Inferences about predictable events: eye movements during reading

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Abstract  Eye fixations were recorded to assess whether, how, and when readers draw inferences about predictable events. Predicting context sentences, or non-predicting control sentences, were presented, followed by continuation sentences in which a target word referred to a predictable event (inferential word) or an unlikely event (non-predictable word). There were no effects on initial target word processing measures, such as launch and landing sites, fixation probability, first-fixation duration, or first-pass reading time. However, relative to the control condition, the predicting context (1) speeded up reanalysis of the inferential word, as revealed by a reduction in second-pass reading time and regressions, and (2) interfered with processing of the non-predictable word, as shown by an increase in regressions. These results indicate that predictive inferences are active at late text integration processes, rather than at early lexical-access processes. The pattern of findings suggests that these inferences involve initial activation of rather general concepts following the inducing context, and that they are completed or refined with delay, after the inferential target word is read.

Introduction

This study used an eye-movement methodology to investigate the time course of predictive inferences during reading. Prior studies have employed experimental tasks that involved rather restrictive conditions, regarding either the presentation of the stimuli (fixed-paced rapid serial visual presentation of the context sentences, e.g., Fincher-Kiefer, 1995; or self-paced moving-window procedures, e.g., Calvo & Castillo, 1996), the interval between the inducing context and the probe (e.g., stimulus onset asynchrony manipulations; e.g., Millis & Graesser, 1994), or the measurement of the responses to assess the inference (e.g., naming isolated target words aloud, while reading silently, e.g., Murray, Klin, & Myers, 1993).

While these procedures have been very useful for determining the conditions under which inferences are made on-line, the interpretation of the findings can be benefited from the use of procedures that allow more natural, non-obtrusive, reading, such as the eye-movement methodology. Such multiple-task convergent approach has proved fruitful to investigate reading (e.g., Schilling, Rayner, & Chumbley, 1998; see Haberlandt, 1994).

Predictive inferences are implicit anticipations of likely outcomes of events, based on the application of our prior world knowledge to explicit information in a message describing such events (e.g., Fincher-Kiefer, 1995; Keefe & McDaniel, 1993; Klin, Guzman, & Levine, 1999; McKoon & Ratcliff, 1986; Trabasso & Magliano, 1996). For example, we would be making a predictive inference if, when reading that “the angry man threw the delicate porcelain vase against the wall”, we were to anticipate that the vase “broke” (e.g., Potts, Keenan, & Golding, 1988). As forward inferences, predictive inferences facilitate processing of subsequent information when they match it. They are also behaviorally useful, because of their preparatory function to recruit resources and plan adaptive behavior in advance of the actual events. Accordingly, they should be made on-line, as soon as the inducing information is processed.

Yet, these elaborations may be restricted under normal reading conditions, because of the overload they could cause during on-line comprehension, and even the risk of wrong anticipations requiring backward corrections. Actually, two extant models of inference processing in reading, such as the minimalist hypothesis (McKoon & Ratcliff, 1992, 1995) and the constructionist theory (Graesser, Singer, & Trabasso, 1994; see Graesser, Millis, & Zwaan, 1997) argue that predictive inferences are unlikely to be drawn on-line. The reason is that these inferences are not required to make statements in the text locally coherent (minimalist hypothesis) or globally coherent (constructionist theory), or to explain
why actions, events and states are mentioned in the text (constructionist theory), which would be necessary conditions to make inferences normally. However, both models admit that predictive inferences can be generated if they are supported by well-known information that is readily available in memory (minimalist hypothesis), or if the predicted outcome is highly constrained by the context, with few, if any, alternative consequences (constructionist theory).

Experimental research on predictive inferences has obtained mixed results. Some studies have found that these inferences can be made on-line (Calvo & Castillo, 1996, 1998; Calvo, Castillo, & Estevez, 1999; Fincher-Kiefer, 1993, 1995, 1996; Keefe & McDaniel, 1993; Klin, Guzmán et al., 1999; Klin, Murray, Levine, & Guzmán, 1999; Murray et al., 1993; Whitney, Ritchie, & Crane, 1992), whereas others have provided negative evidence (Magliano, Baggett, Johnson, & Graesser, 1993; Millis & Graesser, 1994; Potts et al., 1988), or evidence of only minimal, incomplete (McKoon & Ratcliff, 1986, 1989) or nonspecific (Duffy, 1986) inferencing. Some authors (e.g., Calvo & Castillo, 1998; Fincher-Kiefer, 1996; Klin, Guzmán et al., 1999) have argued that the extent to which the passages used to study inferences met the demands of high availability and context constraints, as put forward by the minimalist hypothesis and the constructionist theory, could account for the different findings.

