Verbs, Objects, and Events: Eye-Tracking Reveals the Time-Course of Aspectual Interpretation

David J. Townsend
Montclair State University
Upper Montclair, NJ, US
townsendd@mail.montclair.edu

George Olekson
Montclair State University
Upper Montclair, NJ, US
oleksong1@mail.montclair.edu

Abstract

We evaluated specification and under-specification hypotheses of verb representation by measuring eye-fixations during reading. Participants read two sets of verb phrases that differed in object definiteness and in preference for *in*- vs. *for*-adverbial phrases. Total fixation time on the adverbial phrase depended on a predicted interaction between verb phrase preference and object definiteness. These results are consistent with claims that verbs specify boundedness information.

1 Introduction

Sentences represent events as bounded or not. For example, we interpret *John built a house* to refer to a single completed event (bounded). However, we interpret *John built houses* to refer to an indefinite series of separate house-building events (unbounded). The difference in interpretation appears when we modify these sentences with time-span vs. durative adverbial phrases (Comrie, 1976; Dowty, 1979; Smith, 1991; Vendler, 1957; and many others). A bounded interpretation occurs in *John built a house in six months* but not in *John built houses in six months.* An unbounded interpretation occurs in *John built houses for six months* but not in *John built a house for six months*. We find different patterns in *John pushed a cart* and *John pushed carts*: Both are more acceptable with *for ten minutes* rather than *in ten minutes*. These observations suggest that the mental representations of *build* and *push* differ in boundedness.

Recent discussions suggest two general approaches to the representation of boundedness. Specification maintains that the mental representation of a verb contains information about boundedness. Various theories have expressed this idea in different ways. Type theories place verbs into distinct categories according to aspectual classes such as states, processes, transitions, etc. (e.g., Jackendoff, 1997; Pustejovsky, 1991). Information that conflicts with the aspectual type of a verb introduces semantic content or operators that convert it to another type. Other examples of specification maintain that verbs are marked for boundedness in various ways (Declerck, 1979; Verkuyl, 1989). Still other approaches propose that a verb such as *build* represents boundedness through its entailment of an incremental theme whose status is related to the completeness of an event (Dowty, 1991). In contrast, an unbounded verb such as *push* entails no incremental theme. Despite substantial differences among these theories, they have one property in common: Each specifies boundedness information in verbs.

Under-specification maintains that verbs are under-specified with regard to temporal boundedness. This approach emphasizes that aspectual interpretation requires combining phrases and other elements from the entire sentence (Pickering et al., 2006; Pylkkanen & McElree, 2006).

Two observations support under-specification. First, multiple interpretations often are possible (e.g., Declerck, 1979; Dowty, 1979). For example, we may assign a habitual (unbounded) interpretation to *John built houses in six months* such that John made a practice of building a house in six months and did so on several occasions. We may interpret *John built a house for six months* by shifting the interpretation of *built* to that of *worked on*, producing an unbounded interpretation. *John pushed a cart in ten minutes* has an inchoative interpretation of

the time span that elapsed before the onset of the event. *John pushed carts in ten minutes* has a habitual interpretation of this inchoative meaning. This flexibility of interpretation seems inconsistent with specification of boundedness in verbs.

Second, many factors influence interpretations of boundedness. As noted above, an adverbial phrase with *in* vs. *for* influences these interpretations, as does the definiteness of the direct object. In fact, the definiteness of nearly any noun phrase in the sentence affects aspectual interpretation (Declerck, 1979; Verkuyl, 1993). For example, *John built a house in Pisa* is bounded, *John built a house in many cities* is unbounded. *A liter of water ran out of the tap* is bounded, *Water ran out of the tap* is unbounded (Declerck, 1979). *Den Uyl gave a badge to a congress-goer* is bounded, *Den Uyl gave a badge to congress-goers* is not (Verkuyl, 1993). These facts suggest that aspectual interpretation depends greatly on the context in which a verb appears.

