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Journal of Memory and Language 47 (2002) 386–406

Journal of Memory and Language

www.academicpress.com

When is schematic participant information encoded? Evidence from eye-monitoring

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Received 2 October 2000; revision received 24 September 2001

Abstract

Two eye-monitoring studies examined when unexpressed schematic participant information specified by verbs is used during sentence processing. Experiment 1 compared the processing of sentences with passive and intransitive verbs hypothesized to introduce or not introduce, respectively, an agent when their main clauses were preceded by either agent-dependent rationale clauses or adverbial clause controls. While there were no differences in the processing of passive clauses following rationale and control clauses, intransitive verb clauses elicited anomaly effects following agent-dependent rationale clauses. To determine whether the source of this immediately available schematic participant information is lexically specified or instead derived solely from conceptual sources associated with verbs, Experiment 2 compared the processing of clauses with passive and middle verbs following rationale clauses (e.g., *To raise money for the charity*, *the vase was/had sold quickly*...). Although both passive and middle verb forms denote situations that logically require an agent, middle verbs, which by hypothesis do not lexically specify an agent, elicited longer processing times than passive verbs in measures of early processing. These results demonstrate that participants access and interpret lexically encoded schematic participant information in the process of recognizing a verb.

Keywords: Verb; Sentence processing; Sentence interpretation; Argument structure; Event participant; Eye-monitoring; Construction grammar

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[1] This research was supported (in part) by research grant 1 RO1 MH60133-01 from the National Institute of Mental Health, National Institutes of Health, and by grants from the Center for Cognitive Science at the University at Buffalo. We are indebted to the members of the Center for Cognitive Science at the University at Buffalo for helpful discussions and feedback on this work. We also gratefully acknowledge David Akinbami, Patrick Hoyle, and especially, Kathryn Conklin for their assistance. We also gratefully acknowledge many helpful comments and suggestions made by Keith Rayner and two anonymous reviewers.

PII: S0749-596X(02)00009-8

A fundamental aspect of comprehending a sentence is figuring out the "who did what to whom" part of its meaning. This involves determining how many linguistically necessary participants a sentence introduces and what role each of them plays in the described event. This process is relatively straightforward for sentences such as *Fred kissed Wilma* because the relevant participants, that is Fred, who is the kisser or agent, and Wilma, who is the one kissed or patient, are explicitly mentioned. However, determining what participant information a sentence conveys is not always so easy. Consider the short or agentless passive sentence *Wilma was kissed*. The usual interpretation of this sentence is that Wilma was kissed by someone, even though there is no agent participant explicitly mentioned in the sentence. A number of researchers have hypothesized that unexpressed or implicit agents (and more generally, all implicit arguments) are derived from the lexical representations of verbs (Carlson & Tanenhaus, 1988; Mauner, Tanenhaus, & Carlson, 1995; Roeper, 1987). This hypothesis has recently received empirical support from Mauner and Koenig (2000), who showed that unexpressed agent information is encoded as soon as a passive verb is recognized. In this paper, we provide converging evidence for both the hypothesis that implicit arguments are derived from lexical sources and that lexically encoded event participant information is used early in the process of interpreting a sentence. In addition, because the studies to be presented employ an eye monitoring paradigm and incorporate new stimulus controls, they address concerns that our prior results, which we have interpreted as evidence for the early processing of implicit participants, are due to either task artifacts or stimulus confounds.

The observation that the representations of sentences may include implicit participant information highlights the first of two important issues regarding the processing of sentences like *Wilma was kissed*; namely, how do readers determine what participant information a sentence conveys when it is not explicitly expressed? There are two broadly defined possibilities that we are mainly concerned with. One is that unexpressed participant information is specified by the lexical–semantic representations of verbs (e.g., verb argument structures). This possibility is supported by recent work of Mauner and Koenig (2000) that demonstrates that at least some participant information is lexically specified. A second possibility is that participant information is computed directly from general conceptual knowledge about the events described by a sentence. This possibility is supported by demonstrations that real-world knowledge, in the form of content-based expectations, thematic fit, and/or plausibility information, has an early influence on comprehension (Boland, 1997; Britt, Perfetti, Garrod, & Rayner, 1992; Ferreira & Clifton, 1986; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; McRae, Ferretti, & Amyote, 1996; Rayner, Garrod, & Perfetti, 1992; Schmauder & Egan, 1998; Speer & Clifton, 1998; Spivey-Knowlton & Sedivy, 1995, Taraban & McClelland, 1988, 1990; Trueswell, Tanenhaus, & Garnsey, 1994). A third possibility, which we argue is broadly consistent with the first, is that participant information is encoded in the grammatical representations of sentences (Goldberg, 1995). We will return to this third possibility at the end of the paper.

The second important issue regarding how readers come to interpret sentences like *Wilma was kissed* as including an unexpressed agent is determining when, and under what circumstances, lexical and content-based sources of participant information are consulted during sentence comprehension. The question of when participant information that is derived from lexical sources becomes available to interpretive mechanisms is the main focus of the studies presented here.

Research on when participant information is accessed during the parsing and interpretation of sentences has yielded conflicting results. Some studies have suggested that the use of participant information is delayed in parsing relative to syntactic category information (e.g., Boland, 1997; Ferreira & Clifton, 1986; McElree & Griffith, 1995, 1998; Rayner, Carlson, & Frazier, 1983). Others have suggested that the use of participant information is immediate, at least when strongly biased materials are used (Burgess, 1991; Pearlmutter & MacDonald, 1992; Tabossi, Spivey-Knowlton, McRae, & Tanenhaus, 1994; Trueswell et al., 1994). However, many of these studies manipulated the content-based expectations, plausibility, or thematic fit of subcategorized constituents, not the presence or absence of the putative lexically encoded participants. This has made it difficult to evaluate their relevance to the question of whether lexically specified participant information makes any contribution to parsing and interpretation that is independent of syntactic and pragmatic factors (but cf. McElree & Griffith, 1995, 1998 for a possible approach). An investigation of the encoding of implicit agents may provide an appropriate test case, independent of subcategory and pragmatic cues, for examining the broader issue of when lexically encoded participant information is used.

Representational assumptions. Our working assumption is that implicit participant information that is routinely included in readers' interpretations of sentences is specified by the lexical–semantic representations of verbs. More precisely, we assume that the lexical representations of verbs include at least the following: (i) pointers to the conceptual knowledge of situations they describe and their participants (e.g., transitive uses of *sink* describe an event-type which includes an entity causing the sinking and an entity being sunk), (ii) abstract categorization of the participants included in those situations (e.g., agent and patient for transitive uses of *sink*), and (iii) a selection of which abstract participant information is syntactically active. The first kind of information must obviously be associated in some form with verbs. The second kind of information is routinely assumed to be relevant to grammatical processes (see Fillmore, 1968; Jackendoff, 1990; Dowty, 1991; among many others). We follow Dowty (1991) in assuming that this information is basically a *categorization* of the common properties of the specific participant roles associated with particular situation types. Whether this abstract information plays a role in on-line sentence processing is controversial and is the focus of Mauner and Koenig (2000). The third kind of information is a part of the morphosyntactic properties of verbs and indicates which abstract participant roles can play a syntactic role. By syntactically active, we mean that a participant in a verb's conceptual representation is capable of licensing a semantically dependent expression, either by mapping to an explicit syntactic dependent such as the object of a passive *by*-phrase or by grammatically licensing an expression such as an intentional adverb or rationale clause whose interpretation would otherwise fail to be felicitous in the absence of an appropriate agent participant role. We illustrate the latter two kinds of information on the full passive, short passive, and intransitive forms of the verb *sink* and the middle form of the verb *sell* illustrated in (1)–(3), and (4), respectively.

The full passive sentence in (1a) has two explicitly mentioned participants, a patient—*the ship*, and an agent—*someone*. Example (1b) uses (simplified) standard propositional semantics to model the abstract participant categories associated with the passive verb *sink*. Thus, the lexical–semantic representation of *sink* includes both a patient participant, which is associated with the ship, and an agent participant, which is associated with *someone*. Example (1c) specifies which participant categories are syntactically active, in this case both the agent and patient, as shown by the fact that both categories are morphosyntactically expressed. We call the set of participants in a verb's lexical representation that are also listed as syntactically active a verb's lexically specified argument structure.

