Adults with poor reading skills, older adults, and college students: The meanings they understand during reading using a diffusion model analysis

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ABSTRACT

When a word is read in a text, the aspects of its meanings that are encoded should be those relevant to the text and not those that are irrelevant. We tested whether older adults, college students, and adults with poor literacy skills accomplish contextually relevant encoding. Participants read short stories, which were followed by true/false test sentences. Among these were sentences that matched the relevant meaning of a word in a story and sentences that matched a different meaning. We measured the speed and accuracy of responses to the test sentences and used a decision model to separate the information that a reader encodes from the reader's speed/accuracy tradeoff settings. We found that all three groups encoded meanings as contextually relevant. The findings illustrate how a decision-making model combined with tests of particular comprehension processes can lead to further understanding of reading skills.

Introduction

A complete understanding of a text requires understanding the meanings of its words as they are relevant to it. The full meaning of a word is not necessary and irrelevant aspects of its meaning are not useful and may be detrimental. Contextually relevant meanings are needed for ambiguous words such as "bug," but also for words that are not ambiguous. For a text that mentions a tomato, the relevant aspects of its meaning are different when the text discusses its color than when it discusses its shape. Tomatoes are red is relevant in the context of painting a picture of a tomato but tomatoes are round is relevant in the context of rolling a tomato across a table.

Research on reading is often organized by Perfetti and Stafura's (2014; Perfetti, 2007; also Cromley & Azevedo, 2007) general framework for comprehension. Word knowledge is at the center of this framework. This is reflected in the "lexical quality hypothesis" that skilled reading depends on high-quality, robust knowledge of words (Perfetti & Hart, 2002). High-quality representations are said to be essential to understanding which aspects of a word's meaning are contextually relevant and therefore essential to successful comprehension (Perfetti & Hart, 2002; Perfetti, 2007).

We examined the representations of words' meanings as they were encoded into short stories by testing memory for them. There was a series of blocks of trials and for each block, participants read six stories, one at a time. They then received a list of true/false test sentences, some for which the truth or falsity could be evaluated only by reference to

one of the six stories and some for which the truth or falsity could be evaluated by reference to general knowledge (e.g., "the sky is concrete," "newspapers are reading material," "tomatoes are red," "tomatoes are round"). The materials of interest were pairs of stories like these "tomatoes" stories:

> "This painting would require great accuracy. The painter searched many stores to find the color most suited to use in painting the ripe tomato."

> "The child psychologist watched the infant play. The little girl found a tomato to roll across the floor with her nose."

For the first, the meaning of tomato is more to do with red than round and for the second, it is the reverse. The test sentence "tomatoes are red" matches the first text and not the second, and the test sentence "tomatoes are round" matches the second but not the first. The question was whether verification of a matching sentence was easier than verification of a mismatching sentence.

The diffusion decision model

An important difference between our study and many other studies of comprehension including those that have investigated contextually relevant meaning is that we use a quantitative model of decision making (Ratcliff, 1978; Ratcliff & McKoon, 2008). For the experiments reported here, participants were asked to make two-choice decisions

(true-false).

The model solves problems that have been ubiquitous in decision making research. First, it translates accuracy and RTs into the same underlying components of the decision process, one of which is the information from memory upon which the true-false decisions are based. This allows direct measurement of the degree to which matching versus mismatching information is encoded into the meanings of the texts. Second, it explicitly addresses the speed/accuracy tradeoffs that individuals adopt, which is required because an individual may respond with low accuracy to test items because he or she does not know the relevant information or because he or she does know the information but decides to prioritize speed over accuracy. The criterion that an individual sets to determine the accuracy and RTs of his or her responses is a second component of the model, independent of the first. The third problem that the model addresses is that of scaling. For example, suppose the baseline mean RT for one group of individuals is 1000 ms and for another it is 700 ms. Further, suppose the mean difference in RTs between two experimental conditions is 150 ms for the first group and 80 ms for the other. The problem is how to interpret the effect of the independent variable. In other words, is the size of the effect the same for 150 out of 1000 as for 80 out of 700? The model allows this question to be answered. The fourth advantage of the model is that it can substantially increase the power to observe differences among the conditions of an experiment when there are relatively small numbers of observations and/or the variability in accuracy and RTs is too large to detect effects.

These contributions of the diffusion model to research on text comprehension are crucial for the development of theories about comprehension in general and about the comprehension skills of older and low-literacy individuals in particular. To develop such a theory, it is essential to know to what extent individuals have encoded textual information but this is not possible without separating away individuals' choices of speed/accuracy settings. It is also impossible to compare one individual's skills, or one population's skills, to another's without dealing with scaling issues. And, increasing the power of experiments should allow finer discriminations among theories.

