Running Head: SENSITIVITY TO SYNTAX IN VISUAL CORTEX

Sensitivity to syntax in visual cortex

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ABSTRACT

One of the most intriguing findings on language comprehension is that violations of syntactic predictions can affect event-related potentials as early as 120ms, in the same time window as early sensory processing. This effect, the so-called Early Left Anterior Negativity (ELAN), has been argued to reflect word category access and initial syntactic structure building (Friederici, 2002). In two experiments, we used magnetoencephalography to investigate whether (a) rapid word category identification relies on overt category-marking closed-class morphemes and (b) whether violations of word category predictions affect modality-specific sensory responses. Participants read sentences containing violations of word category predictions. Unexpected items varied in whether or not their word category was marked by an overt function morpheme. In Experiment 1, the amplitude of the visual evoked M100 component was increased for unexpected items, but only when word category was overtly marked by a function morpheme. Dipole modeling localized the generator of this effect to the occipital cortex. Experiment 2 replicated the main results of Experiment 1 and eliminated two non-morphology-related explanations of the M100 contrast we observed between targets containing overt category marking and targets that lacked such morphology. Our results show that during reading, syntactically relevant cues in the input can affect activity in occipital regions at around 125ms, a finding that may shed new light on the remarkable rapidity of language processing.

1. INTRODUCTION

Language is among the most complex of human cognitive systems, yet its processing is extremely automated and fast. Both behavioral and electrophysiological studies suggest that within 600ms of a word's onset - whether presented auditorily or visually - its sensory properties have been analyzed, its syntactic and semantic features have been retrieved from memory, and it has been integrated into the preceding sentential context (e.g., DeLong, Urbach, & Kutas, 2005; Friederici, 2002; Friederici, Pfeifer, & Hahne, 1993; Kutas, Van Petten, & Kluender, 2006; Neville, Nicol, Barss, Forster, & Garrett, 1991; Salmelin, 2007; Tarkiainen, Helenius, Hansen, Cornelissen, & Salmelin, 1999). Of particular interest is a finding from electroencephalography (EEG) showing that syntactic operations can take effect as early as 120-160ms post-stimulus onset, at which point the presence of an unpredicted word category elicits an Early Left Anterior Negativity (ELAN) (Friederici et al., 1993; Neville et al., 1991). The rapidity of this response is surprising because the effect is cotemporaneous with early sensory processing (Bonte, Parviainen, Hytönen, & Salmelin, 2006; Di Russo, Martinez, Sereno, Pitzalis, & Hillyard, 2001; Hickok & Poeppel, 2007; Parviainen, Helenius, & Salmelin, 2005; Salmelin, 2007; Tarkiainen et al., 1999).

The ELAN refers to an enhanced negative-going wave generally found in left anterior electrodes in response to word category violations. This response has been reported for a number of languages, including English (Lau, Stroud, Plesch, & Phillips, 2006; Neville et al., 1991), German (Friederici et al., 1993; Hahne, Schroger, & Friederici, 2002; Rossi, Gugler, Hahne, & Friederici, 2005), Spanish (Hinojosa, Martin-Loeches, Casado, Muñoz, & Rubia, 2003), and French (Isel, Hahne, Maess, & Friederici, 2007). For example, Neville et al. (1991) reported an

ELAN peaking at around 125ms post-stimulus onset for ungrammatically positioned prepositions like *about* in sentence (1b).

(1) a. The boys heard Joe's stories *about* Africa.

b. * The boys heard Joe's *about* stories Africa.

In German, several studies have shown unexpected participles to generate an ELAN, for example when following the contracted preposition-determiner sequence *im* (2b), as opposed to after an inflected verb *wurde* ('was' 2a; taken from Friederici et al. (1993).

(2) a. Das Baby wurde *ge*füttert

The baby was fed

b. * Das Baby wurde im *ge*füttert

The baby was in the fed

In the present study we investigated the effects of word category violations using magnetoencephalography (MEG). In particular, we sought to address what exactly might explain the extremely short latency of these seemingly high-level syntactic effects.

1.1 Interpretations of the ELAN

Friederici (2002) proposes a model of the neurocognition of language that comprises a number of stages, each corresponding to a discretely defined electrophysiological correlate and brain area. Word category, morpho-syntax and semantics are autonomously, and not interactively, processed, and syntactic processing is initiated before semantic processing. In particular, the first

stage of parsing a word in a sentence is argued to be word category access (in the anterior superior temporal gyrus) and then, on the basis of this information, local phrase-structure is built (in the inferior portion of BA 44). Friederici suggests these processes are performed within 200ms of the word's onset (Friederici, 2002; Friederici, Wang, Herrmann, Maess, & Oertel, 2000). In this model, the ELAN is the electrophysiological correlate of this early syntactic processing: an enhanced ELAN is generated by an ungrammatical word category, which impedes normal initial structure building. The ELAN therefore reflects the impossibility of reconciling the word category of the target with its local syntactic environment.

While this interpretation is consistent with the conditions under which an ELAN has been elicited, it does not in itself shed any particular light on its early onset. Work by Lau et al. (2006) has, however, shown that anticipation plays a crucial role in rapid syntactic analysis. These authors compared the ELAN elicited by unexpected prepositions (similar to those tested by Neville et al., 1991) in two different syntactic contexts: in one case, (3a), the preposition violated a strong prediction for a noun, whereas in the other, (3b), the ungrammatical preposition did not violate a strong prediction, because of a possible ellipsis environment.

(3) a. * Although the bridesmaid kissed Mary, she did not kiss Dana's *of* the bride
(- Ellipsis / Ungrammatical)

b. * Although Erica kissed Mary's mother, she did not kiss Dana's *of* the bride
(+ Ellipsis / Ungrammatical)

Consistent with the hypothesis that prediction is a crucial factor for the generation of the ELAN, Lau et al. obtained a greater early negativity to violations of strongly, as compared to weakly,

predicted word categories. This, according to the authors, makes the rapidity of the ELAN less striking, as it suggests that at each word, the parser has already in some form anticipated (and thus pre-processed) its syntactic properties. However, this account still raises questions about what exactly is predicted, and how a mismatch with the prediction is detected.

In our research, we aimed to investigate the nature of the process by which the parser detects a word category mismatch, and in particular to shed light on the rapidity of this detection. To do so we tested the following two hypotheses in two experiments contrasting different types of word category mismatches in sentential contexts:

(a) Rapid word category identification relies on overt category-marking closed-class morphemes;

(b) Violations of word category predictions affect modality-specific sensory responses.

In the following two sections, we discuss and motivate these two hypotheses in detail.

1.2 Do early effects of word category violations depend on the presence of closed-class morphology?

The early latency of word category effects has been controversial as it implies that the syntactic category of any encountered lexical item can be checked within 150ms. The rapidity of these responses would be more plausible if they were limited to a small set of highly frequent words or morphemes. More specifically, word category checking may be restricted to words containing closed-class morphemes that overtly mark word category.

Many behavioral studies have suggested that closed-class morphemes are processed differently from open-class items. In particular, Bradley (1983) has argued that the lexical retrieval of closed-class morphemes is faster than that of open-class items and that closed-class items do not exhibit frequency effects (although see, e.g., Gordon & Caramazza, 1985; Segalowitz & Lane, 2000). There is also evidence that subjects are faster to reject non-words based upon closed-class items to which suffixes have been appended (e.g., *thanage*), than to equivalent open-class items (e.g*., thinage*) (Bradley, 1983; Matthei & Kean, 1989). In addition, eye-tracking studies have shown that while readers tend to fixate open-class words, they frequently skip function words (Carpenter & Just, 1983; Liversedge & Findlay, 2000; Reichle, Rayner, & Pollatsek, 2003). Thus the access of closed-class items appears to be extremely quick and automatic. Consequently, the rapidity of word category effects may in part be due to the rapid and automatic retrieval of frequent word category marking function morphemes.

A possible connection between the ELAN and closed-class morphology has been noted before. In a 1999 paper, Hahne and Friederici observed that thus far the ELAN had only been generated by unexpected or ungrammatical target words containing highly frequent, closed-class morphemes (Hahne & Friederici, 1999). To the best of our knowledge, this fact still holds. Several studies have found an ELAN for ungrammatical or unexpected verbal morphology in contexts where a noun or other word category was expected. ELAN responses for these types of word category violations have been found in German (Friederici, 2002; Friederici et al., 1993; Hahne & Friederici, 1999; Hahne et al., 2002), (for examples of these see (2) above); (Oberecker, Friedrich, & Friederici, 2005), French (Isel et al., 2007), and Spanish (Hinojosa et al., 2003). In English, an early response has been observed in response to unexpected prepositions (Lau et al., 2006; Neville et al., 1991; see (1) above). However, in one study where

word category was violated but the target item did not contain a closed-class morpheme, no ELAN was generated (Friederici & Meyer, 2004).

In sum, the access of closed-class items appears to be extremely quick and automatic. In view of this, the observation that early responses have only been reported for word category violations involving overt closed-class items suggests that their rapidity may at least in part be due to the rapid and automatic retrieval of frequent word category marking function morphemes. Although previous research is compatible with this hypothesis, it has never been tested directly. To address it, we tested for the effects of three different types of word category violations within a single experiment. In one comparison, category was marked by a free closed-class morpheme. In the second case, the category-marking element was a bound closed-class morpheme. Finally, the third comparison involved an open class target with no affixal material attached to it (see Section 2.2 for details).

1.3 Are sensory cortices sensitive to word category violations?

The temporal overlap between the ELAN and sensory responses to visual and auditory stimulation raises the question whether this seemingly high-level response is at least partly generated by enhanced activity in sensory cortices. If some part of it were due to a low-level sensory response, the rapid onset would be less puzzling. This hypothesis is particularly plausible if early responses to word category violations are indeed only obtained for overt closed-class word category markers, since these elements are perceptually salient. Thus we hypothesized that sensory cortices are tuned to recognize highly frequent, salient function morphemes that mark word category information, and that they show more activity when the input contains unexpected word category marking morphemes. Note that the hypothesis that

early sensory responses are sensitive to word category violations does not rule out the existence of an additional left-anterior effect like the (E)LAN, i.e., sensory and left-anterior generators are not mutually exclusive.

In what follows, we review the extant literature on early effects of word category violations, asking whether current evidence is consistent with the hypothesis that early, seemingly syntactic, responses might, at least in part, be generated in sensory cortices.

Latency

As discussed above, the first response to word category violations is cotemporaneous with early sensory responses. Both take place in the first 200ms post stimulus onset. In the auditory modality, early sensory activity is reflected by the N1 in EEG and the auditory M100 in MEG, both peaking at around 100ms. In the visual modality, sensory activity is measured by the P1/N1 complex in EEG (Di Russo et al., 2001; Luck, 2005) and the visual M100 in MEG, followed by the visual M170. The MEG M100 and the M170 have also been called "Type I" and "Type II" activity, respectively (Salmelin, 2007; Tarkiainen, Cornelissen, & Salmelin, 2002; Tarkiainen et al., 1999). Consistent with the timing of these various sensory components, the latency of the early responses to word category violations range from 125ms (Neville et al., 1991) to 160ms (Friederici et al., 1993; Friederici et al., 2000).

However, in certain circumstances, responses to word category violations have also been reported to begin later than the 100-200ms sensory time-window. In spoken stimuli for example, there is some evidence that prefixed words generate an ELAN, but suffixed words generate a later response (typically referred to as a LAN), at 300-500ms (Friederici & Meyer, 2004). This, of course, is not surprising given that prefixes and suffixes become available at different time

points in the spoken word. As Friederici (2001) discusses, the ELAN is obtained only after word category information has become available. Hence, an ELAN will be early for words containing prefixes, and later for words where the category information is contained in a suffix. Furthermore, some studies have indicated that visually presented suffixed words also yield a LAN as opposed to an early response, despite the immediate availability of the suffix in the visual modality. Importantly, though, most of these manipulations have involved inflection violations rather than phrase-structure violations (e.g., Barber & Carreiras, 2005; Morris & Holcomb, 2005; Rodríguez-Fornells, Clahsen, Lleo, Zaake, & Munte, 2001; Rossi et al., 2005), which arguably involve different processes. There is one study that reports a LAN instead of an ELAN for word category violations (Hagoort, Brown & Wassenaar, 2003). However, in this study the word category violations were indirectly marked through an agreement morpheme (3rd person singular verbal morphology on an ambiguous root).

In sum, in the auditory modality, early responses to word category violations are consistently found in the same time period as sensory processing, i.e., within 200ms after the word category information becomes available. In the visual modality, however, the corresponding generalization is somewhat less robust.

Localization

In Friederici's (2000) model, the ELAN is generated by sources in the left inferior frontal gyrus (IFG) and superior temporal gyrus (STG). These localizations are based on evidence from fMRI, lesion, and MEG studies.

In fMRI, Meyer, Friederici, & Von Cramon (2000) used auditorily presented stimuli involving a participial manipulation similar to the one already exemplified in (2) above.

Ungrammatical, as compared to grammatical, stimuli resulted in a reliably enhanced BOLD signal in the anterior portion of the superior temporal gyrus. Importantly however, the BOLD response was also enhanced in both primary and secondary auditory cortex (including Heschl's gyrus and the planum temporale) – sensory cortices typically associated with speech processing and the generation of auditory evoked responses (Hickok & Poeppel, 2007; Näätänen, 1992). Enhanced activity in auditory cortices was also found in a second study, using similar stimuli, which replicated Meyer et al.'s results in primary and secondary auditory cortex (Friederici, Rüschemeyer, Hahne, & Fiebach, 2003), and the anterior superior temporal gyrus. Together these findings suggest that sensory cortices, as well as left anterior temporal regions, are sensitive to word category violations. However, they do not address which regions are active during the ELAN time window, given the low temporal resolution of fMRI.

In lesion studies, the absence of an ELAN in Broca's aphasics with damage to the left inferior frontal gyrus (IFG) (Friederici, Von Cramon, & Kotz, 1999) has been taken as evidence that early responses to word category violations are generated in the left IFG. However, the hypothesis that this area is part of a cortical network that generates the predictions for upcoming word categories is equally compatible with the data. In other words, if the left IFG is involved in generating word category predictions rather than checking whether the input matches them, then damage to this area would block the generation of predictions. Consequently, there would be no predictions for the input to violate and no ELAN would be observed.

Thus both fMRI and lesion studies underdetermine the neural generators of early responses to word category violations. Magnetoencephalography (MEG) offers the requisite temporal and spatial resolution to potentially address this question: brain activity can be monitored millisecond by millisecond and the current generators of the magnetic fields can be

localized with relatively high accuracy (Hämäläinen, Hari, Ilmoniemi, Knuutila, & Lounasmaa, 1993). In an auditory MEG study, Friederici et al. (2000) presented subjects with grammatical and ungrammatical participles similar to example (2) above. A four-dipole model was fit to the ungrammatical data only, including sources in the left and right anterior portions of the superior temporal gyri as well as in fronto-lateral cortices bilaterally. From the model's relatively high goodness-of-fit, it was concluded that the ELAN is generated by these four sources. However, the modeling procedure used in this study makes this conclusion somewhat premature. To create each subject's source-model, four dipoles were seeded in bilateral frontal and temporal locations. Each dipole's orientation and location were fit to the violation conditions' data within a 20ms interval centered on the peak of the subject's ELAN response. Variation in location, however, was constrained to a sphere with a 10mm radius, centered on the initial seed point. Since this constraint *a priori* ensured localization of the ELAN close to the seeded locations, it is difficult to draw firm conclusions, despite the model's relatively high goodness-of-fit. Interestingly, for all subjects the dipole strength of the temporal source in the 20ms time window was higher than that of the frontal source. Given the greater proximity of the temporal (as opposed to frontal) dipole to auditory cortex, this is consistent with enhanced sensory activity, as predicted by the hypothesis that sensory cortices contribute to early effects of word category violations. Perhaps clearer evidence for the sensory hypothesis was obtained in an auditory MEG study by Gross et al. (1998), who reported enhanced and delayed activity in both the auditory cortex and left frontal cortex for word category violations, using Magnetic Field Tomography, a distributed source model. However, the authors did not expand on the possible implications of this finding.