(1a) The ship was sunk by someone.
(1b) $\mathrm{SINK}_{causative}\langle X, Y\rangle$, where X = PATIENT, Y = AGENT, ship = X, and someone = Y
(1c) {X,Y}
(2a) The ship was sunk.
(2b) $\mathrm{SINK}_{causative}\langle X, Y\rangle$, where X = PATIENT, Y = AGENT, ship = X
(2c) {X,Y}
(3a) The ship sank.
(3b) $\mathrm{SINK}_{intransitive}\langle X\rangle$, where X = PATIENT, ship = X
(3c) {X}
(4a) The antique vase was/had sold quickly but no one sold it.
(4b) $\mathrm{SELL}_{middle}\langle X, Y\rangle$, where X = PATIENT, Y = AGENT, vase = X
(4c) {X}

The short passive sentence in example (2) includes only one NP, *the ship*. Yet its lexical–semantic representation, shown in (2b), still includes two participants, a patient corresponding to the NP *the ship*, and an agent, which has no corresponding syntactically realized constituent. Both are also listed as syntactically active, as shown in (2c). Thus, the lexically specified argument structure of the passive verb in a short passive sentence includes both an agent and a patient participant. This representational hypothesis is consonant with the suggestion of a number of researchers who have argued that semantic schemata associated with the lexical representations of verbs may be a source for unexpressed semantic role information in the form of implicit arguments (e.g., Mauner et al., 1995; Roeper, 1987; Williams, 1987) or open roles (Carlson & Tanenhaus, 1988).

The syntactic representation of the intransitive sentence in example (3) is similar to that of the short passive sentence in (2) in the relevant sense; namely, there is only one NP, *the ship*, which is the subject of the sentence. But despite the surface structure similarity of the sentences in (2) and (3), their argument structures differ. In contrast to the lexical–semantic representation of the passive form of *sink* in (2b), the lexical–semantic representation of its intransitive form, shown in (3b), includes only one participant role, a patient, that is mapped to the NP *the ship* and which is also syntactically active, as shown in (3c). Because there is no agent participant in the lexical–semantic representation of the intransitive form of *sink*, the interpretation of sentence (3a) does not include an unexpressed agent participant.

Finally, the short passive and middle clauses in (4a) illustrate the same contrast in their interpretation as the sentences in (2a) and (3a); namely, the short passive clause (*was sold*) is understood to include an unexpressed agent while the middle clause (*had sold*) is not. However, the contrast in interpretation between these clauses cannot be explained by differences in the conceptual knowledge associated with the events described by the passive and middle clauses. The lexical–semantic representation for the middle form of the verb *sell* (adopted from Mauner & Koenig, 2000) in (4b) is similar to that of its passive form in that it includes both agent and patient participants. (We leave open the possibility that the lexical–semantic representations of passive and middle forms of *sell* differ in ways our simplified representations do not capture. But, crucially, these representations will include both agent and patient participant categories.) The presence of an agent is demonstrated by the fact that both short passive and middle clauses *logically require* a seller, since either results in a contradiction when combined with an agent-denying clause, as example (4a) illustrates. However, as the listing of syntactically active participants in (4c) illustrates, the argument structure of a middle verb resembles that of an intransitive verb; it has only one syntactically active participant—a patient. Thus, these clauses differ only in their putative argument structures, which are derived by the mapping between the lexical–semantic representations associated with the verb and the lexically encoded list of syntactically active participants.

Processing assumptions. The experiments presented in this paper also adopt the processing assumptions and experimental logic used by Mauner and Koenig (2000, Experiment 3). Their study examined *when* readers encode lexically derived agent participant information. To do this, they paired short passive and intransitive clauses with sentence-initial rationale clauses as illustrated in examples (5a) and (5b), respectively.

(5a) To reduce the noise coming from next door, the door was shut with great force.

(5b) To reduce the noise coming from next door, the door had shut with great force.

The logic of their study was similar to that used in filler-gap studies (Boland, Tanenhaus, & Garnsey, 1990; Clifton & Frazier, 1986; Crain & Fodor, 1985; Stowe, Tanenhaus, & Carlson, 1991) in which, after a WH-filler is encountered, there is an expectancy for a gap that must be satisfied later in the sentence. The semantic requirement that rationale clauses be predicated of an entity capable of volitional action was used to induce an expectation for an agent that must be satisfied in the next clause. Thus in reading a sentence with a short passive main clause such as (5a), readers would first evaluate whether the subject NP provided an appropriate agent to which the understood PRO subject of the rationale clause could be linked. If it did, then this association would be made provisionally. But in this sentence, because the referent of the NP *the door* is inanimate, no such association is made. When readers then encounter the main verb *shut*, they access its argument structure in the process of recognizing the verb. Because the argument structure of a passive participle includes a syntactically active agent, a link between the PRO in the rationale clause and the agent argument of the passive verb is established. With the intransitive sentence in (5b), processing proceeds in the same way until readers encounter the intransitive main verb. When the argument structure of the intransitive verb is accessed, processing difficulty ensues because the intransitive verb has no agent argument to which PRO can be linked. The results of Mauner and Koenig's Experiment 3 accord well with these processing assumptions. They found that processing difficulty emerged at the verb in intransitive but not short passive sentences when they followed rationale clauses.[2]

[2] Our assumption that passive verbs do not subcategorize for a *by*-PP is consonant with the majority view among linguists (see Grimshaw, 1990; Jackendoff, 1990; Van Valin & Lapolla, 1997). A reviewer points out that the fact that about 20% of passive verbs co-occur with an agent *by*-PP, but middle verbs never co-occur with an agent phrase, might bias readers of short passives to expect an agent-dependent expression, irrespective of the semantic information associated with it. While we cannot exclude this possibility, it is unlikely given the fact that Mauner et al. (1995) found no difference between active and short passive forms of the same verbs in the interpretation of rationale clauses, despite the fact that the former verb forms nearly always co-occur with agent phrases while the latter co-occurs with agents phrases only 20% of the time.

While these results suggest that agent information associated with passive verbs is accessed and used very quickly in forming an interpretation for a sentence, the stops-making-sense task that was employed may have influenced participants' processing in two ways. First, because this task requires participants to make an explicit judgment regarding the sensicality of each stimulus sentence on a word-by-word basis, it may have induced readers to engage in more and earlier semantic processing than is typical during normal reading. Second, the fact that a judgment must be made at each word position also entails slower processing relative to word-by-word reading without a sensicality judgment. This could have provided additional processing time for evaluating agent information at the verbs in short passive and intransitive sentences. Furthermore, Mauner and Koenig's intransitive sentences included the modal auxiliary verb *had*. Thus the difference they found in the processing of passive and intransitive clauses may have been due to readers having difficulty accommodating a temporal presupposition for intransitive clauses rather than to differences in the participant information associated with passive and intransitive verbs. The experiments that follow address these task and materials concerns.[3]

The primary goal of the experiments described in this paper is to examine when implicit agents are included in readers' representations of sentences using eye monitoring, which does not involve either word-by-word reading or incremental semantic anomaly judgments. Experiment 1 addresses the interpretive problem with the anomaly effects Mauner and Koenig obtained for intransitive but not short passive clauses following rationale clauses, namely, whether they could have been due to task artifacts or to readers having to accommodate a temporal presupposition in the former but not the latter, rather than to differences in the argument structures of passive and intransitive verbs. Experiment 2 was conducted to determine whether, when short passive and intransitive clauses were equated for the logical possibility of an agent, evidence for the early encoding of agent participant information would be found.

Experiment 1

In this experiment, we paired short passive and intransitive main clauses with both sentence-initial rationale clauses that engender an expectation for an agent in a following clause and adverbial control clauses that do not engender an expectation for an agent. Our general predictions were that readers should have no more difficulty processing short passive clauses following rationale clauses that require their understood subjects to be associated with an agent in an adjoining clause than following expressions that place no agent requirements on the clauses to which they are adjoined. In contrast, readers should encounter difficulty processing intransitive clauses following rationale clauses because, unlike passive verbs, the lexical representations of intransitive verbs do not include an agent that can be associated with the understood subject of a rationale clause. Evidence of this difficulty should emerge at or shortly after the verb in eye-monitoring dependent measures that are argued to reflect early processing. Moreover, because adverbial control clauses do not require an agent for their interpretation, the processing of short passives that follow rationale or control clauses should not differ from each other or intransitive clauses following adverbial control clauses.

