Parsing Modifiers: The Case of Bare NP Adverbs

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Abstract

Current models of Human Sentence Processing fall into two broad categories: *Constraint Satisfaction* accounts, which emphasise the immediate access of the comprehension processes to detailed linguistic information as parsing progresses (e.g., MacDonald et al., 1994), and *Syntax First* accounts, which hold that parsing is essentially a two-stage process, with initial decisions being made on the basis of a subset of available information (see, e.g., Frazier, 1995). In this paper, we examine evidence from Mitchell (1987) which seems strongly to favour a syntax first position, suggesting that basic lexical information about verbs may have little influence on the early stages of sentence processing. We provide experimental evidence to show (a) that detailed linguistic information is available early, but (b) that bare NP adverbs (a type of modifier) are read surprisingly fast, a finding which appears difficult to reconcile with many current accounts of sentence processing.

Constraint Satisfaction models of Human Sentence Processing rely heavily on detailed information about the combinatorial possibilities and probabilities associated with each word of a sentence. For example, MacDonald et al. (1994) suggest that the reading of a sentence such as (1a) is affected by lexico-syntactic factors including the frequencies with which the word *raced* is used in each of its senses (for example, as a past participle or as a past tense verb), as well as thematic factors such as how good an agent or patient *horse* is of *raced*.

(1a) The horse *raced past the barn* **fell**.[1]

(1b) The landmine *buried in the sand* **exploded**.

This type of account can be contrasted with *Syntax First* positions, according to which initial parsing decisions are made on the basis of a subset of available linguistic information (generally comprising category information and phrase structure rules, e.g., Frazier, 1979). These decisions may later be revised in the light of further (syntactic, thematic or pragmatic) evidence, but these revisions have an associated processing cost. According to such accounts, (1b) should be as hard to understand as (1a), since they are syntactic homomorphs. The constraint satisfaction view, on the other hand, predicts the intuitively observable difference between the two, by pointing out that (thematically) *landmine* makes a poor agent (but a good patient) of *buried*, as well as (syntactically) the statistical facts that *buried* is typically used as a passive past participle (in comparison to *raced* which is typically used as an active past tense verb).

However, evidence from a study by Mitchell (1987) appears highly incompatible with constraint-based accounts. According to Mitchell, the most basic form of information associated with a verb—that of whether a verb is transitive or intransitive, or in other words the verb's subcategorisation information—may not be available during the initial stages of sentence comprehension. Using materials like those in (2), he found that readers of (2a) were typically slow (relative to a control with a disambiguating adverbial phrase such as *during surgery* after *visited* or *sneezed*) at reading the word *wrote*. This is to be expected within almost any framework, since it is syntactically permissible (as well as thematically acceptable) for *the doctor* to be initially interpreted as the direct object of *visited*.

(2a) After the child visited *the doctor* **wrote** him a prescription.

(2b) After the child sneezed *the doctor* **wrote** him a prescription.

Crucially, Mitchell also showed that readers were slow to read *the doctor* in (2b). Since *sneezed* is a (typically) intransitive verb,[2] Mitchell interpreted these findings as suggesting that information about the subcategorisation of *sneezed* was *not* initially available to the parsing process (but was made available as soon as later processes could check the plausibility of *the doctor* as an object of *sneezed*).

Mitchell's findings are clearly problematic for constraint-based accounts of sentence processing. If the differences between (1a) and (1b) are to be accounted for in terms of information about the (probabilistic) 'goodness of fit' between a verb and its arguments (including the relative frequencies with which particular subcategorisation frames of a given verb are used), an account must be made of the apparent *in*sensitivity of the human parser to the fact that *sneezed* is rarely, if ever, used as a transitive verb.

Less often remarked upon is the difficulty that Mitchell's results may pose for many syntax first theories. Although the

[1] Regions of example sentences where more than one interpretation is (potentially) available are typeset in *italics*, and disambiguating regions are set in **bold**.