Questions about the nature of aspectual representation in verbs appear in the literature on sentence processing. One study supports different representations of stative vs. eventive verbs (i.e., activities, accomplishments, and achievements) (Gennari & Poeppel, 2003). Other studies suggest that event semantics has a role in comprehension, but they provide few details about the sequence of interpretive processes during uninterrupted reading or listening (Brennan & Pylkkanen, 2008; Husband et al., 2008; Pinango et al., 1999; Proctor et al., 2004; Todorova et al., 2000; Townsend & Seegmiller, 2004). A third group of studies used analyses of eye-tracking to argue for representation of individuals and events as distinct types (Pickering et al., 2006; Pylkkanen & McElree; Traxler et al., 2002). Results from this group of studies suggest that verbs are underspecified for boundedness.

We evaluated the specification and under-specification approaches in sentence comprehension. To remain theoretically neutral, we defined boundedness in terms of participants' judgments about the acceptability of sentences with *in*- vs. *for*-modification. We used a forced choice test in which we presented pairs of sentences that differed only in *in/for*:

(1) A. *The curious cat killed the grey mouse in 8 minutes*.
    B. *The curious cat killed the grey mouse for 8 minutes*.
(2) A. *The black bear hunted the crimson fox in two hours.*
    B. *The black bear hunted the crimson fox for two hours.*

One sentence in each pair contained an *in*-phrase that specifies a time span for completing a bounded event. The other contained a *for*-phrase that specifies the duration of an unbounded event. In order to increase naturalness, we placed each verb in a unique context, as in (1) and (2).

We asked participants to make one of four choices about the sentences within pairs such as (1) and (2): The sentence with *in* sounds better, the sentence with *for* sounds better, both sound good, or neither sounds good. We defined a bounded verb as one that participants judged more acceptable with an *in*-phrase rather than a *for*-phrase. An unbounded verb is one that they judged more acceptable with a *for*-phrase.

To examine the mechanism of aspectual interpretation, we presented the same sentences to other participants in an eye-tracking experiment. The variables were Verb (bounded vs. unbounded), Object (definite vs. indefinite), and Adverb (*in* vs. *for*). We ended the sentence after the adverbial phrase to increase the effect of sentence "wrap-up" processes. Examples appear in Table 1.

Bounded Verb:
Definite, *in: The curious cat/ killed/ the grey mouse/ in eight minutes.*
Definite, *for: The curious cat/ killed/ the grey mouse/ for eight minutes.*
Indefinite, *in: The curious cat/ killed/ grey mice/ in eight minutes.*
Indefinite, *for: The curious cat/ killed/ grey mice/ for eight minutes.*
Unbounded Verb:
Definite, *in: The black bear/ hunted/ the crimson fox/ in two hours.*
Definite, *for: The black bear/ hunted/ the crimson fox/ for two hours.*
Indefinite, *in: The black bear/ hunted/ crimson foxes/ in two hours.*
Indefinite, *for: The black bear/ hunted/ crimson foxes/for two hours.*

Table 1: Conditions and Scoring Regions for Two Items

We obtained two eye-tracking measures on the adverbial phrase (Liversedge, Paterson, & Pickering, 1998; Kennedy & Murray, 1987; Rayner, 1998). *First pass time* is the sum of fixation times from the first fixation in the adverbial phrase through the last until the eye leaves the adverbial phrase. First pass time assesses attempts to resolve processing difficulties without leaving the adverbial phrase. *Total time* is the sum of all fixation times in the adverbial phrase including fixations during the first pass through the phrase and fixations in the phrase following any regressions.

Specification theories predict an interaction between Verb and Object: An indefinite object phrase increases fixation time following a bounded verb, but not following an unbounded verb. Under-specification maintains that aspectual interpretation depends on integrating all parts of a sentence. Since aspectual interpretation depends on the meanings of phrases rather than on boundedness information in the verb, there is no reason to expect difficulty with any combination of phrases.

2 Method

2.1 Participants

Forty participants came from the Psychology Department subject pool at Montclair State University. All participants were native speakers of English with vision that was normal or corrected to normal. Participants received either course credit or payment for the 40 minute experiment.

2.2 Materials

The materials consisted of 14 bounded verbs and 16 unbounded verbs. Each verb appeared in four conditions depending on Adverb and Object (see Table 1). The direct object was either definite (singular) or indefinite (bare plural); three direct objects had irregular plural forms (e.g., *mice*). The adverbial phrase specified either a time span (*in*) or a duration (*for*). Neither the number of characters in the adverbial phrase nor its Collins Cobuild frequency differed for bounded vs. unbounded verbs, both ps > .25.