Method

Participants. Forty-four participants from the State University of New York at Buffalo community who were native speakers of American English were paid \$2.50 per each half-hour of participation in sessions that lasted from 45 to 90 min. Participants had normal or corrected (with soft contact lenses) vision. In addition, some participants received partial course credit for psychology classes. For a variety of reasons

[3] A reviewer suggests that an alternative explanation for the results reported in Mauner and Koenig (2000), as well as the results reported here, is the "marginality" of intransitive and middles. We note in response that both structures occur in ordinary conversation and informal discourse such as electronic chat rooms, as a quick search would convince the reader. Thus "marginality" can only refer to relatively low frequencies of occurrence, which is not an issue for intransitives, which are in fact more frequent in occurrence than short passives. Given that short passives themselves are quite rare in English, accounting for approximately 3% of written corpora (Quirk, Greenbaum, Leech, & Svartick, 1985), it is unclear that this argument, even if true, could be responsible for the observed effect. (See footnote 2 for further discussion.)

(e.g., eyelids obscuring too much of the eye, insufficient contrast between iris and sclera, or no first pass reading times in a region) the eye-movement records of 18 of these participants were unstable or did not elicit sufficient numbers of data points to form reliable cell means. Data from these participants were not included in analyses.

Materials. Twenty pairs of short passive and intransitive sentences similar to those used in Mauner and Koenig's (2000) Experiments 2–3 were constructed. To avoid forcing participants to complete processing at the verb in the main clauses, passive and intransitive sentences included an adverb following the verb and a sentence-final prepositional phrase, as shown in the examples in (6c) and (6d), respectively. To maintain equal string lengths across passive and intransitive main clauses, the auxiliary verb *had* preceded intransitive main verbs. Short passive and intransitive main clauses followed sentence-initial rationale clauses (e.g., (6a)). These rationale clauses were used to engender an expectancy for an agent that must be satisfied in the subsequent main clause. In addition, because the auxiliary verb *had* in the intransitive main clauses might elicit longer processing time as it requires readers to accommodate a temporal presupposition, both passive and intransitive main clauses were also preceded by an adverbial control phrase whose interpretation did not require an agent in an adjoining clause, as shown in (6b). Processing times to intransitive main clauses should not differ as a function of the initial phrase type if anomaly effects in intransitive main clauses are due to the accommodation of a temporal presupposition rather than to the absence of an agent in the semantic representation of intransitive verbs. Experimental items were interspersed among 60 distractor items. Comprehension questions followed 25% of all trials, but only appeared following distractor sentences. Experimental items were counterbalanced across four presentation lists such that five items from each condition occurred on each list and no item from a stimulus set occurred more than once on any presentation list. The entire set of materials for this experiment and Experiment 2 is provided in Appendix.

(6a) To accommodate the heavy traffic,...
(6b) Due to the heavy traffic,...
(6c) | the nature trail | was widened | slightly | at several points.
(6d) | the nature trail | had widened | slightly | at several points.

Apparatus and procedure. Eye movements for each participant were recorded using a Dr. Bouis oculometer that continuously transmitted horizontal eye position within 20 min of arc to a MacIntosh Quadra 650 interfaced with a National Instruments analog-to-digital conversion board. Our software sampled the analog signal at 1000 Hz. Stimulus presentation and the recording of eye movements were controlled by the Quadra 650. Participants' heads were stabilized during calibration routines and stimulus presentation by use of individually prepared dental bite bars and a forehead rest. So that the critical regions in the main clauses would always be presented on a single line, first (rationale clauses or adverbial controls) and second (main) clauses were presented sequentially on a 13″ AppleColor High Resolution RGB monitor in reverse video. (This presentation format was necessary because of the poor vertical resolution of the Dr. Bouis oculometer.) Main clauses that contained the critical tracking regions spanned no more than 16.5° of visual angle, with each character and space subtending approximately 17 min of arc. Although viewing was binocular, only right eye movements were monitored.

At the beginning of a session, each participant's horizontal eye positions were calibrated across five horizontal screen positions. Following this calibration routine, participants completed five practice trials. The presentation rate for each line of text was controlled by the participant. Presentation of both the first and second lines was preceded by a fixation cross, positioned at the left of the screen approximately one character space to the left and below where text begins on stimulus trials. Participants fixated on the cross and then clicked the mouse button. This removed the fixation cross and replaced it with a clause. Participants read each first clause at their own pace and then clicked a mouse button to replace it with the second clause, either a short passive or intransitive in experimental trials. Participants ended each trial with a click of a mouse. Following some trials, participants read a Yes–No comprehension question. They responded by moving the mouse-controlled cursor to a YES or NO box and clicking on their answer. Participants received auditory feedback ("Correct" or "Incorrect") after answering each comprehension question. Following the practice trials, the experiment began. After each practice and experimental trial, the accuracy of a participant's eye positions was checked and, if necessary, recalibrated. Participants were encouraged to disengage from the bite bar if they began to feel tired or uncomfortable.

Regions. For both Experiments 1 and 2, we recorded eye movements for four regions, the subject noun phrase (e.g., *The nature trail*); a verb region, which included the auxiliary *was* or *had* and the main verb (e.g., *widened*); a postverb region, which typically included an adverb (e.g., *slightly*)[4] which was always at least seven character spaces in length; and a prepositional phrase (e.g., *at several points*), as indicated by the vertical bars in example (6). Trials on which tracking was inaccurate were excluded from further analysis. Any trial which had an eye fixation outside the defined tracking region, a zero first pass fixation time in a given region, or a first fixation more than nine characters into the first scoring region was excluded with the following exception. The NP tracking region was extended leftward by two character spaces. Increasing the region size for the NP region allowed our software to capture a first pass fixation in the NP region for 73 otherwise normal looking sentence trials. We also extended the postverb tracking region rightward by two character spaces. This allowed us to retain six additional otherwise normal looking eye-movement records. Of the total number of data points, 3.7% were affected by these extensions. These region extensions allowed us to retain a greater number of participants who met our criterion of contributing a stable cell mean to each tracking region. These region extensions had no effect on other portions of the eye-movement records of sentences in which a fixation was captured by these means or on the eye movement records of trials in which all fixations fell within the original nonextended boundaries. Although region extensions did not alter the overall pattern of data, they did increase the power of the computed analyses because more participants were retained.

Measures. We examined a number of eye movement variables that summed fixations in terms of either spatially or temporally contiguous sequences as well as the proportion of regressive eye movements originating in post-NP regions. Among measures typically argued to reveal initial processing, we report *first pass reading times*, which are the sums of all fixation times in a region before exiting it to either the right or the left. In the postverb region, which typically consisted of a single word, this measure corresponds to what Rayner and Duffy (1986) termed gaze duration. *First fixation durations* are the reading times associated with the first fixation a reader makes in a region. We also report *second pass reading times*, a measure that indicates rereading rather then initial processing. Second pass reading times are the sum of all fixations in a region that occur when a reader returns to a previously read region from a region either to the right or left of it. Mean second pass reading times were computed by averaging across the total number of items per condition for participant means and the total number of participants for item means.

When readers enter a region for the first time they can either continue to fixate in that region or exit it with a forward movement into the next region or a regressive movement to a previously read region. Regressive eye movements in which participants reread a region are often taken as an indication of processing difficulty (see, for example, Altmann, Garnham, & Dennis, 1992). Moreover, first pass reading times typically consist of a mixture of trials that end in either a forward or regressive eye movement out of the region. In cases where a substantial number of trials in a region end in a regressive eye movement, processing difficulty that might otherwise be reflected by longer first pass reading times can be obscured because these longer reading times are averaged with reading times for trials that ended in a regressive eye movement, which are often of shorter duration. Altmann et al. have argued that when a substantial number of trials end in a regressive eye movement, it may be appropriate to examine what they term regression contingent analyses in which trials are divided into those which end in a regressive eye movement and trials which do not, which we term nonregression trials. Thus, in addition to examining first pass reading times and first fixation durations for all trials, we also separately examined trials in which readers made a regressive eye movement out of a region during first pass reading and nonregression trials, in which first pass reading did not terminate with a regressive eye movement. In this paper, we report data only from nonregression trials. We report data only from nonregression trials because of the low frequency of trials that ended in a regressive eye movement. We used the procedure suggested by Winer (1962) (see also Boland et al., 1990; Altmann et al., 1992) to estimate missing cells for approximately 1% of the data from trials on which no regressive eye movement was made in

[4] For three items in Experiments 1 and 2, the expression immediately following the verb region was not an adverb but an adverbial prepositional phrase. For these sentences the postverb region consisted of a preposition and the immediately following word.