[2] Almost every 'intransitive' verb, as Adams et al. (1998) note, can be used in some transitive senses, if only in highly stylised phrases such as *He sneezed a tiny sneeze*, *She yawned a big yawn*, etc.

details of models differ, a number of current positions converge on the importance of (potential) argumenthood, with incoming constituents being preferentially attached to the current phrase marker as arguments rather than as modifiers or adjuncts (e.g., Crocker, 1992; Frazier & Clifton, 1996). In order to adjudicate between the attachment of a constituent as a modifier or as an argument, the human parser *must be aware* that a potential site for argument attachment exists. If this information is unavailable at the time a verb is encountered, then an argument attachment strategy would provide a poor account, at least at the explanatory level, of the parser's behaviour.

Interpretations of Mitchell's findings tend to assume that detailed information about the verb *is* initially available, but that either linguistic or experimental factors give rise to the results obtained. For example, Tanenhaus and Trueswell (1995) observe that there may be a residual bias to interpret a noun phrase following a verb as its object, lexical biases notwithstanding. This has the advantage of providing a straightforward account of Mitchell's findings within a constraint satisfaction framework, but the disadvantage that it damages the predictive power of the theory (if difficulty in reading (1a) is accounted for in terms of information associated with a particular verb, but Mitchell's findings are interpreted in the light of the behaviour of verbs in general, how are we to know which factors are likely to influence the interpretations of hitherto untested sentences?).

Critics of Mitchell's experimental design have noted that he used a self-paced reading paradigm in his initial study. Due to the way that the materials were segmented (such that participants saw the words ... *sneezed the doctor* in a single display before pressing a key to view the matrix verb of which *the doctor* was the subject), participants may have been misled into 'strategically' attempting to interpret *the doctor* as the object of *sneezed*. This criticism (effectively of the ecological validity of the self-paced reading paradigm) was addressed by Adams, Clifton, and Mitchell (1998), who replicated Mitchell's experiment using an eyetracker, so that materials did not have to be artificially segmented. Although their findings contradict Mitchell's, they remain unconvinced that subcategorisation information *is* initially available. One argument that they make is that Mitchell's findings must still be accounted for: even if segmentation affects the way in which subjects read Mitchell's materials, it is clear that it does not cause subjects to violate phrase-structure rules (when attaching adverbials in control materials), whereas subcategorisation information appears to be easily overridden.

In this paper, we offer a different interpretation of Mitchell's findings. This rests on the observation that although intransitive verbs such as *sneezed* do not subcategorise for *object* NPs, there is a class of NPs which can legitimately follow them: namely, bare NP adverbs (Larson, 1985). For example, the sentence in (3) is a perfectly acceptable sentence in English.

(3) After the child sneezed the other day, the doctor wrote him a prescription.

The other day serves an adverbial function; that is, it seems to modify, rather than serve as an argument of, the verb *sneezed*. If participants *are* initially aware of the subcategorisation properties of verbs, the delay in reading *the doctor* in (2b) relative to its control might be accounted for by a system which was working on the assumption that any NP following an intransitive verb such as *sneezed* would be a bare NP adverb; the delay reflects the fact that *the doctor* must be rejected in this case.

Parsing Bare NPs

The primary aim of the first study which follows is to test this interpretation of Mitchell's findings, by explicitly including bare NP adverbs in a set of experimental materials modelled on those used by Adams et al. (1998). We have chosen to use a self-paced reading paradigm, precisely because we are interested in what happens when subjects are 'forced' to attach an NP to a verb. If our assumptions are right, then bare NP adverbs (henceforth 'bNPs') should be read faster than 'normal' NPs ('nNPs') following intransitive verbs in the subordinate clause. There should also be a cost of revision, reflected in the time taken to read the disambiguating matrix verb, in all conditions except that where an nNP follows an intransitive (in this case the revision should already have been made, in line with Mitchell's findings). The study also allows us to explore the parsing of modifiers vs. arguments. According to many 'syntax first' accounts, both bNPs and nNPs should initially be attached as arguments of the verbs, assuming that this is permissible: exact predictions are dependent on whether it is believed that subcategorisation information is initially available.

