The role of anticipation in reading*

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The paper introduces measurement of fixation-speech intervals (FSI) as an important tool for the study of the reading process. Using the theory of the organism-environment system (Järvilehto 1998a), we developed experiments to investigate the time course of reading. By combining eye tracking with synchronous recording of speech during reading in a single measure, we issue a fundamental challenge to information processing models. Not only is FSI an authentic measure of the reading process, but it shows that we exploit verbal patterns, textual features and, less directly, reading experience. Reading, we conclude, is not a matter of decoding linguistic information. Far from being a text-driven process, it depends on integrating both sensory and motor processes in an anticipatory meaning generation based on the history of experience and cultural context of the reader. Finally, we conclude with remarks on the social character and cognitive history of reading.

Keywords: anticipation, eye tracking, fixation-speech interval, neural basis, organism-environment system, reading

1. Introduction

Experimental research on reading has long been dominated by the view that language is based in text-like entities or words that are processed by the brain. Thus, the first experiments on reading used single words in the study of the speed of naming (Cattell 1886). During the last century the experimental possibilities were enlarged by the development of methods for tracking eye movements and for recording electrophysiological and hemodynamic measures of brain activity. However, there has been a surprising lack of interest in methods for determining the time course of the events in the reading process. In study of oral reading, most work has used different kinds of naming experiments where participants make lexical decisions or rapidly articulate single words, pseudowords, or short separate sentences (for a review, see e.g., Altmann 2001). However, since context matters

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to reading (e.g., Stanovich 2000: 3ff), this is open to criticism. No comprehensive theory of reading can be based on studies based on measures of how participants name single words or read short sentences.

The easiest way to determine the time course of reading is by continuous measurement of the interval between the instant of the fixation to a word by the eyes and the start of word articulation. In fact, such a measure was developed over a hundred years ago. Pioneering quantitative measures, Quantz (1897) recognised that, before articulation, the eye identifies the word. Further, since the eye led the voice, Quantz called the spatial distance between the two *eye-voice span* (EVS). In the beginning of the 20th century EVS was usually specified by the number of characters or words whereby the eye led the voice (Buswell 1920). However, probably for technical reasons, temporal measurements were seldom made. After the middle of the century the measurement of EVS continued to be used (see Levin 1979), as an indicator of the reading process and reading skills. In more recent decades, however, interest in such measurements has fallen away. This may be because, in the information processing framework, reading is seen as a predominantly visual coding/decoding process. Accordingly, there is little interest in oral reading. Further, as Rayner (1998: 384–385) suggests, many believe that eye movement dynamics and cognitive processes differ (at least in respect to the time scale).

2. Information processing or anticipation?

Reading research is still dominated by the information processing model. On this view, reading is seen in terms of how the brain processes information that is stored in the written text. While theorists debate how the processing is realised (e.g., Rayner 1998: 388), models generally trace the process to when eyes fixate on the word. They assume that this leads to the transfer and further processing of visual information. It is posited that visual or phonological codes (or both) serve in identifying word and sentence meaning. When reading aloud, the perceptual part of the process is said to be *followed* by selection of motor programs and realisation of speech sounds.

Such a conceptualisation of the reading process follows the general cognitive model of perception and motor action as linear/parallel information processing in the nervous system. While willing to debate whether reading is based on transmission of single letters, syllables or whole words, or whether word recognition is based on dual route or interactive models (see, e.g., Altmann 2001), these theories share a single assumption. Their cornerstone is the claim that word recognition occurs only *after* the presentation of a stimulus or fixation on a textual item. Recognition is based on comparing incoming information with representations that are stored in a putative inner lexicon. It is often said that these psychological models gain support from the use of EEG or MEG brain imaging that traces sequential activations of the brain (e.g., Sereno and Rayner 2003; Parviainen et al. 2006).

Even 19th century work challenged linear information processing models of perception (Bain 1855; Dewey 1896). More recent traditions have pursued this critique (e.g., v. Uexküll and Kriszat 1932; Gibson 1979). Using the theory of the organism-environment system (Järvilehto 1998a), experimental work on animals and humans has been used to defend an alternative. Accordingly, Järvilehto (1999: 97) suggests that:

> Perception is not a linear process proceeding from the stimulus to the percept, but, rather, a circle involving both the sensory and motor organs as well as the events in the environment. A perceptual process does not start with the stimulus, rather the stimulus is an end of this process. The stimulus is like the last piece in a jig-saw puzzle. The last piece of the puzzle fits in its place only because all other pieces of the puzzle have been placed in a particular way. It is just this joining of the other pieces, their coordinated organization, which leaves a certain kind of hole into which this last piece can be fitted. Thus, it is just the organization of the other pieces which defines a possible last piece with which we may finish the puzzle. Exactly in the same way, a stimulus is present only if there is an organisation into which this stimulus may be fitted. Thus, the stimulus is as little in a causal relation to the percept as the last piece of the puzzle to the constructed picture. The stimulus is a part of the process of reorganization of the structure of the organism-environment system, which forms the basis of new knowledge.

