



Linguistic experience affects pronoun interpretation

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ARTICLE INFO

Keywords:

Pronoun comprehension
Individual differences
Print exposure
Discourse

ABSTRACT

We test the hypothesis that language experience influences the cognitive mechanisms used to interpret ambiguous pronouns like *he* or *she*, which require the context for interpretation. Pronoun interpretation is influenced by both the linguistic context (e.g., pronouns tend to corefer with the subject of the previous sentence) and social cues (e.g., gaze can signal the pronoun's referent). We test whether pronoun comprehension biases are related to the individual's linguistic exposure. We focus on written language experience as a metric of linguistic exposure, given that reading experience varies widely, and can be probed with the Author Recognition Task (ART). In three experiments, people with higher ART scores assigned pronouns to the grammatical subject more consistently. ART scores correlated with some skill measures, but pronoun comprehension was not explained by working memory, theory of mind, or socioeconomic status. Our results suggest that language exposure affects language comprehension at the discourse level.

How does our linguistic experience influence the mechanisms of language processing? There is no doubt that one must hear a language to learn it, so experience must be involved at some level. Yet it is unclear whether specific individual differences in experience affect the strategies or mechanisms used to process language, in particular at the discourse level. Here we address this question by investigating individual differences in the comprehension of ambiguous pronouns like *he* and *she*.

Recent evidence suggests that lexical and syntactic processing mechanisms are modulated by language experience (Farmer, Fine, Misyak, & Christiansen, 2017; Farmer, Monaghan, Misyak, & Christiansen, 2011; James, Fraundorf, Lee, & Watson, in press; Wells, Christiansen, Race, Acheson, & MacDonald, 2009) and the frequency of syntactic structures in natural language (MacDonald, 2013; Montag & MacDonald, 2015; Tanenhaus & Trueswell, 1995). These findings raise questions about whether exposure also affects the processing of larger units of text, such as anaphoric relations between pairs of utterances. Here we test this question with respect to spoken pronoun comprehension, by asking whether individual differences in print exposure correlate with spoken pronoun comprehension biases. This question is important to examine, given that many current models of pronoun comprehension suggest that people rely on calculations of probabilities, such as the probability that the speaker would refer to a particular referent (Arnold, 1998; Kehler, Kertz, Rohde, & Elman, 2008), or the probability that the speaker would use a pronoun (Kehler et al., 2008).

These theories raise questions about whether pronoun comprehension is related to the comprehender's knowledge about which referential patterns are more frequent in discourse.

One well-known finding is that pronouns are assigned to linguistically salient referents. One linguistic feature that signals contextual salience is grammatical position, where characters mentioned in grammatical subject position are considered salient and topical (Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000; Brennan, Friedman, & Pollard, 1987; Garnham, 2001; Gordon, Grosz, & Gilliom, 1993; Stevenson, Crawley, & Kleinman, 1994). For example, in *Ella ate lunch with Leona. She had a salad*, the pronoun *she* could refer to either Ella or Leona. Nevertheless, listeners tend to assume that Ella is the referent, since she was in subject position in the first sentence, and was the first mentioned (Gernsbacher & Hargreaves, 1988). This is known as the "subject bias", where subjects are generally preferred as pronoun referents. This bias is not grammatically required, in that pronouns can also be used to refer to the object (*Birdie gave Kay a cookie, and she ate it*). Instead, the subject bias represents a general tendency. Other linguistic constraints influence listeners' preferences as well, for example a parallel syntactic function bias (Chambers & Smyth, 1998; Grober, Beardsley, & Caramazza, 1978), linguistic focusing constructions (Almor, 1999; Arnold, 1998; Cowles, Walenski, & Kluender, 2007; Foraker & McElree, 2007), or prior pronominalization (Kaiser, 2011; Kameyama, 1996).

Theoretically, these linguistic patterns have been explained in terms

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of the conceptual status of the referent. Pronouns tend to be used for referents that are salient, or accessible in the context (e.g., Ariel, 1990; Gundel, Hedberg, & Zacharski, 1993), and they are understood more quickly if they have a focused or salient antecedent (e.g., Garnham, Traxler, Oakhill, & Gernsbacher, 1996; MacDonald & McWhinney, 1995). Salience is not merely a property of the discourse context, and can even be affected by nonlinguistic, social information like pointing or gazing (Goodrich Smith & Hudson Kam, 2012; Hanna & Brennan, 2007). A finding that is key to the current study is that pronoun comprehension is influenced by gaze and pointing gestures, where people are more likely to assign pronouns to referents when the speaker has gazed or pointed at them (Nappa & Arnold, 2014).

However, defining salience/accessibility is difficult, which has led several researchers to suggest that probability representations instead provide a concrete mechanism for characterizing information status. For example, recently mentioned entities are considered salient in the discourse, and are good candidates as pronoun referents, as in *Lester wrote a book, and he gave it to his grandchildren*. In addition, recently mentioned entities are highly likely to feature in the subsequent discourse, and therefore are **referentially predictable**. Arnold (1998, 2001, 2010) suggested that this predictability underlies the constraining effects of the linguistic context. For example, in addition to recently mentioned entities, grammatical subjects are more likely to be re-mentioned than other entities in an utterance, other things being equal (Arnold, 1998; Brown, 1983). Thus, predictability may also underlie the subject bias in pronoun comprehension. These patterns of re-mention provide evidence to language learners about the kinds of things that speakers tend to be attending to and what is likely to be important in the upcoming discourse.