Experiment 1

Participants 24 volunteers from the University of Edinburgh undergraduate population took part in this study. All were native speakers of English, had normal or corrected-to-normal vision, and had no professed reading difficulties.

Materials The experimental materials were adapted from those used by Adams et al. (1998). 24 materials were created, where each material had four versions similar to those in (4). Examples like (4a) and (4b) had optionally transitive verbs in the preposed subordinate clause, whereas in (4c) and (4d) these verbs were strictly intransitive. Transitive and intransitive verbs were matched for length, and for frequency according to norms from Kučera and Francis (1967).

(4a) Although the dog scratched *the old vet* / **seemed** / very relaxed.

(4b) Although the dog scratched *the whole day* / **seemed** / very relaxed.

(4c) Although the dog struggled *the old vet* / **seemed** / very relaxed.

(4d) Although the dog struggled *the whole day* / **seemed** / very relaxed.

Each material contained a (potential) ambiguity[3] in that the NP following the subordinate verb could be interpreted as an argument, or modifier, of that verb; in each case, the second (matrix) verb resolved the ambiguity in favour of an interpretation where the NP was the subject of the matrix clause. In (4a) and (4c) the NP in question was an 'object-like' NP (nNP), which might be interpreted as an argument of the subordinate verb; in (4b) and (4d) the NP was a bare NP (bNP), which might be interpreted as a modifier.

The 24 sets of four materials were sorted into four experimental packages, such that each package contained an equal number of materials in each of the four conditions in (4). Each material appeared in exactly one version in each of the experimental packages. To counterbalance the experimental materials (and dissuade subjects from assuming that all subordinate clauses read during the experiment ended with a verb) 32 control sentences were constructed, in which the NP following the first verb always belonged to the subordinate clause (e.g., *Because the waitress spat the chewing gum we demanded a refund*). 16 of these contained nNPs, and 16 contained bNPs. Finally, 46 filler sentences, of unrelated syntactic structures, were created. The 78 control and filler sentences were added to each experimental package, resulting in four experimental packages which consisted of 102 sentences each.

Materials were deliberately segmented into presentation regions in such a way that subjects would be encouraged to treat the ambiguous NP as a part of the subordinate clause (segmentation points are marked with "/" in (4)). Of critical interest are the times taken to read the first segment, which includes the ambiguous NP, and the second segment, which provides a disambiguation. Control materials were segmented analogously to experimental items, and filler materials were segmented arbitrarily.

44 of the materials (about 43%) were followed by yes/no questions referring to the content of the materials. These were used to ensure that participants read each sentence for comprehension; each participant answered 80% or more of the questions correctly (mean 92.2%), and thus all participants were included in the analysis.

Procedure Materials were presented and response times were recorded using the EXMORE experimentation package (Mitchell & Barchan, 1984) on an Acorn RISC OS computer. A five-trial practice session preceded the experiment proper, to clarify the experimental procedure. The practice and experimental sessions were identical in all respects except randomisation and content. Before both practice and experimental sessions, instructions appeared on the screen, informing participants that they would be reading sentences split into 'chunks', followed in some cases by yes-no questions.

Each trial consisted of the presentation of one material, in successive displays, followed on occasion by a related question. The trial began with the words 'Press space-bar'; this caused the first display to appear. Each successive press of the space-bar caused the display currently in view to be replaced with the next display of the material. After the final display, one of two things could happen: if there was no question, the words 'Press space-bar' indicated the beginning of the following trial; otherwise the word 'Question' was displayed for two seconds, followed by the question itself (to which participants responded using the 'Y' and 'N' keys). Once the question had been answered, participants were instructed to press the space-bar, as usual, indicating the beginning of the subsequent trial.

For the experimental session proper, materials were randomised prior to being displayed, subject to the constraint that no more than two items which were not fillers could occur in sequence. Additionally, the first four items were always filler materials. Records were kept of the key pressed and the time to respond (in milliseconds) for each display. Subjects were informed by the computer when the experimental session had ended.