Applied to reading, the model denies that the brain analyses and interprets marks or inscriptions in a linear fashion. Rather, the organism-environment system integrates what can be seen with current organisation. Far from processing 'word or sentence stimuli', inscriptions serve to create words and meanings. This is because, like single pieces of a jigsaw puzzle, inscriptions take on significance only as they become constituents of the organism-environment system. Since they lack intrinsic meaning, it is a mistake to say that words and sentences exist on paper or that they are decoded by a brain. Rather, reorganisation of the whole organism-environment system gives rise to these results. To look[1] at inscriptions on paper enables written marks to be included in anticipatory organisation that leads to the formation of the personal meaning and/or an articulatory act (in reading aloud). This process is not determined by the stimulus. Rather, it is to be traced to how the reader's cultural and experiential history set the structural conditions for the dynamics of the organism-environment system.

Although fixation is often viewed as the starting point of information transfer from the written word, there are competing explanations. On the basis of 'miscue' analysis of oral reading, Goodman (1969: 9) likened reading to a "guessing game" and, quite explicitly, denied that it depended on veridical information transfer. More recently, McDonald and Shillock argue that "the remarkable efficiency of reading is due, at least in part, to the on-line formation of predictions about upcoming words. The statistical properties of the linguistic environment offer a viable source for these predictions" (2003: 651). In recent work on comprehension, Levy (2007: 11) stresses expectations in his theory of *resource-allocation processing difficulty*. In parallel, Federmeier (2007) used recording of event related potentials (N400) associated with expected and unexpected words to suggest that "the brain seems to deal with the speed and complexity of language processing by "thinking ahead", by generating information about likely upcoming stimuli and preparing ahead of time, at multiple levels, to process them" (Ibid.: 502). Reading is a special skill that is carried out at a remarkable speed. This is why anticipation is likely to have a major role in reading just as it does on other temporally demanding skills (see, e.g., Abernethy et al. 2001).

3. Fixation-speech interval (FSI) as a measure of temporal dynamics in reading

The relative ease with which words with transposed letters can be read also suggests the likely importance of anticipation (Rayner et al. 2006). However, Rayner et al. (2006: 192–193) also found that there is a cost when the order of letters in the word is changed: reading rate decreases and the number of fixations increases. This was interpreted by Rayner et al. (2006: 192–193) in terms of the mainstream information processing model.

3.1 FSI and type of text

Järvilehto et al. (2008) examined the effect of letter transposition in more detail. In so doing, we introduced two kinds of controls alongside 'scrambled' text: normal 'discrete' text and 'continuous' text without spaces between words. Further, in addition to recording the usual eye movement parameters, we developed a measure of reading efficiency. This consists in *fixation-speech interval* (FSI) or the time-interval between initial fixation to a word and the start of articulation (in reading aloud). The FSI measure allows ecologically valid investigation of parameters that impact on time-intervals between fixating an inscription and articulating its meaning. In this way, the whole reading situation opens up to temporal investigation. Eye tracking has an important part in this general process in that it serves to capture the use made of separate parts as defined by a series of fixations and saccades.

Were the linear processing hypothesis correct, we would expect striking differences in time-intervals between 'normal' and 'scrambled' text. This is because, on the decoding model, text is analysed and processed in a linear fashion. Thus, analysis of scrambled words should take longer than that of the normal words and, it would be predicted, this would apply even where these were *continuous* (viz. writtenwithoutspaces). By contrast, on the anticipatory model, the scrambling of letters is expected to make less difference than whether they are *discrete* (normal) or *continuous*. This is because to generate meaning, an anticipatory model requires only that we use fragments of an inscription.

Since the most conspicuous changes were associated with 'continuous' text, this supports the anticipatory model. In fact, participants had little difficulty in reading the scrambled text. It was the 'continuous' condition that slowed reading down and significantly disrupted the normal reading rhythm. Such findings are contrary to the linear model. They suggest that appeal to linear decoding of inscriptions provides little insight into the reading process.

