IMPLICIT ARGUMENT INFERENCES IN ON-LINE COMPREHENSION[1]

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Abstract

While people are capable of constructing a variety of inferences during text processing, recent work on inferences suggests that only a restricted number of inferences are constructed on-line. We investigated whether implicit semantic information associated with the arguments of verbs is automatically encoded. Short passives such as "The ship was sunk" are intuitively understood as containing an implicit Agent, e.g. that someone is responsible for the ship's sinking. To investigate whether implicit Agents are encoded automatically, short passives were compared to intransitive sentences with the same propositional content. The experimental logic used depended on a specific property of rationale clauses such as "to collect an insurance settlement"; namely, that the contextual element associated with the understood subject of the rationale clause must be capable of volitional action. If people encode an implicit Agent while processing short passives, then they should be able to associate it with the understood subject of a rationale clause. No such association should be possible with intransitives. In two experiments, intransitives elicited longer reading times and were judged to be less felicitous than short passives at the earliest point possible in the the rationale clause. Short passives were judged fully felicitous and their reading times did not differ from control sentences with explicit agents.

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Introduction

While a reader's representation of a text or discourse clearly contains a mixture of information that is explicitly represented in the text and information that is inferred, it remains unclear what types of inferences are typically drawn during immediate or "on-line" comprehension. Research in the 1970's that relied mostly on memory paradigms led to the conclusion that a rich variety of inferences are encoded when a reader constructs an interpretation of a text. However, recent work using on-line paradigms has suggested that inferencing may be much more restricted and limited (see McKoon and Ratcliff, 1991). In fact, McKoon and Ratcliff argue for a minimal inferencing model in which the only inferences that are routinely drawn are those that are easily accessible (e.g. based on associations) and those that are required for local coherence. This last type might include inferences triggered by syntactic or semantic information that is implicitly represented in sentences.

Many sentences in English contain implicit syntactic and semantic information. For example, many verbs can occur with optional arguments. Often these arguments are not expressed in a sentence when their content is provided by information in the context. For example, the prepositional phrase that expresses the recipient of the donation in sentence (1) is likely to be omitted when the recipient is provided by the context, as in (2). In (2), there is an implicit "Recipient" argument that may function anaphorically to integrate the sentence with the context (Carlson and Tanenhaus, 1988).

(1) John donated five dollars to the United Fund.
(2) The United Fund asked John for a contribution. John donated five dollars.

In addition, there may be other implicit arguments that are not anaphoric, but which may also be encoded as part of the normal understanding of a sentence (Fillmore, 1986). One likely candidate is the English passive construction. Full passives contain an explicit "by-phrase" which introduces either an "Agent" or an instrument, as in (3). However, short passives such as (4) do not specify an Agent. Nonetheless, we have the strong intuition that the interpretation of the sentence includes an understood or implicit Agent. These intuitions can be highlighted by comparing a short passive to a sentence with the same explicit propositional content, as in (5). In contrast to (4), sentence (5) does not seem to imply that someone was responsible for the sinking of the ship.

(3) The ship was sunk by the captain.
(4) The ship was sunk.
(5) The ship sank.

This paper presents two experiments that were conducted to determine whether the hypothesized implicit Agent associated with short passives is, in fact, encoded during sentence processing.

How one should go about finding evidence for the encoding of non-anaphoric implicit arguments is not immediately clear. Studies investigating empty categories and anaphoric implicit arguments have often looked at whether the referential expression primes its antecedent. However, the one study that has used a priming methodology to investigate implicit Agents did not find reliable priming effects (MacDonald, 1989). However, this result is not surprising because priming depends upon the anaphoric properties of the implicit Agent. To the extent that implicit Agents are not, as we have argued, anaphoric, then one should not expect to see priming to a potential Agent that has been introduced earlier in the discourse.

The logic we used depends on a specific property of rationale clauses. Rationale clauses are adverbial infinitive modifiers that carry a connotation of purpose (see Jones, 1991 for extensive discussion). Like all infinitive clauses, rationale clauses have an understood subject. Although some infinitive clauses allow their subjects to be interpreted arbitrarily, the understood subject of many others must be associated with a noun in the preceding context. Rationale clauses are of this second type. Moreover, rationale clauses require the contextual element that is associated with its understood subject to be capable of volitional action (e.g. to be agentive), as the sentences in (6) illustrate.