The results of a recent EEG study, using visual stimuli, are also suggestive of the contribution of sensory cortices to the detection of word category violations. Specifically,

Hagoort, Wassenaar, & Brown (2003) reported a significant interaction of grammaticality by electrode site at 100-300ms for Dutch word category violations. The interaction was due to enhanced activity in posterior electrodes (i.e., over the visual cortex), which in isolation however did not show a reliable modulation.

Further properties of the ELAN consistent with a sensory generator

If the sensory cortices are sensitive to word category violations, the topography of the ELAN might plausibly resemble that of sensory responses. This prediction is supported by findings from Hahne et al. (2002), who reported that the topography of early responses to word category violations was statistically indistinguishable from responses to deviance in low-level auditory stimulation. In this study, word category violations of the type in (2) above were crossed with a manipulation of auditory expectancy, where deviants were presented from a different location from the rest of the sentence fragment. This physical manipulation was predicted to elicit an auditory Mismatch Negativity (MMN) (Näätänen, 1992). The primary generators of the auditory MMN have been reported as the planum temporale (Liegeois-Chauvel, Musolino, Badier, Marquis, & Chauvel, 1994), and near-by regions around auditory cortex (Virtanen, Ahveninen, Ilmoniemi, Näätänen, & Pekkonen, 1998). In contrast, as pointed out above, in Friederici's model the ELAN is generated by two sources in the anterior left superior temporal gyrus, and in the inferior portion of BA 44. Instead of separate responses for the two manipulations, Hahne et al. (2002) found no topographical differences between the word category deviances and the physical deviances, consistent with the sensory hypothesis outlined above.

Similar results have also been obtained by Pulvermüller and colleagues with an oddball paradigm using linguistic stimuli only. Using MEG, Shtyrov, Pulvermüller, Näätänen, &

Ilmoniemi (2003) found that hearing deviant syntactic violations (16.7% of the stimuli) interspersed with standard grammatical sequences (83.3% of the stimuli) resulted in magnetic mismatch negativity (MMNm), the MEG response corresponding to the classical MMN (Näätänen, 1992). Minimum-norm estimation suggested the effect was generated in the left superior temporal lobe (although see Pulvermüller & Shtyrov (2003) for evidence from EEG for an additional frontal generator). Pulvermüller & Shtyrov (2006) argued that the syntactic MMN is highly similar to the ELAN in terms of latency, topography, and laterality. Although these authors did not contrast linguistic and non-linguistic manipulations directly, this result in combination with Hahne et al.'s (2002) findings suggests that early responses to word category violations may be generated by the same sources that respond to low-level auditory deviance.

Finally, there is also evidence in the visual modality that early syntactic responses may be modulated by the same factors that affect sensory components. Gunter, Friederici, & Hahne, (1999) demonstrated that no ELAN is observed in the visual modality when a target word is presented against a low contrast (dark grey) background. This result was interpreted to indicate that fast and automatic structure building is dependent upon good signal quality. However, this finding is equally consistent with the sensory hypothesis. In other words, low signal quality could hamper the sensory detection of a mismatch between word category expectations and properties of the visual (or auditory) input.

In sum, the ELAN literature at large is quite consistent with the hypothesis that sensory cortices are sensitive to word category violations. However, the picture is far from conclusive. FMRI provides no information regarding the timing of the effects in auditory cortex and EEG may yield null results regarding the topography of the ELAN vs. the MMN because of its low spatial resolution.

To address the sensory hypothesis we used MEG, which offers the same temporal accuracy as EEG but with enhanced spatial resolution. Further, we presented stimuli visually, as opposed to the auditory presentation used in the previous MEG studies reviewed above (Friederici et al., 2000; Gross et al., 1998). An obvious implication of the sensory hypothesis is that responses to word category violations should be modality dependent: one would expect modulation of activity in auditory cortex when stimuli are presented aurally and in visual cortex when stimuli are presented in the visual modality. We chose the visual modality since the visual cortex is further away from left anterior regions than the auditory cortex. Thus detecting a sensory modulation not attributable to left anterior generators should be easier in the visual than in the auditory modality. The next section reviews the visual evoked components relevant to our study.

1.4 Early visual evoked responses in MEG

Early stages of visual word recognition in MEG are primarily characterized by two response components. The first component is the co-called visual M100, also called "Type I activity" (Tarkiainen et al., 2002; Tarkiainen et al., 1999). This response is generated bilaterally in the occipital lobe, close to midline, at 100-150ms, i.e., in a similar time window as the ELAN. A detailed localization study using the Synthetic Aperture Magnetometry technique has suggested that the visual M100 has maximum intensity in the cuneus, lingual gyrus, and BA 17 (Itier, Herdman, George, Cheyne, & Taylor, 2006). Due to the close proximity of the bilateral generators, M100 activity is usually modeled by a single dipole, although bilateral two-dipole solutions are also possible (e.g., Pylkkänen, Llinas, & Murphy, 2006). The field distribution of the M100 typically shows a single posterior right-lateralized outgoing magnetic field and a left-

lateralized posterior re-entering field (for examples, see Itier et al., 2006; Pylkkänen et al., 2006). The M100 is primarily sensitive to manipulation of low-level visual features, such as the noise and size of letter strings and other similar stimuli, with no sensitivity to the content of the stimulus (Tarkiainen et al., 1999). An exception to this has been observed in the domain of face perception, where the visual M100 has been shown to be modulated by face categorization (Liu, Harris, & Kanwisher, 2002).

The second prominent response to visual stimulation is the M170 component, or "Type II activity" (Tarkiainen et al., 2002; Tarkiainen et al., 1999), peaking at 150-200ms. fMRI evidence from manipulations similar to those affecting the M170 suggests that the M170 is generated in the left and right fusiform gyri (Cohen et al., 2000; Dehaene et al., 2004; Kanwisher, McDermott, & Chun, 1997; Tong, Nakayama, Vaughan, & Kanwisher, 1998). The left and right generators of the M170 appear to differ in functional specialization: the left generator has been reported as sensitive to the presence of letter-strings (Tarkiainen et al., 2002; Tarkiainen et al., 1999), whereas the right generator shows increased amplitudes for faces in comparison to various control categories (e.g., Kanwisher et al., 1997; Liu et al., 2002;; Lueschow et al., 2004; Tarkiainen et al., 2002; although see Liu, Higuchi, Marantz, & Kanwisher, 2000, for a bilateral M170 modulation for face stimuli). In the fMRI literature, the left and right fusiform regions sensitive to letter-strings and faces have been dubbed the Visual Word Form Area (VWFA) and the Fusiform Face Area (FFA) respectively. In addition to showing sensitivity to the linguistic vs. non-linguistic nature of stimuli, the M170 has recently been reported as sensitive to morphological complexity, showing higher amplitudes for bimorphemic than for orthographically matched monomorphemic words (Zweig & Pylkkänen, submitted).

On the sensory hypothesis, both the M100 and the M170 components constitute candidates for an early visual effect of word category expectations. Given that the M170 has already been reported to be sensitive to linguistic factors, an M170 effect of category mismatch would perhaps be less surprising than an M100 modulation. However, the latency of the M100, which on average peaks at 130ms, is in fact in better correspondence with ELAN latencies than the M170. In studies using English stimuli, the ELAN has peaked exactly around 130ms (Neville et al., 1991; Yamada & Neville, 2007). The M100 is also sensitive to the same noise manipulations as the ELAN (Gunter et al., 1999; Tarkiainen et al., 2002).

It is of course also possible that the M100 and the M170 might both show sensitivity to word category violations. Such a result would in fact conform well with the fMRI finding that in the auditory modality, word category violations elicit an increased BOLD signal across all areas of the superior temporal gyrus.

2. EXPERIMENT 1

Two hypotheses were tested in Experiment 1

(a) Rapid word category identification relies on overt category-marking closed-class morphemes;

(b) Violations of word category predictions affect modality-specific sensory responses.

Participants read sentences word-by-word while their brain activity was monitored with MEG. Each sentence contained a target item whose word category was either expected or unexpected. To test hypothesis (a), the target varied in whether or not category was marked with a closed -

class morpheme. Each target item was either a preposition (a free, closed-class morpheme), a regularly inflected participle (a category-marking closed-class morpheme bound to an open-class morpheme), or a bare nominal stem (a free, open-class morpheme).

To test hypothesis (b), the current generators of activity at the M100 and the M170 were estimated for each condition with multi-dipole modeling. Root-mean-square (RMS) analyses of sensor data were further used to assess whether the effects obtained in the source waves were also observable in sensor-space.

2.2 Methods

2.2.1 Participants

15 healthy right-handed subjects (7 male) participated. All had normal or corrected-to-normal vision and gave informed consent. All were students or employees at New York University (ages 19 - 39). Two subjects were excluded for not showing typical M100 and M170 components in their individual across conditions grand-average.

2.2.2 Materials

To test whether early effects of unexpected word category are limited to closed-class morphemes, we used three types of manipulations**,** shown in Table 1.

Condition	Expected		Unexpected		Nature of the violation
	Example sentence	***Cloze-P***	***Example sentence***	***Cloze-P***	
Preposition	The boys heard Joe's stories ***about*** Africa.	0.44	The boys heard Joe's ***about*** stories Africa.	0	**Presence** of an unpredicted **free** closed-class morpheme.
Participle	The discovery was ***reported***.	0.29	The discovery was in the ***reported***.	0.002	**Presence** of an unpredicted **bound** closed-class morpheme.
Bare stem	The discovery was in the ***report***.	0.91	The discovery was ***report***.	0.002	**Absence** of a necessary **bound** closed-class morpheme.

TABLE 1 LEGEND - *Examples of the experimental stimuli of Exp. 1. 300 target sentences (60 per condition for Participles and Bare stems, 30 per condition for Prepositions) were intermixed with 240 filler sentences. See Appendix 1 for a complete list of the target sentences. Cloze-probabilities reflect the proportion of the word category of interest filled in during an off-line sentence completion task (see text): cloze-probabilities for unexpected targets were at or close to zero.*

The first comparison used the exact materials of Neville et al.'s original ELAN study, where the target items were unpredicted prepositions, i.e., free closed-class morphemes (Neville et al., 1991). As a second contrast, we tested unexpected participles, which contained the bound closed-class morpheme *-ed*. This manipulation formed a close English approximation to the German stimuli presented in (2). One obvious difference is that in these German sentences the participial morpheme is a circumfix (***ge***-*STEM*-***t***), rather than a suffix. Note that both the German and the English manipulations involve unexpected rather than ungrammatical targets: in both languages a participial modifier can follow a determiner (so long as this modifier is followed by a noun). In German, the participle should carry a suffixed case marker in order to be grammatical in this context, but under auditory presentation the suffix has not become available yet at the point where the ELAN is recorded. Thus the ELAN generated by participles of the form ge-STEM-t has to be a response to the prefix rather than the lack of a case-marking suffix. Finally, we tested whether an early response would be dependent on closed-class morphological markers by

including a third contrast containing unexpected bare stems which lacked any overt category-marking morphology.

Since we aimed to obtain very early differences between conditions, differences in the lexical material that immediately preceded the target item were of considerable importance. Lau et al. (2006) have pointed out that there may be a serious problem with the baseline of the prepositional manipulation, since the characteristics of the word presented just before the target vary dramatically between conditions (*stories* vs. *John's*). However, Lau et al. found an ELAN response even for prepositions whose baseline was controlled for. Note that our participle and bare stem conditions do not suffer from this possible confound, as they form a perfect cross-over between target (*report* and *reported*) and baseline (*was* and *was in the*). In other words, as shown in Table 1, the baselines of the expected participles were also the baselines of the unexpected bare stems, and similarly, the baselines of the unexpected participles were identical to the baselines of the expected bare stems. Consequently, results which are not inversed between participles and bare stems are unlikely to result from the intended manipulation.

Example sentences of each condition (6 in total) are presented in Table 1. 300 target sentences (60 per condition for participles and bare stems, 30 per condition for prepositions (replicating Neville et al., 1991) were intermixed with 240 filler sentences. All test sentences are listed in the Appendix 1. Each subject saw all sentences in a pseudorandom order.

To confirm that our manipulation in fact varied the predictability of word-category, an off-line cloze-probability test was carried out. 60 subjects each read one of four different sets of 140 sentences; each set contained one quarter of the sentences used in the current study (45 sentences), divided such that no subject saw both members of a pair of sentences (e.g., *The discovery was…* and *The discovery was in the…*). The remaining sentences in each set consisted

of fillers from a separate experiment. Sentences were presented up-to-and-including the pre-target word, and subjects were then asked to write a word, or a short phrase, which they felt completed the sentence. Cloze-probabilities were calculated in terms of the word category of the first word filled in by subjects for each sentence fragment. Note that our definition differs from the typical use of 'cloze-probability', which refers to the probability of a specific lexical item. The mean cloze probabilities of the target categories are given in Table 1. The cloze probabilities of the unexpected categories were uniformly at zero, or very close to zero. Thus, across all three manipulations, the probability of the target category was significantly greater (by at least two orders of magnitude) for the Expected than for the Unexpected condition (Prepositions: $t(58) = 4.1$, $p < 0.001$; Participles: $t(118) = 12$, $p<0.001$; Bare Stems: $t(118) = 62.7$, $p<0.001$). These results confirm for all conditions that unexpected word categories were in fact extremely unlikely continuations of the sentence fragments. For example, in the Unexpected Bare Stems condition, although *was* can be followed by a bare noun, as in *the man was president*, participants did not generate this type of sentences in the cloze probability test.

2.2.3 Procedure

During the experiment, subjects lay down in a dimly lit, magnetically shielded room. The participants viewed the stimuli through fiberoptic goggles (Avotec, FL). Each trial began with a fixation point in the center of the screen. Participants initiated each trial by pressing a button. The sentences were presented word by word (300ms on, 300ms off), in non-proportional Courier font (font size = 90), and the end of each sentence was indicated with a question mark. At the question mark, participants were instructed to judge whether or not the sentence was well-formed by pressing a button with either the middle or the index finger of their left hand.

Data were collected using a 148-channel whole-head magnetometer (4-D Neuroimaging, Magnes WH 2500), sampling at 678Hz in a band between 0.1 and 200Hz. The entire recording session lasted approximately one hour.

2.2.4 Analysis

Prior to averaging, the MEG data were cleaned of artifacts and trials on which participants provided an incorrect well-formedness judgment. On average, this resulted in the exclusion of 18% of the data per subject (SD = 7 %). Data were averaged by stimulus category over a 1300ms epoch with a 300ms pre-stimulus interval, time-locked to the appearance of the target word. Prior to analysis, the recordings were high and low-pass filtered at 1 and 40 Hz respectively.

Dipole Modeling

In order to obtain a maximally complete characterization of the neural sources activated by our stimuli during the first 200ms, the current generators of all prominent response components at 0-200ms were estimated with a multiple-source model using BESA (Brain Electrical Source Analysis 5.1). Subjects typically showed two major peaks in this time-window, associated with the M100 and M170 field patterns (see Fig, 1 for grandaveraged sensor waveforms from all subjects). Thus we created two multiple source solutions, aimed at characterizing all activity present at the M100 and M170 components. BESA minimum norm estimates (a distributed source model) were used to guide the hypothesis about how many sources were active at each component and data from all sensors were then used to estimate the discrete locations of these generators. In other words, we did not use sensors of interest but rather aimed to obtain a global characterization all early activity. Thus although our hypothesis pertained to the early visual

activities, our method was equally suited for identifying any other relatively focal early sources, such as potential left anterior generators.