The type of text has a significant effect on fixation-speech interval. Thus, as noted, the longest intervals were associated with the *continuous* text. Other significant differences were found in how fixation-speech intervals correlated with an item's location on the text line. While 'words' at the beginning of the text line were associated with short intervals, those in the middle of the text line elicited much longer fixation-speech intervals. This indicates that the duration of FSI is not correlated with parafoveal preview (for the possible significance of parafoveal preview in reading, see Vitu 1991).[2]

3.2 FSI in relation to articulation, sentence structure, and reading experience

Recent work has used FSI measures that are accurate to within 4 milliseconds.[3] This allows closer investigation of relation between reading and speech (especially at the role of articulation), sentence structure, and reading experience. In the experiments we presented for oral reading three types of Finnish texts (a fairy tale about sheep and mountain goats, not known earlier to the subjects). As above this was presented in *scrambled*, *discrete*, and *continuous* versions. Each participant was asked to use normal reading speed in dealing with screens of text (with approximately the same number of letters in each trial). Each screen consisted in a trial: the first consisted in discrete text. In the second, letters were scrambled (for about 50% of the words only the beginning and the end was correct: e.g., the subject had to raed this knid of wodrs) and, in the third continuous trial, words were written without spaces (e.g., thesubjecthadtoreadthiskindoftext).

Eye movements were recorded with an EyeLinkII (SR Research) tracker using pupil and corneal reflection tracking (accuracy of sampling 4 ms; noise < 0.1

degrees of visual angle). Before the start of the experiment the recording system was calibrated. Drift correction was carried out in the beginning of each trial. The voice signal was recorded synchronously by the display program (programmed by Experiment Builder, SR Research) with the help of miniature microphone attached to the tracker close to the mouth of the S. The program produced two separate data files for storing of eye movement measurements and voice signals with synchronised timing information.

The results confirm the findings of the previous study (Järvilehto et al. 2008) with respect to FSI measures of discrete, scrambled and continuous text. Detailed

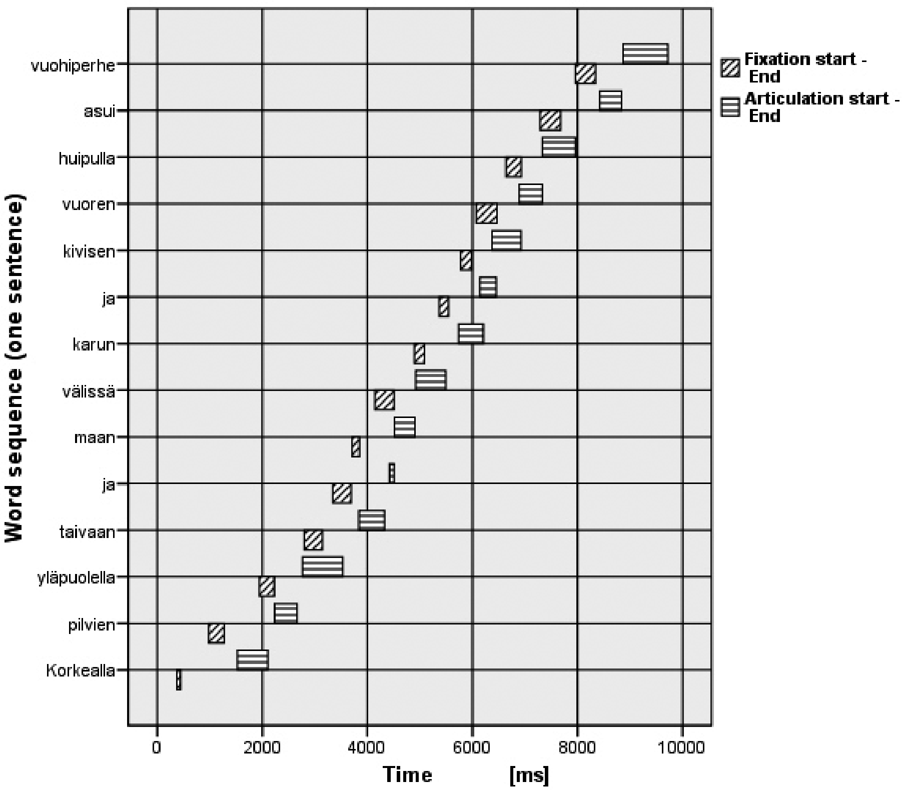

Figure 1. Example of fixation-speech relations for reading of one sentence by one subject. Abscissa shows time in ms and ordinate the sequence of the words in the sentence (starting from the bottom of the figure). The symbols at the line corresponding to each word show the duration of fixation and articulation of the word (Fixation start-End, and Articulation start-End). Eye movements were recorded with an EyeLinkII tracker using pupil and corneal reflection tracking (accuracy of sampling 4 ms; noise < 0.1 degrees of visual angle). The voice signal was recorded synchronously with the help of miniature microphone attached to the tracker close to the mouth.

