1, 136) < 1$; and UP location, $F_1(1, 7) = 1.87$, $MS_e = 0.54$, $p = .22$, $F_2(1, 136) < 1$, were significant. The interaction between UP location and length was significant by subjects, $F_1(1, 7) = 15.75$, $MS_e = 0.14$, $p < .01$, but not by items, $F_2(1, 136) = 1.19$, $MS_e = 0.84$, $p = .28$. All other interactions, UP Location × Frequency, $F_1(1, 7) = 2.01$, $MS_e = 1.53$, $p = .20$, $F_2(1, 136) = 1.62$, $MS_e = 0.84$, $p = .21$; Length × Frequency, $F_1(1, 7)$ and $F_2(1, 136) < 1$; and the three-way interaction UP Location × Length × Frequency, $F_1(1, 7)$ and $F_2(1, 136) < 1$, were nonsignificant in both analyses. It is clear that none of the effects of interest at the level of RTs can be explained through a speed–accuracy trade-off.

Table 5 shows mean scanning times per letter before and after the UP for items with medial UP, together with mean overall scanning time for items with final UP. Mean pre-UP times were slightly shorter than post-UP times and comparable to mean times for final UP words (which, of course, are also pre-UP times). The data for medial UP words were submitted to two ANOVAs, one based on mean scanning time per subject for each region (pre- vs. post-UP), frequency, and length, and the other on mean scanning time per item. The effect of region was nonsignificant by subjects, $F_1(1, 7) = 1.97$, $MS_e = 8{,}524$, $p = .21$, but highly significant by items, $F_2(1, 68) = 77.31$, $MS_e = 527.6$, $p < .001$. This pattern means that some of the present subjects slowed down after the UP with sufficient consistency to affect mean speeds in the two regions systematically across the items, but that this pattern of scanning was not general. Inspection of the data showed that 1 of the 8 subjects was largely responsible for the effect observed at the level of means. The effect of length was significant in both analyses, $F_1(1, 7) = 10.98$, $MS_e = 3{,}335$, $p < .025$, $F_2(1, 68) = 6.31$, $MS_e = 1{,}282$, $p < .025$: overall scanning speed was slightly (15 ms by cell) but consistently faster for the longer words. The small effect of frequency is significant by subjects, $F_1(1, 7) = 7.14$, $MS_e = 26.5$, $p < .05$, but not by items, $F_2(1, 68) = 1.08$, $MS_e = 1{,}282$, $p = .30$. The

Table 3
Experiment 3: Gender Classification of Braille Words: Percentage Discarded Trials

Category	UP Medial	UP Final	UP Total
Incorrect response	5.40	5.90	5.65
Regression	6.25	6.60	6.42
Out of range RT	6.25	5.34	5.82
Equipment failure or experimenter mistake	1.74	1.74	1.74
Data regarding passage of UP missing	1.22	0.69	0.95
Total	20.86	20.27	20.58

Note. UP = uniqueness point; RT = reaction time.

interaction between region and length was significant by subjects, $F_1(1, 7) = 5.69$, $MS_e = 72.0$, $p < .05$, but not by items, $F_2(1, 68) = 2.72$, $MS_e = 527.6$, $p = .10$. No other interaction reached significance in either analysis.

Actograms representing finger location on successive cycles of each trial were plotted and examined by eye for deviations from linearity. One subject appeared systematically to slow down toward the end of each word. He is of course the subject whose deviant scanning behavior was mentioned in the previous paragraph. The typical slowing down appeared as well for final UP words as for medial UP ones and is thus not related to the existence of lexical neighbors. No systematic deviation from linearity was evident in any of the other subjects. As an example of the kind of data obtained, Figure 1 shows the mean actograms of 1 typical subject for medial and final UP high-frequency nine-letter words, respectively. The white line represents the mean location for each successive cycle and the black area corresponds to the 2-standard deviation interval. Finger scanning proceeds in the same linear fashion after the UP as before it.

Discussion

Regarding the question asked in the Introduction to the present experiment, a clear effect of usage frequency on the latency of gender-classification responses to braille words was apparent. The overall difference between low-frequency and high-frequency words, 190 ms, is a substantial one. That result would have posed problems to the original cohort model, which (as noted in the Introduction) had no way of accommodating effects of word frequency. There is no problem for activation models. A simple possibility is that the increase in activation of each lexical unit produced by the same amount of matching evidence is a function of the frequency of the unit. This kind of relation is, for instance, a prediction of many connectionist models (e.g., Brown, 1987).

On the other hand, the effect of UP location was significant, both by subjects and by items, for high-frequency words and by neither criterion for low-frequency ones. The possible implications of these results, which had not been predicted, are examined in the General Discussion.