Nevertheless, even if predictive inferences can be made on-line in some limited conditions, both the minimalist hypothesis (McKoon & Ratcliff, 1992, 1995) and the constructionist theory (Graesser et al., 1994) assume that these inferences are not automatic. Rather they would involve elaborative construction of meaning, i.e., post-lexical strategic processes. Accordingly, they should take time to develop. The possibility of multiple alternatives to forecast, the limitation of working memory resources, and the interruption of other on-going processes would impose a delay in the on-line generation of these inferences. A number of prior studies have manipulated time parameters, such as the fixed-pace presentation of the context and the interval between the inducing context and the probe, which allow us to estimate the time course of predictive inferences. Essentially, these inferences have not been detected within the first 500 ms after the onset of the last word in the context (whereas causal consequence or bridging inferences have; Magliano, Baggett et al., 1993; Millis & Graesser, 1994). Rather, it has been shown that predictive inferences take at least 750 ms or more after the end of the last word in the context (Fincher-Kiefer, 1995, 1996; Calvo & Castillo, 1996, 1998; Calvo et al., 1999).

However, the results obtained with the aforementioned approach might have some limitations, because the tasks employed did not allow participants to read the way they do in normal circumstances. The eye-movement method assesses reading processes under more natural conditions (see Rayner & Sereno, 1994). We used this methodology to validate, refine and extend prior findings regarding the time course of inferences about predictable events. As far as we know, eye-fixation measures have not been previously used to investigate these inferences (see Rayner, 1998). A main purpose of the present study is to determine to what extent predictive inferences involve early or late processing stages.

In our study, participants were presented with inducing or control context sentences, followed by continuation sentences that included a pretarget region, a target word, a posttarget region, and a final region. Evidence for on-line predictive inferencing will involve facilitation in reading a target word that represents the predicted event following the predicting context, relative to when that word follows the non-predicting control context. Furthermore, relevant evidence for the time course of these inferences, and the processes involved, are provided by two groups of eye-fixation measures (see Liversedge, Paterson, & Pickering, 1998; Rayner, 1998): (1) initial processing measures, such as probability of first-pass fixation (i.e., skipping rate) or first-fixation duration, and (2) reanalysis measures, such as second-pass reading time and regressions (see description of all measures in the Method section).

If predictive inferences affect early lexical-access processes, facilitation should occur on the inferential target word in the initial processing measures. These measures have proved to be sensitive to predictability of words within a context sentence, as a function of lexical or semantic association. Thus, Altarriba, Kroll, Sholl, and Rayner (1996), Ehrlich and Rayner (1981), Rayner and Well (1996), or Schustack, Ehrlich, and Rayner (1987) have found that high-predictable words are skipped (i.e., not fixated) more frequently, and fixated more shortly than low-predictable words (see Brysbaert & Vitu, 1998, for a detailed discussion). Accordingly, if predictive inferences involve lexical predictability, they

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1 Other studies, though demonstrating the on-line occurrence of predictive inferences, could not determine their time course with precision, because the procedures allowed self-paced presentation of the inducing contexts and/or the probe (e.g., Fincher-Kiefer, 1993; Keefe & McDaniel, 1993; Klin, Guzmán et al., 1999; Murray et al., 1993; Whitney et al., 1992). On-line, as opposed to "offline", means that the cognitive processes are performed during comprehension of the stimuli, as opposed to being induced by a test at later retrieval. Presumably, there is a continuum from automatic to elaborative on-line processes, ranging from less than 500 ms to a little over 1 s following the stimulus (e.g., Till, Mross, & Kintsch, 1988).

2 Nevertheless, also using eye-movement measures, O'Brien, Shank, Myers, and Rayner (1988) obtained evidence for a different type of semantic inferences, involving elaboration of contextually appropriate meanings or instantiation of noun category (e.g., inferring 'knife' from the phrase 'the mugger stabbed the woman with his weapon'). There was reduced gaze duration when reading the word that represented the implied concept (e.g., knife) following the implying context phrase. However, this occurred only when the phrase strongly suggested (e.g., stabbed vs assaulted) the implied concept, and when there was an anaphoric relationship between the implying and the implied concepts (Garrod, O'Brien, Morris, & Rayner, 1990).