We conducted two surveys to evaluate judgments about the materials. For both surveys we adapted the forced-choice test developed by Townsend & Seegmiller (2004). Thirty-two college students who did not participate in eye-tracking took both surveys.

We first established that the two groups of verbs produce different interpretations. We presented pairs of sentences that differed only in *in/for*, as in (1) and (2). One sentence contained an *in*-phrase that specifies a time span for completing a bounded event. The other contained a *for*-phrase that specifies the duration of an unbounded event. Participants indicated whether a sentence containing a bounded or unbounded verb sounds better with *in* or *for*, whether both *in*- and *for*-sentences are acceptable, or whether neither sentence is acceptable. The results showed that participants prefer bounded verbs with *in*-phrases (75% preferred a bounded verb with *in* while 5% preferred a bounded verb with *for).* They prefer unbounded verbs with *for*-phrases (74% preferred an unbounded verb with *for* while 7% preferred an unbounded verb with *in*). The two groups of verbs differed in preference for both *in*, $F(1, 28) = 165$, $p < .001$, and *for*, $F(1, 28) = 304$, $p < .001$. The verb groups did not differ in choices of "both" (14 vs. 17% for bounded and unbounded verbs respectively) or "neither" responses (6 vs. 3% respectively), both *p*s > .25. Thus, sentences with verbs from different groups differ in interpretation but not in acceptability.

A second survey examined transitivity preferences for bounded vs. unbounded verbs. Participants received a pair of questions such as "What did the cat kill?" vs. "When did the cat kill?" They indicated whether "What…" sounds better (indicating a preference for transitive), "When…" sounds better (indicating a preference for intransitive), both are acceptable, or neither is acceptable. Verb group was unrelated to the percentage of choices of transitive questions (43 vs. 45% for bounded vs. unbounded respectively), intransitive questions (21 vs. 16%), both (33 vs. 35%), or neither (3 vs. 4%), all *F*s < 1.

2.3 Procedure

We conducted the experiment with an SR Research Eye Link 1000 desktop system, and Eye Tracking and data processing software

from http://www.umass.edu/eyelab/software/. The monitor was 50 cm from the participant. Participants rested their chin and forehead on bars. The system was calibrated for right eye tracking with corneal reflection. Maximum drift error was set at 0.4 degrees and checked several times during each session. A trial began when the participant focused on a circle in the center of the screen. When the participant's gaze was stable, the Eye Track software presented a square near the left edge of the screen. When the participant looked at the square, the software displayed the sentence. The font was Arial 18. The screen width was 160 characters with a resolution of 1280 by 1024. Participants were instructed to read each sentence normally. When they reached the end of a sentence, participants looked at a sequence of XXX one line below and 5 spaces to the right of the period. They then pressed a button on the left side of a game controller. This button press either initiated another trial or presented a question. Participants answered questions by pressing a button on the right or left side of the game controller.

Each participant read 128 sentences. Thirty sentences had the form of those in Table 1. Four lists had 7-8 sentences in each of four conditions: 2 Adverb (*in* vs. *for*) x 2 Object (definite vs. indefinite). Of the remaining 98 filler sentences, 24 had clauses conjoined with *and*, 48 had clauses conjoined with a subordinating adverbial conjunction, and 26 were a mixture of one- and two-clause sentences. A question followed 48% of both filler and test sentences. Half of these questions concerned agent and patient roles (e.g., *Who did the hunting? Fox vs. Bear*); half concerned the number of events (e.g., *How many killings were there*? *Just one vs. More than one*).

Data processing software adjusted vertical displacement. The software combined fixations that were shorter than 80 ms. It excluded trials in which gaze duration exceeded 2000 ms or no fixation occurred in the region. First pass data in the adverbial phrase was missing on 1.9% of the trials.

We evaluated the statistical significance of differences in first pass time and total time for the adverbial phrase with analysis of variance by participants and by items. The variables in these analyses were Verb (bounded vs. unbounded), Object (definite vs. indefinite), and Adverb (*in* vs. *for*). We used residual reading times to factor out the effects of variability in length of the adverbial phrase. The residual reading time in a region is the difference between the actual fixation time and the fixation time that linear regression predicts from the number of characters in the region (Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). The basis for these predictions was fixation time in the subject phrase; the verb; the direct object phrase; the adverbial phrase. Table 1 marks these regions with a /.