The comparison of mean scanning speed before and after the UP has produced a mainly negative conclusion. The small slowing down of scanning in the post-UP region observed at the level of mean speed appeared to result from the unusual scanning pattern of 1 subject. For that reason, the effect was significant by items only and not by subjects. As was suggested already by the recordings analyzed in Experiment 1, there is no systematic effect on scanning speed of the fact of reaching the UP. The inspection of individual actograms confirmed

Table 4
Experiment 3: Gender Classification of Braille Words: Mean Time to Uniqueness Point (UP), Mean Reaction Time (RT) From Word Onset, and Percentage Errors

Measure	Low frequency Medial	Low frequency Final	Low frequency Difference[a]	High frequency Medial	High frequency Final	High frequency Difference[a]
Seven-letter words						
Time to UP	694	1,371	677	679	1,411	732
RT	2,122	2,140	18	1,868	2,023	155
Percentage errors	9.0	4.9	−4.1	3.5	6.2	2.7
Nine-letter words						
Time to UP	861	1,846	985	891	1,746	855
RT	2,340	2,378	38	2,124	2,203	79
Percentage errors	5.6	4.9	−.7	3.5	7.6	4.1

Note. All times are in milliseconds.
[a] The difference between items with medial and final UP.

Table 5
Experiment 3: Gender Classification of Braille Words: Mean Scanning Time per Character Before and After Uniqueness Point (UP)

Region	Low frequency			High frequency		
	Before	After	Difference[a]	Before	After	Difference[a]
			Seven-letter words			
Medial UP	232	268	36	226	265	39
Final UP	229	—	—	235	—	—
			Nine-letter words			
Medial UP	215	253	38	223	239	16
Final UP	231	—	—	218	—	—

Note. All times are in milliseconds.
[a] The difference between before and after measurements.

the results regarding overall speed and in addition did not reveal systematic deviations from linearity.

General Discussion

The main question asked in the present study was whether the kind of evidence of on-line processing found earlier with speech material could be obtained also with braille. As in our previous work with spoken words (Radeau et al., 1989), the criterion for the occurrence of on-line processing was the effect on word-recognition RT, measured from word onset, of the time at which the UP is reached, and the main task was gender classification. The effect of the location of the UP was examined in the three experiments through the comparison of mean RTs to words with early and with late UPs, respectively, and in Experiments 1 and 2 also through computation of correlations between RT and time necessary to reach the UP. Both measures provided significant effects of UP location. In Experiment 3, however, the effect was obtained only for high-frequency words.

These results support the notion that in reading braille, like in attending to speech, the process of selecting a lexical interpretation for each word can occur on-line, in step with the acquisition of the data. On-line processing would thus not be specific to the speech medium.

To go one step further, a quantitative comparison of the effects of UP location with speech and with braille, respectively, was attempted in Experiment 2. To avoid the problems resulting from the differences in input timing between the two modalities, the RT difference between words with late and with early UP was related to the difference between times necessary to reach the UP. By this relative gain measure, which provides a measure of the efficiency of on-line processing, no difference was obtained between the modalities. It would thus seem that the selection process follows comparable time courses in braille reading and in listening.

Another word-recognition task, pronunciation, was also used in Experiment 1, to allow some assessment of the generality of the effect obtained with gender classification. The effect of UP location was obtained at the level of the correlation between RT and time to UP, and at that of differences between mean RTs to words with early and late UPs, but here only by subjects and not by items. The effect on mean RT was somewhat smaller for pronunciation than for gender classification, but the difference tested on the Task × UP Location interaction was nonsignificant. Although these data are not as clear as one would have liked, they nevertheless suggest that on-line processing does not occur only in gender classification. To further establish the generality of the effect, more systematic comparisons, involving a wider sample of

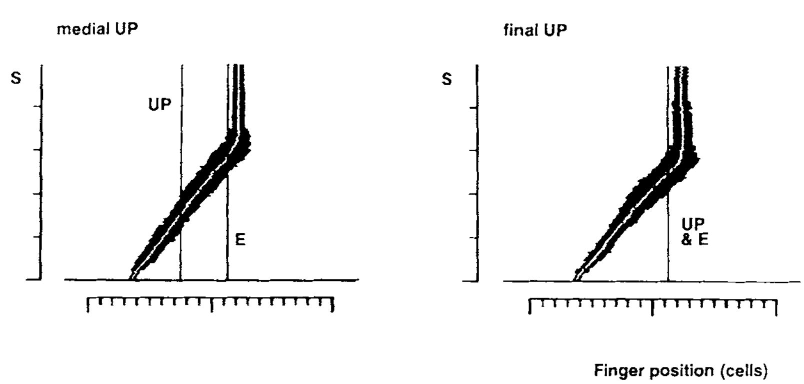

Figure 1. Experiment 3: Mean actograms of 1 typical subject, showing mean lateral position (white line) of reading finger on successive cycles of the video recording, with 2-standard deviation interval (black area). (High-frequency nine-letter words. Abscissa = lateral position of reading finger, in braille cells; ordinate = time in seconds; UP = uniqueness point; E = end of word.)

word-recognition tasks (e.g., lexical-decision and semantic-classification), are necessary.