Dipole modeling is often performed using each individual's grandaveraged data across conditions (e.g., Pylkkänen et al., 2006), to ascertain that the models are based on data with a maximally high signal-to-noise ratio. This procedure, however, was less than ideal for our data: Although it should give an accurate characterization of sensory activity - and thus allow us to address our main hypothesis - it risks missing non-sensory ELAN sources that may not be active across all conditions. Therefore we aimed to model activity using data from the individual conditions. This was successful for the M100 component, but less so for the M170, whose bilateral sources can be difficult to distinguish with this type of multi-dipole modeling (cf., Zweig & Pylkkänen, submitted). To enhance signal-to-noise ratio, we instead modeled the activity at the M170 using the combined data from the Expected and Unexpected conditions for each word category (resulting in three M170 models per subject: one for the Prepositions grandaverage, one for the Participles grandaverage, and one for the Bare Stems grandaverage). This model was then applied to the Expected and Unexpected conditions.

Only models that were consistent with both the magnetic field maps and the minimum norm estimates were accepted for analysis. This resulted in the inclusion of 11 subjects in the analysis of the M100 time-window. In the M170 time-window, 9 subjects' dipole models were accepted for the participles and the bare stems, but only 6 subjects' for the prepositions. The average source locations of all M100 and M170 dipoles are shown in Figures 2 and 3 respectively.

Our multi-dipole modeling did not yield any consistent source clusters apart from the M100 and the M170 generators. In other words, although other dipoles were present in many

subjects' models, their locations did not exhibit any observable generalization across subjects. Thus statistical analysis was only possible on the M100 and M170 dipoles. M100 and M170 peaks were first identified for each condition using across-subjects grandaveraged source waveforms. After this, an interval of interest, 15ms around the peak, was defined for each condition. Dipole strength was calculated and averaged across this interval per subject and condition. These values were then entered into a 2 (Expectedness: Expected vs. Unexpected) by 3 (Word Category: Preposition vs. Participle vs. Bare Stem) within-subjects ANOVA. Separate ANOVA's were performed for the M100 and M170 components. Planned comparisons tested for the effects of expectedness for each target word category.

RMS Analysis

A root-mean-square analysis of sensor data was used as a second analysis to further assess the robustness of the findings from the multi-dipole modeling analysis. This also allowed us to test whether left-anterior effects might be obtained in sensor data. This analysis was performed over 5 equally sized regions of interest (ROI's) (see Figs. 4 and 5), each containing approximately 18 sensors. To test for visual M100 effects, we examined two posterior ROI's, which captured the field pattern of the M100 component (the right-hemisphere posterior ROI captured the outgoing magnetic-field produced by the M100 generator, the left-hemisphere posterior ROI captured the re-entering field). To investigate possible activity in left temporal and frontal areas, the remaining left-hemisphere sensors were also examined. They were divided into three ROI's in order to differentiate between more posterior and anterior sources. The regions and sensors within them were held constant across subjects to ensure a consistent analysis.

RMS waveform analysis followed the same procedure used in the source wave analysis, described above. To analyze activity in each ROI, the averaged root-mean-square value of the sensor activity in the ROI was first calculated for each subject in each condition. For each condition, the grand-average RMS wave of all subjects was then examined to identify peak activity. This revealed a consistent and prominent peak in the M100 time-window (100-150ms). Our RMS analysis focused on this activity. Activity was averaged across a 15ms window around this peak, per condition, per subject and per ROI, and then entered into a 2 (Expectedness: Expected vs. Unexpected) by 3 (Word Category: Preposition vs. Participle vs. Bare Stem) within-subjects ANOVA.

For the most frontal ROI, no clear peak activity in the time-window of interest was identified. In this case, we also averaged each subject's RMS data, for each condition, over the window between 100ms and 150ms. This was then also entered into a 2 (Expectedness: Expected vs. Unexpected) by 3 (Word Category: Preposition vs. Participle vs. Bare Stem) within-subjects ANOVA, in the same way as for the other measure.

2.3 Results

2.3.1 Behavioral Data

Overall accuracy was very high; 96% of sentences were correctly classified in the well-formedness judgment task.

2.3.2 MEG Data

Figure 1 visualizes the across participants (n=13) grandaveraged MEG signals for each of the six conditions. The magnetic field patterns associated with sensor activity during the first peak

(indicated by the dashed line) showed a typical M100 distribution in all conditions. Visual inspection of this peak revealed that its amplitude increased for unexpected items containing a closed-class morpheme (participles and prepositions), as compared to the expected items. However, there appeared to be no change in M100 amplitude for unexpected items not containing a closed-class item (the bare stems). The second peak, around 170ms, represents the M170 activity. Note that this peak was less consistent across conditions for these 13 subjects. The preposition conditions in particular did not show a clear peak.

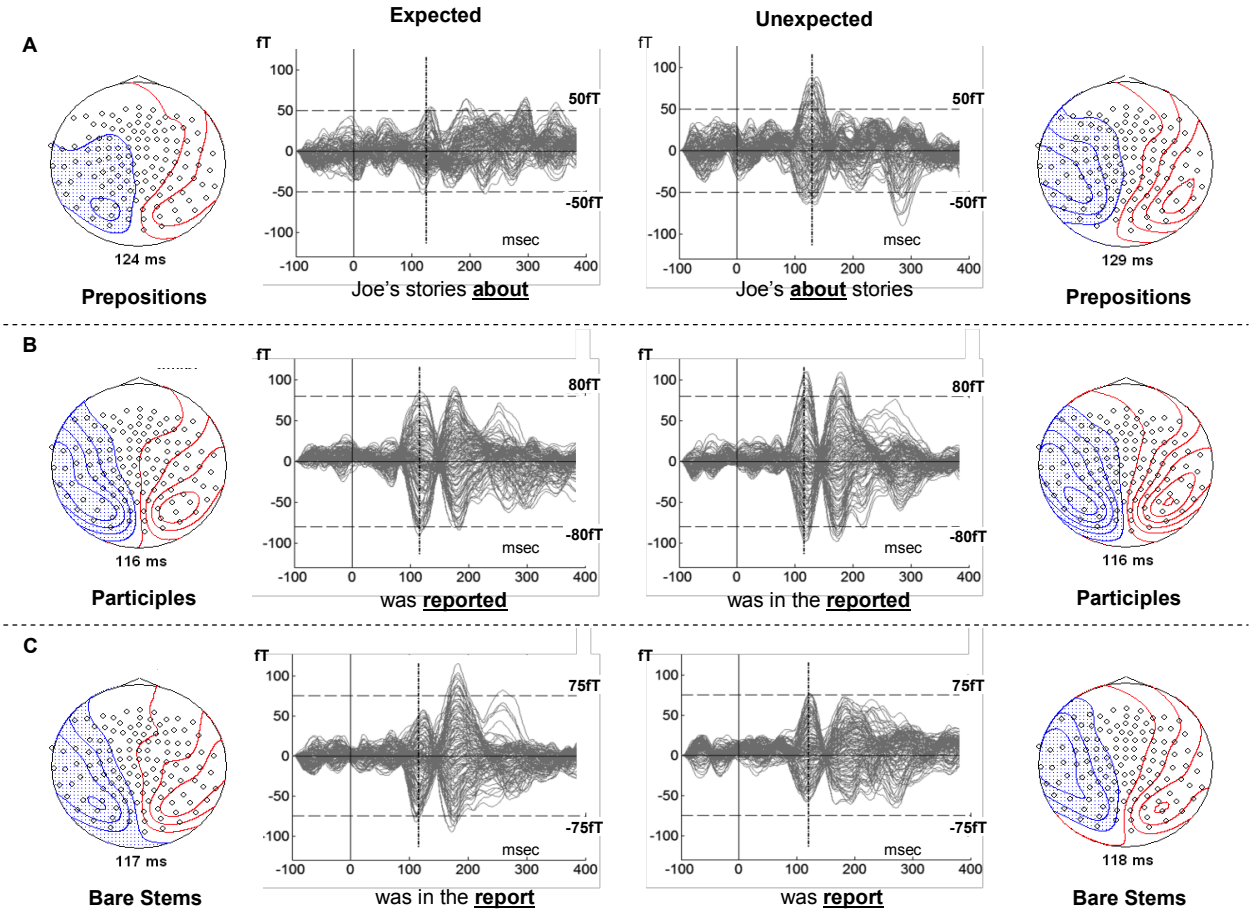

FIGURE 1 LEGEND - *Grandaveraged waveforms and field distributions (n=13) for each condition. All sensors are shown. In the waveforms, the cursor is pointed at the largest peak within 100-150ms. The gradient maps on the left and right depict the magnetic field patterns associated with these peaks (10fT/line). In each case, the field pattern is a canonical M100 pattern. Both the waveforms and the field maps suggest an effect of expectedness at the visual M100 for unexpected prepositions and participles, but not for the bare stems.*

2.3.3 Dipole Results

2.3.3.1 The M100 time-window

Consistency in the multi-dipole models

Dipole solutions for the eleven subjects included in the analysis contained a typical posterior M100 dipole in all conditions (Tarkiainen et al., 1999). Each subject also required other dipoles to be included in their solutions in order for the M100 dipole to localize accurately. There was no consistent pattern in the location/direction of these additional dipoles, and no reliable difference between conditions with regard to the number of additional dipoles. Average goodness of fit for the multi-dipole models was very high, greater than 90% in every condition (overall mean 92.5%, SD = 6.0), and did not reliably vary between conditions.

To test whether conditions differed in M100 dipole location or orientation, we ran 2 (Expectedness: Expected vs. Unexpected) by 3 (Word Category: Preposition vs. Participle vs. Bare Stem) within-subjects ANOVA's for the x, y and z location and orientation measures (on a Cartesian coordinate system). These analyses revealed no reliable main effects or interactions, except for a reliable interaction between Word Category and Expectedness on location along the *x*-axis ($F(2,20) = 3.81$, $p = 0.04$). However, these differences were not significant when the effect of Expectedness was analyzed separately per word category.

Effects of Expectedness at the M100

The averaged waveforms of M100 dipole strength over time are shown in Figure 2.

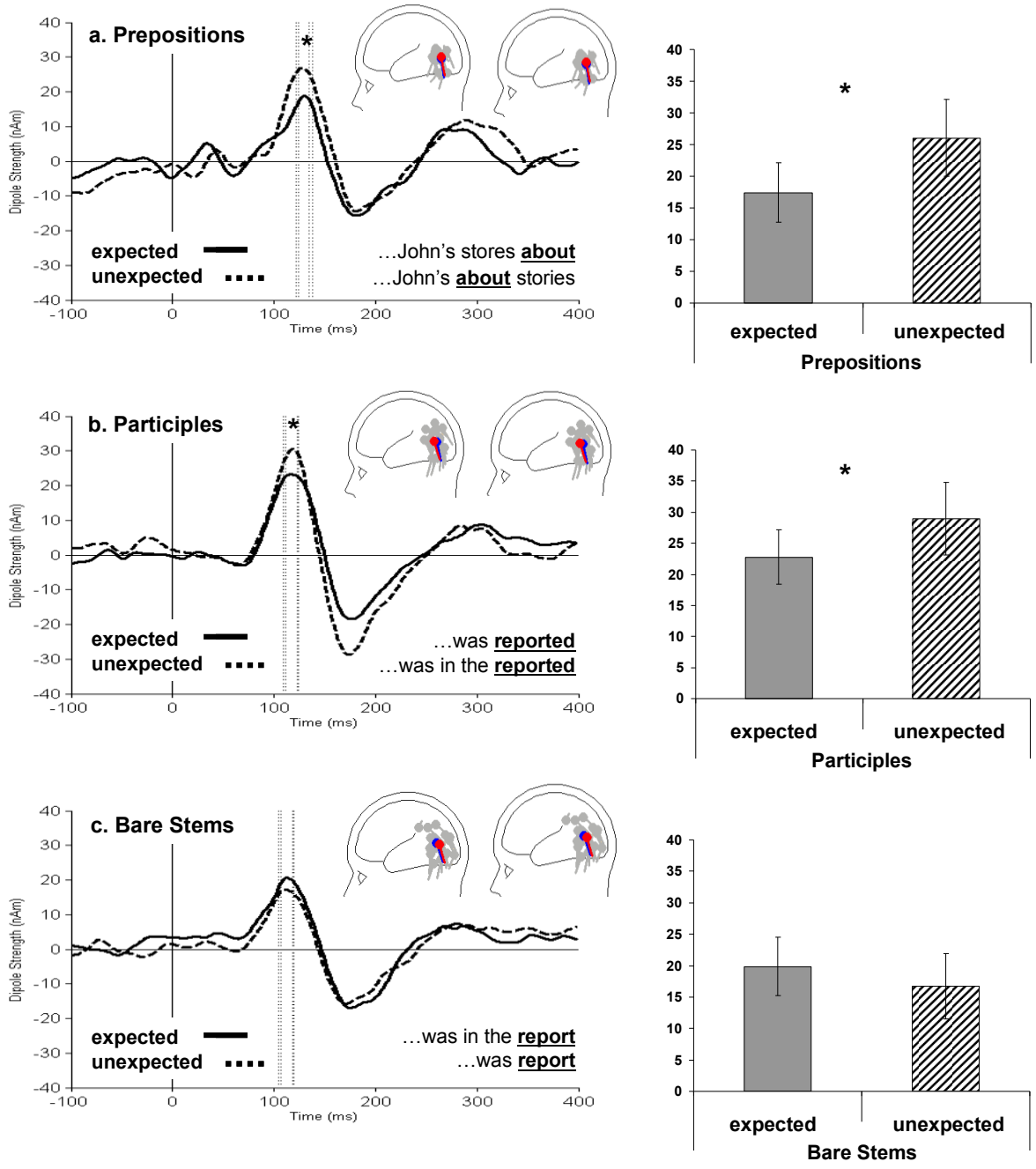

FIGURE 2 LEGEND – *Grandaveraged waveforms for the M100 dipole sources per comparison (n=11) and mean amplitudes in nAm for the 15ms intervals centered around the M100 peaks (the time-window between the dotted lines in the waveform graphs). Mean dipole locations and orientations (blue = expected / red = unexpected) as well as the dipoles from the individual participants (grey) are plotted per word category. Results reveal effects of expectedness on M100 amplitude, but only for the Prepositions and Participles (* = p <.05).*

M100 peak amplitudes were entered into a 2 (Expectedness: Expected vs. Unexpected) by 3 (Word Category: Preposition vs. Participle vs. Bare Stem) within-subjects ANOVA. This revealed no main effect of Word Category ($F(2,20) = 1.62$, $p = 0.22$), a marginal main effect of Expectedness ($F(1,10) = 4.65$, $p = 0.056$), and a reliable interaction between Word Category and Expectedness ($F(2,20) = 4.22$, $p = 0.030$).

Planned comparisons revealed that, for the Preposition and Participle conditions, Unexpected items generated a reliable increase in M100 amplitude (Prepositions: $t(10) = 2.45$, $p = 0.034$. Participles: $t(10) = 2.46$, $p = 0.033$). However, there was no reliable effect for the Bare Stem conditions ($t(10) = 1.03$, $p = 0.33$). Thus these results support both the sensory hypothesis as well as the hypothesis that early effects of category violations are limited to closed-class morphemes.