Analysis All analyses were carried out using within-subjects analysis of variance, taking into account participants (F1) and experimental items (F2) as random factors.

Results and Discussion

Figure 1 shows the mean reading times in milliseconds per character for the ambiguous (1a) and disambigiuating (1b) regions respectively. Taking the disambiguating region first, it appears from figure 1b that the matrix verb is read faster when the ambiguous region preceding it contains an intransitive verb (181.8 and 215.5 ms vs. 226.1 and 233.2 ms).[4] This impression is borne out by statistical analysis: There is a main effect of type of verb ($F1(1,23) = 5.86$, $p = .024$; $F2(1,23) = 4.96$, $p = .037$). There is also a significant effect (by participants; marginally significant by items) of type of NP ($F1(1,23) = 5.32$, $p = .030$; $F2(1,23) = 2.96$, $p = .099$). From the figure, this appears to reflect the fact that once an intransitive verb has been followed by an nNP, which could not be attached into the VP, the disambiguating information is fastest to read, although the interaction is not significant ($F1 < 1$; $F2(1,23) = 1.28$).

At first glance, these findings appear to support the view that human sentence processing is sensitive to subcategorisation information about verbs, but not to properties of NPs (this would be compatible with 'verb-driven' accounts such as that of Ford, Bresnan, & Kaplan, 1982). However, further analysis reveals that the time taken to read a disambiguating verb after an intransitive verb + nNP is faster than for any other condition, and crucially, faster than for an intransitive verb + bNP ($F1(1,23) = 4.48$, $p = .045$; $F2(1,23) = 5.11$, $p = .034$). We take this to support the view that parsing *is* sensitive to properties of NPs as well as of verbs: a revision is more likely to be necessary if a bNP follows an intransitive

[3]Clearly, whether each material is *actually* ambiguous depends on whether subcategorisation information from the first verb (*sneezed* or *scratched* in (4)) is initially available to the sentence comprehension processes.

[4]The fact that per-character reading times are higher in this region than for the longer ambiguous region may be accounted for by 'overspill' from a long to a short region (cf. Mitchell & Green, 1978).

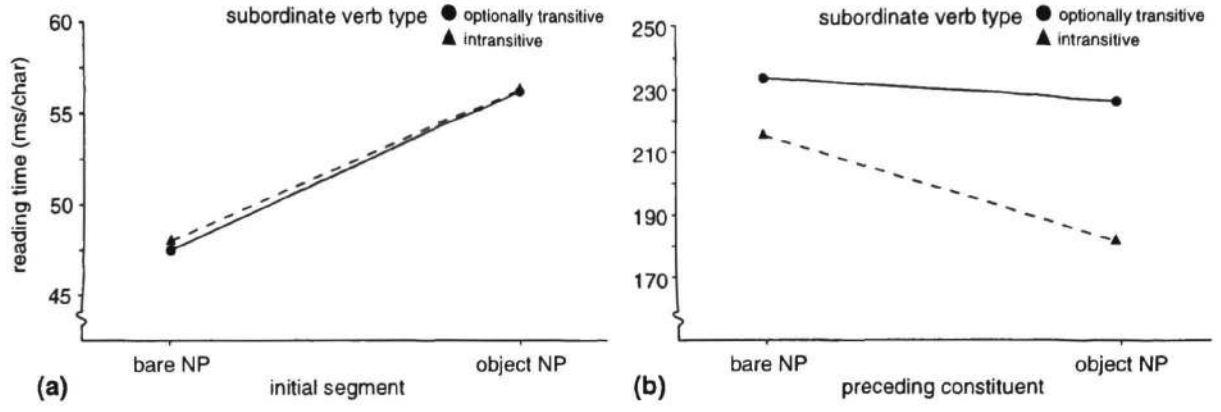

Figure 1: Mean reading times (in ms/char) for: (a) ambiguous region, including nNP or bNP; and (b) disambiguating region, consisting of matrix verb.

verb because that bNP can be incorporated into the current phrase marker as a modifier.