analysis of how FSI varies (Figures 1 and 2) shows that articulation of one word often starts before fixation to the next. Most typically, fixation leads speech by one or, perhaps, two words.[4] Variability in FSI is also evident in the distribution of intervals. These may be less than 200 ms (the means of different Ss (N = 33; age range 14–59 yrs.) and range from 443 to 824 ms; grand mean = 625 ms, standard deviation = 217 ms).

Intervals as short as these cast doubt on the view that nervous systems carry out the many 'inner' operations posited in standard reading models. This is especially so when account is given to the approximately 100 ms interval between activating laryngeal EMG and the vocal signal (Gallena et al. 2001). It would, of course, be possible to interpret this as indicating that subjects use text context to 'guess'. However, on such a view, one faces the task of explaining how 'guessing' can be accomplished by a brain. It is thus preferable to posit that the word is formulated in an anticipatory process in the nervous system. If this is so, the process will start *before* the subject generates the exact content of the word.

As to the role of articulation, FSI may be influenced by speech performance. In other words, the interval may be 'contaminated' by articulatory factors. For

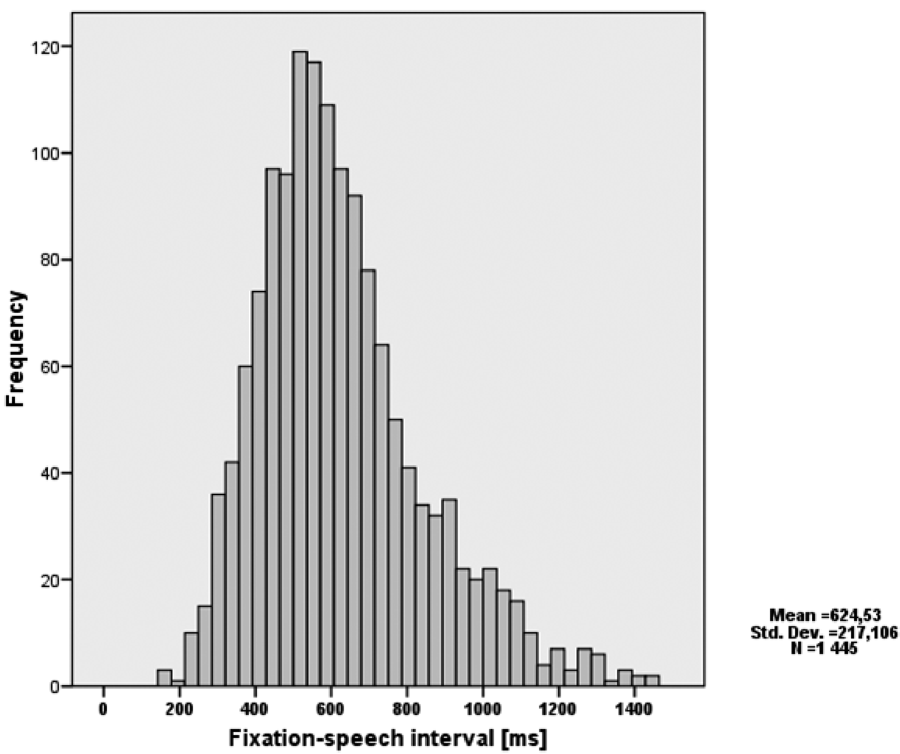

Figure 2. Pooled distribution of fixation-speech intervals of all subjects (n = 33).