2.3.3.2 The M170 time-window

Consistency in the multi-dipole models

For the bare stems and the participles, the dipole-models of 9 subjects included two (bilateral) dipoles whose location, orientation, and latency was typical for the M170 component (Tarkiainen et al., 1999). For the prepositions, this was the case for only 6 subjects.

Eight subjects' models required additional, non-M170-like, dipoles to be included in the solutions (2 dipoles on average, SD = 1.2, maximum: 4 additional dipoles for 2 subjects). Again, there was no consistent pattern in the location/direction of these dipoles. Average goodness of fit for the multi-dipole models was high, greater than 90% for the participle and bare stem conditions, and greater than 85% for the preposition conditions (overall mean 92.3 %, SD=7.1), and did not vary reliably between conditions.

Because activity was modeled on the basis of the combined expected and unexpected data for each word category, and because the number of subjects included in the analysis varied across word categories, we did not run statistical analyses on the locations and orientations of the M170 dipoles. However, visual inspection of the dipoles in Figure 3 suggests a high consistency in both location and orientation.

Effects of Expectedness at the M170

The averaged waveforms of M170 dipole strength over time are shown in Figure 3. Because the M170 is generated by a pair of bilateral sources, average source-waveform activity centered around the M170 peaks was entered into a 2 (Hemisphere: Left vs. Right) by 2 (Expectedness: Expected vs. Unexpected) within-subjects ANOVA for the prepositions, and a 2 (Hemisphere: Left vs. Right) by 2 (Expectedness: Expected vs. Unexpected) by 2 (Word Category: Participle vs. Bare Stem) within-subjects ANOVA for the participles and bare stems.

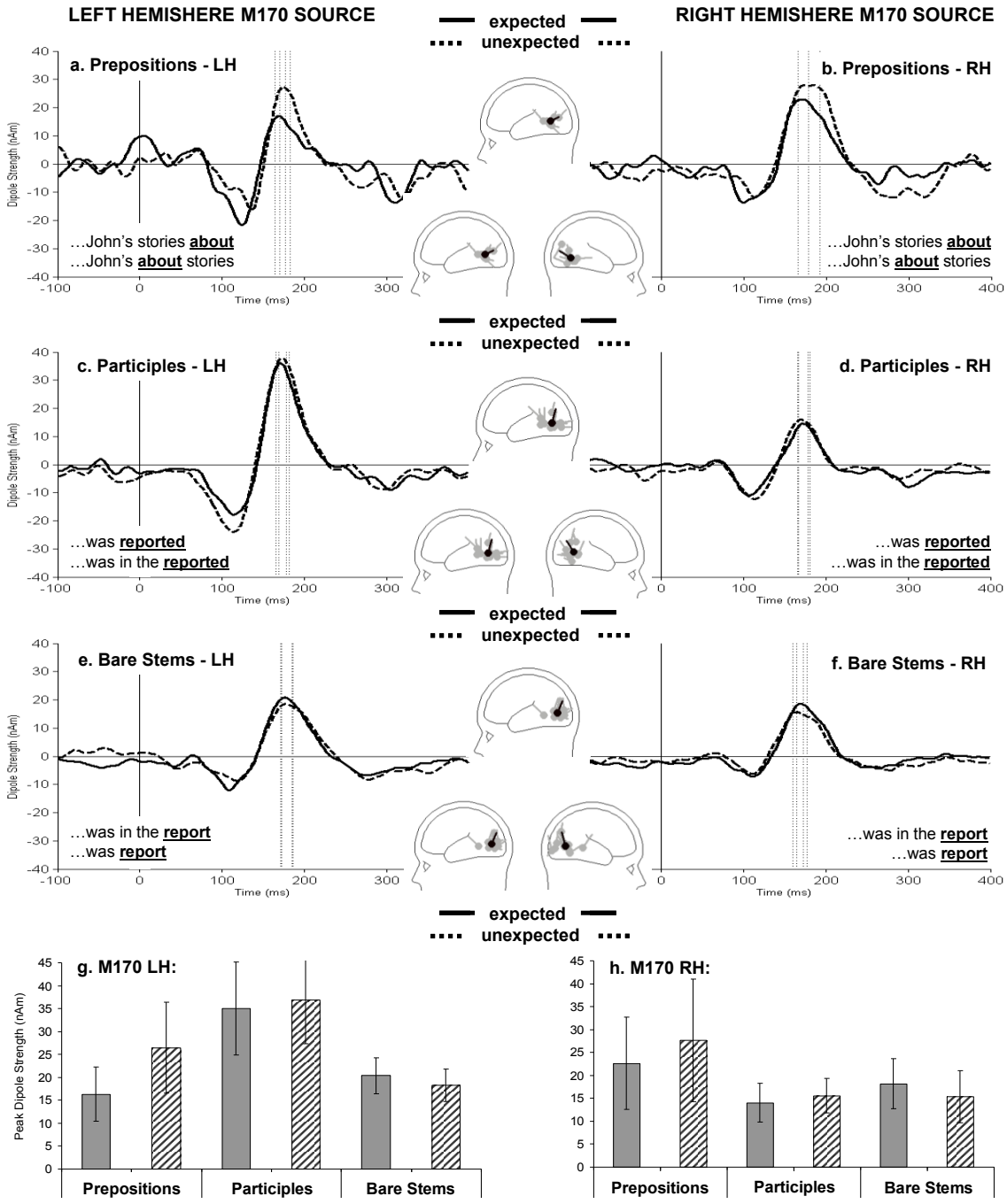

FIGURE 3 LEGEND – *Grandaveraged waveforms for the left and right M170 dipole sources per condition and mean amplitudes in nAm for the 15ms intervals centered around the left and right M170 peaks (the time-window between the dotted lines in the waveform graphs). Mean dipole locations and orientations (black) as well as the dipoles from the individual participants (grey) are plotted in the center for each word category. Results reveal no effects of expectedness on M170 amplitude.*

As can be seen in Figure 3, M170 amplitudes appeared larger for unexpected than for expected prepositions, but this effect was not reliable: the prepositions showed no main effects and no interactions. The participles and bare stems also showed no main effects, but they did exhibit a reliable Hemisphere by Word Category interaction ($F(1,8) = 6.37$, $p = 0.036$), as well as a reliable Expectedness by Word Category interaction ($F(1,8) = 14.68$, $p = 0.005$).

To explore these interactions, we ran follow-up 2 (Hemisphere: Left vs. Right) by 2 (Expectedness: Expected vs. Unexpected) within-subjects ANOVAs separated by word category. This showed no effects for the Bare Stem comparisons. For the participles, there was a marginal main effect of Hemisphere ($F(1,8) = 5.12$, $p = 0.054$), with the Left Hemisphere M170 dipole showing more activity than the Right Hemisphere M170 dipole. There was no main effect of Expectedness, nor did Expectedness interact with Hemisphere. A 2 (Word Category: Participle vs. Bare Stem) by 2 (Expectedness: Expected vs. Unexpected) within-subjects ANOVA by hemisphere showed no effects for the Right Hemisphere M170 source. For the Left Hemisphere Source, there were no main effects, but there *was* an interaction between Word Category and Expectedness ($F(1,8) = 6.60$, $p = 0.033$), suggesting that the Unexpected Participles yielded a higher M170 amplitude than the Expected Participles, while the reverse was true for the Bare Stem conditions. However, post-hoc t-tests revealed no reliable difference by Expectedness for either the Participles ($t(8) = 1.06$, $p = 0.322$), or the Bare Stems ($t(8) = 1.66$, $p = 0.136$).

2.3.3.3 Anterior Sources?

In addition to the M100 and M170 generators, we would have expected to capture any consistent left anterior sources clusters, at least in the unexpected conditions, if these stimuli were

associated with a left-anterior effect. However, there was no consistent grouping of dipoles in anterior regions of the left-hemisphere.

This could indicate that there were no left-anterior discrete sources. However, it may also be because the sensory components dominate our time-window of interest. Especially the visual M100 is usually reflected by a very strong magnetic field pattern covering most of the sensors. Since we did not perform dipole analyses based on sensors-of-interest but rather let the dipole locations and orientations vary freely, a weaker left-anterior field may have been masked by the M100. To further test for left anterior effects, and to confirm the posterior effects, we carried out an RMS analysis of posterior and left anterior ROI's.

2.3.4 RMS Results

2.3.4.1 Posterior Octants

To capture the ingoing and outgoing field maxima of the visual M100, we first collapsed the RMSs of the two most posterior regions of interest (Figure 4A). Surprisingly, there was no significant main effect of Expectedness or Word Category, nor a reliable interaction between the two.

Given that the M100 is bilaterally generated, we then tested for potential effects of laterality by analyzing the two posterior ROIs separately (Figures 4B and 4C). This analysis did reveal a significant main effect of Expectedness in the left posterior ROI ($F(1,12) = 5.19$, $p = 0.042$), showing increased amplitudes for the expected items. No significant main effect of Word Category ($F(2,24) = 1.46$, $p = 0.25$) and no significant interaction between Expectedness and Word Category ($F(2,24) = 0.65$, $p = 0.53$) were obtained. However, planned comparisons revealed that the main effect of Expectedness on peak amplitude was driven by those conditions

containing overt closed-class morphemes. In other words, reliable increases in amplitude were found for the Preposition condition ($t(12) = 2.31$, $p = 0.04$) and the Participle condition ($t(12) = 2.18$, $p = 0.049$), but not for the Bare Stem condition ($t(12) = 0.47$, $p = 0.65$).

In contrast, the right posterior ROI (Figure 4C) displayed no effect for any of the manipulations, nor an interaction. Planned comparisons also revealed no reliable effects of Expectedness for any word category. However, the Participles did show a marginal effect of Expectedness, but this was due to an increase in activation in the expected condition ($t(12) = -2.09$, $p = .059$).

In summary, analyses of the posterior ROIs revealed a left-lateralized effect of Expectedness at the visual M100 peak. In the planned comparisons, this effect was limited to the preposition and participle contrasts, i.e., to targets containing either a free or a bound overt closed-class category-marking morpheme. This pattern of findings is consistent with the dipole-analysis – the mean dipole locations across conditions were medial, but slightly left-lateralized.

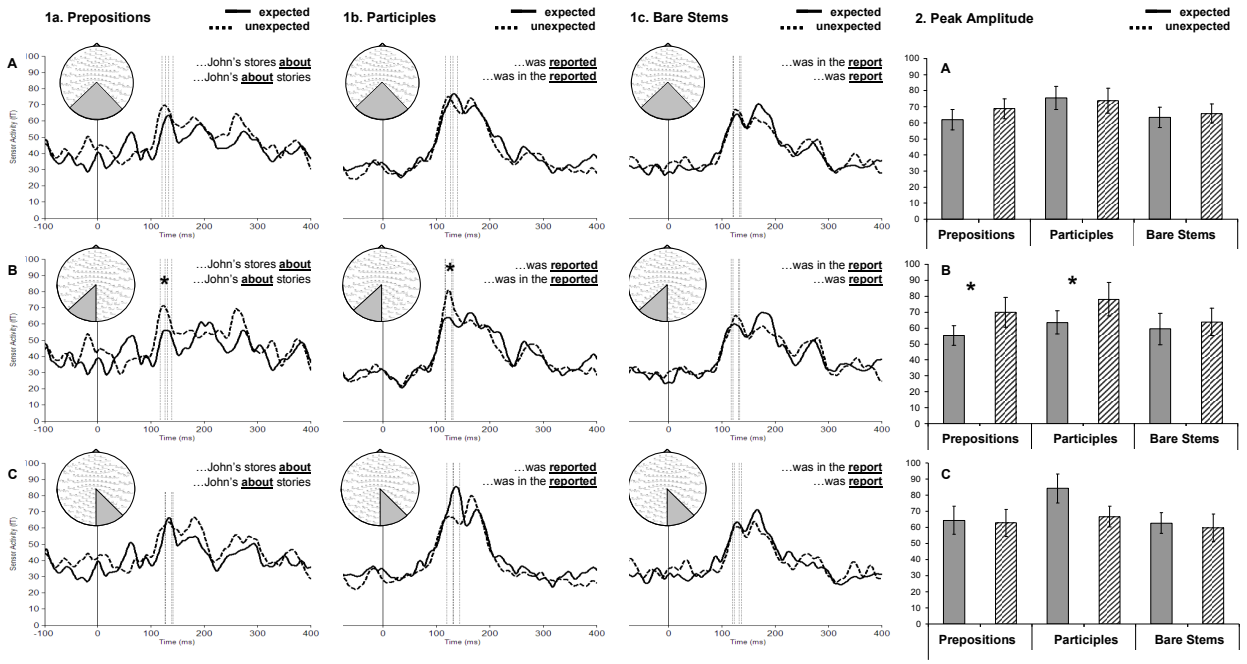

FIGURE 4 LEGEND

Left to right: Grandaveraged RMS's per condition and mean amplitudes in fT for the 15ms intervals of interest (indicated by the dotted lines in the RMS waveform graphs).

The three regions-of interest (ROIs), top to bottom: the two posterior octants combined (A), the left posterior octant (B), and the right posterior octant (C). ROIs are highlighted in sensor space. Results reveal reliably enhanced activity for the unexpected conditions in the left posterior ROI only (= $p < .05$; $n = 13$).*

2.3.4.1 Anterior Octants

To assess the possible contribution of additional left anterior generators to the effects of expectedness, we analyzed the remaining three left lateralized regions of interest in the same manner as above.

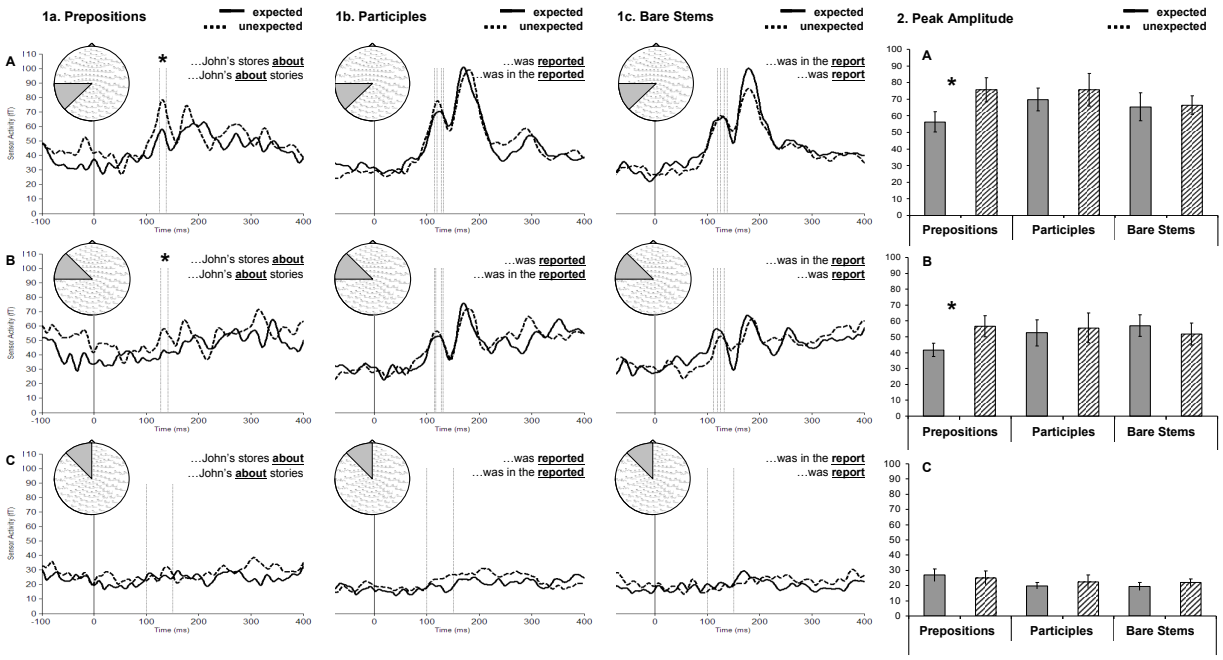

FIGURE 5 LEGEND

Left to right: Grandaveraged RMS's per condition and mean amplitudes in fT for the 15ms intervals of interest (indicated by the dotted lines in the RMS waveform graphs).
Three regions-of interest (ROIs), top to bottom: the left medial-posterior (A), left medial-anterior (B), and left-anterior octant (C). ROIs are highlighted in sensor space.