Experiment 1. This was not necessary in Experiment 2. As additional indicators of differential processing in regions, we also report the *probability of making a first pass regression*, which is computed as the proportion of trials, summed across either participants or items, which ended in regressive eye movements out of a region to a previously read region (Altmann et al., 1992).

As argued by a number of researchers (e.g., Liversedge, Patterson, & Pickering, 1998; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989), it is important to examine a variety of eye movement measures to avoid failing to detect effects and because correlations across measures may have diagnostic value. In addition to measures that sum spatially contiguous fixations, a number of researchers (Brysbaert & Mitchell, 1996; Clifton, Kennison, & Albrecht, 1997; Konieczny, Hemforth, Scheepers, & Strube, 1997; Liversedge, 1994; Liversedge et al., 1998; Pickering, Traxler, & Crocker, 2000) have argued for the importance of examining eye movement measures that aggregate fixations in terms of temporal instead of spatial sequences. We report two such measures. The first is *regression path durations*, which sum all of the fixations that occur starting with the first fixation in a region of interest until a fixation is made in a region to the right of the region of interest (Liversedge et al., 1998; see also Brysbaert & Mitchell, 1996; Clifton et al., 1997; Liversedge, 1994; Konieczny et al., 1997; Pickering et al., 2000, for discussion of similar measures). The second is *first regression path times* (Konieczny et al., 1997) which are similar to regression path durations in that they aggregate first pass reading times in the region of interest with fixations that represent reading of prior regions and terminate when the reader goes past the right boundary of the region of interest. However, in first regression path times only the first rereadings in each region along a regression path are aggregated with first pass reading times in the region of interest. This measure was used for analyses of the sentence-final region to partially eliminate the problems of having regression paths contaminated by processing associated with end of clause processing (Just & Carpenter, 1980; Rayner et al., 1989) and the button press that ended each trial. Although first regression path durations are typically defined as ending with a forward movement out of a region, this kind of termination was not possible for our sentence-final region. Thus, first regression path results in this and the following experiment should be viewed with caution.

Results and discussion

All participants answered the comprehension questions with 90% or better accuracy. The eye movement records for passive and intransitive main clauses were segmented into four regions—a subject NP (plus two leftward character spaces), a verb region consisting of an auxiliary and main verb, a postverb region usually consisting of an adverb, and a final region typically consisting of a prepositional phrase (and two rightward character spaces). With three exceptions in the verb region of Experiment 1 and one in Experiment 2, where there was a one character difference in length in the verb region, there were no differences in string length within regions across sentence pairs. Consequently, no adjustments for differences in length were made.

Table 1 presents participant condition means for subject NP, auxiliary + main verb, postverb, and final regions of short passive and intransitive main clauses following rationale and control clauses for the indicated dependent measures. Condition means were computed separately for participants and items and were submitted to separate 4 (list) $\times$ 2 (initial clause type) $\times$ 2 (sentence type) $\times$ 4 (region) analyses of variance (ANOVA). Measures based on the possibility of making a regressive eye movement never included the NP region because of the impossibility of regressing out of the NP region. Thus region was a three-level factor for probability of regressions. Region was a two-level factor for regression path durations because the final region was also excluded for reasons discussed above. Finally, first regression path durations for the sentence final region were submitted to separate 4 (list) $\times$ 2 (initial clause type) $\times$ 2 (sentence type) analyses of variance with either participants or items as random variables. List was included as a factor to increase power (see Pollatsek & Well, 1995). The results of the statistical analyses for these data are shown in Table 2. Note that because there were no effects of list on any measure, effects of list are not included. We have also not included in Table 2 any effects of region. Including these effects, which are largely attributable to differences in string length across regions and which were observed in all measures, would have lengthened these tables enormously without contributing much of theoretical interest. To further simplify the statistical tables for both experiments, we have tabulated results only when the value for the F statistic equaled or exceeded 2.1 in analyses by participants.

Table 1
Experiment 1 means and standard errors (in parentheses) for short passive and intransitive clauses following rationale and adverbial control clauses across NP, verb, postverb, and final regions for noncontingent and nonregression (Nonregr.) trials of first pass reading times (FPRTs), and first fixation durations (1st fixations), second pass reading times (SPRTs), and probability of regression (Prob. of regr.) data. For regression (regr.) path durations (Regr. paths), means and standard errors are only for the verb and postverb regions. For first regression path durations (1st regr. paths) they are only for the final region

	Short passive				Intransitive			
	NP	V	Post-V	Final	NP	V	Post-V	Final
Rationale clause								
FPRTs	437(27)	445(29)	350(22)	535(58)	507(20)	453(31)	335(22)	542(37)
Nonregr.	— —	377(26)	456(48)	524(47)	— —	355(30)	565(52)	444(27)
1st fixations	173(11)	251(14)	268(15)	250(13)	173(8)	258(11)	273(12)	273(12)
Nonregr.	— —	258(15)	252(15)	267(10)	— —	271(12)	289(13)	238(10)
Regr. paths	— —	492(33)	368(21)	636(72)	— —	516(37)	427(30)	816(87)
1st regr. paths	— —	— —	— —	622(70)	— —	— —	— —	784(83)
Prob. of regr.	— —	9(3)	8(3)	27(6)	— —	14(5)	15(4)	41(6)
SPRTs	39(11)	77(21)	71(22)	56(20)	85(20)	212(35)	124(27)	57(15)
Control clause								
FPRTs	457(27)	426(28)	326(13)	524(38)	501(30)	436(28)	335(22)	546(46)
Nonregr.	— —	353(24)	516(35)	436(32)	— —	357(22)	579(67)	451(30)
1st fixations	181(8)	238(10)	265(10)	244(11)	175(9)	257(12)	262(9)	254(15)
Nonregr.	— —	268(12)	242(11)	252(12)	— —	271(10)	250(19)	247(14)
Regr. paths	— —	484(26)	395(25)	611(52)	— —	476(36)	401(23)	635(71)
1st regr. paths	— —	— —	— —	592(50)	— —	— —	— —	612(67)
Prob. of regr.	— —	10(3)	17(4)	25(5)	— —	6(3)	14(4)	20(5)
SPRTs	44(12)	112(18)	84(20)	40(14)	56(23)	116(24)	66(15)	25(10)

Table 2
Experiment 1 ANOVAs by participants (*F*1) and items (*F*2) for noncontingent and nonregression (Nonregr.) trials of first pass reading times (FPRTs) and first fixation durations, as well as second pass reading times (SPRTs), first regression path durations, and probability of regression measures

Source	*F*1		*F*2	
Clause × sentence interaction				
1st regression path durations	2.40	(69438)	1.48	(40634)
Probability of regression	9.16^{**}	(303)	6.77^{*}	(277)
SPRTs	8.49^{**}	(13340)	5.27^{*}	(15782)
Effect of clause				
1st fixation durations	2.10	(1440)	1.55	(1324)
1st regression path durations	3.55 ms	(63548)	3.09 ms	(72472)
Probability of regression	3.43 ms	(252)	2.43	(296)
SPRTs	3.91 ms	(12120)	6.34^{*}	(11296)
Effect of sentence				
FPRTs	2.54	(16743)	< 1	(13850)
1st fixation durations	5.00^{*}	(1215)	< 1	(1744)
1st regression path durations	3.95 ms	(58728)	3.35 ms	(36486)
SPRTs	5.39^{*}	(14379)	2.20	(14415)

Note. Parenthesized values represent mean square errors. Degrees of freedom are (1, 22) for participants and (1, 16) for items.

.06 < ms < .10.

$^{*}p < .05$.

$^{**}p < .01$.

$^{***}p < .001$.

