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The influence of cloze probability and item constraint on cloze task response time

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ABSTRACT

In research on the role of lexical predictability in language comprehension, predictability is generally defined as the probability that a word is provided as a sentence continuation in the *cloze task* (Taylor, 1953), in which subjects are asked to guess the next word of a sentence. The present experiments investigate the process by which subjects generate a cloze response, by measuring the latency to initiate a response in a version of the task in which subjects produce a spoken continuation to a visually presented sentence fragment. Higher probability responses were produced faster than lower probability responses. The latency to produce a response was also influenced by item constraint: A response at a given level of probability was issued faster when the context was more constraining, i.e., a single response was elicited with high probability. We show that these patterns are naturally produced by an activation-based race model in which potential responses independently race towards a response threshold. Implications for the interpretation of cloze probability as a measure of lexical predictability are discussed.

Introduction

Lexical predictability plays an important role in incremental language comprehension. In reading, the eyes spend less time on a word when it is predictable in its sentence context than when it is a less predictable but plausible sentence continuation (e.g., Ehrlich & Rayner, 1981; Smith & Levy, 2013; Staub, 2011). In event-related potential (ERP) research, the amplitude of the N400 component, which is elicited by each word of a sentence in both written and spoken language comprehension, is modulated by a word's predictability (e.g., Federmeier & Kutas, 1999; Kutas & Hillyard, 1984), with N400 amplitude decreasing as a word becomes more predictable. Thus, we have evidence that lexical predictability influences overt processing behavior, and we also have direct evidence of the influence of predictability on the neural processes that presumably underlie this behavior. Recent reviews of predictability effects, and discussion of their interpretation, can be found in Federmeier (2007), Pickering and Garrod (2007), and Van Petten and Luka (2012). Lexical predictability also plays a central role in recent computational models of sentence processing that have emphasized the conditional probability of a word as a determinant of processing difficulty (Hale, 2001; Levy, 2008).

In such research, a word's predictability in a given context is almost always operationalized in terms of *cloze probability* (Taylor, 1953). This measure is simply the proportion of participants who provide the word in question as the next word of the sentence, given the preceding words. Due to the extensive interest in predictability effects, and also due to the fact that researchers often control for predictability when investigating effects of other

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lexical or sentence-level variables, the cloze task has become one of the most widely used laboratory tasks in psycholinguistics. In standard practice, a fragment of a sentence is presented in written form to a group of subjects in a norming session prior to the comprehension experiment that is the researchers' main focus. Usually, two distinct groups of subjects complete the cloze task and the comprehension experiment. The subjects in the cloze task are asked to write the word that seems most likely as the next word of the sentence, though there is great variability in instructions, with some researchers asking for the most natural continuation, the most plausible continuation, the 'best' continuation, or the first word that comes to mind. In the associated comprehension experiment, researchers usually assess the effect of predictability in one of two ways: by comparing the processing of a given word in contexts in which this word has high or low cloze probability (as in 1a–b; target words italicized), or by holding the context constant, and comparing two different words that have high and low cloze probability in this context (2a–b). The first of these designs maintains control over lexical variables, at the cost of contextual variability, while the second maintains control over the context, at the cost of lexical variability. On occasion, context and target are fully crossed (3a–d).

(1) a. The athlete pulled a *muscle* in his leg during the competition.
b. Peter says that a *muscle* in his leg was bothering him during soccer practice. (Sheridan & Reingold, 2012)

(2) a. He scraped the cold food from his *plate* before washing it.
b. He scraped the cold food from his *spoon* before washing it. (Rayner & Well, 1996)

(3) a. Before warming the milk, the babysitter took the infant's *bottle* out of the travel bag.
b. To prevent a mess, the caregiver checked the baby's *bottle* before leaving.
c. Before warming the milk, the babysitter took the infant's *diaper* out of the travel bag.
d. To prevent a mess, the caregiver checked the baby's *diaper* before leaving. (Rayner, Ashby, Pollatsek, & Reichle, 2004)

The cloze task is itself a language production task. It is an off-line task, in the sense that it does not require the subject to make a rapid, or even timed, response. The use of cloze probability as a predictor variable in language comprehension research rests, then, on the assumption that the off-line production probability of a word obtained from one group of subjects predicts some aspect of on-line comprehension of that word for a different group of subjects. This broad assumption appears justified, as cloze probability is a very useful predictor variable indeed. Smith and Levy (2011) found that a word's cloze probability is a better predictor of self-paced reading time than is the word's empirically determined conditional probability, as estimated from either a book corpus or a web-based corpus. Indeed, corpus-based conditional probability explained no additional reading time variance in a model that included cloze probability. Similarly, Frisson, Rayner, and Pickering (2005) found that even small differences in cloze probability at the low end of the scale influence eye fixation durations in reading, and that corpus-based transitional probability has no additional effect when cloze probability is carefully controlled (cf. McDonald & Shillcock, 2003).

The present work is motivated by the question of what the cloze probability of a word actually represents, in cognitive terms. The answer to this question requires a theory of how subjects perform the cloze task. This is the situation for most dependent variables in laboratory tasks; for example, the probability that a particular stimulus will be identified as 'old' in a recognition memory task receives a psychological interpretation only in the context of a theory of how subjects perform old/new judgments. At the broadest level, cloze probability has been assumed to represent native speakers' estimates of a word's probability given the preceding sentential context, such that, if in (2) above *plate* has cloze probability of .8 and *spoon* has cloze probability of .2, it can be reasonably concluded that native speakers estimate the probability of *plate* in this context to be .8 and *spoon* to be .2. But what kind of implicit theory of how the task is performed links cloze probabilities to speakers' estimates of conditional probability?

There are two possible theories that researchers may have in mind. The literal meaning of cloze values of .8 for *plate* and .2 for *spoon*, in (2) above, is that *plate* was provided as a sentence continuation by 80% of the participants in a cloze norming session, while *spoon* was provided by 20% of participants. Thus, one apparently plausible interpretation is that there are two groups of subjects who are genuinely different, in terms of their linguistic experience and real-world knowledge, so that for 80% of subjects *plate* is the most expected word, and for 20% *spoon* is the most expected word, with each subject producing his or her most expected word. On this view, the cloze probability of a word represents its predictability for the community of speakers in the aggregate, but not for individual speakers. For each individual speaker there is a single most expected word. (See Van Petten & Luka, 2012, for further discussion of this idea.)

If this were the model linking cloze probabilities to predictability, a comprehension experiment with sentence (2) above would be expected to reveal two distinct groups of subjects, with approximately 80% of participants responding to *plate* as if it is the expected word, showing relatively fast reading of this word and a reduced N400 amplitude, and the other 20% of participants showing the opposite pattern, with a processing advantage for *spoon*. No such distinction between subgroups of comprehension subjects has ever been reported or, to our knowledge, seriously considered. We infer that this is not, in fact, the link between cloze probabilities and predictability that researchers have in mind.

The alternate theory assumes that though each subject in the cloze task provides only a single response (leaving aside the relatively few cloze studies in which subjects are asked to provide multiple responses, e.g., Roland,