That on-line processing is observed for the recognition of braille words as well as for spoken words opens the possibility that it could occur for any sequential linguistic input. Bradley and Forster (1987) described a situation, studied in their laboratory by Blosfelds (1981), in which the letters of a word are displayed in incremental fashion on a screen, successive frames containing the first letter, the two first letters, and so on. They mentioned that the subjects adapt easily to this incremental presentation, but that they find a strictly sequential situation, in which each letter is erased at the time the next one is presented, very difficult. An exploratory experiment has been carried out in this laboratory in which the subjects performed gender classification on words presented in the incremental visual mode (Radeau, Morais, Mousty, Saerens, & Bertelson, in press). The words were those used previously to study the effect of UP location on the recognition of spoken words (Radeau et al., 1989; Experiment 2 in this study), and the rate of incrementation was set for each word at a rate such that the time necessary to present all the letters was equal to the duration of the corresponding auditory presentation. The difference in mean RT between words with late and early UP locations, respectively, was 109 ms, a value close to those that have been obtained with auditory presentations to sighted subjects (133 and 110 ms in Experiment 1, Condition 1, and Experiment 2, Condition 1 of Radeau et al.). That result certainly concurs with those from the present study in supporting the notion that input sequentiality is an essential condition for the occurrence of on-line selection. Before the conclusion can be accepted in its generality, one should of course extend the finding to a larger range of tasks. One should also understand why, as mentioned by Bradley and Forster (1987), purely sequential visual presentations are difficult to deal with.

A result that deserves special consideration is the interaction between UP location and usage frequency obtained in Experiment 3: The effect of UP location is stronger for high-frequency than for low-frequency words. As a matter of fact the effect was significant, both by subjects and by items, for high-frequency words and not for low-frequency ones. The interaction itself was, however, significant only by subjects, not by items. Further work is thus necessary to establish the reliability and the generality of the result. It would in particular be important to know whether the pattern is obtained for any word-recognition task, or whether it is specific to gender classification. One possible implication of the result would be that the on-line selection process does not take into consideration the whole vocabulary, but samples on each trial a subset of frequent items, the chance of an item to be taken into consideration depending on its usage frequency. This notion, according to which only the more frequent items are processed on-line, implies of course that another, off-line, procedure must be available for the classification of those words that were not considered in the on-line procedure. Further speculation about these possibilities should wait until *the phenomenon* is better documented.

Throughout the present study, the effect of UP location on word-recognition RT was used as a criterion of on-line processing. To that choice, one might object that the effect of UP location was a specific prediction of the original all-or-none cohort model, for which a word was identified exactly at the UP, and that this model has now been generally abandoned. Activation models as a matter of fact predict that, because candidate words are no longer eliminated as soon as a mismatch with incoming evidence is detected, processing will generally have to go on past the UP. There are, however, good reasons to expect the UP still to be an important index of the evolution of the neighborhood of the target word. For instance, simulations carried out by Peeters, Frauenfelder, and Wittenburg (1989) with TRACE show an important effect of UP location on the build up of activation of the target word. On the other hand, it is clear that the UP, which reflects only that at a particular point the target has at least one neighbor or none, provides a very impoverished picture of the neighborhood pattern. The results of current work on neighborhood effects (e.g., Grainger, 1990) show that a more satisfactory description should, in addition, take into account such variables as the relative frequency of the target and its neighbors.

The question of the effect of the UP on scanning speed was considered in Experiments 1 and 3. Neither the comparisons of mean scanning speed over pre- and post-UP regions of the word nor the cycle-by-cycle analyses of finger position carried out in Experiment 3 revealed any change connected in a systematic way with the passage of the reading finger past the UP. These findings add to a corpus of data showing that the speed of first-pass scanning is little sensitive to local changes in processing load. In another study (Bertelson & Mousty, 1990; Mousty & Bertelson, in press), we found that garden path effects created by structural ambiguities manifest themselves in the form of increased incidence of regressions and not through changes in first-pass scanning. We suggested that because of the rapid adaptation of cutaneous perception (Geldard, 1972), a more or less constant speed of scanning is necessary for efficient signal acquisition, hence regressions become the major repair device available to the braille reader.