In the medial-posterior ROI (Figure 5A), clearly over-lapping with the M100 field distribution, peak amplitude in the time-window of interest showed a marginal main effect of Expectedness ($F(1,12) = 3.89$, $p = 0.072$), but no main effect of Word Category or reliable interaction between the two. Planned comparisons revealed a significant effect of Expectedness for the Preposition condition ($t(12) = 2.57$, $p = 0.025$), but no other effects.

In the medial-anterior ROI (Figure 5B), capturing only the very edges of the M100 distribution, peak amplitude in the 100-150 time-window no longer showed any significant main

effects or interactions. Again, planned comparisons revealed an effect of Expectedness for the Preposition condition ($t(12) = 2.32$, $p = 0.039$) but no other effects.

The most anterior ROI (Figure 5C) was the most crucial for any potential left anterior effects: while for the other ROIs examined so far, the modulation found for the Preposition conditions could be due to spill-over from a posterior M100 effect, a posterior generator alone would be unlikely to explain an effect in this ROI. Thus an effect in this ROI would strongly suggest an additional left-anterior generator. However, analysis of this ROI's peaks in the 100-150 time-window showed no reliable main effects of Expectedness or Word Category, and no reliable interaction between the two. In addition, planned comparisons revealed no significant differences between the conditions. The analysis of this ROI was complicated by the low amplitude of the responses, which impeded detection of peaks. To ensure our result was not an artifact of this, we also performed an identical ANOVA for the mean amplitude of the 100-150ms interval, as explained in Section 2.2.4. This revealed a significant main effect of Word Category ($F(2,24) = 6.73$, $p = 0.005$), Participles showing a higher amplitude than the other word categories overall, but no other effects.

2.3.5 Summary of Results

The peak amplitude of the visual M100, a neuromagnetic sensory response to visual stimulation, was modulated by the expectedness of target category, but only when the target was overtly marked for word category by a closed-class morpheme. This effect of expectedness was found in both the M100 dipole and RMS analyses. The peak amplitude of the subsequent M170 component demonstrated no effects of Expectedness in any of the conditions. There was a

marginal effect of Hemisphere for the Participles, showing increased activity for the Left as compared to the Right M170 dipole.

Neither the dipole nor the sensor analysis showed evidence for anterior generators.

2.4 Discussion

Experiment 1 investigated two hypotheses about the generators and generating conditions of early neural responses to unexpected word category violations in sentential contexts. Using magnetoencephalography, we tested whether early syntactic responses depend on the presence of category-marking closed-class morphemes in unexpected target words and whether these early responses are at least partly generated by enhanced activity in sensory cortices. Consistent with both hypotheses, we found the peak amplitude of the visual M100 response to be modulated by expectedness but only when the target word contained overt category-marking functional morphology.

Multi-dipole modeling suggested a posterior generator for this effect, and did not reveal further left-anterior sources in any conditions. RMS analyses of regions of interest also revealed a posterior effect, although this effect was left lateralized. No effect was found in the most anterior region of interest. Further, no reliable modulation of the M100 was found for the morphologically unmarked bare stems in any ROI.

The visual M170 response, a slightly later component that has been associated with the VWFA, did not show any effects of expectedness for any of the word categories. Thus in this experiment, we found no evidence suggesting that the M170 participates in the post-M100 computation of category violations. However, due to the relative difficulty in modeling the M170, this conclusion must remain tentative. For example, in the preposition manipulation, there

was in fact a clear numerical M170 difference between the expected and unexpected conditions, but this effect was not reliable, potentially because of the small number of subjects for which a clear bilateral M170 source could be modeled.

Although our data offer a rather strong confirmation of the sensory hypothesis, the evidence from this experiment for the crucial role of closed-class morphology is somewhat more tentative. Below, we outline four alternative explanations for the lack of an M100 effect for the bare stems. Two of these are challenged by extant data in the literature; the other two are tested in Experiment 2.

Given that the M100 reflects a response to visual features, one might hypothesize that any unexpected perceivable indicator of category information would generate an M100 effect. In English, it is hard to imagine what such an indicator might look like, but evidence against this type of account exists for German, where nouns and no other word classes are capitalized. The examples in (4) illustrate stimuli used by Friederici & Meyer (2004) in an EEG study that was designed to compare word category and argument structure violations in German. In German, subordinate clauses have SOV word order when introduced by a complementizer such as *dass* (4a), but SVO order when *dass* is absent, as in (4c). In the ungrammatical (4b), the noun *Ärger* occurs where an inflected verb is expected.

(4) a. Er meinte dass Lisa *Ärger* verursacht,
'He mentioned that Lisa trouble causes'

b. * Er meinte auch Lisa *Ärger* verursacht
lit: 'He mentioned also Lisa trouble causes'

c. Er meinte auch Lisa verursacht *Ärger* (grammatical version of 4b)

In these stimuli, the target word contained no closed-class morpheme indicating word category. However, the materials were presented visually and thus the capitalization of *Ärger* was an overt cue to its nominal category. The manipulation (4a vs. 4b) failed to generate an ELAN and instead yielded a later left-anterior negativity (LAN), at 300-500ms. These results are consistent with an interpretation where early responses are sensitive to the *linguistic* dimension of closed vs. open class, and inconsistent with an account where the M100 is driven by any physically perceivable category-marking.

Another possible explanation for our results might be that the M100 effect reflects a response to an unexpected length of the target. For example, it could be the case that when one expects a noun, such an expectation includes a form-based estimate in terms of how much visual space the next word may occupy. A participle would then exceed this expected amount of visual input (since our participial targets all contained an *-ed* string added onto the stem), thereby generating an enhanced visual response. Conversely, in the case of unexpected prepositions, the amount of visual stimulation would be less than expected. Indeed, it has been shown that the M100 is sensitive to stimulus size (Tarkiainen et al., 1999). Under this type of an account, one would not need to attribute any linguistic sensitivity to sensory cortices. However, it is unlikely that our M100 effect for the participles was carried by the fact that all participles contained two letters more than their bare stem counterparts. Our stimuli included bare stems from one to three syllables, ranging between three and nine letters in length. Compared to the bare stems, some participles were in fact shorter. In addition, we saw no main effects of word category in our analysis of the M100 dipole's strength, or our RMS analysis of posterior regions of interest, suggesting the magnitude of potential length differences between words was not sufficient to reliably modulate the M100.

There are, however, two factors in Experiment 1 which partially confound the conclusion that the null result for the bare stems was due to the lack of closed-class morphology. First, unlike the participles and prepositions, the word category of the bare stems was ambiguous between noun and verb. Second, the expectations violated by the unexpected participles and the unexpected prepositions were considerably stronger than the expectations violated by the unexpected bare stems (see cloze-probabilities in Table 1). Experiment 2 tested whether either of these two factors was responsible for our null results for the bare stems.

3. EXPERIMENT 2

3.1 Introduction

Experiment 2 was designed to assess whether the bare stems of Experiment 1 failed to show an M100 modulation because of their category ambiguity or because of the lesser contrast in prediction strength between the expected and unexpected conditions.

As already observed above, in Experiment 1 all bare stems were ambiguous for word category (nominal/verbal). It is possible that this ambiguity, rather than the lack of closed-class morphology, resulted in the absence of an M100 effect. To test whether this may have confounded the results of Experiment 1, Experiment 2 included unambiguously nominal stems like ‘tree’, in addition to the ambiguous stems tested in Experiment 1 (e.g., ‘report’):

(5) a. The owl was in the TREE.

b. * The owl was TREE.

In addition, the unexpected bare stem condition in Experiment 1 violated a weaker prediction for a specific word category than the unexpected participle condition. Recall that Lau et al. (2006) found that the ELAN is sensitive to the strength of a violated prediction (see example 3). The M100 modulation may thus be dependent upon violating a particularly strong prediction, and the bare stem condition in Experiment 1 may not have met this criterion. For the sentence fragment preceding the target word in the unexpected bare stem condition (e.g., *The discovery was...*), the cloze-probability of a participle was only 29% and there was no strong prediction for any other category either. Thus the unexpected bare stems contrasted with the unexpected participle condition (e.g., *The discovery was in the* ***reported***), where the cloze-probability of a noun was 91%. This discrepancy raises the question whether the relatively low prediction strength in the unexpected bare stem condition may have caused the lack of M100 modulation.

To investigate this, we created a very strong prediction for a participle by inserting an adverb into the stimuli of Experiment 1 (e.g., *The discovery was solemnly* ***report***) As discussed in Experiment 1, it is important to control for possible effects that may be due to the baseline of a target word rather than the intended manipulation. In Experiment 1, we solved this problem by making sure that in each stimulus the baseline for an expected word (e.g., ... *was reported*) was also the baseline for an unexpected item in another condition (e.g., … *was report*) and vice versa (e.g., … *in the report* / … *in the reported*). To ensure that a similar baseline cross-over held for the conditions in Experiment 2, we also inserted an adjective in the expected bare stem/noun conditions (e.g., *The discovery was in the solemn* ___; see section 3.2.2 for details). In addition to these conditions, all other conditions of Experiment 1, except the prepositions, were also included in Experiment 2.

In summary, in Experiment 2 we added two additional factors to the design of Experiment 1, namely category ambiguity and prediction strength, in order to investigate whether M100 effects are limited to close-class morphemes or modulated by these other factors.

3.2 Methods

3.2.1 Participants

12 healthy right-handed subjects (3 male) participated. All had normal or corrected-to-normal vision and gave informed consent. All were students or employees at New York University (ages 19-42).

3.2.2 Materials

Our materials consisted of three types of manipulations. First we tested unexpected participles containing the bound closed-class morpheme *–ed*, exactly as in Experiment 1, with the exception of a few items that were replaced because they did not lend themselves to the addition of an adjective or adverb (see below). Second, we included the bare stem manipulation as in Experiment 1, but with the added participles. Again, as in Experiment 1, the only difference between the participle conditions and the bare stem conditions was the presence of the *–ed* morpheme. Finally, we included sentences that contained unambiguous nouns (items defined as nouns by the COBUILD corpus, and which COBUILD listed as either not having a verbal form, or whose verbal form's COBUILD frequency was below 750 and rarer by at least two orders of magnitude than the noun form). These unambiguous nouns were open class, but were not productively used as any other word category. This condition allowed us to test whether the

presence of closed-class morphology is indeed a prerequisite for the M100 effect, or whether this effect is also obtained for unexpected open-class morphemes that are category unambiguous.

To investigate whether the absence of an M100 effect for the bare stems in Experiment 1 was caused by a lack of a strong category prediction, prediction strength was varied across word category, including in the participle manipulation, by inserting either an adjective or a manner adverb. As pointed out above, the intention of inserting this additional material was to create a very strong prediction for a participle after sentence fragments such as *the discovery was solemnly*. The full design (6 conditions total) is shown in Table 2. 60 sentences were presented in each condition (720 sentences overall, see Appendix 2 for full list).

Condition			**Expected**		**Unexpected**		
Word Category	***Category Ambiguity***	***Prediction Level***	***Example sentence***	***Cloze-P***	***Example sentence***	***Cloze-P***	
Participle	Unambiguous	Weak	The discovery was ***reported***.	0.27	The discovery was in the ***reported***.	Part: 0	Noun: 0.86
		Strong	The discovery was solemnly ***reported***.	0.79	The discovery was in the solemn ***reported***.	Part: 0	Noun: 0.90
Bare stem	Ambiguous	Weak	The discovery was in the ***report***.	0.86	The discovery was ***report***.	Noun: 0	Part: 0.27
		Strong	The discovery was in the solemn ***report***.	0.90	The discovery was solemnly ***report***.	Noun: 0	Part: 0.79
Noun	Unambiguous	Weak	The owl was in the ***tree***.	0.79	The owl was ***tree***.	Noun: 0	Part: 0.23
		Strong	The owl was in the high ***tree***.	0.89	The owl was highly ***tree***.	Noun: 0	Part: 0.59

TABLE 2 LEGEND - *Examples of the experimental stimuli of Exp. 2 (60 per condition). See Appendix 2 for a complete list of the test sentences. Cloze-probabilities reflect the proportion of the word category of interest filled in during an off-line sentence completion task (see text). For the unexpected conditions, cloze-probabilities are also given for the violated word category expectation (i.e., participles for the unexpected bare stems and the unexpected unambiguous nouns, and nouns for the unexpected participles).*

Cloze-probability

To confirm that the different conditions manipulated predictions for the target word-category, an off-line cloze-probability test was carried out, as in Experiment 1 (see Section 2.2.2). Cloze-probabilities were calculated in terms of the word category of the first word filled in by subjects for each sentence fragment. Results are given in Table 2.

As in Experiment 1, the probability of the word category of the target word was significantly greater for the Expected than for the Unexpected conditions across all three manipulations. Importantly, for each Word Category, there was a significant effect of Prediction Strength on cloze-probability: A participle was significantly more often filled in after an adverb than after a auxiliary ($t(118) = 14.13$, $p < 0.001$), and a noun was more often filled in after an adjective than after a determiner (Bare Stems: $t(118) = 3.17$, $p = 0.002$; Nouns $t(118) = 5.16$, $p < 0.001$). Notice however that the percentage point difference between the likelihood of a participle after an adverb vs. after an auxiliary was much greater (27% vs 79%) than the difference between the likelihood of a bare stem after an adjective vs. after a determiner (86% vs. 90%); this interaction between our prediction strength manipulation and condition was reliable ($F(1,236) = 150.3$, $p < 0.001$). Our manipulation therefore succeeded in increasing the strength of the violated prediction in the Unexpected Bare Stem and the Unambiguous Noun manipulations.

3.2.3 Procedure

During the experiment, subjects sat in a dimly lit, magnetically sealed chamber. The participants viewed the stimuli on a screen approximately 17 inches from their head. Each trial began with a fixation point in the center of the screen. Participants initiated each trial by pressing a button.

The sentences were presented word by word (300ms on, 300ms off), in non-proportional Courier font (font size = 90), and the end of each sentence was indicated with a question mark. At the question mark, participants were instructed to judge whether the sentence was well-formed or not by pressing a button with either the middle or the index finger of their left hand. The entire recording session lasted approximately 75 minutes.

Data were collected using a whole-head 275-channel gradiometer (CTF, Vancouver Canada) system sampling at a 600Hz in a band between 0.1 and 200Hz. Since Experiments 1 and 2 used different MEG machines, our study also serves to address to what extent the results of Experiment 1 replicate with a different machine.

3.2.4 Analysis

Prior to averaging, the MEG data were cleaned of artifacts. On average, this resulted in the exclusion of less than 10 % of the data per subject. Data were averaged by stimulus category over a 900ms epoch with a 300ms pre-stimulus interval, time-locked to the appearance of the target word. Prior to analysis, the recordings were high and low-pass filtered at 1 and 40 Hz respectively.

M100 activity was modeled for each condition and each subject separately following the procedure outlined for Experiment 1, in section 2.2.4.

3.3 Results

3.3.1 Behavioral Data

Overall accuracy in the grammaticality judgment task was again very high, averaging at 94%.