(6) a. John$_i$ hit the man$_j$ [e$_i$ to stop him$_j$]
b. *The bat$_i$ hit the man$_j$ [e$_i$ to stop him$_j$]

Thus, the logic for the following studies is this: if people encode an implicit Agent as part of their representation of a short passive, then this implicit argument, being agentive, should provide a contextually appropriate antecedent for the understood subject of a rationale clause. In contrast, if a rationale clause is preceded by an intransitive, there should be no contextually appropriate antecedent available for interpretation. As a result, comprehension difficulties should be encountered. The sentences in (7) appear to confirm this hypothesis; (7a) appears to be felicitous, whereas (7b) is not.

(7) a. The ship was sunk to collect a settlement from the insurance company.
b. The ship sank to collect a settlement from the insurance company.

These intuitions suggest that interpretation of a short passive includes the representation of an implicit agent. However, intuitions alone do not provide evidence about when in the time course of comprehension the implicit Agent is encoded; and whether encoding an implicit Agent requires making a resource-demanding inference. The experiments that we report were designed to answer these questions.

Experiment 1.

Experiment 1 was designed to experimentally establish the contrast between short passives and intransitives presented in (7). In order to do so, we used a word-by-word self-paced reading task in which subjects also pressed a button if the sentence stopped making sense at any point. This "stop-making-sense" task has proved useful in studying the time course of processing of sentences with other types of infinitive clauses (Boland, Tanenhaus, and Garnsey, 1990) and sentences with filler-gap relationships e.g. Tanenhaus, Garnsey & Boland, 1990).

Method

Stimuli consisted of 20 sentence pairs formed from a passivized transitive verb and its intransitive correlate followed by a rationale clause, like the pair given in (7). Within each stimulus pair, the same inanimate subject and rationale clause were used. Both presentation lists contained 10 passive-initial sentences and 10 intransitive-initial sentences randomly interspersed among 36 distractor sentences, 11% of which did not make sense. Items from the two experimental conditions were counterbalanced for length and condition across the two lists. The critical region of each sentence consisted of the transitive or intransitive verb and the first four words of the rationale clause, which always consisted of the infinitive marker "to" followed by a verb, a determiner, and a noun. A 4-word post-critical

region was included to avoid contaminating critical region latencies with a "wrap-up" effect (end of sentence increases in response times). No item was longer than a single line. Prior to completing 10 practice trials, 26 native English-speaking undergraduates from the University of Rochester were given examples of sentences that did not make sense and explanations of why they did not make sense. In both practice and experimental trials, after presentation of a trial number, subjects controlled the word-by-word presentation rate of sentences with a button press, as each sentence accumulated across the screen of a video monitor. Subjects continued pressing a "Yes" button as long as a sentence made sense. When a sentence ceased to make sense, subjects pressed a "No" button which then ended the current trial and initiated a new one.

RESULTS AND DISCUSSION

We collected two types of data, the percentage of "no" judgments and the amount of time it took subjects to make "yes" judgments (latency data). Recall that when a "no" response is made at a given word position, the trial ends. As a result, simple frequencies of "no" responses at each word position are dependent on whether any "no" responses were made at previous word positions. Thus, to minimize the dependence of values at later positions on earlier ones, judgment data were transformed into percentages adjusted to reflect the remaining number of opportunities to respond "no" at each word position. These percentages of remaining "no" responses were then entered into analyses of variance.

Judgments. The cumulative percentages of "no" judgments in Figure 1 and analyses of variance on the percentages of remaining "no's" reveal no differences between passives and intransitives at the first and second word positions and, as expected, intransitives elicited a significantly greater proportion of "no" responses than passives at the verb, $F1(1,24)=6.63$, $p<.02$; $F2(1,18)=9.27$, $p<.01$, in both subject and items analyses.

Latencies. Latencies for "yes" judgments provide information about processing differences that may not be reflected in judgment data. In word-by-word reading, subjects frequently encounter locally incoherent points that resolve coherently in a word or two. Consequently, even when a sentence stops making sense, subjects may wait for a word or two before pressing the "no" button. It is assumed that when subjects encounter a point of local incoherence but still respond "yes", that they must be encountering some processing difficulty and that this difficulty will be reflected as an increase in response times. The response latencies for "yes" judgments shown in Figure 2 revealed that intransitives elicited longer response times than short passives at the verb $F1(1,24)=6.12$, $p<.03$; $F2(1,18)=1.35$, $p>.2$, and at the determiner $F1(1,24)=7.01$, $p<.02$, $F2(1,18)=2.85$, $p>.1$, but that the effect was significant only in the subjects analysis.