Figure 1a shows the reading times for the ambiguous region, containing a subordinate verb followed by either a bNP or nNP. As is clearly visible from the figure, the time to read bNPs (mean = 47.79ms) is lower than that for nNPs (56.50ms). This difference is statistically significant, in that there is a clear main effect of NP type ($F1(1,23) = 20.35$, $p < .001$; $F2(1,23) = 18.30$; $p < .001$). There are no other significant effects in the ambiguous region (all F's < 1).

The finding that bare NPs are read *faster* than nNPs is difficult to account for within a constraint-based framework, since, at least following optionally transitive verbs, nNPs should be significantly more frequently encountered than bNPs.[5] Equally, this finding is problematic for 'syntax-first' accounts which suggest that arguments should be preferred over modifiers. However, experiment 1 has the potential confound that the head nouns of the bNPs chosen are significantly more frequent than those of the nNPs (mean head noun frequency for bNPs: 583; for nNPs: 60. Figures from Kučera & Francis, 1967).

Experiment 1 has clearly demonstrated that detailed linguistic information is available during the early stages of sentence processing: by modifying Mitchell's (1987) experiment to include bare NPs we have provided the basis of an account of the differences between his findings and those of Adams et al. (1998). In experiment 2, we aim to remove the confounds from experiment 1 and explore the reading of bNPs in more detail, since confirmation that bNPs are read faster than nNPs, contrary to what would be predicted both by constraint-based and argument-favouring accounts, would have serious consequences for models of sentence processing.

Experiment 2

Experiment 2 was designed to investigate two aspects of the processing of bNPs. As well as attempting to confirm that they were read faster than nNPs, we were interested in whether they were attached into VPs in a similar way to nNPs. One potential account of bNPs (derived from Frazier & Clifton, 1996) would be that, as modifiers, they are 'construed' as being associated with a VP rather than being explicitly connected to the current phrase marker. If the processes by which they are attached to VPs differ from those for nNPs, it might be possible to construct an account in which reading times reflect less 'structural work'. To investigate this possibility, we omitted intransitive verbs from experiment 2 and instead included an explicit control condition in which the ambiguous NPs remained associated with the subordinate clause. We predicted (a) that bNPs would be read faster than nNPs, and (b) that there would be a cost in encountering a matrix verb disambiguation, relative to a control, for both types of NP, reflecting the fact that both types of NP are similarly attached into the VP.

Participants A further 12 male and 12 female undergraduates volunteered to take part in the experiment (other details as for experiment 1).

Materials 24 new materials, each having four versions, were created for experiment 2 (see (5)). Materials like (5a) and (5b) were analogous to (4a) and (4b) from experiment 1; (5c) and (5d) were explicitly disambiguated (at the word *the*) in favour of an interpretation where the ambiguous NP remained associated with the subordinate clause.

(5a) After the dogs / scratched *the whole home* / **was** / ruined / and the family were upset.

(5b) After the dogs / scratched *the whole day* / **was** / ruined / and the family were upset.

(5c) After the dogs / scratched *the whole home* / **the** / atmosphere / was ruined and the family were upset.

(5d) After the dogs / scratched *the whole day* / **the** / atmosphere / was ruined and the family were upset.

[5] A random sample of 176 sentences containing the structure 'V+NP' from the British National Corpus yielded only 6 examples judged by the authors to contain bare NPs.

