# Keeping an Eye on the Text: Some Aspects of Eye Movements and Discourse Processing

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## Abstract
Differences in processing syntactical and lexical information and evidence that the former helps to structure the latter in central cognitive processes are related to a theory of discourse processing. An eye movement experiment shows that word categories important for the construction of propositions of the text tend to be fixated longer than words not included in propositions. Different independent variables on fixation time are related to the different stages of a human information-processing model.

## Background
A commonly used model of discourse processing, the Human Information Processing System (HIPS) (cf. Rayner and Pollatsek 1989, Van Dijk and Kintsch 1983), distinguishes three stages in information processing

I. Sensory Store: temporary memory store which processes physically available information from the stimulus. This store is highly transient.
II. Short Term Memory: central executive system that functions as a short-circuit processor with limited storage. Its main task is the organization of information.
III. Long Term Memory: highly organized and permanent memory store.

These three stages are not clearly separated, neither are they positioned in particular parts of the brain. They have to be seen as functions of the entire brain, although it is possible to locate globally the main parts of the brain where these functions are operative. Furthermore, it becomes clear that information processing is a parallel rather than a sequential process (cf. Rumelhart and McClelland 1986). For reasons of simplicity, a sequence of more or less independent stages is assumed. A model of parallel distributed processing can be integrated in this model later.

### I. Sensory Store
Physical information (position of the word on the screen, word length) is processed in the Sensory Store. Only a literal copy of the input is stored. Information in this store is therefore precategorical (cf. Rayner and Pollatsek 1989).
The evidence that word length effect appears before any phonological processing (Baddeley, Lewis, Vallar 1984) and the impression that phonological processing takes place before syntactic and semantic processing (cf. Levelt, Schriefers, Vorberg, Meyer, Pechmann, Havinga 1991; Shillcock and Bard 1993), places word length effect (as example of physical stimuli) at an early stage of the reading process.

### II. Short Term Memory
In processing language, we use two kinds of representations: a linguistic representation encodes the surface structure of the information and a cognitive representation encodes the semantic information. Linguistic information is used for constructing the mental (cognitive) representation (Johnson-Laird 1983, Garnham and Oakhill 1992).

There is lots of good evidence for the distinction between a linguistic and a cognitive representation:

- Neuroscientific studies show that syntactic and semantic processing are indeed distinct operations, of which the former is autonomous (Neville, Nicoll, Barss, Forster and Garrett 1991).
- In Broca’s aphasia, aphasia patients show a syntactic disorder, having difficulty in sequencing the different language units. Their comprehension however is intact: they understand discourse (almost) as well as ‘normal’ language users (Miyake, Carpenter and Just 1994; cf. Jones 1985).
- In the lexicon, grammatical words and lexical words can be distinguished. The former is strongly related to the syntactic structure of the language (determiners, conjunctions, prepositions etc.). The latter cover the ‘meaningful’ items in a language (nouns, verbs, adverbs, adjectives etc.). Psycholinguistic studies give evidence for difference in accessing, producing and priming these two classes.

The capacity of the STM is very limited. Processing information with a large demand on the STM will result in syntactic disorder (Miyake, Carpenter and Just 1994; 1995). Processing information of a text therefore means that one has to be able to select and to discard specific information. The grammatical items form the universal grammar which helps to structure the lexical items in central cognitive processes (Cann 1996).

Additional organization seems to take place in compound units consisting of predicates and arguments (cf. Kintsch 1994; Van den Broek 1994), often called propositions. Without confusing the two *different* levels of representation, we could say that particular word categories are mainly responsible for the construction of propositions: (verbs and adjectives for predicates, nouns for arguments (Kintsch 1974; Bovair and Kieras 1985; Graesser, Gernsbacher, Goldman 1997).

### III. Long Term Memory
The organized information is stored permanently in the LTM. In the case of language the organization is in the

form of propositions classified in propositional networks (cf. Kintsch 1988, 1991, 1994).

Translated in the HIPS model, the reader extracts information from the text, stores it in the buffers of the SS and starts the construction of propositions in the STM: The surface structure is the first guide in structuring this information which is then organized in proposition-like chunks, containing at least the most important meaningful information, i.e. particular categories of lexical items.

## The Experiment

### Experiment

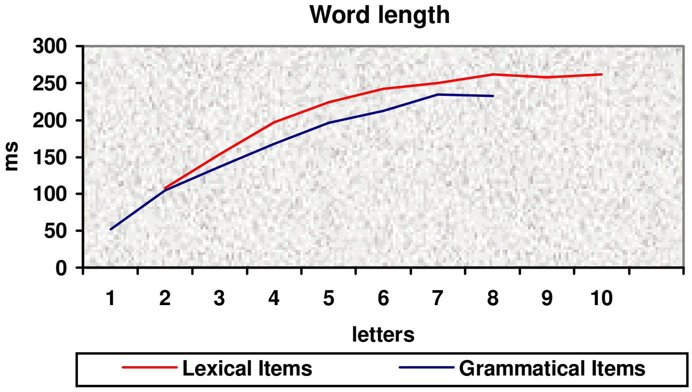
Nine native speakers of English from the Glasgow University read ten screens of the novel *An Awfully Big Adventure* by Beryl Bainbridge drawn from the British National Corpus. The reader's gaze was monitored by a Dual Purkinje Eye tracker. The accuracy of the eye tracker was carefully checked before each experiment.