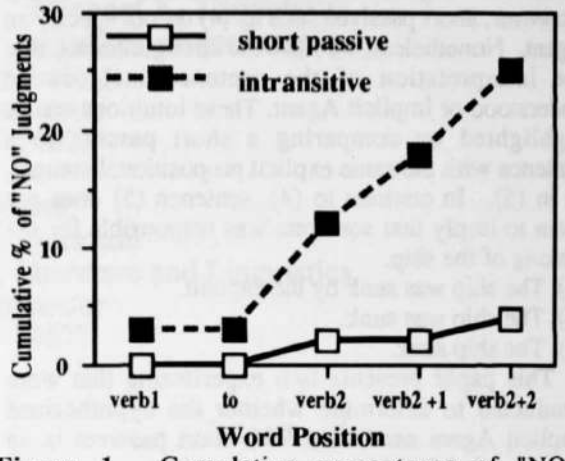

Figure 1. Cumulative percentages of "NO" judgments to short passives and intransitives by word position.

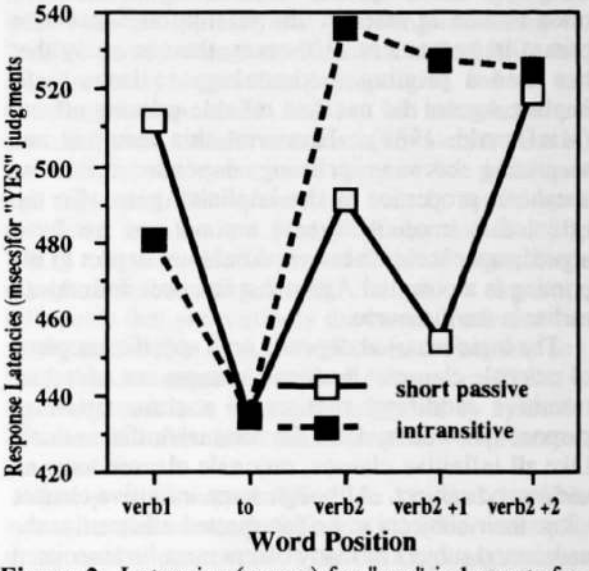

Figure 2. Latencies (msecs) for "yes" judgments for short passives and intransitives by word position.

The reader may wonder why clear effects in the subject analyses do not approach significance in the item analyses for the latency data. The reason is discussed in detail in Boland et al (1990). Subjects who are reading quickly tend to respond "no" a word or two later than subjects who are reading more slowly. However, their "no" responses are often extremely fast, indicating that they probably detected the oddity on the preceding word. As a result, fast subjects contribute relatively more data than slow

subjects to the intransitive conditions beginning at the verb in the rationale clause, and this varies somewhat by item. If item means are adjusted (using a conservative data replacement method) to estimate what the means would have been given equal contributions from all subjects, then the item statistics show the same pattern as the subject statistics.

Discussion. While the results of Experiment 1 clearly establish a difference between short passives and intransitives, they do not indicate whether or not encoding the implicit Agent for the short passives required a resource-demanding inference. In order to answer this question, it is necessary to compare the short passives to constructions that provide an explicit Agent. Experiment 2 was conducted for this purpose.

Experiment 2.

Two control conditions, an active declarative and a full passive, were added to the short passive/ intransitive manipulation of Experiment 1. Unlike the short passive, both control conditions contained an explicit Agent. Full passives are structurally similar to short passives, but their Agent by-phrases can introduce unintended infelicities (Mauner, 1991). Actives, while dissimilar structurally, have the same explicit arguments as full passives and are fully felicitous. Both control conditions were included because, a priori, it was not clear which would be the more appropriate control. A set of sample materials is given in (8).