3.3.2 M100 Dipole Results

M100 multi-dipole models

For 5 of the 12 subjects, the M100 activity could be modeled by a single dipole in all conditions. All other subjects required at least one additional dipole. The mean number of dipoles for all subjects was 1.4; there were no reliable differences in the number of dipoles between conditions. As in Experiment 1, there was also no consistent pattern with respect to Expectedness or Word Category for either the number or location of the additional non-M100 dipoles. The mean goodness of fit for the dipole solutions was 89.5%. (SD = 5.9%). Figure 6 shows the average waveform and average dipole for each condition (blue = expected / red = unexpected), as well as the individually modeled dipoles (grey).

To investigate possible consistent variation in dipole location and orientation across conditions, the x, y, and z locations and orientations of the individual M100 dipoles per condition were entered into a series of 2 (Expectedness: Expected vs. Unexpected) by 2 (Prediction Strength: Weak vs. Strong) by 3 (Word Category: Participle vs. Bare Stem vs. Unambiguous Noun) within-subjects ANOVAs.

For dipole location, an interaction was observed between Word Category and Expectedness along the anterior-posterior axis (y-location) ($F(2,22) = 5.278$, $p = 0.021$). For the Participles the generators of the M100 for Unexpected Participles were significantly more arnterior (-.676) than for the Expected Participles (-.725) overall ($F(1,11) = 11.328$, $p = 0.006$). In the Unambiguous Noun comparison, in contrast, the M100 dipoles for Unexpected conditions were significantly more posterior (-.678mm) than for Expected conditions (-.652mm) overall ($F(1,11) = 5.737$, $p = 0.036$). However, as can be seen in Figure 6, these location differences

were extremely slight, smaller than the resolution of MEG (0.04mm for the Participles and 0.02mm for the Unambiguous Nouns), and do not warrant any strong conclusions.

Dipole orientation vectors also demonstrated a very slight (less than .04) but reliable main effect of Expectedness on the y-coordinate ($F(1,11) = 5.527$, $p = 0.038$; Expected: -.223; Unexpected: -.186). No further effects on dipole orientation or location were found.

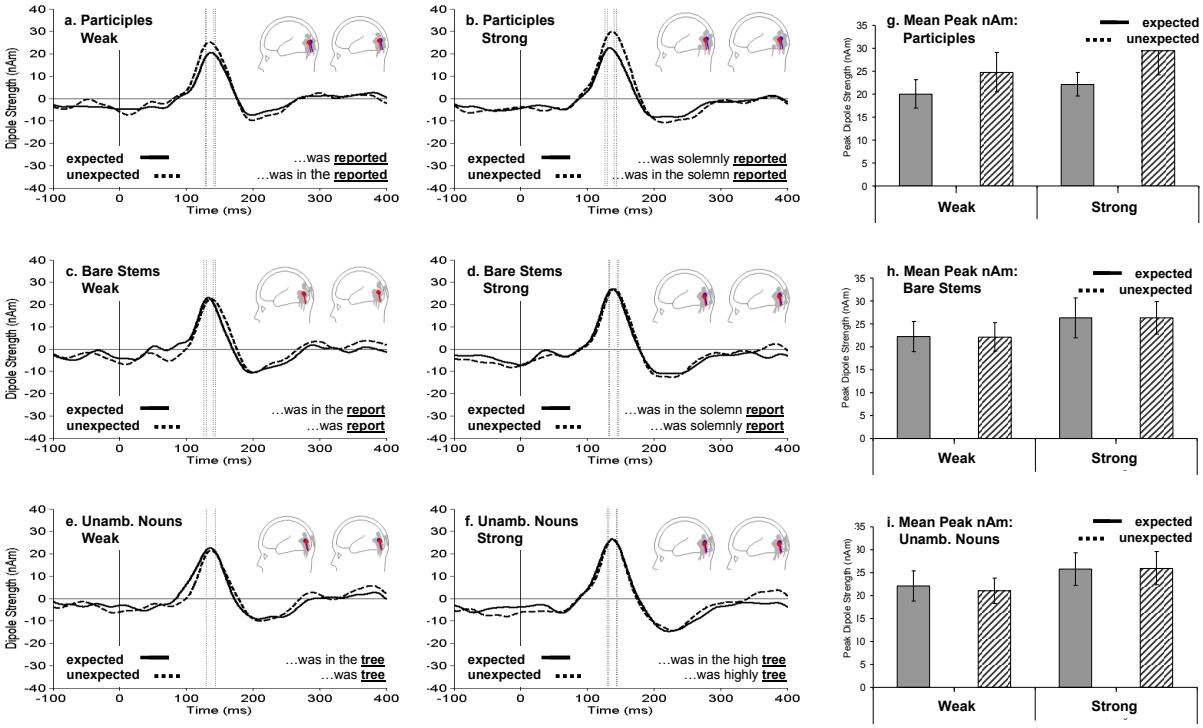

FIGURE 6 LEGEND – *Grandaveraged waveforms for the M100 dipole sources per comparison (n=12) and mean amplitudes in nAm for the 15ms intervals centered around the M100 peaks (time-window between dotted lines in graphs). Mean dipole locations and orientations (blue = expected / red = unexpected) as well as the dipoles from the individual participants per condition (grey) are plotted.*

Effects of Expectedness at the M100

Following the same procedure as in Experiment 1, amplitudes of the M100 component over a 15ms interval (9 time samples) centered around the component's peak (indicated with dotted lines in Figure 6) for each condition were entered into several within-subjects ANOVAs. A 2 (Expectedness: Expected vs. Unexpected) by 2 (Prediction Strength: Weak vs. Strong) by 3 (Word Category: Participle vs. Bare Stem vs. Unambiguous Noun) within-subjects ANOVA revealed a significant main effect of Expectedness ($F(1,11) = 4.93$, $p = 0.048$) as well as a reliable interaction between Expectedness and Word Category ($F(2,22) = 5.08$, $p = 0.028$). Follow-up 2 (Expectedness: Expected vs. Unexpected) by 2 (Prediction Strength: Weak vs. Strong) ANOVAs separated by Word Category were carried out to clarify this interaction.

First, the Participle comparisons revealed a main effect of Expectedness ($F(1,11) = 8.82$, $p = 0.013$): Unexpected Participles yielded higher M100 amplitude than the Expected Participles overall. There was no main effect of Prediction Strength ($F(1,11) = 2.13$, $p = 0.17$), nor was there an interaction between Expectedness and Prediction Strength ($F(1,11) = 0.51$, $p = 0.49$). In other words, the Expectedness effect was not modulated by Prediction Strength.

In contrast to the Participle conditions, the Bare Stems manipulations showed no main effect of Expectedness ($F(1,11) = 0.002$, $p = 0.97$), but there was a marginal main effect of Prediction Strength ($F(1,11) = 4.29$, $p = 0.063$), which did not interact with Expectedness ($F(1,11) = 0.002$, $p = 0.96$). In other words, participants showed higher amplitudes for contexts that set up strong predictions, irrespective of whether this prediction was violated or satisfied. The Unambiguous Nouns showed a similar pattern as the Bare Stems (Expectedness: $F(1,11) = 0.22$, $p = 0.65$; Prediction Strength: $F(1,11) = 13.66$, $p = 0.004$; Expectedness x Prediction

Strength: F(1,11) = 0.099, p = 0.76). Thus, as in Experiment 1, Expectedness only modulated the M100 generated by items containing closed class morphemes.

Finally, the overall ANOVA including all conditions and word categories revealed a main effect of Prediction Strength (F(1,11) = 14.72, p = 0.003), which did not interact with Expectedness (F(1,11) = 0.216, p = 0.651), or Word Category (F(2,22) = 0.65, p = 0.889): participants displayed increased M100 amplitudes to targets appearing in strongly predictive contexts, irrespective of word category or whether the expectation was violated. That targets satisfying a strong prediction and targets violating a strong prediction should both be associated with the same M100 amplitude increase is quite surprising and certainly does not follow from any of the hypotheses we tested in this work. This effect was robust though and thus merits further investigation.

3.4 Discussion

Experiment 1 demonstrated that the amplitude of the visual M100 is modulated by the presence of an unexpected word category, but only when the target item contains a closed-class category marking morpheme. To assess whether the closed/open class distinction was in fact the critical factor, Experiment 2 tested two alternative explanations of this effect, one based on category ambiguity and the other on prediction strength. Specifically, we tested whether we would obtain an M100 effect for category unambiguous nouns which lack closed-class category-marking morphology and violate a strong prediction for a participle.

Our results clearly support the hypothesis that closed-class morphology is indeed the crucial factor. Category disambiguation and the increase in prediction strength did not result in an M100 effect for the category unambiguous nouns. Bare stems also failed to show an effect, as

in Experiment 1. The only word category showing an M100 effect of expectedness was the Participles, i.e., the items containing closed-class category marking morphology.

Surprisingly, we obtained a main effect of prediction strength – both strongly expected and unexpected items showed increased M100 amplitudes as compared to the weak prediction conditions. In other words, overall higher M100 amplitudes were found for participle, bare stem and noun targets after adverbs and adjectives than after determiners and the copula. Thus prediction strength does affect the M100, although perhaps in a somewhat complicated way.

4. GENERAL DISCUSSION

In this research we aimed to elucidate why the human brain seems to react to certain types of syntactic violations at the same speed as it generates primary sensory responses. Specifically, when the parser's word category expectations mismatch with the actual input, the brain seems to detect the mismatch within 130-150ms (Friederici, 2002; Friederici et al., 1993; Hahne & Friederici, 1999; Neville et al., 1991). We tested two hypotheses which, if true, would render this intriguing finding somewhat less surprising. First, we hypothesized that these early effects are limited to words whose category is marked by an overt closed-class category-marking morpheme. For such words, word category can be identified without any deep semantic analysis. Second, we hypothesized that already the sensory cortices might be able to check category predictions, in particular when category is marked by an overt function morpheme, whose form the sensory cortices might be tuned to detect. If the early effects of category mismatch were, in fact, at least partly sensory responses, then their occurrence in the same time-window with sensory responses would obviously be expected.

The results of two MEG experiments supported both hypotheses. In Experiment 1, we found an effect of expectedness on the visual M100 response, but only when the unexpected item contained a category-marking closed-class morpheme. Experiment 2 replicated this finding and further showed that the lack of an M100 effect for the monomorphemic open-class stems in Experiment 1 was not due to their category ambiguity nor to their weakly predictive contexts.

The current work is the first to demonstrate that early visual responses to word forms can be influenced by prior syntactic context. Our results underdetermine whether left-anterior regions, such as those previously proposed to generate the ELAN, also participate in the early detection of word category violations. In the current data sets, we found no evidence for this, but from the null result we are obviously unable to draw any firm conclusions. Our study used a different technique from the vast majority of the ELAN literature. Furthermore, the failure to find a left anterior effect may be due to our rate of presentation (300ms on, 300ms off); it has previously been hypothesized that early left anterior effects are only found under very fast visual presentation (Kotz & Friederici, 2003). Ultimately, simultaneous EEG and MEG recordings should contribute to a more complete picture regarding these early stages of syntactic processing.

What mechanism might underlie the ability of visual cortex to respond to syntactic mismatches? This question can be broken down to two subparts: what types of predictions are visual regions sensitive to and what are the computations by which the incoming stimulus is evaluated with respect to the predictions? As regards the range of syntactic phenomena that might elicit early sensory effects, the extant EEG literature suggests that word category mismatches are the main generator of very early violation effects, and our results are obviously consistent with this. As discussed in the Introduction, agreement violations, for example, have primarily generated later ERP effects. However, there are some recent studies where very early

Mismatch Negativities have been obtained for local agreement violations, at the same latency and with a similar scalp distribution as word category violations (see Hasting & Kotz 2008, for a review). Thus whether there really is something special about word category predictions, as opposed to other types of predictions about the upcoming word, remains an open empirical question in need of additional studies. Further, where in the brain predictions are generated and whether multiple regions are involved — potentially differentiated by type of prediction — remain interesting questions for future research.

As regards the mechanisms by which sensory cortices evaluate predictions, one possibility is that predictions about upcoming word categories include form-based estimates (cf., Tanenhaus & Hare, 2007), which are then checked against perceptually salient elements in the input that signal word category, i.e., closed-class morphemes. Under this hypothesis, the primary role of visual cortex would be to match very specific instructions regarding the visual form of upcoming elements. A mismatch is only detected if there is strong visual indicator in the input that does not match the prediction, e.g., a frequent closed-class morpheme.

However, although some type of top-down process seems perhaps the most plausible, on the basis of the current data we cannot reject the possibility that the visual cortex actually contains some type of representations of closed-class category marking morphemes. On this account, the generating regions of the M100 would be a type of Visual Word Form Area, but dedicated to closed-class category-marking morphemes. Such a finding would obviously be extremely striking, but our data set raises it as a real possibility for future research.

Regarding the nature of the information that triggers the visual M100 effect, there is at least one viable hypothesis in addition to the closed/open class distinction that might be relevant to our results, namely the typical orthographic properties of different word categories. A recent

study by Farmer and colleagues revealed for open-class items that certain letter-string combinations are more canonically associated with nominal stems whereas others occur more frequently in verbal stems (Farmer, Christiansen, & Monaghan, 2006). This canonicity affects processing time: in unambiguous sentential contexts, more 'verby' verb forms are processed faster than verbs that share phonological properties with nouns, and vice versa for 'nouny' nouns. Recent research by Hauk and colleagues has, in fact, already demonstrated that orthographic typicality modulates event-related potentials at only 100ms (Hauk et al., 2006). The combination of this research and our results raise the possibility that early visual responses may be sensitive to this canonicity, an interesting hypothesis to contrast in future studies with the more categorical account that appeals to the closed-class/open-class distinction.

5. CONCLUSION

In the current studies, salient indices of word category (i.e., closed-class category marking morphemes) generated an enhanced sensory response when presented in an unexpected syntactic context. This finding suggests that syntactically relevant cues affect processing in sensory cortices after only 125ms. Although the exact nature of this response and its relation to high-level syntactic processing require further investigation, the finding that sensory areas show sensitivity to these cues in any way is a striking one, and potentially a key element for understanding how language processing can be so remarkably fast.

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APPENDIX 1. EXPERIMENT 1 STIMULI

Prepositional targets

Expected

1. The girl resented Tom's comments about her looks.
2. The reviewer despises Richard's films about murder.
3. The police discovered Bob's pictures of the suspect.
4. The child enjoys Terry's cartoons about animals.
5. Most people enjoy Jim's stories about the past.
6. The boys heard Joe's stories about Africa.
7. The boys saw Ted's films about America.
8. The children enjoyed Ed's stories about the farm.
9. The crowd shouted Marx's slogans about peace.
10. The editor published Harry's report about drugs.
11. The firm needed Mike's ideas about marketing.
12. The judge read Chuck's article about crime.
13. The lady sold Mary's portrait of her father.
14. The man admired Don's sketch of the landscape.
15. The man bought Larry's painting of the ocean.
16. The man read Peter's report of the case.
17. The network broadcast Kevin's lecture about planets.
18. The newspaper printed John's picture of the accident.
19. The people disliked Fred's jokes about the Queen.
20. The police circulated Ruth's sketch of the thief.
21. The police received Sam's note about the ransom.
22. The professor praised Alan's poem about the moon.
23. The scientist criticized Max's proof of the theorem.
24. The students discussed Frank's speech about migrants.
25. The students enjoyed Bill's review of the play.
26. The students sang Lisa's songs about freedom.
27. The visitors accepted Gary's advice about the money.
28. The widow asked Fred's advice about taxes.
29. The women ignored John's complaints about the noise.