In earlier research, the insights gained by application of the diffusion model have been demonstrated for elderly adults in a number of tasks, including lexical decision, recognition memory, numerosity judgments, and perceptual tasks. Generally, prior to application of the diffusion model, it had been assumed that all, or almost all, cognitive processes slow with age and so less information can be brought to bear on decisions. However, application of the model showed this is not the case for many tasks (e.g., Ratcliff, Thapar, & McKoon, 2004, 2010, 2011): elderly adults are slower than young adults in large part because they set their speed/accuracy settings to value accuracy more than young adults do.

The three experiments

We tested whether words' meanings were encoded in a contextually relevant fashion in three experiments. For Experiment 1, the participants were college students, for Experiment 2, they were older adults with a mean age of 70.6, and for Experiment 3, they were adults who read at only about the seventh grade level. McKoon and Ratcliff (1988) found that college students show contextually relevant encoding in an experiment similar to that reported here and so we expected to replicate their finding. The more important questions were whether this ability declines with age and whether it is an ability missing from the comprehension skills of poor readers. If word knowledge is indeed at the center of comprehension, then if older adults fail to properly encode it, there are serious implications for their abilities to use, for example, financial or health information. If poor readers fail, constructing meanings in context should be a focus of classes aimed at improving their reading skills.

Older adults

As we describe in more detail later, studies of context effects with older adults have produced mixed results, some indicating that they do encode meanings in a contextually relevant fashion and some that they do not. There have been many hypotheses about the effects of age on cognitive processes that are relevant to reading comprehension. Older adults may have a deficit in short-term memory, in binding one piece of information to another, in processing speed, and/or in the ability to discard irrelevant information. Especially relevant here, Craik and Byrd (1982) proposed that older adults are limited in the richness with which they encode words' meanings and therefore limited in the extent to which context determines what they encode.

In Experiment 2, we found that the older adults did encode contextually relevant meanings. Their responses were slower than those of the young adults but, as with the earlier research mentioned above, this was due, in the main, to differences in their speed-accuracy criteria settings. Older adults generally set their boundaries to strongly value accuracy, setting them within only a few percent of the boundaries that would give the maximum possible accuracy (Starns & Ratcliff, 2010; Starns & Ratcliff, 2012).

Adults with poor reading skills

Low literacy is a dramatically large problem in the United States (The National Center for Education Statistics; Baer, Kutner, & Sabatini, 2009; Kutner, Greenberg, & Baer, 2006; Miller, McCardle, & Hernandez, 2010; Greenberg, 2008). The International Adult Literacy Survey Institute. (2011) found that about 23% of adults in the United States read prose at the lowest level scored, indicating difficulty with comprehending even the most basic textual information; the National Assessment of Adult Literacy (Kutner et al., 2006) found that 43% lack the necessary literacy skills for most living wage jobs; and the Organization for Economic Co-operation and Development (OECD, 2013) found that one in six adults, about 36 million (two-thirds of them born in the United States) have low literacy skills. As Nicholas Kristof of the New York Times has put it (October 26, 2014), these data "should be a shock" to all Americans.

Previous research with poor readers has been interpreted as showing that they have difficulties with most, if not all, elements of comprehension, including establishing contextually relevant meanings. However, as with the older adults, we found that they did encode such meanings. And, again, their responses were slower than those of the young adults mainly because they set their boundaries farther apart, valuing accuracy more than speed.

College students: Experiment 1

Many studies have been interpreted as showing that good readers' understandings of word meanings during reading are context dependent. For college-age adults who read well, Barsalou (1982), Tabossi and Johnson-Laird (1980), Tabossi (1982), and McKoon and Ratcliff (1988) all found that the time taken to verify a true sentence was shorter when the information in the sentence was relevant to the information in an immediately preceding text. For example, in Tabossi's experiment, the time to verify that banks contain money was shorter after "the bank was robbed by three bandits" than after "the bank was built 10 years ago."

For good readers, context-dependent meanings appear not only to be available immediately after a context sentence but also encoded into memory with their context sentences. Anderson et al. (1976) and Anderson and Ortony (1975) used cued recall paradigms. Anderson et al. had participants study sentences (in mimeographed booklets) like "the fish attacked the swimmer" and "the fish avoided the swimmer" and found that "shark" was a better cue for the "attack" sentence than for the "avoid" sentence and Anderson and Ortony (1975) found that