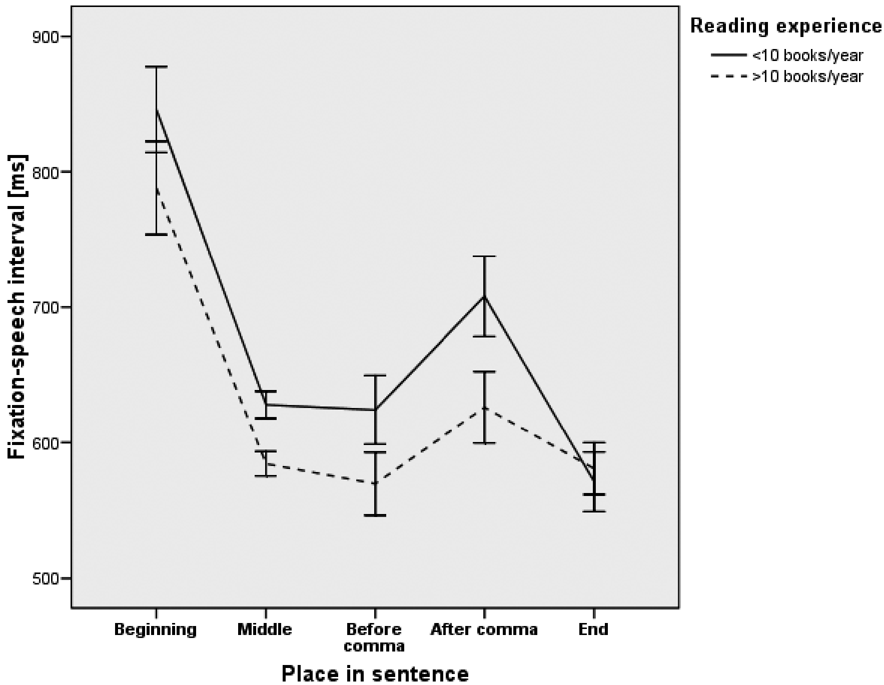

Figure 3. Average FSI as a function of the place of the word in the sentence for more (n = 17) and less (n = 16) reading Ss. The bars show standard error of the mean.

example, it could be that the longer the articulation, the longer the FSI. We therefore investigated the relation between FSI, the previous item's articulation duration and pause between articulations. While there is a positive correlation ($r = .167$, $p < .01$, $n = 1287$, Pearson) between articulation-duration and current FSI, other findings are more striking. There are also significant positive correlations in the pause between articulations ($r = .332$, $p < .01$, $n = 1184$; Pearson), and (at higher levels of significance) between the pause-duration after preceding and current items FSI d ($r = .479$, $p < .01$, $n = 1164$; Pearson). Rather than emphasise how the length of a textual item contaminates FSI, we take this to show that FSI captures the rhythm of reading.

Such interpretation gains further support when we consider how FSI maps onto where a textual item occurs. For each text type FSI consistently depends on whether these are sentence initial or occur after a comma (Figure 3; place in sentence effect significant at $p < .001$; $F(4, 1440) = 32.14$; one-way ANOVA). This modulation of FSI correlates better with the rhythm of reading (producing meaningful thoughts) than sentence marks. Indeed, even where there are no such marks, continuous texts show the same pattern. Finally, correlation between articulation duration of the preceding word and the current FSI depends on the place of the word in the sentence. Thus the sentence initial position gives a high positive correlation (r = .256, $p < .05$, n = 91; Pearson), and, in sentence final position, correlation is negative (r = −.166, $p < .05$, n = 161; Pearson).

Eye tracking data give related results. While average duration of a first fixation to an item varies between 186 and 354 ms (mean = 254, standard deviation = 119), saccade amplitudes vary between 1.3 to 2.3 degrees of visual angle (mean = 1.7; sd = 1.37 degrees of visual angle). Thus the place of a word in the sentence influences gaze duration (sum of fixation durations/word) in a way that is inversely related to FSI. Specifically, on FSI measures, duration was longest before a comma, and at the end of a sentence.[5] In contrast to FSI, gaze duration was longest at the start of a text line and shortest at the end.

We also examined the relation between reading performance and FSI. This was done by examining the relation between the FSI, reading duration, and the subject's reports of reading experience (measured by the number of books claimed to be read per year). We found marked positive correlation between FSI and reading duration (r = .519, $p < .01$, n = 33, Pearson). Strikingly, subjects with more reading experience (n = 17) had significantly shorter FSIs than those who read less (n = 16); on average, the difference was 46 ms (difference significant at $p < .001$; t = 3.789, df = 1443). Differences were most marked in the middle of sentences (Figure 3). In relating reading to eye movement parameters, we found that people with more reading experience used fewer fixations and larger saccades. These differences too were more pronounced within sentences and with mid-line items.