30. The parents saw Jean's pictures of her friends.

Unexpected

1. The girl resented Tom's about comments her looks.
2. The reviewer despises Richard's about films murder.
3. The police discovered Bob's of pictures the suspect.
4. The child enjoys Terry's about cartoons animals.
5. Most people enjoy Jim's about stories the past.
6. The boys heard Joe's about stories Africa.
7. The boys saw Ted's about films America.
8. The children enjoyed Ed's about stories the farm.
9. The crowd shouted Marx's about slogans peace.
10. The editor published Harry's about report drugs.
11. The firm needed Mike's about ideas marketing.
12. The judge read Chuck's about article crime.
13. The lady sold Mary's of portrait her father.
14. The man admired Don's of sketch the landscape.
15. The man bought Larry's of painting the ocean.
16. The man read Peter's of report the case.
17. The network broadcast Kevin's about lecture planets.
18. The newspaper printed John's of picture the accident.
19. The people disliked Fred's about jokes the Queen.
20. The police circulated Ruth's of sketch the thief.
21. The police received Sam's about note the ransom.
22. The professor praised Alan's about poem the moon.
23. The scientist criticized Max's of proof the theorem.
24. The students discussed Frank's about speech migrants.
25. The students enjoyed Bill's of review the play.
26. The students sang Lisa's about songs freedom.
27. The visitors accepted Gary's about advice the money.
28. The widow asked Fred's about advice taxes.
29. The women ignored John's about complaints the noise.
30. The parents saw Jean's of pictures her friends.

Participial targets

Expected

1. The coat was quilted.
2. The discovery was reported.
3. The passenger was seated.
4. The picture was shaded.
5. The man was rescued.
6. His brain was scanned.
7. Her hair was styled.
8. The boxes were shipped.
9. The books were ordered.
10. The criminal was stoned.
11. The car was stopped.
12. The parcel was mailed.
13. The plants were studied.
14. The students were tested.
15. The problem was documented.
16. The prisoner was tracked.
17. The mouse was trapped.
18. The clothes were washed.
19. The novel was reviewed.
20. The excursion was planned.
21. The routes were mapped.
22. The appointments were scheduled.
23. The points were scored.
24. The problem was noted.
25. The shirt was painted.

26. The song was recorded.
27. The plants were watered.
28. The picture was framed.
29. The meal was microwaved.
30. The string was knotted.
31. The entrance was blockaded.
32. The flowers were bunched.
33. The team was coached.
34. The bicycles were claimed.
35. The robber was cornered.
36. The couch was stored.
37. The amendment was debated.
38. The songs were debuted.
39. The terms were demanded.
40. The chapel was designed.
41. The girl was dressed.
42. The story was ended.
43. The pictures were exhibited.
44. The field was farmed.
45. The park was fenced.
46. The information was faxed.
47. The elephant was filmed.
48. The horseshoe was forged.
49. The virus was emailed.
50. The steak was grilled.
51. The kids were grouped.
52. The tourists were guided.
53. The pan was heated.
54. The actor was interviewed.
55. The apartment was leased.
56. His qualities were listed.
57. The clothes were modeled.
58. The student was lectured.
59. The horse was harnessed.
60. The play was staged.

Unexpected

1. The coat was on the quilted.
2. The discovery was in the reported.
3. The passenger was in the seated.
4. The picture was in the shaded.
5. The man was at the rescued.
6. His brain was on the scanned.
7. Her hair was in a styled.
8. The boxes were on the shipped.
9. The books were in the ordered.
10. The criminal was on a stoned.
11. The car was at a stopped.
12. The parcel was in the mailed.
13. The plants were in the studied.
14. The students were in a tested.
15. The problem was in the documented.
16. The prisoner was on the tracked.
17. The mouse was in the trapped.
18. The clothes were in the washed.
19. The novel was in the reviewed.
20. The excursion was in the planned.
21. The routes were on the mapped.
22. The appointments were on the scheduled.
23. The points were in the scored.
24. The problem was on the noted.
25. The shirt was in the painted.
26. The song was on the recorded.
27. The plants were in the watered.
28. The picture was in the framed.
29. The meal was in the microwaved.
30. The string was in a knotted.
31. The entrance was behind the blockaded.
32. The flowers were in a bunched.
33. The team was behind the coached.
34. The bicycles were in the claimed.
35. The robber was around the cornered.
36. The couch was in the stored.
37. The amendment was in the debated.
38. The songs were in her debuted.
39. The terms were in the demanded.
40. The chapel was in the designed.
41. The girl was in the dressed.
42. The story was at the ended.
43. The pictures were in the exhibited.
44. The field was by the farmed.
45. The park was inside the fenced.
46. The information was in the faxed.
47. The elephant was in the filmed.
48. The horseshoe was in the forged.
49. The virus was in the emailed.
50. The steak was on the grilled.
51. The kids were in a grouped.
52. The tourists were with the guided.
53. The pan was on the heated.

54. The actor was in an interviewed.
55. The apartment was on a leased.
56. His qualities were on the listed.
57. The clothes were on the modeled.
58. The student was in the lectured.
59. The horse was in a harnessed.
60. The play was on the staged.

Bare stem targets

Expected

1. The coat was on the quilt.
2. The discovery was in the report.
3. The passenger was in the seat.
4. The picture was in the shade.
5. The man was at the rescue.
6. His brain was on the scan.
7. Her hair was in a style.
8. The boxes were on the ship.
9. The books were in the order.
10. The criminal was on a stone.
11. The car was at a stop.
12. The parcel was in the mail.
13. The plants were in the study.
14. The students were in a test.
15. The problem was in the document.
16. The prisoner was on the track.
17. The mouse was in the trap.
18. The clothes were in the wash.
19. The novel was in the review.
20. The excursion was in the plan.
21. The routes were on the map.
22. The appointments were on the schedule.
23. The points were in the score.
24. The problem was on the note.
25. The shirt was in the paint.
26. The song was on the record.
27. The plants were in the water.
28. The picture was in the frame.
29. The meal was in the microwave.
30. The string was in a knot.
31. The entrance was behind the blockade.
32. The flowers were in a bunch.
33. The team was behind the coach.
34. The bicycles were in the claim.
35. The robber was around the corner.
36. The couch was in the store.
37. The amendment was in the debate.
38. The songs were in her debut.
39. The terms were in the demand.
40. The chapel was in the design.
41. The girl was in the dress.
42. The story was at the end.
43. The pictures were in the exhibit.
44. The field was by the farm.
45. The park was inside the fence.
46. The information was in the fax.
47. The elephant was in the film.
48. The horseshoe was in the forge.
49. The virus was in the email.
50. The steak was on the grill.
51. The kids were in a group.
52. The tourists were with the guide.
53. The pan was on the heat.
54. The actor was in an interview.
55. The apartment was on a lease.
56. His qualities were on the list.
57. The clothes were on the model.
58. The student was in the lecture.
59. The horse was in a harness.
60. The play was on the stage.

Unexpected

1. The coat was quilt.
2. The discovery was report.
3. The passenger was seat.
4. The picture was shade.
5. The man was rescue.
6. His brain was scan.
7. Her hair was style.
8. The boxes were ship.
9. The books were order.
10. The criminal was stone.
11. The car was stop.
12. The parcel was mail.
13. The plants were study.
14. The students were test.
15. The problem was document.
16. The prisoner was track.
17. The mouse was trap.

18. The clothes were wash.
19. The novel was review.
20. The excursion was plan.
21. The routes were map.
22. The appointments were schedule.
23. The points were score.
24. The problem was note.
25. The shirt was paint.
26. The song was record.
27. The plants were water.
28. The picture was frame.
29. The meal was microwave.
30. The string was knot.
31. The entrance was blockade.
32. The flowers were bunch.
33. The team was coach.
34. The bicycles were claim.
35. The robber was corner.
36. The couch was store.
37. The amendment was debate.
38. The songs were debut.
39. The terms were demand.
40. The chapel was design.
41. The girl was dress.
42. The story was end.
43. The pictures were exhibit.
44. The field was farm.
45. The park was fence.
46. The information was fax.
47. The elephant was film.
48. The horseshoe was forge.
49. The virus was email.
50. The steak was grill.
51. The kids were group.
52. The tourists were guide.
53. The pan was heat.
54. The actor was interview.
55. The apartment was lease.
56. His qualities were list.
57. The clothes were model.
58. The student was lecture.
59. The horse was harness.
60. The play was stage.

APPENDIX 2. EXPERIMENT 2 STIMULI

Participle Targets

Weak Prediction Level

Expected

1 The elephant was filmed.
2 The coat was quilted.
3 The terrace was shaded.
4 The hair was styled.
5 The books were ordered.
6 The rubbish was dumped.
7 The problem was documented.
8 The routes were mapped.
9 The appointments were scheduled.
10 The problem was noted.
11 The cactus was watered.
12 The picture was framed.
13 The flowers were bunched.
14 The team was coached.
15 The amendment was debated.
16 The chapel was designed.
17 The girl was dressed.
18 The story was ended.
19 The pictures were exhibited.
20 The information was faxed.
21 The plants were potted.
22 The kids were grouped.
23 The actor was interviewed.
24 The apartment was leased.
25 Everyone's qualities were listed.
26 The clothes were modeled.
27 The student was lectured.
28 The horse was harnessed.
29 The play was staged.
30 The king was throned.
31 The papers were filed.
32 The glasses were packed.
33 The discovery was reported.
34 The passenger was seated.
35 The man was rescued.
36 The brain was scanned.
37 The boxes were shipped.
38 The car was stopped.
39 The plants were studied.
40 The students were tested.

41 The prisoner was tracked.
42 The mouse was trapped.
43 The clothes were washed.
44 The novel was reviewed.
45 The excursion was planned.
46 The shirt was painted.
47 The song was recorded.
48 The meal was microwaved.
49 The string was knotted.
50 The entrance was blockaded.
51 The items were claimed.
52 The robber was cornered.
53 The couch was stored.
54 The songs were debuted.
55 The terms were demanded.
56 The field was farmed.
57 The park was fenced.
58 The virus was emailed.
59 The steak was grilled.
60 The tourists were guided.

Weak Prediction Level
Unexpected
61 The elephant was in the filmed.
62 The coat was on the quilted.
63 The terrace was in the shaded.
64 The hair was in a styled.
65 The books were in the ordered.
66 The rubbish was in the dumped.
67 The problem was in the documented.
68 The routes were on the mapped.
69 The appointments were on the scheduled.
70 The problem was on the noted.
71 The cactus was in the watered.
72 The picture was in the framed.
73 The flowers were in the bunched.
74 The team was behind the coached.
75 The amendment was in a debated.
76 The chapel was in the designed.
77 The girl was in the dressed.
78 The story was at an ended.
79 The pictures were in the exhibited.
80 The information was in the faxed.
81 The plants were in the potted.
82 The kids were in the grouped.
83 The actor was in an interviewed.
84 The apartment was on a leased.
85 Everyone's qualities were on the listed.
86 The clothes were on the modeled.
87 The student was in a lectured.
88 The horse was in a harnessed.
89 The play was on a staged.
90 The king was on the throned.
91 The papers were in the filed.
92 The glasses were in the packed.
93 The discovery was in the reported.
94 The passenger was in the seated.
95 The man was at the rescued.
96 The brain was on the scanned.
97 The boxes were on the shipped.
98 The car was at a stopped.
99 The plants were in the studied.
100 The students were in a tested.
101 The prisoner was on the tracked.
102 The mouse was in the trapped.
103 The clothes were in the washed.
104 The novel was in the reviewed.
105 The excursion was in the planned.
106 The shirt was in the painted.
107 The song was on the recorded.
108 The meal was in the microwaved.
109 The string was in a knotted.
110 The entrance was behind the blockaded.
111 The items were in the claimed.
112 The robber was in the cornered.
113 The couch was in the stored.
114 The songs were in the debuted.
115 The terms were in the demanded.
116 The field was by the farmed.
117 The park was inside the fenced.
118 The virus was in the emailed.
119 The steak was on the grilled.
120 The tourists were with the guided.

Strong Prediction Level
Expected
121 The elephant was silently filmed.
122 The coat was finely quilted.

123 The terrace was continuously shaded.
124 The hair was elaborately styled.
125 The books were regularly ordered.
126 The rubbish was locally dumped.
127 The problem was eloquently documented.
128 The routes were incorrectly mapped.
129 The appointments were inaccurately scheduled.
130 The problem was politely noted.
131 The cactus was sparsely watered.
132 The picture was tastelessly framed.
133 The flowers were carelessly bunched.
134 The team was excellently coached.
135 The amendment was carefully debated.
136 The chapel was carefully designed.
137 The girl was wrongly dressed.
138 The story was swiftly ended.
139 The pictures were masterfully exhibited.
140 The information was rashly faxed.
141 The plants were incorrectly potted.
142 The kids were smartly grouped.
143 The actor was cleverly interviewed.
144 The apartment was dishonestly leased.
145 Everyone's qualities were systematically listed.
146 The clothes were capably modeled.
147 The student was proficiently lectured.
148 The horse was loosely harnessed.
149 The play was sparsely staged.
150 The king was royally throned.
151 The papers were neatly filed.
152 The glasses were expensively packed.
153 The discovery was solemnly reported.
154 The passenger was safely seated.
155 The man was heroically rescued.
156 The brain was accurately scanned.
157 The boxes were properly shipped.
158 The car was abruptly stopped.
159 The plants were objectively studied.
160 The students were rigorously tested.
161 The prisoner was correctly tracked.
162 The mouse was ingeniously trapped.
163 The clothes were quickly washed.
164 The novel was honestly reviewed.
165 The excursion was stupidly planned.
166 The shirt was brightly painted.
167 The song was comically recorded.
168 The meal was badly microwaved.
169 The string was tightly knotted.
170 The entrance was firmly blockaded.
171 The items were verbally claimed.
172 The robber was quietly cornered.
173 The couch was cheaply stored.
174 The songs were proudly debuted.
175 The terms were anxiously demanded.
176 The field was organically farmed.
177 The park was securely fenced.
178 The virus was anonymously emailed.
179 The steak was excellently grilled.
180 The tourists were excitedly guided.

Strong Prediction Level
Unexpected

181 The elephant was in the silent filmed.
182 The coat was on the fine quilted.
183 The terrace was in the continuous shaded.
184 The hair was in an elaborate styled.
185 The books were in the regular ordered.
186 The rubbish was in the local dumped.
187 The problem was in the eloquent documented.
188 The routes were on the incorrect mapped.
189 The appointments were on the inaccurate scheduled.
190 The problem was on the polite noted.
191 The cactus was in the sparse watered.

192 The picture was in the tasteless framed.
193 The flowers were in the careless bunched.
194 The team was behind the excellent coached.
195 The amendment was in a careful debated.
196 The chapel was in the careful designed.
197 The girl was in the wrong dressed.
198 The story was at a swift ended.
199 The pictures were in the masterful exhibited.
200 The information was in the rash faxed.
201 The plants were in the incorrect potted.
202 The kids were in the smart grouped.
203 The actor was in a clever interviewed.
204 The apartment was on a dishonest leased.
205 Everyone's qualities were on the systematic listed.
206 The clothes were on the capable modeled.
207 The student was in a proficient lectured.
208 The horse was in a loose harnessed.
209 The play was on a sparse staged.
210 The king was on the royal throned.
211 The papers were in the neat filed.
212 The glasses were in the expensive packed.
213 The discovery was in the solemn reported.
214 The passenger was in the safe seated.
215 The man was at the heroic rescued.
216 The brain was on the accurate scanned.
217 The boxes were on the proper shipped.
218 The car was at an abrupt stopped.
219 The plants were in the objective studied.
220 The students were in a rigorous tested.
221 The prisoner was on the correct tracked.
222 The mouse was in the ingenious trapped.
223 The clothes were in the quick washed.
224 The novel was in the honest reviewed.
225 The excursion was in the stupid planned.
226 The shirt was in the bright painted.
227 The song was on the comical recorded.
228 The meal was in the bad microwaved.
229 The string was in a tight knotted.
230 The entrance was behind the firm blockaded.
231 The items were in the verbal claimed.
232 The robber was in the quiet cornered.
233 The couch was in the cheap stored.
234 The songs were in the proud debuted.
235 The terms were in the anxious demanded.
236 The field was by the organic farmed.
237 The park was inside the secure fenced.
238 The virus was in the anonymous emailed.
239 The steak was on the excellent grilled.
240 The tourists were with the excited guided.