(8) a. One of the owners sank the ship to collect a settlement from the insurance company. **active**
b. The ship was sunk by one of its owners to collect a settlement from the insurance company. **full passive**
c. The ship was sunk to collect a settlement from the insurance company. **short passive**
d. The ship sank to collect a settlement from the insurance company. **intransitive**

Because both control conditions have explicit agents they should both be judged felicitous. Short passives should pattern with active and passive controls if they too contain an Agent in their representation. Judgment data alone may not provide clear evidence about when readers encode an implicit Agent in short passives. An Agent could be encoded at the first verb if the semantic information associated with the verb is accessed and interpreted when that verb is recognized. Alternatively, an Agent may be inferred only after the verb in the rationale clause is encountered. On this view, an inference that creates an agent is easier following a short passive than following an intransitive, but it is the properties of the rationale clause that drive the inference. The latencies for subjects' "yes" decisions, can be used to decide between these two alternatives. This is because subjects might require time to make an inference but still say "yes". If an inference is required to create an Agent following the short passive, then we should expect longer latencies early in the rationale clause for short passives as compared to actives and full passive controls. If, however, the Agent was already encoded, then latencies for short passives should pattern with full passives and actives.

Method

The stimuli for Experiment 2 consisted of 20 sets of four sentences, each containing a short passive/ intransitive pair from Experiment 1 and their active and full passive correlates, as illustrated in (8). Although some control sentences extended onto a second display line, the critical region plus at least one additional word were always displayed on the first line. Distractor items were modified to include the display and structural characteristics of the new items. Items in each set of materials were counterbalanced for length and condition across four presentation lists and within each list, the 20 experimental items were interspersed among 36 distractor sentences, 11% of which were constructed to not make sense. Forty native English-speaking undergraduates from the University of Rochester participated in this experiment following the same procedure as Experiment 1.

RESULTS AND DISCUSSION

Judgment and latency data were collected and treated in the same manner as in Experiment 1. However because the first word of the critical region differed in terms of category across the conditions, this word position was not included in the latency analyses.

Judgments. The adjusted percentages of "no" responses in Figure 3 and the analyses of variance performed on the percentages of remaining "no"responses reveal no differences across conditions until the verb in the rationale clause, at which point "no" responses rise sharply for intransitives. At the verb, intransitives elicited more "no" responses than short passives $F1(1,36)=11.92$, $p<.001$, $F2(1,16)=12.70$, $p<.003$; actives $F1(1,36)=7.05$, $p<.02$, $F2(1,16)=12.89$, $p<.003$ and full passives $F1(1,36)=8.75$, $p<.006$, $F2(1,16)=12.90$, $p>.003$, when either subjects or items were random. These differences continued to be significant at later word positions with probability levels of $p=.05$ or less.

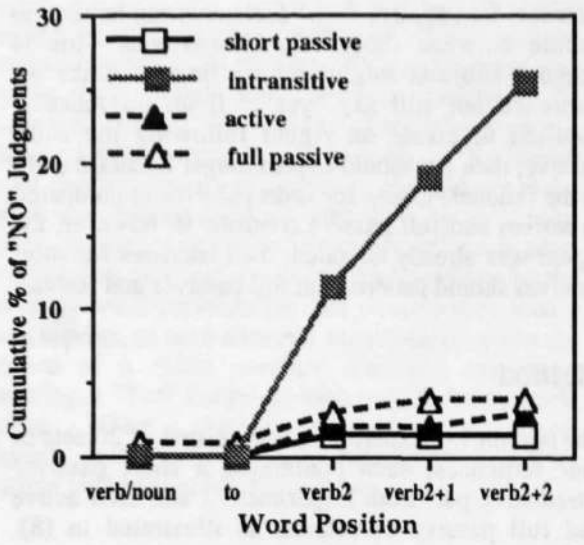

Figure 3. Cumulative percentages of "No" judgments to short passives, full passives, actives and intransitives by word position.

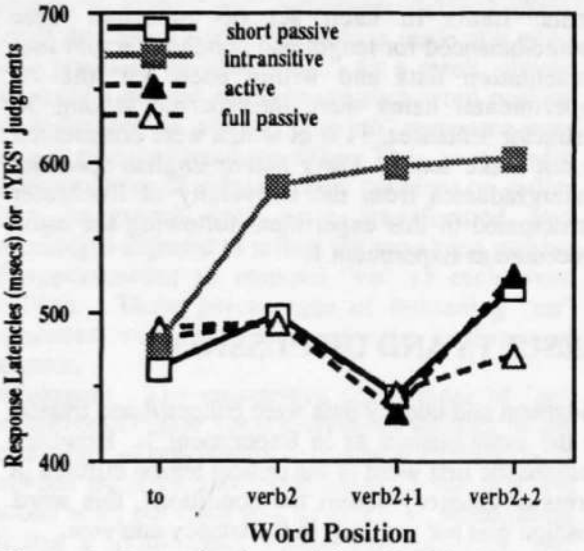

Figure 4. Latencies (msecs) for "Yes" judgments to short passives, full passive, actives and intransitive by word position.