The first goal of this study was to determine whether differences in the processing of intransitive and short passive clauses paired with rationale clauses were due to hypothesized differences in the participant information associated with passive and intransitive verb forms or to other factors. The results in Table 2 reveal that intransitive clauses elicited greater processing difficulty than short passive clauses, but only following rationale clauses. Specifically, readers made more regressive eye movements to previously read regions in intransitive sentences following rationale clauses than intransitive sentences following adverbial control clauses or short passive following rationale clauses. This pattern was observed in the significant interaction between clause and sentence type in probability of regressions and second pass reading times. Readers made more regressive eye movements in intransitive sentences than short passive sentences, but only when intransitives were coupled with a sentence-initial rationale clause. While the interaction between clause and sentence type was not significant in the analysis of first regression path durations, the effects of both clause and sentence type were marginally significant. First regression path durations were longer for intransitive than short passive sentences and longer for sentences with rationale clauses than sentences with control clauses. Taken as a whole, these results confirm that the anomaly effects observed for intransitive verb clauses following rationale clauses, both in this study and in Mauner and Koenig's (2000) Experiment 3, are not due to any markedness or marginality of intransitives relative to passives or to the presence of the auxiliary verb *had* requiring readers to accommodate a temporal presupposition in these data. Instead they are due to differences in the participant information associated with passive and intransitive forms of verbs.

A second goal of this study was to determine when readers access and use unexpressed participant information during sentence interpretation when not required to make a judgment regarding whether a sentence makes sense at each word position. In Mauner and Koenig's (2000) Experiment 3, intransitive sentences began to elicit significantly more "No" judgments than short passives at the main verb, although the difference was quite small and clear differences in reading times did not emerge until the end of the sentence. We conducted planned comparisons within each region to examine when processing differences occurred when eye movements were being recorded. We report the results of these planned comparisons region by region in Table 3.

NP region. At the NP region, we observed an unexpected interaction between sentence and clause type in first pass reading times. While first pass reading times for the subject regions of intransitive clauses did not differ as a function of initial clause type, the subject region of short passives were read faster when they followed rationale clauses than when they followed control clauses. We also observed a sentence by clause interaction in second pass reading times at the NP region. But in this case, the form of the interaction was as predicted. Participants spent more time rereading the subject regions of intransitives following rationale clauses than control clauses but no more time rereading the subject regions of short passives following rationale clauses than control clauses.

Verb region. Processing differences between intransitive and short passive clauses emerged at the verb region only in second pass reading times. Participants spent more time rereading the verb regions of intransitive sentences when they followed rationale clauses than adverbial control clauses. In contrast, they spent no more time rereading the verb regions of short passives when they followed rationale clauses than when they followed control clauses.

Postverb region. Processing differences were observed in the postverb region in first fixations and first pass reading times for nonregression trials and in second pass reading times. With the exception of second pass reading times, these effects were significant only in analyses by participants. The clause by sentence type interaction did not reach significance ($p_1 = .11$) in first fixation durations, but the main components of this interaction did.[5]

[5] We are basing our discussion of results in Experiments 1 and 2 primarily on by-participants effects. In a number of analyses, items effects were not significant even when analyses by participants were. A close inspection of which items patterned with significant effects in by-participants analyses revealed that there was no particular subset of items that consistently patterned together across regions or measures that could account for all of significant by-participants effects. Rather, what we observed was considerable variability across items when readers launched regressive eye movements, both within and across regions. The fact that no particular subset of items appears to be driving the by-participants effects and that items effects were almost always significant in second pass reading times suggests that our short passive items are reliably different from our intransitive and middle items.

Table 3
Experiment 1 planned contrasts within NP, verb, postverb, and final regions of short passive and intransitive sentences following rationale or control clauses by participants (*F*1) and items (*F*2) for noncontingent and nonregression (Nonregr.) trials of first pass reading times (FPRTs) and first fixation durations, as well as second pass reading times (SPRT), regression path durations, first regression path durations, and probability of regression measures

Source	*F*1		*F*2	
Contrasts within NP region				
Clause × sentence interaction				
FPRTs	5.22*	(16507)	<1	(12444)
SPRTs	5.26*	(4838)	1.97	(8015)
Effect of sentence				
FPRTs	7.44**	(11580)	<1	(9838)
SPRTs	3.45 ms	(7417)	2.84	(5565)
Effect of sentence within rationale clause sentences				
FPRTs	4.00*	(16507)	<1	(12432)
SPRTs	6.44*	(4838)	2.57	(8015)
Effect of clause within intransitive sentences				
SPRTs	2.50	(4839)	1.8	(8015)
Contrasts within verb region				
Clause × sentence interaction				
SPRTs	24.77***	(4838)	6.19*	(8015)
Effect of sentence				
1st fixation durations	2.22	(1622)	<1	(1394)
SPRTs	16.16***	(7417)	8.91**	(5565)
Effect of clause				
SPRTs	3.96*	(5965)	8.75**	(4618)
Effect of sentence within rationale clause sentences				
SPRTs	48.34***	(4838)	16.52***	(8015)
Effect of clause within intransitive sentences				
SPRTs	24.96***	(4838)	15.16***	(8015)
Effect of clause within short passive sentences				
SPRTs	3.50 ms	(4838)	<1	(8015)
Contrasts within postverb region				
Clause × sentence interaction				
1st fixation durations	3.14 ms	(2825)	2.95 ms	(1674)
1st fixation nonregr. trials	2.60	(2219)	<1	(2435)
Effect of sentence				
FPRT nonregr. trials	8.36**	(24651)	<1	(14895)
1st fixation nonregr. trials	5.32*	(2670)	<1	(1994)
Effect of clause				
1st fixation nonregr. trials	5.03*	(3329)	<1	(2383)
Effect of sentence within rationale clause sentences				
FPRT nonregr. trials	5.95*	(30526)	<1	(17990)
1st fixation nonregr. trials	8.59**	(2219)	<1	(2439)
Regression path durations	2.52	(14574)	1.77	(24753)
SPRTs	8.58**	(4838)	3.47 ms	(8015)
Effect of clause within intransitive sentences				
1st fixation nonregr. trials	9.51**	(2219)	<1	(2439)
SPRTs	9.53**	(4838)	4.31*	(8015)

Table 3 (*continued*)

Source	*F*1		*F*2	
Effect of clause within short passive sentences				
Probability of regressions	2.39	(445)	2.32	(428)
Contrasts within final region				
Clause × sentence interaction				
1st fixation durations	3.14 ms	(2825)	2.95 ms	(1674)
1st regression path durations	6.81*	(34079)	3.70 ms	(33006)
Probability of regressions	4.38*	(445)	4.07*	(428)
Effect of sentence				
1st fixation durations	5.47*	(1622)	3.80 ms	(1814)
1st fixation nonregr. trials	2.54	(2670)	<1	(1994)
1st regression path durations	7.17**	(32382)	5.36*	(22807)
Effect of clause				
FPRTs nonregr. trials	2.21	(21498)	<1	(18064)
1st regression path durations	7.69**	(29343)	6.55*	(34196)
Probability of regressions	9.06**	(366)	4.90*	(594)
Effect of sentence within rationale clause sentences				
FPRTs nonregr. trials	2.92 ms	(30526)	<1	(17954)
1st fixation durations	3.04 ms	(2825)	2.43	(1674)
1st fixation nonregr. trials	5.17*	(2219)	1.54	(2439)
1st regression path durations	5.70*	(69443)	4.35*	(40637)
Probability of regressions	5.14*	(445)	3.60 ms	(428)
Effect of clause within intransitive sentences				
Second pass RTs	2.58	(4838)	2.22	(8015)
1st regression path durations	5.61*	(69443)	6.35*	(40638)
Probability of regressions	11.62***	(445)	10.70**	(428)
Effect of clause within short passive sentences				
FPRTs nonregr. trials	3.48 ms	(30526)	<1	(17954)

Note. Parenthesized values represent mean square errors. Degrees of freedom are (1, 22) for participants and (1, 16) for items.

.06 < ms < .10.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Readers' first fixations were longer in the postverb regions of intransitive than short passive sentences and longer in sentences with rationale clauses than adverbial control clauses. Most importantly, the effect of sentence was significant only in sentences with rationale clauses, where intransitive sentences elicited longer first fixations than short passives, and the effect of clause type was only significant in intransitive sentences, where intransitive sentences with rationale clauses elicited longer first fixations than intransitive sentences with control clauses. Recall that the processing of intransitive and short passives with rationale clauses did not differ from each other in the verb region on any measures sensitive to initial processing. Nonetheless, the spillover times from nonregression trials in the postverb region suggests that readers did encounter difficulty in processing intransitive sentences paired with rationale clauses at the verb region.