A related idea emerges in several Bayesian models of reference comprehension. For example, in Kehler and Rohde's (2013) computational model (see also Kehler et al., 2008), pronoun interpretation depends on estimating both the probability that a particular entity will be mentioned again and the probability that the speaker will use a pronoun. Their model has been used to account for contexts such as *Dorothy impressed Lucy because she...*, where people tend to associate "she" with Dorothy. They suggest that this stems from two probabilities: first, the high probability that Dorothy would be mentioned in this context, given that she is the most likely cause of the impressing event, and second, the fact that speakers tend to use pronouns when referring to entities last mentioned in subject position, i.e. Dorothy.

Similar Bayesian models are proposed by Hartshorne, O'Donnell and Tenenbaum (2015) for pronoun comprehension, and by Frank and Goodman (2012) for reference modification. Frank and Goodman's model addresses the use of modifiers like "blue" for shapes in a display. They calculate the probability of referring to each shape (without any discourse context) by telling people that a speaker has used an unknown word to refer to one of three shapes, and asking them to bet which object it is. Thus, they use an experimental task to estimate probability of reference. Hartshorne et al.'s model is specifically about pronoun comprehension, but it calculates the probability of the message, rather than the probability of a referent per se. Hartshorne et al. focus on implicit causality sentences like *Archibald angered Bartholomew because he is reckless*, which tap into the calculation that the speaker probably meant that Archibald is reckless, because the semantics of "angered" makes that the most probable meaning. Thus, inferences about the most probable message have direct consequences on inferences about the most probable referent.

These models raise a critical question: where do referential probabilities come from? One possibility is that people use semantic knowledge to calculate the speaker's likely content, as in Hartshorne, O'Donnell, and Tenenbaum's (2015) model. An alternate (and not mutually exclusive) possibility, which is the idea behind the current study, is that comprehenders may draw on their experience with how linguistic units are used. For example, they may learn that speakers tend to continue talking about recently mentioned entities, especially

subjects (Arnold, 1998, 2001, 2010). That is, discourse-level relations are systematic, and listeners may learn which patterns are most frequent. If so, we would predict that people with greater exposure to language should learn these patterns more strongly, and be more likely to access them during language processing.

Support for this hypothesis comes from the fact that effects of both frequency and linguistic experience have been found for syntactic and lexical processing. First, studies demonstrate that frequency affects language processing. Comprehenders are faster to understand both words (Solomon & Howes, 1951) and structures (MacDonald, 1994, 2013; Tanenhaus & Trueswell, 1995) that occur more frequently. Second, recent work even suggests that adult language users continue to implicitly learn about the frequency of linguistic structures in their environment, such that recent experience changes the way new input is processed (Farmer et al., 2011, 2017; Fine & Jaeger, 2013; Fine, Jaeger, Farmer, & Qian, 2013; James et al., in press; Wells et al., 2009). Some support for this idea comes from studies that manipulate experience within the experiment. For example, the comprehension of relative-clause constructions was facilitated when subjects were exposed to similar structures over a 3-week training period (Wells et al., 2009). Likewise, comprehension biases changed through exposure to exemplars of syntactic constructions, especially rare ones (Fine & Jaeger, 2013). Other support comes from studies that look at individual differences in print exposure – that is, reading and exposure to books – which is one source of language experience. For example, people with greater print exposure are more accurate in written syntactic processing tasks (e.g., James et al., in press), and more likely to use literate structures like passives (Montag & MacDonald, 2015).

In addition, Oakhill and Yuill (1986) found that children classified as high-skill readers had better pronoun comprehension than low-skill readers. In their study, 7–8 year old children read sentences like "Peter lent ten pence to Liz because she needed it," which required an inference based on implicit causality judgments. Low-skilled readers made more errors, even in stories where the two characters differed in gender (and thus the pronoun was unambiguous by gender). Given that reading skill typically correlates with reading exposure (Stanovich & West, 1989), this provides initial evidence that exposure does affect comprehension accuracy. However, their study focused entirely on sentences requiring a semantic inference to understand a pronoun (with or without a gender cue), and it is not clear whether exposure also affects sensitivity to information-status cues like the subject bias. In addition, their study critically showed that reading skill predicted performance on a reading task. Here we ask instead whether exposure affects comprehension in spoken language.

The importance of language exposure is also indirectly supported by research on working memory. Many studies have shown that individuals vary in their working memory capacity, i.e. their ability to hold information in memory while doing cognitive tasks (Baddeley, 1992). Daneman and Carpenter (1980) developed a language-specific version of this task, the sentence span task, in which subjects judge the grammaticality of sentences while holding words in memory. They demonstrated that this verbal memory span correlates with successful language comprehension. Verbal memory span also predicts performance on discourse comprehension tasks (Calvo, 2001; Linderholm, 2002), including pronoun comprehension tasks (Daneman & Carpenter, 1980; Nieuwland & van Berkum, 2006). Yet some researchers have argued that the sentence span task is not a pure indicator of memory capacity, and that it is heavily influenced by individual variation in language experience (MacDonald & Christiansen, 2002). Indeed, Farmer et al. (2017) found that Caplan and Waters' (1999) sentence span task correlated significantly with other proxy measures of reading exposure, such as the Author Recognition Task (Stanovich & West, 1989). Thus, evidence that verbal span correlates with pronoun comprehension may suggest a role for reading experience.

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