

Early association of prosodic focus with *alleen* ‘only’: evidence from eye movements in the visual-world paradigm*

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Abstract

In three visual-world eye tracking studies, we investigated the processing of sentences containing different prosodic focus, such as the Dutch *Ik heb alleen SELDERIJ aan de brandweerman gegeven* ‘I only gave CELERY to the fireman.’ versus *Ik heb alleen selderij aan de BRANDWEERMAN gegeven*. ‘I only gave celery to the FIREMAN.’. Dutch focal stress is like English focal stress. Unlike previous studies (Gennari, Meroni, & Crain, 2005; Paterson et al., 2007), we report eye gaze patterns as they unfold during the utterance with early or late stress. We conclude that focus processing is fast and incremental: eye-gaze patterns start to diverge across the two conditions already as the indirect object is being heard. Our data also indicate that participants anticipate the continuation of the utterance (Altmann & Kamide, 1999; Kamide, Altmann, & Heywood, 2005; Ito & Speer, 2008), providing further evidence for early focus processing, and that focus evaluation is proposition-based.

Keywords: semantics, focus, marked stress, incremental language processing, eye tracking, visual world paradigm, anticipatory eye movement

1 Introduction¹

1.1 Syntax and semantics of ‘only’

Focus is an important information-structuring device. It occurs in every utterance, and it signals to the hearer the most prominent part of the utterance: what is new, or what is contrasted or highlighted. In many languages including English and Dutch, it is marked by prosodic prominence, specifically, with a pitch accent. Focus processing is thus crucial for fast comprehension of utterance meanings in context.

Utterances like (1) are at the heart of the present study. Such sentences involve the operator *only*.

(1) I only gave some tea to the woman.

Presented in writing, (1) is ambiguous; its meaning depends on its accentuation pattern. Thus, in (2a), with pitch accent on the indirect object, *only* associates with the stress-bearing indirect object, *the woman*, while in (2b), with stress on *tea*, *only* associates with the direct object, *some*

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¹ For ease of exposition, we illustrate the characteristics of focal stress and *only* with English examples. Everything we claim here holds for Dutch in the same way.

tea. Brackets indicate syntactic constituency. Stress (and corresponding pitch accent) is indicated throughout by small capitals.

- (2) a. I only [gave some tea to the woman].
 = The only person I gave some tea to was the woman.
 b. I only [gave some tea to the woman].
 = The only thing I gave to the woman was some tea.

Linguistic theories agree that the different interpretations in (2a) and (2b) are an indirect result of the two stress patterns; they arise because the operator *only* is focus-sensitive, meaning that it associates in its interpretation with the focus of the utterance (Rooth, 1992). Focus in turn is determined by main stress and corresponding pitch accent in English (Chomsky, 1971).^{2, 3}

In this study, we are interested in utterances involving a verb-phrase-level *only* and indirect object stress (see 3a) or direct object stress (see 4a). Utterances with *only* can be decomposed into two conjoined propositions (Horn, 1969; Krifka, 1992; Rooth, 1992). The first conjunct, (3b) and (4b) respectively, correspond to the meaning of the proposition without *only*. This is called the ‘presupposition’ or the ‘nonfocal meaning component’. This part of the meaning is shared by the two utterances with indirect object and direct object stress (3b & 4b). The second conjunct is entailed by the original *only*-sentence. It expresses the intuition that the presence of *only* has the effect that the proposition does not hold for any other relevant alternatives. This part of the meaning is called the ‘assertion’ or the ‘focal meaning component’ (3c & 4c).

- (3) a. I only gave some tea to the woman. Indirect Object Stress
 b. I gave some tea to the woman AND
 c. For all x [x ≠ the woman], I did not give some tea to x.
- (4) a. I only gave some tea to the woman. Direct Object Stress
 b. I gave some tea to the woman AND
 c. For all y [y ≠ some tea], I did not give y to the woman.