The effects of sentence and clause were also significant in the first pass reading trials that did not end in a regressive eye movement. Readers spent more time reading the postverb regions of intransitive sentences than short passive sentences and more time reading sentences with rationale clauses than control clauses. Finally, the postverb regions of intransitive sentences with rationale clauses elicited longer rereading times than the postverb regions of short passives or intransitive controls.

Final region. The most consistent differences in the processing of short passive and intransitive sentences paired with rationale clauses at the final region were observed in first regression path durations and probabilities of regressions. Sentence type significantly interacted with clause type in both measures. More regressive eye movements were triggered by intransitive sentences paired with rationale clauses than their intransitive controls or short passives paired with rationale clauses. This same pattern was observed in first regression path durations. Thus, what we observed in the final region is that readers continued to have difficulty in processing intransitive sentences paired with rationale clauses in the final sentence region relative to sentences in other conditions. This difficulty led them to launch significantly more regressive eye movements to earlier regions of these intransitive sentences which accounts for the longer first regression path durations for these sentences in this region.

Two important results emerge from this experiment. First, it is clear that differences in the processing of short passive and intransitive sentences following rationale clauses are not due to materials variables such as intransitives being more marked than short passives or requiring temporal presuppositions that are not needed for interpreting short passives. The processing of intransitive and passive sentences with control clauses did not differ within any region on any measure we examined. The second finding is that readers begin to experience difficulty with intransitive sentences paired with rationale clauses soon after they have recognized the main verbs in these sentences. Readers' first fixations for nonregression trials in the region immediately following the verb were longest for intransitive sentences with rationale clauses. This result demonstrates that participant information that is associated with the lexical representations of verbs is accessed and used early on to interpret sentences and that this is not dependent on reading word by word or on making an incremental sensicality judgment. However, the short passive and intransitive materials in this study were not equated for the logical necessity of an agent. Thus, it is still possible that conceptual factors could have been the primary cause of the observed processing differences. Experiment 2 was designed to determine whether only agent information that is specified by the lexical representations of verbs is accessed rapidly during on-line comprehension.

Experiment 2

The main purpose of this study was to determine whether schematically encoded agent information is immediately accessed when the conceptual availability of an agent is controlled for. To do this, we compared the processing of agent-equated short passive and middle clauses following agent-dependent rationale clauses. While this study uses the agent equated passive and middle main clauses from Mauner and Koenig (2000, Experiment 3), it differs crucially in that the critical scoring regions for anomaly effects for their study were in sentence-final rationale clauses. Thus, their results are not informative regarding when lexically specified schematic agent information first becomes available for interpretation. To examine this question, we paired sentence-initial rationale clauses (e.g., (7a)), used to engender an expectancy for an agent that must be satisfied by an argument in an adjoining clause, with short passive (e.g., (7b)) and middle (e.g., (7c)) clauses that both logically require an agent. Only the passive verbs were hypothesized to introduce a syntactically active agent that would license the interpretation of the rationale clause. We predicted that middle clauses would elicit longer processing times in the verb or postverb regions when compared to short passive clauses.

(7a) To raise money for the charity,...
(7b) | the antique vase | was sold | immediately | to a collector.
(7c) | the antique vase | had sold | immediately | to a collector.

Method

Participants. The 22 participants in this study were drawn from the same population as those in Experiment 1 and were compensated in a similar fashion. The eye-movement records of three participants did not yield a sufficient number of data points to form stable participant cell means. Data from these participants were not analyzed.

Materials. We adapted Mauner and Koenig's (2000, Experiment 2) 14 agent-equated short passive and middle sentence pairs and sentence-initial rationale clauses (e.g., examples (7b), (7c), and (7a), respectively) in a manner similar to that described in Experiment 1. In particular, rationale clauses appeared sentence-initially, and because most middle verbs require an adverbial modifier, main verbs in both verb types were followed by an adverbial modifier or prepositional phrase that could be interpreted as a manner adverbial. To avoid forcing readers to complete processing at the adverbial modifier, sentences ended with a prepositional phrase. As in the previous study, middle clauses included the modal auxiliary verb *had* to minimize string length differences between middle and passive clauses. However, in this study we did not include sentence-initial subordinate control clauses because the results of Experiment 1 demonstrated that processing differences between short passive and intransitive clauses were not due to accommodation of the temporal presupposition associated with *had*. Experimental sentences were randomly intermixed with 60 surface-similar distractor sentences. Comprehension questions followed 25% of distractor items. Experimental items were counterbalanced across two presentation lists such that seven short passive and seven intransitive sentences appeared on each list and no member of a stimulus pair appeared more than once on a list.

Apparatus and procedure. The apparatus and procedure were identical to those described for Experiment 1. The main clause was divided into four regions for analysis: a subject NP region (plus two character spaces to the left) (e.g., *the antique vase*), the verb region (e.g., *was/had sold*), the post-VP region (e.g., *immediately*), and a final region (e.g., *to a collector*) as indicated by the bars dividing regions in examples (7b) and (7c). We excluded from analysis any trial that had an eye fixation outside the defined tracking region, a zero first pass fixation time in a given region, or a first fixation more than nine characters into the first scoring region. The NP tracking region was extended leftward by two character spaces. This allowed us to retain the eye-movement records for 39 otherwise normal looking trials. By increasing the subject NP region slightly, we were able to retain three participants whose data otherwise would not have met our criterion of contributing a minimum of three scores per condition. While increasing the subject region did not alter the observed data patterns, it provided a small boost in power and ensured an equal contribution of data points to all regions from all participants.

Results and discussion

In Table 4, we present participant cell means for short passive and middle clauses across NP, verb, postverb, and final regions, which are indicated by the vertical bars (|) in example (7), for each of the measures we examined. Condition means were computed separately for participants and items. Means for spatially summed dependent measures were submitted to separate 2 (list) × 2 (sentence type) × 4 (region) analyses of variance. As in Experiment 1, region was a three-level factor for probability of regressions and a two-level factor for regression path durations. First regression path durations for the sentence final region were submitted to separate 2 (list) × 2 (sentence type) analyses of variance with either participants or items as random variables. Again, list was included in as a factor to

Table 4
Experiment 2 means and standard errors (in parentheses) for short passive and middle clauses following rationale clauses across NP, verb, postverb, and final regions for nonregression contingent and noncontingent first pass reading times (FPRTs) and first fixation durations, as well as second pass reading times (SPRTs), and probability of regression (Prob. of regr.) data. For regression path durations (Regr. paths), means and standard errors are only for the verb and postverb regions. For first regression path durations (1st regr. paths) they are only for the final region

	Rationale clause							
	Short passive				Middle			
	NP	V	Post-V	Final	NP	V	Post-V	Final
FPRTs	559(24)	363(18)	318(19)	341(31)	542(31)	381(24)	343(15)	361(33)
Nonregr.	— —	365(20)	313(20)	297(37)	— —	406(27)	344(17)	394(70)
1st fixations	199(6)	249(9)	247(7)	219(18)	192(9)	241(10)	266(9)	205(14)
Nonregr.	— —	251(10)	251(10)	201(23)	— —	241(10)	262(11)	181(20)
Regr. paths	— —	400(28)	353(42)	412(67)	— —	449(32)	474(38)	628(73)
1st regr. paths	— —	— —	— —	399(65)	— —	— —	— —	593(66)
Prob. of regr.	— —	5(2)	11(5)	28(5)	— —	11(4)	25(5)	40(5)
SPRTs	43(21)	79(32)	84(22)	36(12)	121(28)	208(33)	159(31)	49(15)

Table 5
Experiment 2 ANOVAs by participants (*F*1) and items (*F*2) for noncontingent and nonregression (Nonregr.) trials of first pass reading times (FPRTs) and first fixation durations (1st fixation durations), as well as second pass reading times, regression path durations, and probability of regression measures

Source	*F*1		*F*2	
Sentence × region interaction				
2nd pass reading times	3.97^{**}	(4804)	2.63 ms	(2880)
Effect of sentence				
1st pass reading times	2.24	(2176)	<1	(4649)
FPRTs nonregr. trials	5.36^{*}	(16669)	5.58^{*}	(8724)
Regression path durations	7.04^{*}	(17458)	16.15^{**}	(5459)
Probability of regressions	12.03^{**}	(274)	14.30^{**}	(263)
2nd pass reading times	8.70^{**}	(22649)	7.10^{*}	(13097)
Effect of region				
FPRTs	27.29^{***}	(14108)	11.61^{***}	(22073)
1st fixation durations	9.97^{***}	(3088)	6.11^{**}	(2990)
1st fixation nonregr. trials	9.76^{***}	(4869)	<2	(3843)
Probability of regressions	16.50^{***}	(385)	13.24^{***}	(333)
2nd pass reading times	9.58^{***}	(7714)	9.98^{***}	(5441)

Note. Parenthesized values represent mean square errors. Degrees of freedom are (1, 17) for participants and (1, 12) for items for effects of sentence and (3, 51) and (3, 36) for the sentence × region interactions and effects of region, except for regression path measures and the probability of regressions, where they are (2, 34) and (2, 24).