The present data are certainly compatible with the notion of a tendency to maintain a steady scanning rate. By themselves, they bring, however, no important new support, because existing models of on-line selection provided no strong predictions regarding the changes an immediately adjustable scanning system would produce on reaching the UP. For the original cohort model, the word was identified on the basis of the evidence collected before the UP. It followed that no scanning of post-UP text was necessary, but that predicted no particular pattern of movement: Acceleration, continuation at the same speed, slowing down, or stopping were equally possible. Activation models, on the other hand, share the notion that some processing must go on past the UP. Stopping, or some important slowing down of scanning past the UP, would have been inconsistent with that hypothesis. The present finding of no difference between pre- and post-UP scanning speed does not provide further constraints on models of scanning control.

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(Appendixes follow on next page)

Appendix A

Words Used in Experiment 1

The underlined position corresponds to the uniqueness point (UP).

Early UP Words		Late UP Words	
mayonnaise	ébullition	individu_	classeur
salsifis	hanneton	carrosse_	automate
horoscope	lendemain	langouste	groseille
bicarbonate	vilebrequin	cabriolet	aggloméré
suprématie	jaquette	attribution	coopération
genièvre	chéquier	périphérie	bouilloire
rhubarbe	diarrhée	dérivatif	indicatif
urticaire	kangourou	autonomie	mandarine
subterfuge	labyrinthe	diphtérie	nécessité
amygdale	pénombre	internat_	orphelinat
précurseur	sagittaire	dispense_	saucisse
biographie	anthologie	embauche_	teinture_
avènement	déodorant	comparatif	pensionnat
arbalète	jacinthe	ivrognerie	orthopédie
percolateur	funiculaire	muscadet	handicap_
élocution	armistice	retouche_	collecte_
progéniture	malédiction	théologien	astrologue
dimanche	toboggan	journalisme	bafouillage
guirlande	rébellion	carburant	appendice
sorcellerie	culpabilité	malpropreté	camionnette
ménopause	randonnée	cambriolage	fédéralisme
événement	belvédère	dispositif	symbolisme
raquette	kermesse	paillasson	télégraphe
récépissé	anagramme	publicité	apparence
taffetas	apéritif	usufruit_	synonyme
vivisection	arrestation	framboise	particule
aspérité	araignée	déterminant	congélateur
mocassin	breuvage	fantaisie	étrangeté
euthanasie	connivence	contracture	sollicitude
métabolisme	soulèvement	argument_	chaudron_
myosotis	achèvement	descendance	toxicomanie
prélèvement	coefficient	affluent	ébéniste_
pacotille	amabilité	clarinette	commande_
mappemonde	bicyclette	différend	cornichon
braguette	écrevisse	libéralisme	championnat
embonpoint	corbillard	orfèvrerie	oreillette
macchabée	batracien	moutarde	zoologie
aubépine	omoplate	spécialité	chrétienté
ingrédient	enlèvement	diminutif	escalavage
ingestion	dimension	récidive_	matraque_
subdivision	diapositive	sacrifice	saxophone
pavillon	nénuphar	carabine	enseigne_

Appendix B

Words Used in Experiment 3

The underlined position corresponds to the uniqueness point (UP).

Seven-Letter Words: *Medial UP*	Seven-Letter Words: *Final UP*	Nine-Letter Words: *Medial UP*	Nine-Letter Words: *Final UP*
tunique	symbole	lassitude	saxophone
glucose	coureur	sparadrap	particule
bégonia	capuche	cabillaud	collectif
puberté	ellipse	nervosité	revendeur
rivière	relique	pourboire	diphtérie
obésité	récital	glossaire	éclaircie
arbuste	cuisson	sinuosité	grammaire
gorille	clocher	pellicule	arquebuse
daurade	maillon	déception	sacrifice
ardoise	créance	dividende	mandoline
bosquet	taverne	balluchon	esclavage
acolyte	vanneur	girouette	bouquetin
bonjour	fanfare	forestier	dérivatif
clenche	microbe	proximité	ambulance
dortoir	réactif	dénuement	miniature
pelisse	charité	avalanche	accusatif
falaise	névrose	perfusion	mandarine
hamster	donneur	hortensia	pantoufle
juillet	théorie	sarriette	mirabelle
mécénat	échasse	obscénité	trompette
antenne	maillot	curiosité	franchise
truelle	parenté	manuscrit	raconteur
ouragan	ablatif	firmament	volailler
horaire	période	glycérine	profiteur
literie	ouvreur	bouvreuil	publicité
calumet	poivron	mollusque	cordonnet
loterie	beignet	marmelade	moustique
auspice	guitare	rossignol	monarchie
nacelle	cantate	gentleman	cascadeur
gamelle	monstre	récession	fantaisie
gouffre	papille	répulsion	moustache
liaison	bottine	vainqueur	pénitence
papyrus	granulé	calebasse	cochonnet
brugnon	béguine	manganèse	métropole
pitance	chignon	villosité	loqueteux
lucarne	serveur	crocodile	follicule

Received May 20, 1991
Revision received September 9, 1991
Accepted September 10, 1991 ■