3.3 FSI: Implications for reading

It is misguided to idealise reading as a linear analysis. There is no evidence for the view that it is a process of neural comparison driven by fixations on data strings. Far from being descriptions of data decoding, information-processing models are flawed by unacknowledged theoretical assumptions. This establishes the importance of the FSI measure. It provides a novel means of obtaining data about normal reading that opens up the study of contextual aspects of the reading cycle. It thus contrasts with approaches based on measuring separate parameters of reading activity (such as duration or number of fixations).[6]

The fixation-speech interval is an authentic measure of a person's reading performance. Our results show that FSI captures, not mechanical (speech) characteristics of the reading process, but the rhythm of reading (sentence structure) and reading experience. By connecting FSI measures with analysis of eye tracking, we can throw new light on the time course of events in the reading process. In the future, moreover, the approach might be combined with electrophysiological or hemodynamic measures of brain activity.

In information processing models, decoding is data driven. For theoretical reasons, we are assumed to approach texts with grammars and/or mental lexicons in the brain. By investigating the time-course of reading, we have shown this view to be implausible. Measurement of FSI, however, enables stronger claims. Hitherto work on distributed language has emphasised the role of dynamics, i.e., language is grounded not just in word-forms, but in "the embodied, situated and cultural dynamics of talk" (Cowley 2007a: 106, 2007b). Given the focus on dialogical and directed speech, little or no experimental work has examined the dynamics of reading. It is thus important that FSI shows reading to be anticipatory. The subject integrates inscriptions with previous experience by making sense of what is before the eyes.

4. Anticipatory dynamics in reading

Information processing models use a weak notion of *anticipation* (or 'readiness', 'preparation'). The term is used to evoke waiting for the activation of an inner model with which a stimulus can be compared (see e.g., Neisser 1976; Rosen 1985), or, in other contexts, as a general process said to advance the processing of the incoming stimuli.

4.1 The concept of anticipation

On the view taken here, the organism-environments system organises by means of anticipation (Järvilehto 1998a: 331). This shapes both prospective acts and how features of the environment influence the processes that lead to *action results* (e.g., reading aloud). The nervous system does not wait to compare stimuli with inner models but rather shapes events in a process of continuous transformation. The organism-environment systems' anticipatory organisation determines what environmental constituents will serve to realise a person's actions. Long before accomplishing a task, continuous transformation readies a system to use environmental constituents (e.g., inscriptions on paper) while configuring prospective movements (e.g., control of laryngeal activity when uttering the word). Action is thus almost simultaneous in any task that makes critical use of environmental features.

In reading, many processes that are often posited to *follow* stimulus presentation occur even before measures are made. This is because in an experimental setting there is much that a subject knows in advance. It comes as no surprise that a text is presented in visual form or that it has to be read aloud. Anticipatory organisation is thus completed as the eye fixates an inscription and, by so doing, comes up with the action result (e.g., articulation of a specific word).

4.2 Neural models of anticipation

In contrast to neural information-processing models, the theory of the organism-environment system posits that the nervous system is organised together with bodily elements and environmental constituents to obtain action results (Järvilehto 1998b). According to this theory, there is nothing for which neurons could decode information. Rather, like other cells, neurons seek to maintain their metabolism. When this is disturbed they fire and, by so doing, influence neurons that form complex neural nets. By using neurotransmitters, the net can influence the muscles and, as a result, restore its metabolic state by cessation of firing. If what results is of no value, the neuron dies. In the nervous system, this happens all the time. Neuron firing is therefore not 'information processing'.

Neurons are living cells organised in metabolic systems that connect with other neurons. As cells, they cannot perform psychological 'functions' (like perception or reading). No neural network can analyse features of a written text, undertake mental operations, or build models and representations. Rather, they enable the organism and environment to use dynamics in a single functioning system. While reading does not happen in the brain, the brain is, of course, important for the reading process. However, reading does not happen in the brain, but in a larger system consisting of the organism and environment as well as of the whole cultural context where the reading occurs. The agent of the reading process is not a neuron or the brain, but *a person* who cannot be defined by physiological concepts.

The organism-environment system features an anticipatory neural system as is sketched in Figure 4. On this view, it is important that sensory receptors or receptor matrices are not literally 'receptive'. Rather, they create the environmental connections that support the formation of the whole organism-environment system. Efferent influences on receptors are of special importance. This is because, as Järvilehto (1999) shows in detail, they condition receptor matrices for the selective use of environmental constituents (such as inscriptions of the text on paper). Without this conditioning, the system could not achieve its action results. Similarly, muscles are efferent organs that also contain afferents ('muscle afferents' in Figure 4) whose significance appears in the interplay with receptors. It is because muscles and receptors have a similar structure (afferent and efferent innervation), that, together, they define parts of the environment (e.g., certain inscriptions on the paper) which enable the whole organism-environment system to achieve useful action results (e.g., understanding of the text). Perception and action are not separate sensory and motor processes, but simply two aspects of the same coin, of an integrated whole. Thus reading is a sensory as well as a motor process.