Bare Stem Targets

Weak Prediction Level

Expected

241 The elephant was in the film.
242 The coat was on the quilt.
243 The terrace was in the shade.
244 The hair was in a style.
245 The books were in the order.

246 The rubbish was in the dump.
247 The problem was in the document.
248 The routes were on the map.
249 The appointments were on the schedule.
250 The problem was on the note.
251 The cactus was in the water.
252 The picture was in the frame.
253 The flowers were in the bunch.
254 The team was behind the coach.
255 The amendment was in a debate.
256 The chapel was in the design.
257 The girl was in the dress.
258 The story was at an end.
259 The pictures were in the exhibit.
260 The information was in the fax.
261 The plants were in the pot.
262 The kids were in the group.
263 The actor was in an interview.
264 The apartment was on a lease.
265 Everyone's qualities were on the list.
266 The clothes were on the model.
267 The student was in a lecture.
268 The horse was in a harness.
269 The play was on a stage.
270 The king was on the throne.
271 The papers were in the file.
272 The glasses were in the pack.
273 The discovery was in the report.
274 The passenger was in the seat.
275 The man was at the rescue.
276 The brain was on the scan.
277 The boxes were on the ship.
278 The car was at a stop.
279 The plants were in the study.
280 The students were in a test.
281 The prisoner was on the track.
282 The mouse was in the trap.
283 The clothes were in the wash.
284 The novel was in the review.
285 The excursion was in the plan.
286 The shirt was in the paint.
287 The song was on the record.
288 The meal was in the microwave.
289 The string was in a knot.
290 The entrance was behind the blockade.
291 The items were in the claim.
292 The robber was in the corner.
293 The couch was in the store.
294 The songs were in the debut.
295 The terms were in the demand.
296 The field was by the farm.
297 The park was inside the fence.
298 The virus was in the email.
299 The steak was on the grill.
300 The tourists were with the guide.

Weak Prediction Level
Unexpected
301 The elephant was film.
302 The coat was quilt.
303 The terrace was shade.
304 The hair was style.
305 The books were order.
306 The rubbish was dump.
307 The problem was document.
308 The routes were map.
309 The appointments were schedule.
310 The problem was note.
311 The cactus was water.
312 The picture was frame.
313 The flowers were bunch.
314 The team was coach.
315 The amendment was debate.
316 The chapel was design.
317 The girl was dress.
318 The story was end.
319 The pictures were exhibit.
320 The information was fax.
321 The plants were pot.
322 The kids were group.
323 The actor was interview.
324 The apartment was lease.
325 Everyone's qualities were list.
326 The clothes were model.
327 The student was lecture.
328 The horse was harness.
329 The play was stage.
330 The king was throne.
331 The papers were file.

332 The glasses were pack.
333 The discovery was report.
334 The passenger was seat.
335 The man was rescue.
336 The brain was scan.
337 The boxes were ship.
338 The car was stop.
339 The plants were study.
340 The students were test.
341 The prisoner was track.
342 The mouse was trap.
343 The clothes were wash.
344 The novel was review.
345 The excursion was plan.
346 The shirt was paint.
347 The song was record.
348 The meal was microwave.
349 The string was knot.
350 The entrance was blockade.
351 The items were claim.
352 The robber was corner.
353 The couch was store.
354 The songs were debut.
355 The terms were demand.
356 The field was farm.
357 The park was fence.
358 The virus was email.
359 The steak was grill.
360 The tourists were guide.

Strong Prediction Level
Expected

361 The elephant was in the silent film.
362 The coat was on the fine quilt.
363 The terrace was in the continuous shade.
364 The hair was in an elaborate style.
365 The books were in the regular order.
366 The rubbish was in the local dump.
367 The problem was in the eloquent document.
368 The routes were on the incorrect map.
369 The appointments were on the inaccurate schedule.
370 The problem was on the polite note.
371 The cactus was in the sparse water.
372 The picture was in the tasteless frame.
373 The flowers were in the careless bunch.
374 The team was behind the excellent coach.
375 The amendment was in a careful debate.
376 The chapel was in the careful design.
377 The girl was in the wrong dress.
378 The story was at a swift end.
379 The pictures were in the masterful exhibit.
380 The information was in the rash fax.
381 The plants were in the incorrect pot.
382 The kids were in the smart group.
383 The actor was in a clever interview.
384 The apartment was on a dishonest lease.
385 Everyone's qualities were on the systematic list.
386 The clothes were on the capable model.
387 The student was in a proficient lecture.
388 The horse was in a loose harness.
389 The play was on a sparse stage.
390 The king was on the royal throne.
391 The papers were in the neat file.
392 The glasses were in the expensive pack.
393 The discovery was in the solemn report.
394 The passenger was in the safe seat.
395 The man was at the heroic rescue.
396 The brain was on the accurate scan.
397 The boxes were on the proper ship.
398 The car was at an abrupt stop.
399 The plants were in the objective study.
400 The students were in a rigorous test.
401 The prisoner was on the correct track.
402 The mouse was in the ingenious trap.
403 The clothes were in the quick wash.

404 The novel was in the honest review.
405 The excursion was in the stupid plan.
406 The shirt was in the bright paint.
407 The song was on the comical record.
408 The meal was in the bad microwave.
409 The string was in a tight knot.
410 The entrance was behind the firm blockade.
411 The items were in the verbal claim.
412 The robber was in the quiet corner.
413 The couch was in the cheap store.
414 The songs were in the proud debut.
415 The terms were in the anxious demand.
416 The field was by the organic farm.
417 The park was inside the secure fence.
418 The virus was in the anonymous email.
419 The steak was on the excellent grill.
420 The tourists were with the excited guide.

Strong Prediction Level
Unexpected
421 The elephant was silently film.
422 The coat was finely quilt.
423 The terrace was continuously shade.
424 The hair was elaborately style.
425 The books were regularly order.
426 The rubbish was locally dump.
427 The problem was eloquently document.
428 The routes were incorrectly map.
429 The appointments were inaccurately schedule.
430 The problem was politely note.
431 The cactus was sparsely water.
432 The picture was tastelessly frame.
433 The flowers were carelessly bunch.
434 The team was excellently coach.
435 The amendment was carefully debate.
436 The chapel was carefully design.
437 The girl was wrongly dress.
438 The story was swiftly end.
439 The pictures were masterfully exhibit.
440 The information was rashly fax.
441 The plants were incorrectly pot.
442 The kids were smartly group.
443 The actor was cleverly interview.
444 The apartment was dishonestly lease.
445 Everyone's qualities were systematically list.
446 The clothes were capably model.
447 The student was proficiently lecture.
448 The horse was loosely harness.
449 The play was sparsely stage.
450 The king was royally throne.
451 The papers were neatly file.
452 The glasses were expensively pack.
453 The discovery was solemnly report.
454 The passenger was safely seat.
455 The man was heroically rescue.
456 The brain was accurately scan.
457 The boxes were properly ship.
458 The car was abruptly stop.
459 The plants were objectively study.
460 The students were rigorously test.
461 The prisoner was correctly track.
462 The mouse was ingeniously trap.
463 The clothes were quickly wash.
464 The novel was honestly review.
465 The excursion was stupidly plan.
466 The shirt was brightly paint.
467 The song was comically record.
468 The meal was badly microwave.
469 The string was tightly knot.
470 The entrance was firmly blockade.
471 The items were verbally claim.
472 The robber was quietly corner.
473 The couch was cheaply store.
474 The songs were proudly debut.
475 The terms were anxiously demand.
476 The field was organically farm.
477 The park was securely fence.
478 The virus was anonymously email.
479 The steak was excellently grill.
480 The tourists were excitedly guide.

Unambiguous Noun Targets

Weak Prediction Level
Expected

481 The towel was in the sun.
482 The view was from the office.
483 The team was in a league.
484 The order was for the thing.
485 The silence was for a minute.
486 The payment was for the chairman.
487 The car was in the street.
488 The view was of the hill.
489 The bird was behind the window.
490 The owl was in the tree.
491 The ship was in the sea.
492 The protest was against the crisis.
493 The basket was for the fruit.
494 The building was in the city.
495 The promotion was for the spokesman.
496 The meeting was about an idea.
497 The toaster was in the sale.
498 The taxes were for the situation.
499 The boy was in a hotel.
500 The tree was on a property.
501 The shirt was for the son.
502 The bird was on the animal.
503 The water was for the mile.
504 The cheer was for the theatre.
505 The bid was for the dollar.
506 The equipment was for the army.
507 The memory was of the crime.
508 The monster was in the story.
509 The film was about the affair.
510 The plan was for a weekend.
511 The document was about a fact.
512 The gift was for the queen.
513 The criminal was in the area.
514 The song was on the album.
515 The altar was in the church.
516 The house was on the road.
517 The computer was for the secretary.
518 The mother was with the baby.
519 The boot was on the foot.
520 The abuse was for the loss.
521 The photo was of a husband.
522 The advertisement was for a job.
523 The present was for the family.
524 The appointment was for the Sunday.
525 The application was for a college.
526 The shop was in a community.
527 The form was with the agency.
528 The experience was for a moment.
529 The pill was for a body.
530 The conversation was about the goal.
531 The punishment was for the boy.
532 The bill was for a cent.
533 The mud was on the ball.
534 The dress was for the wife.
535 The fence was for the cow.
536 The grief was about the daughter.
537 The resort was on the island.
538 The method was in the example.
539 The word was in a language.
540 The check was for the course.

Weak Prediction Level
Unexpected

541 The towel was sun.
542 The view was office.
543 The team was league.
544 The order was thing.
545 The silence was minute.
546 The payment was chairman.
547 The car was street.
548 The view was hill.
549 The bird was window.
550 The owl was tree.
551 The ship was sea.
552 The protest was crisis.
553 The basket was fruit.
554 The building was city.
555 The promotion was spokesman.
556 The meeting was idea.
557 The toaster was sale.
558 The taxes were situation.
559 The boy was hotel.
560 The tree was property.
561 The shirt was son.
562 The bird was animal.
563 The water was mile.
564 The cheer was theatre.
565 The bid was dollar.
566 The equipment was army.

567 The memory was crime.
568 The monster was story.
569 The film was affair.
570 The plan was weekend.
571 The document was fact.
572 The gift was queen.
573 The criminal was area.
574 The song was album.
575 The altar was church.
576 The house was road.
577 The computer was secretary.
578 The mother was baby.
579 The boot was foot.
580 The abuse was loss.
581 The photo was husband.
582 The advertisement was job.
583 The present was family.
584 The appointment was Sunday.
585 The application was college.
586 The shop was community.
587 The form was agency.
588 The experience was moment.
589 The pill was body.
590 The conversation was goal.
591 The punishment was boy.
592 The bill was cent.
593 The mud was ball.
594 The dress was wife.
595 The fence was cow.
596 The grief was daughter.
597 The resort was island.
598 The method was example.
599 The word was language.
600 The check was course.

Strong Prediction Level
Expected

601 The towel was in the blazing sun.
602 The view was from the amazing office.
603 The team was in an awful league.
604 The order was for the beautiful thing.
605 The silence was for a brief minute.
606 The payment was for the brilliant chairman.
607 The car was in the broad street.
608 The view was of the charming hill.
609 The bird was behind the clean window.
610 The owl was in the high tree.
611 The ship was in the dangerous sea.
612 The protest was against the deep crisis.
613 The basket was for the delicious fruit.
614 The building was in the enormous city.
615 The promotion was for the excellent spokesman.
616 The meeting was about an exciting idea.
617 The toaster was in the exhaustive sale.
618 The taxes were for the expensive situation.
619 The boy was in an extravagant hotel.
620 The tree was on a famous property.
621 The shirt was for the fashionable son.
622 The bird was on the ferocious animal.
623 The water was for the final mile.
624 The cheer was for the great theatre.
625 The bid was for the historical dollar.
626 The equipment was for the hopeless army.
627 The memory was of the horrible crime.
628 The monster was in the horrid story.
629 The film was about the incredible affair.
630 The plan was for an intense weekend.
631 The document was about an interesting fact.
632 The gift was for the kind queen.
633 The criminal was in the local area.
634 The song was on the loud album.
635 The altar was in the magnificent church.
636 The house was on the narrow road.

637 The computer was for the new secretary.
638 The mother was with the noisy baby.
639 The boot was on the painful foot.
640 The abuse was for the pathetic loss.
641 The photo was of a peculiar husband.
642 The advertisement was for a permanent job.
643 The present was for the poor family.
644 The appointment was for the previous Sunday.
645 The application was for a reasonable college.
646 The shop was in a rural community.
647 The form was with the secret agency.
648 The experience was for a short moment.
649 The pill was for a sick body.
650 The conversation was about the significant goal.
651 The punishment was for the sinful boy.
652 The bill was for a single cent.
653 The mud was on the strange ball.
654 The dress was for the stunning wife.
655 The fence was for the stupid cow.
656 The grief was about the terrible daughter.
657 The resort was on the tropical island.
658 The method was in the ultimate example.
659 The word was in an unusual language.
660 The check was for the useful course.

Strong Prediction Level
Unexpected
661 The towel was blazingly sun.
662 The view was amazingly office.
663 The team was awfully league.
664 The order was beautifully thing.
665 The silence was briefly minute.
666 The payment was brilliantly chairman.
667 The car was broadly street.
668 The view was charmingly hill.
669 The bird was cleanly window.
670 The owl was highly tree.
671 The ship was dangerously sea.
672 The protest was deeply crisis.
673 The basket was deliciously fruit.
674 The building was enormously city.
675 The promotion was excellently spokesman.
676 The meeting was excitingly idea.
677 The toaster was exhaustively sale.
678 The taxes were expensively situation.
679 The boy was extravagantly hotel.
680 The tree was famously property.
681 The shirt was fashionably son.
682 The bird was ferociously animal.
683 The water was finally mile.
684 The cheer was greatly theatre.
685 The bid was historically dollar.
686 The equipment was hopelessly army.
687 The memory was horribly crime.
688 The monster was horridly story.
689 The film was incredibly affair.
690 The plan was intensely weekend.
691 The document was interestingly fact.
692 The gift was kindly queen.
693 The criminal was locally area.
694 The song was loudly album.
695 The altar was magnificently church.
696 The house was narrowly road.
697 The computer was newly secretary.
698 The mother was noisily baby.
699 The boot was painfully foot.
700 The abuse was pathetically loss.
701 The photo was peculiarly husband.
702 The advertisement was permanently job.
703 The present was poorly family.
704 The appointment was previously Sunday.
705 The application was reasonably college.
706 The shop was rurally community.
707 The form was secretly agency.
708 The experience was shortly moment.
709 The pill was sickly body.

710 The conversation was significantly goal.
711 The punishment was sinfully boy.
712 The bill was singly cent.
713 The mud was strangely ball.
714 The dress was stunningly wife.
715 The fence was stupidly cow.
716 The grief was terribly daughter.
717 The resort was tropically island.
718 The method was ultimately example.
719 The word was unusually language.
720 The check was usefully course.