$.06 < \text{ms} < .10$.

$^{*}p < .05$.

$^{**}p < .01$.

$^{***}p < .001$.

increase power and did not elicit any significant effects. We present the results of the statistical analyses for these data in Table 5. The results of planned comparisons examining the effects of sentence type within individual regions are presented in Table 6.[6] As in Experiment 1, we computed regression path durations to examine effects at the postverb region and first regression path durations to examine effects at the sentence-final region.

As can be seen in Table 5, there were effects of sentence in two measures of early processing. Middle sentences elicited longer first pass reading times for trials that did not end in a regression and longer regression path durations than short passives. Overall, readers made more regressive eye movements while reading middle than short passive sentences. They also spent more time rereading the NP, verb, and postverb regions of middle sentences than short passive sentences. As in Experiment 1, there were no differences in second pass reading times. Table 5 also reveals an effect of sentence in the regression probability measure.

NP and verb regions. The only measure to reveal any processing differences between short passive and middle sentences at the NP and verb regions was second pass reading times. Participants spent more time rereading both the NP and verb regions of middle sentences than short passive sentences.

Postverb region. Readers made significantly more regressive eye movements out of the postverb region during first pass reading of middle sentences than short passive sentences. This was also reflected in significantly longer regression path durations at this region. There was a nonsignificant trend ($p_1 = .12$) for making longer first fixations in the postverb regions of middle than short passive sentences. Readers also spent more time rereading the postverb regions of middle than short passive sentences.

Final region. As in the postverb region, readers made more regressive eye movements while reading the final regions of middle sentences when

[6] Effects for first regression path durations appear only in Table 6 where we report within region effects. This is because this measure is computed only for the final region and no factor other than sentence can be examined.

Table 6
Experiment 2 planned contrasts within NP, verb, postverb, and final regions of short passive and middle sentences following rationale clauses by participants ($F1$) and items ($F2$) for noncontingent and nonregression (nonregr.) trials of first pass reading times (FPRTs) and first fixation durations (1st fixation durations), as well as second pass reading times, regression path durations, first regression path durations, and probability of regressions measures

Source	$F1$		$F2$	
Contrasts within NP region				
Effect of sentence				
SPRTs	11.32**	(4804)	6.82*	(2880)
Contrasts within verb region				
Effect of sentence				
SPRTs	30.49***	(4804)	23.33***	(2880)
Contrasts within postverb region				
Effect of sentence				
1st fixation durations	2.45	(1477)	2.63	(1602)
Regression path durations	8.01**	(15896)	24.56***	(5348)
Probability of regressions	7.26**	(255)	6.64*	(246)
SPRTs	10.68**	(4084)	9.25**	(2880)
Contrasts within final region				
Effect of sentence				
FPRTs nonregr. trials	4.60*	(21381)	4.68*	(9903)
1st regression paths.	15.08***	(24905)	4.29 ms	(44366)
Probability of regressions	5.62*	(255)	5.64*	(246)

Note. Parenthesized values represent mean square errors. Degrees of freedom are (1, 17) for participants and (1, 12) for items.
.06 < ms < .10.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

compared to short passive sentences. And, as in the postverb region, this was mirrored in longer first regression path durations. Similar to the pattern observed in Experiment 1, readers spent no more time rereading the final regions of middle sentences than short passive sentences.

The results of this study support the hypothesis that lexically specified schematic agents become available to interpretive mechanisms soon after recognizing a verb. This support is derived from the pattern of first regression path durations and differences in the distribution of regressive eye movements across postverb regions of middle and short passive clauses that both logically require an agent participant.

Overall, the results of Expeirments 1 and 2 are quite similar. Yet it is interesting to note that the measures of early or initial processing difficulties for sentences whose verbs do not provide a syntactically active agent participant differ across the two experiments. In Experiment 1, first fixations and first pass reading times in the immediate postverb region (when trials on which readers made a regressive eye movement were excluded) were longer for intransitives than short passives following rationale clauses. In Experiment 2, regression paths from the immediate postverb regions were longer for middles than short passives. Thus the lack of an appropriate lexically encoded agent participant was observed earlier and led to potentially different kinds of reading behaviors in intransitive sentences than in middles. Assuming for a moment that participants were engaging in different kinds of reading behaviors, we speculate on why that might be.

To account for the differences we observed across Experiments 1 and 2, we need to further clarify our processing assumptions. These assumptions are grounded in the belief that one of the main goals in reading is to arrive at a coherent interpretation for each sentence that is read. We assume that readers will try their best to make this happen. With this in mind, we envision the processing of short passive, intransitive, and middle sentences paired with rationale clauses to proceed in the following manner. After reading the rationale clause, readers have a strong expectancy for an agent. In terms of probabilistic cues, the subject NP of a sentence is most likely to be the source of that information. This means that readers are biased to initially pursue a transitive analysis for the main clause following the rationale clause. However, upon encountering the subject NPs of our intransitive, middle, and passive sentences, the evidence for a transitive analysis diminishes because these subject NPs are not plausible agents. But the transitive analysis is not completely eliminated because readers sometimes find themselves in the situation of having to coerce participant information in sentences where the referents of NPs are otherwise implausible (e.g., *The ham sandwich at table four wants a refill on coffee* and *That red car is driving too fast.*) When readers encounter the auxiliary verb *be* and a passive participle, they have sufficient confirmatory evidence against a transitive analysis and instead pursue a passive analysis which provides them with an unexpressed but syntactically active agent. In contrast, when they encounter the auxiliary verb *had* and the past participle of a verb, there is strong evidence from the syntactic form of the sentence thus far for both intransitive/middle and transitive analyses. In the case of intransitive sentences, when they encounter the postverb region, it becomes clear that the transitive analysis is impossible because there is no direct object. Consequently, the only way to rescue the interpretation of the sentence is to try and coerce the subject NP into being an acceptable agent. Coercion should lead to longer first fixation durations and first pass reading times in the postverb region of intransitives following rationale but not control clauses. In the case of middle sentences, the situation is slightly more complex in that middle verbs introduce a conflict between participant information associated with their conceptual representations and participant information which is syntactically active. Rationale clauses not only require an agent, but require one that is syntactically active. Middles satisfy only part of this requirement. Thus, readers are faced with conflicting cues regarding whether an appropriate agent is available for the event described by the rationale clause, which may lead them to reread the main clause in order to ascertain whether they had misread the sentence by skipping over a form of the auxiliary verb *be* (i.e., *The vase had been sold*). Consequently, in middles, rather than observing longer first fixation duration or first pass reading times in the postverb region, instead, we observed that readers are more likely to initiate regressive eye movements. This explanation of the difference in reading behaviors in the postverb regions of intransitive and middle sentences should be considered speculative at this point without a prior well-grounded understanding of the processing reflected by longer first fixation durations and first pass reading time vs regression paths, respectively.

General discussion

The results we have presented provide converging evidence for the early processing of schematic participant information. In Experiment 2, regression path durations originating in the postverb region were longer for middle than short passive sentences following rationale clauses. And in Experiment 1, intransitive postverb regions elicited longer first fixations and first pass reading times (when trials on which readers made a regressive eye movement were excluded) than passive verb regions when intransitive and passive sentences were coupled with sentence-initial rationale clauses. That readers' first fixations were selectively longer in the immediate postverb regions of intransitive sentences and that they selectively returned to reread middle verb regions only when an agent dependency had to be satisfied suggests that participant information must have been encoded during readers' first pass through the verb region.