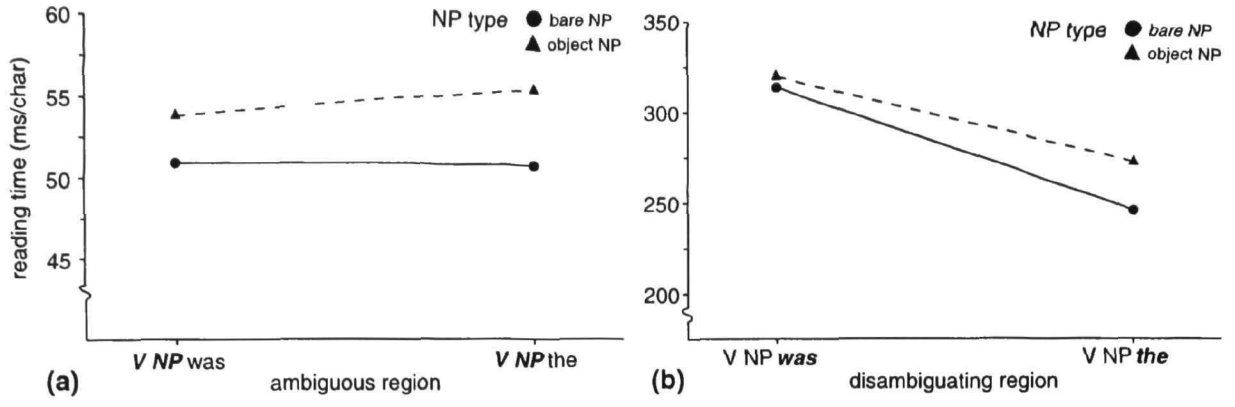

Figure 2: Mean reading times (in ms/char) for: (a) ambiguous region, including nNP or bNP; and (b) disambiguating region, consisting of *was* or *the*.

The head nouns of the nNPs and bNPs were carefully matched for frequency (using figures from Kučera & Francis, 1967)[6] and length (to ± 1 character); other words in the ambiguous NPs were identical in all conditions. The disambiguating region always consisted of the single word *was* or *the*. A further four variants were added to those in (5); these had explicit disambiguating commas before or after the ambiguous NP, as appropriate (for reasons of space, reading times for these sentences are not considered below, as they do not affect the general pattern of results).

The 24 sets of 8 materials were sorted into 8 experimental packages, in a similar way to that for experiment 1. Since each experimental package contained equal numbers of disambiguations favouring attachment of the ambiguous NP to the matrix and to the subordinate clause, additional control items were not used in this experiment, but 43 of the filler items from experiment one were added to each package file, so that each consisted of 77 sentences.

Segmentation points in the experimental materials are indicated with "/" in (5). The shorter ambiguous segment, consisting of just the verb and following NP, was chosen to reduce the variance between items. 24 Materials (about 31%) were followed by yes/no questions; one participant scored less than 80% correct and was replaced. Mean question-answering accuracy for included participants was 90.7%.

Pretest Twenty Open University students volunteered to rate the experimental materials for plausibility and acceptability. Each volunteer was given a pamphlet in which the subordinate verb + NP sections of (5) (e.g., *The dog struggled the whole day*) were followed by two seven-point scales, one for (semantic) "plausibility", and the other for (syntactic) "acceptability" The questionnaire was administered in two versions, each of which had half nNP and half bNP versions of the materials, randomised together with 24 filler materials.

Two of the 24 materials were given mean plausibilities of less than 2, and were discarded from all analyses. Mean ratings for the remaining 22 materials were 4.86 and 4.80 (plausibility and acceptability respectively) for bNPs, and 5.42 and 5.74 for nNPs. As nNPs were rated more highly than bNPs, any processing advantage for bNPs due to plausibility/acceptability can be ruled out.

Procedure and Analysis The procedure was identical to that used for experiment 1. As for experiment 1, within-subjects analyses of variance were used to analyse the data.

Results and Discussion

Figure 2 shows the mean reading times for the ambiguous (2a) and disambiguating (2b) regions respectively. Taking the disambiguating region first, faster reading appears to occur when the ambiguous NP must be part of the subordinate clause than when it is forced to be the subject of the matrix clause; different NP types do not appear to have different effects. Statistical analyses confirm this interpretation: there is a main effect of disambiguation type ($F1(1,23) = 8.74$, $p = .004$; $F2(1,21) = 4.93$, $p = .038$); no other effects are significant (all F's ≤ 1.20). The findings for the disambiguating region confirm that there is a cost of revision for both bNPs and nNPs where they must be interpreted as the subject of the matrix clause: there is no evidence that bNPs are "less strongly" attached to the subordinate VP than are nNPs.