The results of interest are the three-way interaction between Verb, Object, and Adverb, and the two-way interaction between Verb and Object. Specification theories predict that fixation time is longer for indefinite objects than definite objects only following bounded verbs.

3 Results

Table 2 shows mean first pass time and total time in the adverbial phrase region.

First pass time showed a small effect of object definiteness when the adverb was *in* and the verb was bounded: Fixation time was longer for indefinite objects than for definite objects (655 vs. 631 ms). The opposite occurred when the adverb was *in* and the verb was unbounded (633 vs. 670 ms), and when the adverb was *for* regardless of verb (bounded verbs: 668 vs. 724 ms for indefinite and definite objects respectively; unbounded verbs: 639 vs. 656 ms). However, neither the three-way interaction in residual reading time nor the interaction between Verb and Object was significant, all ps > .10.

Total time showed a similar pattern. When the adverb was *in* and the verb was bounded, fixation time was longer for indefinite objects than for definite objects (843 vs. 754 ms). The opposite occurred when the adverb was *in* and the verb was unbounded (803 vs. 854 ms), and when the adverb was *for* regardless of verb (bounded verbs: 853 vs. 887 ms for indefinite vs. definite objects respectively; unbounded verbs: 750 vs. 861 ms). Again, the three-way interaction in residual reading time was not significant, both ps > .10. However, fixation time overall was longer for indefinite than for definite objects following bounded verbs (848 vs. 821 ms) but not following unbounded verbs (777 vs. 858 ms), $F1 (1, 39) = 6.38$, $p < .05$, $F2 (1, 28) = 6.58$, $p < .05$.

		In				*For*			
		Bounded Verb		Unbounded Verb		Bounded Verb		Unbounded Verb	
		Definite	Indefinite	Definite	Indefinite	Definite	Indefinite	Definite	Indefinite
FPT	M	631	655	670	633	724	668	656	639
	s.e.	41.3	32.5	32.0	34.0	42.3	43.0	33.9	33.9
	RRT	28.4	51.6	35.5	-8.1	92.1	33.4	-3.1	-26.5
TT	M	754	843	854	803	887	853	861	750
	s.e.	46.6	54.7	42.4	42.7	53.3	51.6	53.7	46.5
	RRT	-17.5	71.1	43.2	-13.3	83.9	49.0	12.4	-97.7

Table 2: Mean Fixation Time (ms) in the Adverbial Phrase Depending on Verb, Object, and Adverb
Note. FPT = first pass time; TT = total time; M = mean; s.e. = standard error; RRT = residual reading time.

4 Discussion

We considered two hypotheses about the role of the verb in aspectual interpretation. The specification hypothesis maintains that boundedness information appears in the representation of verbs. This hypothesis proposes that the processor adopts an aspectual interpretation when it recognizes a verb. If subsequent information conflicts with this interpretation, the processor shifts its interpretation to agree with the (conflicting) new information. The specification hypothesis predicts that verb semantics interacts with conflicting information during sentence processing.

The under-specification hypothesis maintains that the mental representations of verbs do not contain information about boundedness. The processor forms an aspectual interpretation by integrating non-aspectual meanings at the end of the sentence. The under-specification hypothesis predicts no interactions between verb, object and adverbial phrase.

The present data support the view that boundedness information appears in the representation of verbs. When the verb was bounded, total time on the adverbial phrase was longer for indefinite objects than for definite objects. When the verb was unbounded, this difference did not occur. A similar but non-significant trend appeared in first pass time. These results support the view that aspectual interpretation occurs during sentence processing.

Our design suggests caution in concluding that recognition of a verb immediately establishes an interpretation of boundedness. The optimal comparisons for evaluating this claim is first pass time on definite vs. indefinite objects or on the following region. To increase the naturalness of our materials, we allowed the content of object phrases to vary across verbs. This feature of our design prohibits conclusive comparisons of fixation time on object phrases. In addition, our data showed only non-significant effects in first pass time on the following adverbial phrase. Although we cannot conclude that the processor adopts an aspectual interpretation at the moment of recognizing a verb, we can conclude that it does so at the time of processing the adverbial phrase. The appearance of significant effects in total time on the adverbial phrase suggests that the processor initiates aspectual re-interpretation on the adverbial phrase, and continues it in regressions and in re-reading the adverbial phrase. Thus, our data confirm that representations of verbs contain boundedness information and that the sentence processor uses this information during comprehension.