The data from Experiment 1, obtained with a paradigm that does not require incremental semantic judgments or word-by-word reading, replicate Mauner and Koenig's (2000) Experiment 3 results, which showed greater processing difficulty at intransitive verbs relative to passive verbs in sentences following agent-dependent clauses. The current results suggest that their results are unlikely to have been due either to participants having to make incremental sensicality judgments or to having more time for processing verb regions because of the word-by-word stimulus presentation. Moreover, in the present study, anomaly effects were not observed for intransitive relative to short passive clauses when they were coupled with sentence-initial adverbial controls rather than agent-dependent rationale clauses. Thus, it is also unlikely that the longer reading times and greater proportion of negative sensicality judgments that Mauner and Koenig observed at the verbs in intransitive sentences could be due either to readers accommodating a temporal presupposition introduced by the modal auxiliary *had* in intransitive but not short passive sentences or to differences in the markedness or frequency of intransitive relative to passive verb forms.

The processing differences between middle and short passive clauses that emerged in the regression paths from the postverb region in Experiment 2, even when the events described by both clause types logically required an agent, provide not only evidence for the early interpretation of schematic participant information, but also further support for the representational claims made for intransitive, middle, and passive verbs first articulated in Mauner and Koenig. In particular, the processing of sentences with middle verbs patterned with that of sentences with intransitive but not passive verbs. This supports a view in which the encoding of *schematic* participant information cannot be entirely reduced to general conceptual knowledge in the form of verb-specific concepts (e.g., McRae et al., 1996) as MacDonald (1997) has suggested. This in no way implies that readers do not make early use of such conceptual information but it does require that verbs contribute to sentence interpretations abstract semantic participant information that is grammatically potent in addition to verb-specific, contextually determined conceptual information.

One possibility for preserving the view that verbs contribute only contextually determined, verb-specific concepts is to argue that both the current and our previous results do not reflect anything about the semantics of verbs. Instead, the longer processing times for intransitive and middle clauses relative to short passive clauses are due entirely to the fact that agent information is an inherent component of the passive construction but not of the middle or intransitive constructions. Under an extreme version of a constructional view, sentence constructions, e.g., passive and middle sentences, and not verbs are the sole repository of schematic participant information. Thus, *schematic* participant information is reducible to meanings correlated with syntactic patterns, in this case the combination of the auxiliary verb *was* and a participial form of a verb. Because the agent participant information we examined in these studies is confounded with syntactic structure, this possibility cannot be entirely discounted. However, there are a number of factors that strongly argue against it.

First, it should be noted that although many alternative syntactic frames in which verbs can occur are clearly associated with participant information (see Davis & Koenig, 2000; Goldberg, 1995; Levin, 1993; Pinker, 1989; Wechsler, 1995; among others), the alternation between a passive and its corresponding active structure is generally agreed not to be semantically potent (but see Pinker, 1989, for a dissenting view). In other words, actives and passives differ not in semantics, but in discourse properties (Foley & Van Valin, 1984; Givón, 1995). Moreover, since the notion of constructional meaning is necessarily indexed to classes of verbs that are united by virtue of having similar semantics, as argued by Goldberg (1995), the independent motivation for recording agent information in the passive template, in addition to information about the verbs which can occur in a passive sentence, is unclear.

Second, verbs in the passive voice can license rationale clauses even when they do not combine with a form of the auxiliary *be*, as the sentence in (8) illustrates. Conversely, middles cannot license rationale clauses, irrespective of the presence of the auxiliary *had* or of the morphological form of the verb, as the sentences (9a) and (9b) illustrate:

(8) The aide fired to appease the candidate's opponents turned over documents to investigators

(9a) *The antique vase (had) sold to pay off some debts.

(9b) *I anticipate the antique vase's selling to pay off the museum's debts.

The contrast between sentence (8) and the sentences in (9) shows that the syntactic surface pattern with which the presence of an agent is correlated must be the verb or verb form itself. Note that this makes the constructional analysis empirically indistinguishable from our lexical approach, since in both cases it is the recognition of the verb which will lead one to include or not include an agent participant in the representation of a sentence. Whether this is the result of combining a verb with its subject (and the syntactic knowledge that participles that modify NPs can only have a passive interpretation) or the result of combining a verb base with a lexical rule or lexical template, as in lexicalist approaches to grammar (Bresnan, 1982; Koenig, 1999; Pollard & Sag, 1987, 1994) cannot be ascertained. Distinguishing between these two possible sources of schematic participant information for other sentence structures is also difficult, since, as we mentioned, syntactic frames are typically indexed to verb classes (see Goldberg, 1995). This is an issue we are pursuing in current research.

Appendix

Experiment 1

Rationale and control clause sentence-initial alternatives appear as lines one and two of each item. The passive or intransitive final clause is shown in the third line.

To deceive investigators about the cause of death,
The woman could not identify her friend because
the body was/had burned completely in the wreckage.

To produce the best wines possible,
The produce buyer was told that
the grapes were/had grown naturally on a hillside.

To honor the heroes who had died in the war,
During the ceremony honoring the war heroes,
some rifles were/had fired repeatedly into the air.

To lure the puppy out from under the couch,
The baby was surprised that
the ball was/had rolled quickly across the floor.

To avoid waking the children,
The children didn't wake up because
the door was/had shut slowly with little noise.

To coerce the government into signing a treaty,
The UN workers were appalled to see that
the children were/had starved slowly in the prison.

To demonstrate a crucial principle in physics,
During the physics demonstration,
the gyroscope was/had spun clockwise for three minutes.

To provide some more head room,
Before it broke completely,
the passenger seat was/had lowered almost to the floor.

To test the adjustments that were made to the fuel injector,
While stopped at the light,
the car's engine was/had revved loudly for several seconds.

To prevent an outbreak of harmful bacteria,
The health inspector checked to see whether
the meat was/had thawed thoroughly in the refrigerator.

To mourn the death of the mayor,
During the mayor's funeral,
the church bell was/had rung solemnly for several minutes.

To prepare the surface for wedding decorations,
Although it was too warm,
the white icing was/had spread neatly over the cake.

To accommodate the heavy traffic,
Due to the heavy traffic,
the nature trail was/had widened slightly at several points.

To avoid setting off the sound-sensitive alarm,
The night watchman was unaware of the prowlers because
the safe's lock was/had turned noiselessly during the burglary.

To ensure the immediate death of the convicted murderer,
The prisoner began to pray when
the noose was/had tightened firmly around his neck.

To frighten the witness into not testifying,
The woman was devastated to learn that
her husband was/had drowned yesterday in the river.

To keep the child safe from harm,
The insurance company wanted to know whether
the seat belt was/had buckled securely in the back.

To protect the children from lightning,
Because of the thunderstorm,
the little league game was/had ended early in the fifth.

To distract the baby from pulling on the dog's ears,
The baby giggled after
the rattle was/had shaken rhythmically to the music.

To unload the stolen property,
The detective told the museum director that
the antique vase was/hadsold illegally to a collector.

Experiment 2

To attract the attention of the judges at the competition,
the horse's mane was/had braided tightly with ribbons.

To lessen the noise in the busy hospital lobby,
some new carpeting was/had installed with special padding.

To test the adjustments made to the fuel pump yesterday,
the car's engine was/had started repeatedly this morning.

To prepare the cake for the wedding this morning,
the vanilla icing was/had spread evenly on top.

To complete the book before the children's bedtime,
the last chapter was/had read immediately after dinner.

To forestall a mutiny by the ship's crew,
the pirate's loot was/had divided equally into piles.

To keep the rider from falling off the untamed horse,
the leather saddle was/had buckled securely and carefully.

To prevent the little boy from walking barefoot outside,
his shoes were/had laced tightly and knotted.

To fix the walls before the apartment inspection,
the holes were/had filled neatly with plaster.

To raise money to cover some gambling debts,
the antique vase was/had sold for $1500 cash.

To make brushing the poodle's hair a lot easier,
the matted hair was/had cut evenly with scissors.

To avoid frightening the deer with an unexpected noise,
the shotgun was/had loaded quietly and quickly.

To complete a set of collectible baseball cards,
a valuable card was/had traded for three others.

To distract the baby from pulling on the dog's ears,
the child's rattle was/had shaken repeatedly and loudly.

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