We cannot afford to ignore such claims when we use changes in brain activity as the basis for measuring the time course of reading (Sereno and Rayner 2003;

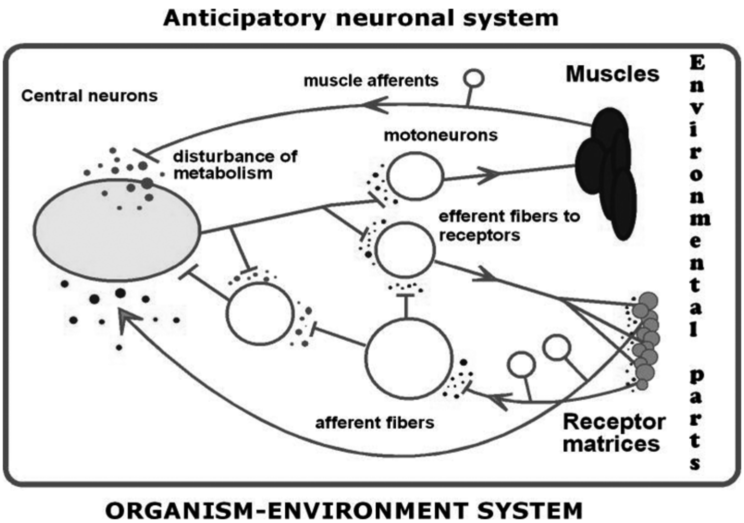

Figure 4. Anticipatory neural net as part of the organism-environment system. In the anticipatory neural net muscles and receptors act together and define the environmental parts that can be fitted to the organism-environment system. Of special importance are the efferent connections to receptors that condition the receptors for specific environmental connections. Small dots around neurons depict transmitters.

Parviainen et al. 2006). Indeed, if an inscription on the page *completes* anticipatory organisation, event-related potentials following the stimulus presentation (or fixation of the eyes to an inscription) cannot be indicators of sensory processing of the stimulus. Rather, they reflect completion of integrated anticipatory organisation and thus the transition from one act to another. Much of what is conceptualised as stimulus related 'processing' occurs before looking at the page. The 'processing' has been carried out before using the page as a 'trigger' to completion of the action or, in oral reading, to articulating what is seen.

Linear and hierarchical models of reading conflate psychological and neurophysiological concepts. Since they begin by describing operations deemed 'necessary' to a reading task, they are bound to ignore the temporal dynamics of the nervous system. Indeed, it is traditional to present the task components in boxes whose contents are fixed by how peripheral processing enables us to 'decode' the stimulus. For theoretical reasons, the nervous system is said to follow this logic. There is, however, no reason for the nervous activity to follow the temporal order of hypothetical psychological operations. The posited stimulus 'input' may differ from neural processes following the stimulation of the receptors. As we read, we do not have to wait for events in the environment. Indeed, the task structure itself sets off anticipatory neural processes before actual performance. Not surprisingly, then, systems form for dealing with the action results. The reader is not an empty bag to be filled by information from the text. Rather people actively use the inscriptions encountered in the situation to achieve useful action results or, specifically, articulation of meaning.

5. Reading as generation of meaning

Meaning is based on relations within the organism-environment system. In other words, far from being contained in the inscriptions of a text, any factor that leads to an action result has meaning. Where we regard text perception as a result, then all perceived inscriptions carry meaning and, crucially, this is necessary to reading both silently and aloud. Thus, even 'mechanical reading' generates meaning. When attributing sound to letters (as in reading phonetic nonsense words), we engage in meaningful activity. It thus follows that meaning is not like understanding. It can be correctly attributed to even single words, letters, or even parts of letters. Its basis lies in the reader's ability to formulate a word (or sound-pattern) on the basis of inscriptions on the paper (cf. for a related interpretation, Cowley 2007c: 83–104).

5.1 The unit of meaning in reading

In reading for understanding we are not aware of the meaning of words or their graphic counterparts. Rather, as we read, we generate thoughts and ideas because the anticipatory process is directed to just such action results. Where reading for understanding, therefore, the unit is larger (e.g., sentence or thought) than in 'mechanical reading'. This interpretation is confirmed by variations in length of FSI that occur in reading continuous texts (oneswithoutwordbreaks). Since no information is transferred, eye fixations serve in modulating the process of meaning generation or, in other terms, confirming the results of anticipatory organisation. Fixations neither start with feature analysis (cf. Paulson 2002 for a related interpretation) nor do inner representations feed the verbal content into a 'speech processor'. Rather, they serve in managing the production of speech. Since fixations modulate the ongoing speech process, it is not surprising that measures of FSI can be as short as reaction times. Further, far from needing to fixate on a particular inscription, it is enough to identify a fragment for meaningful articulation.