Turning to the ambiguous region, there appears to be a small advantage for bNPs over nNPs, confirming the results of experiment 1. This advantage, however, is only marginally significant by subjects ($F1(1,23) = 3.59$, $p = .071$) and is not significant by items ($F2(1,21) = 2.15$, $p = .158$). No other effects are significant (all F's < 1). Although it would be an over-interpretation to claim that bNPs are read more quickly than nNPs on the basis of this evidence, it is apparent that there is *no* evidence that they are read more slowly, despite being frequency-matched to, and less plausible than, their nNP counterparts. This finding remains difficult to account for within either a constraint-based or an argument-favouring framework.

General Discussion

Experiment 1 provides evidence which appears to contradict Mitchell's (1987) findings. The fact that an object NP can

[6]Mean frequency = 288 (bNP), 277 (nNP), $F < 1$.

be easily reinterpreted as the subject of the matrix clause in sentences like (4) (as witnessed by the fact that the disambiguating matrix verb is read faster for (4c) than for any other condition), coupled with the fact that there is no difference in the time taken to read nNPs following transitive or intransitive subordinate verbs, strongly suggests that detailed linguistic information *is* available initially to comprehension processes.

Experiment 1 also showed that bare NP adverbs are read more quickly than nNPs, following any kind of verb. However, the bNPs used had more frequent head nouns than their nNP counterparts, and may also have been more plausible, either of which would provide the basis for an explanation of this finding. Alternatively, it may be the case that bare NPs are not explicitly attached to VPs, perhaps resulting in a lessened cognitive load as a result of not having to alter the current phrase marker. Experiment 2 controlled for frequency and plausibility, and attempted to demonstrate that bNPs were at least as difficult to *de*tach from their host VPs as were nNPs. This latter hypothesis was confirmed by the differences in reading times for *was* and *the* in examples like (5). If there *is* a differential cost of attachment, the end results appear to be equally difficult to undo. In the absence of further evidence we choose parsimony in assuming that the attachment processes for different types of NP do not differ substantially.

Whereas experiment 1 showed a clear advantage for bare NPs, in experiment 2 the times taken to read the two types of NP did not differ. Note, however, that both constraint satisfaction and argument-favouring syntax first accounts would appear to predict that nNPs should be read more quickly than bNPs (either because it is more frequently the case that NPs following verbs are object NPs, or because attachment as an argument is a preferred strategy).[7] Constraint based accounts might further predict that (other things being equal) there should be an interaction between verb type and NP type, since NPs following intransitive verbs are much more likely to be bNPs.

One possible interpretation of these results comes from recent suggestions of a *rational analysis* of parsing (Chater, Crocker, & Pickering, 1998). Chater et al. stress the need to take into account the information gained from making a parsing decision, as well as the cost of making a revision and the probability of making a recovery. Choosing to interpret incoming NPs as bare NPs *regardless* of the type of verb that precedes them may have advantages, since (given a set of 40 or so potential head nouns for bNPs; Larson, 1985) the correctness of the parse can be quickly assessed (compare this with the situation for nNP objects, which have a far greater number of potential head nouns). Being able to quickly assess and reject a particular analysis may confer advantages on the processing mechanism, compared to pursuing a strategy where a potentially wrong analysis may be entertained for longer than necessary and may subsequently be difficult to revise. Whether this provides a useful account of the ease with which bare NP adverbs are read remains a question for future research; what seems clear from the evidence provided in this paper is that current accounts of sentence processing have difficulties in accounting for cases where modifiers do not suffer at the expense of arguments.

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[7] It is also difficult to argue that bNPs can constitute a purely syntactic category, since the same sequence of words can serve as an nNP or a bNP (and might be differentiated by, e.g., prosody).