### Results

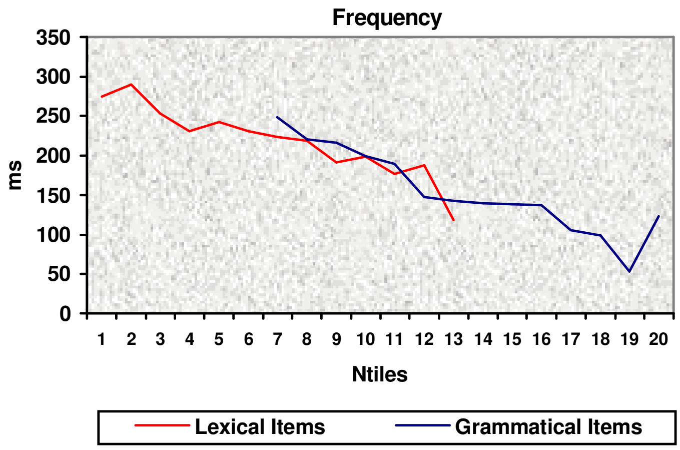
The fixation times vary from 0 ms (N=4580) to 1897 ms (N=1), with an average of 165.43 ms (SD=152.91). This includes the 0 ms fixations. Subjects show differences in reading time and regressions; however, these differences are not significant and could be related to individual differences in capacity of the STM (cf. Carpenter and Daneman 1980). Important here is that each of the tendencies described below can be noticed in the subjects' individual data.

Looking at the effects of physical stimuli on fixation times, the position of the word on the screen offers a significant contribution. The word's last position on the line has a negative correlation with fixation time. The most important variable however is the word length.

If the effect of word length is processed in the Sensory Store, no syntactic and semantic differences should be noticed. This was confirmed by the data. For instance, no significant difference could be seen between the fixation times of lexical versus grammatical items.



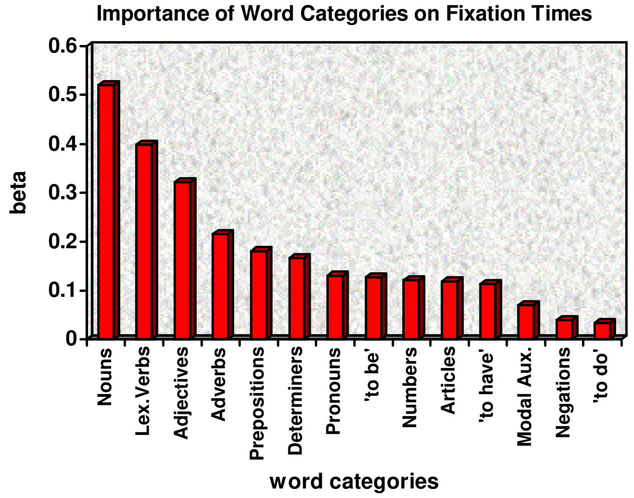

Words that are more frequent are less fixated. There is not a significant frequency effect between lexical and grammatical items, suggesting that the linguistic organization of the text had not taken place. Although frequent words tend to be shorter, there is not a significant correlation between frequency and word length.




Albeit there does not seem to be a significant difference between lexical and grammatical items in word length and frequency effects, the data do show evidence that confirms other psycholinguistic studies.

| | *Lexical Items* | *Grammatical Items* |
|---|---|---|
| **Fixated** | 47% | 42% |
| **Not fixated** | 14% | 57% |
| **Fixation time > Average** | 57% | 41% |

If we look at the differences within the lexical and grammatical items, we can see that particular word categories offer an important contribution to fixation times. These categories are identical to the ones mainly used in the formation of propositions: nouns, lexical verbs and adjectives contribute mostly to fixation time. These word categories also have the highest fixation times, whilst their importance can not be explained by word length, frequency or any other independent variable.



## Conclusion

Word length, frequency, position of the word on the line as well as word categories are important variables influencing fixation times. This is shown in many experiments wherein these variables are studied separately. The theories derived from these studies give a general idea in what stages discourse is processed: physical information in a Sensory Store, linguistic information in a Short Term Memory, propositional information in a Short Term Memory in order to store it in a Long Term Memory. Despite the sequential character of the model, it does not exclude a model of parallel distributed processing, but integrates it. The results of an eye movement experiment confirm the results of these studies. They give additional evidence for the different stages reading processes. Although eye movement data between readers differ, general tendencies are very consistent.

The word categories *nouns*, *lexical verbs* and *adjectives* (on the level of a linguistic representation) form the basic components for propositions (on the level of a mental representation). It is shown that these categories get the highest fixation times and most of the regressions (ceteris paribus).

### Notes

This is a derived version of the poster presentation I gave at the 1997 Seventh Annual Meeting of the Society for Text and Discourse and contains the main information presented in a paper presentation at the departmental Post Graduate Conference 1997.

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