An inscription exists as a word or meaningful unit only as it is integrated into the organism-environment system. There is no need for feature analysis or lexical search. Since inscriptions contain no information, they are informative only in the context of the organism-environment system's anticipatory organisation. This arises from the subject's history of social relations in a cultural context that, as a result, determines the unfolding of the anticipatory process.

5.2 Silent and oral reading

Where reading is viewed as a visual process, little interest is shown in reading aloud. Accordingly, on information-processing models, fixation-speech intervals are seen as indexing processes unlike those of silent reading. In this "snap-shot" theory, it is posited that fixations should "wait" for word articulation (Rayner 1998: 375). This leads to a prediction. In principle, there should be differences between the timing of eye movement control and cognitive processing when we read aloud and silently. In fact, our research provides no support for this view which has been questioned also in comparisons of oral and silent reading by Kondo and Mazuka (1996: 358).

Where text perception is regarded as meaning generation that integrates sensory and motor constituents in social action, the time course of oral and silent reading is expected to be similar. Indeed, both processes are posited to draw on the same anticipatory processes. This is confirmed by the fact that our fixation durations and saccade amplitudes are of the same order of magnitude as those of Rayner's (1998) work on silent reading. Not only do our eye tracking results[7] confirm the organism-environment view, but they suggest a general conclusion. Reading silently or 'out loud' are, it seems, different aspects of a single process. In both cases, the text acts as a means to speaking even if, in silent reading, this is inhibited. In silent reading, we articulate subvocally as is found in studies of the EMG activation of laryngeal muscles (Sokolov 1972; Abramson and Goldinger 1997).

Reading used to be entirely oral. While occasional instances of silent reading occur before the tenth century (Manguel 1996: 40–53), our findings reflect on our history. Texts are written to be spoken and, in many languages, no lexical contrast marks acts of reading from speaking (ibid.). Since language is social activity that creates cooperation this is, perhaps, not especially surprising (Järvilehto 2000: 48–49). Indeed, like dialogue, reading may be regarded as a process directed towards the expression of the ideas conveyed by the writer. Given the importance of semantic aspects of the text, there is some dispute whether phonological processing is necessary (see e.g., Perfetti and McCutchen 1982; Wagner and Torgerson 1987). In learning to read however, phonology plays an important role (Wagner and Torgerson 1987; see also Lukatela et al. 2004). Accordingly, silent reading is best seen as s special case of oral reading where one component, overt speech, does not occur.

Reading is a social process which encompasses both the reader and the writer of the text who engage in a cultural context. It is a dialogue with the writer, a kind of cooperation which does not, in principle, differ from dialogue between two people (for a different view, see Kravchenko 2009). Far from being 'interaction' between people, dialogue can be seen as a process of generating shared meaning as we concurrently orient to each other. In reading the author is not physically present but, in spite of this, participates in the generation of meaning. Just as if the other was present, the reader can pose questions to a text and, strangely, find answers. The text permits cooperation between the writer and the reader which can result, among other things, in the creation of new thoughts and ideas.

Notes

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1. It should be pointed out that, according to the theory of the organism-environment system, *behaviour* (such as looking) is reorganisation of the whole organism-environment system. Psychological concepts (such as perception) describe different aspects of dynamics of organisation of the organism-environment system (see Järvilehto 2000).

2. Parafoveal preview means the possibility of using textual information that is projected to the parafoveal region of the retina.

3. For technical reasons, in the results reported in the study above (Järvilehto et al. 2008) the accuracy of measurement of FSI was 40 milliseconds.

4. It is not known how much our results depend on specific features of the Finnish language (e.g., complexity of morphosyntax), but comparable eye-voice span was earlier reported by e.g., Levin (1979) for English. Levin, however, did not measure temporal parameters, such as FSI.

5. Taken together these results could be indications of 'prosody of looking', i.e., rhythm of action related to the generation of meaning.

6. As pointed out in the Introduction, a related measure is the EVS, but it has been applied only for spatial measurements, and it thus offers no possibility for determination of the time course of the reading process. Another related method is the presentation of single words or short sentences and measuring the voice reaction time, but this measure has the disadvantage of bad ecological validity.

7. There are, however, no systematic comparisons for different languages.

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