Latencies. As the adjusted percentages of "No" response and cumulative percentages in Figure 4 show, intransitives elicited longer response times than the short passives $F1(1,33)=6.68$, $p<.01$, $F2(1,16)=.86$, $p<.3$; or active $F1(1,33)=5.58$, $p=.02$, $F2(1,16)=3.85$, $p<.07$, or full passive controls $F1(1,33)=5.31$, $p<.03$, $F2(1,16)= 2.90$, $p>.12$. These differences were weakly significant at the verb and clearly significant ($p<.02$) at following word positions. Moreover, short passives did not elicit longer response times than either control condition early in the rationale clause. Except at the noun position, there were no differences among these three conditions. At the noun, mean latencies were found to differ significantly ($p<=.05$) when subjects but not items were random. Further investigation revealed that while short passives and actives did not differ from each other, both elicited significantly longer latencies than full passives at the noun.

Discussion. In Experiment 2, short passives patterned with full passive and active controls in both judgment and latency data. Unlike the intransitives, which began to show felicity effects at the verb, short passives were judged to be as felicitous as full passive and active controls throughout the critical region. This suggests that the implicit Agent is indeed encoded as part of subjects' representations of short passives. Also in contrast to intransitives, short passives did not elicit longer response latencies than control conditions at any word position in the critical region. This suggests first, that no costly inference is required to encode implicit Agents, and second, that the processes that are involved in determining the grammatical relationships that exist between a verb and its explicit arguments are also likely to be involved in the encoding of implicit Agents.

General Discussion

These experiments demonstrated that rationale clauses that are preceded by short passives are no more difficult to process than rationale clauses that are preceded by clauses that introduce an explicit agent (full passives or active sentences with transitive verbs). In contrast, rationale clauses that are proceeded by a clause with an intransitive verb (with a subject that does not have agentive properties) are difficult to comprehend. Taken together, these results demonstrate that the encoding of implicit Agents in short passives takes place rapidly and that it does not involve a resource-demanding inference. While subjects could have inferred the presence of an Agent in the intransitive cases, it appears that either they did not, or that this inference was not constructed automatically. These results are consistent with McKoon and Ratcliff's (1991) suggestion that inferences are constructed automatically only if they are required to satisfy demands for local coherence. This minimalist position might seem to be too restrictive, at first. However, if one takes into account the range of implicit arguments and relations, as well as contextually dependent expressions in natural language, then the minimalist and constructivist positions are not as far apart as they might appear, although they differ in spirit. One can think of the implicit information in sentences as structural triggers that indicate what aspects of context, real-world knowledge, etc., are likely to be relevant to interpreting a sentence in context. In addition, some of the information that is part of the

understanding of a sentence may not be specific enough to be revealed by many of the methodologies that are currently most popular. The work we have presented here is a small step towards exploring the role that implicit information that is part of the syntactic and semantic structure of a sentence plays in guiding comprehension processes.

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REFERENCES

Boland, J.E.; Tanenhaus, M.K; and Garnsey, S.M., 1990. Evidence for the Immediate Use of Verb Control Information in Sentence Processing. *Journal of Memory and Language* 29:413-432.

Carlson, G.N. and Tanenhaus, M.K. 1988. Thematic Roles and Language Comprehension. In W. Wilkins ed., *Thematic Relations*. New York: Academic Press.

Fillmore, C. J. 1986. Pragmatically Controlled Zero Anaphora. Proceedings of the Twelth Annual Meeting of the Berkeley Linguistics Society, 97-107.

Jones, C. 1991. *Purpose Clauses*. Dordrecht: Kluwer Academic Publishers.

MacDonald, M. 1989. Priming Effects from Gaps to Antecedents. *Language and Cognitive Processes*, 4(1):35-56.

McKoon, G. and Ratcliff, R. Inference during Reading. Forthocoming.

Mauner, G. Syntactic Context and the Interpretation of VP Anaphors. Proceedings of the Twenty-Second Annual Meeting of the New England Linguistics Society. Forthcoming.

Tanenhaus, M. K., Garnsey, S.M., and Boland, J.E. 1991. Combinatory Lexical Information and Language Comprehension. In G. Altman ed. *Cognitive Models of Speech Processing: Psycholinguistic and Computational Perspectives.* Cambridge, MA: MIT Press.