Acknowledgments
This research was supported by NIH 1R15HD055680-01A1. We are grateful to Chuck Clifton, Steve Seegmiller, and Mary Call for advice on the manuscript, to three anonymous reviewers for their valuable comments, and to the members of the Eye Tracking Lab at Montclair State University for assistance in testing participants.

References

Brennan, J., & Pylkkanen, L. (2008). Processing events: Behavioral and neuromagnetic correlates of aspectual coercion. *Brain & Language, 106*, 132-143.

Comrie, B. (1976). *Aspect: An introduction to the study of verbal aspect and related problems.* Cambridge: Cambridge University Press.

Declerck, R. (1979). Aspect and the bounded/unbounded (telic/atelic) distinction. *Linguistics, 17*, 761-794.

Dowty, D. R. (1991). Thematic proto-roles and argument selection. *Language, 67*, 547–619.

Dowty, D. R. (1979). *Word meaning and Montague grammar*. Dordrecht: Reidel.

Ferreira, F. & Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25*, 348-368.

Gennari, S., & Poeppel, D. (2003). Processing correlates of lexical semantic complexity. *Cognition, 89*, B27-B41.

Husband, E. M., Stockall, L., & Beretta, A. (2008). VP-Internal event composition. Unpublished manuscript, Michigan State University. World wide web: http://eyelab.msu.edu/people/matt/vp-internal_final_submitted.pdf (July 1, 2008).

Jackendoff, R. (1997). *The architecture of the language faculty*. Cambridge, MA: MIT Press.

Kennedy, A., & Murray, W. W. (1987). The components of reading time: Eye movement patterns of good and poor readers. In J. K. O'Regan & A. Levy-Schoen (Eds.). *Eye movements: From physiology to cognition.* (pp. 509-520). New York: Elsevier Science.

Liversedge, S. P., Paterson, K. B., & Pickering, M. J. (1998). Eye movements and measures of reading time. In G. Underwood (Ed.). *Eye guidance in reading and scene perception*. (pp. 55-75). Amsterdam: Elsevier Science Ltd.

Pickering, M. J., McElree, B., Frisson, S., Chen, L., & Traxler, M. J. (2006). Underspecification and aspectual coercion. *Discourse Processes, 42*, 131-155.

Pinango, M. M., Zurif, E., & Jackendoff, R. (1999). Real-time processing implications of enriched composition at the syntax-semantics interface. *Journal of Psycholinguistic Research*, 28, 395-414.

Proctor, A. S., Dickey, M. W., & Rips, L. (2004). The time-course and cost of boundedness inferences. *Proceedings of the 26th Annual Meeting of the Cognitive Science Society*, Chicago.

Pustejovsky, J. (1991). The syntax of event structure. *Cognition, 41*, 47-81.

Pylkkanen, L., & McElree, B. (2006). The syntax -semantics interface: On-line composition of sentence meaning. In M. J. Traxler & M. A. Gernsbacher (Eds.). *Handbook of psycholinguistics: 2nd Edition.* (pp. 539-579). Amsterdam: Elsevier.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*, 372-422.

Smith, C. S. (1991). *The parameter of aspect.* Dordrecht: Kluwer Academic Publishers.

Todorova, M., Straub, K., Badecker, W., & Frank, R. (2000). Aspectual coercion and the online computation of sentential aspect. *Proceedings of the annual conference of the Cognitive Science Society, 22*, 523-528.

Townsend, D. J., & Seegmiller, M. S. (2004). The linguistic representation and processing of event structure. *Journal of Cognitive Science, 5*, 157-244.

Traxler, M. J., Pickering, M. J., & McElree, B. (2002). Coercion in sentence processing: Evidence from eye-movements and self-paced reading. *Journal of Memory and Language, 47*, 530-547.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language, 33*, 285-318.

Vendler, Z. (1957). Verbs and times. *Philosophical Review, 66*: 143-160.

Verkuyl, H. J. (1989). Aspectual classes and aspectual composition. *Linguistics and Philosophy, 12*: 39-94.