² Note that (2a) with indirect object stress is in fact ambiguous in itself between the readings indicated in (i) and (ii). This is not important for the present study for two reasons. First, adults strongly prefer the reading in (i), which is the one targeted in this study (Crain & Steedman, 1985). Second, the experiments involve phonetically marked accent on the indirect object, which again makes the reading in (i) to be the preferred one.

(i) The only person I gave some tea to was the woman. = indirect object focus reading
 (ii) The only thing I did was give some tea to the woman. = verb phrase focus reading

³ *Only* cannot associate with just any focus-bearing element; the focus-bearing element must be in its scope syntactically. Utterances like (1) are syntactically distinct from utterances like (i) in the sense that *only* in (1) is a verb-phrase-level adverb, while it directly modifies the subject noun phrase in (i).

(i) Only [the WOMAN] gave a banana to the monkey.

The kind of ambiguity that was present in (1) with *only* modifying the verb phrase, disappears in (i), because the operator *only* takes scope over its c-command domain, which is the verb phrase in (1) and the subject noun phrase in (i). Therefore, (i) can only have the reading exemplified in (iia).

(ii) a. The only person that gave a banana to the monkey was the woman.
 b. *The only event that took place was the woman giving a banana to the monkey.

The focal meaning component is a set of conjoined propositions. In the case of (3c), we can spell it out as in (5a), while (5b) corresponds to the focal meaning component of the direct object stress utterance, (4c).

- (5) a. {I didn't give any tea to the man AND I didn't give any tea to the boy AND I didn't give any tea to ...}
 b. {I didn't give any coffee to the woman AND I didn't give any biscuits to the woman AND I didn't give any ... to the woman}

The exact number of alternatives in each assertion set is determined by the actual context of the utterance. So, for instance, in (5a) we used a context where a man and a boy are present in addition to the woman, while in (5b) we used a context where some coffee and biscuits were available alongside the tea.

This paper investigates how *only*-sentences are processed on-line. Is there an early association between *only* and the prosodically marked focal constituent? What is the earliest point that we can find evidence that prosodic focus information is integrated? Previous work suggests that focus is interpreted in an incremental fashion (Crain, Ni, & Conway, 1994; Gennari, Meroni & Crain, 2005; Paterson et al., 2007). However, none of these studies reported the time course of looks accompanying the comprehension of *only*-sentences involving different prosody. We carried out three visual-world paradigm experiments to investigate these issues, measuring response times and eye movements.

1.2 Previous psycholinguistic work on 'only' and prosodic focus

Eberhard, Spivey-Knowlton, Sedivy and Tanenhaus (1995) report an experiment involving a reference resolution task in a real world setting. The instructions involved either contrastive or neutral stress and there were two different visual contexts. The results showed that in the contrastive stress condition, the latency of eye movements to the target referent was significantly shorter in the setting where contrastive stress was informative than in the uninformative setting. The eye movement latency was also shorter in the contrastive stress condition compared to the unstressed condition. So, contrastive stress facilitated reference resolution (but cf. Arnold, 2008). Note that in this task, reference resolution can also take place without contrastive stress. This is different in our *only*-sentences, where the correct semantics cannot be determined without accentual information.

Another important contribution is the self-paced reading experiment by Crain et al. (1994), extended by Sedivy (2002) (cf. Clifton Jr., Bock, & Radó, 2000; Filik, Paterson, & Liversedge, 2005; Liversedge, Paterson, & Clayes, 2002; Paterson, Liversedge, & Underwood, 1999). This study investigated variants involving *only* of established garden-path sentences:

- (6) a. Businessmen loaned money at low interest were told to record their expenses.
 b. Only businessmen loaned money at low interest were told to record their expenses.

The results indicated that the presence of *only* facilitated a reduced relative reading of *loaned money* and thus helped avert the usual garden path effect. Crain et al. (1994) explain this in terms of their referential theory of parsing: the presence of *only* generates a set of alternatives; the domain of the variable can either be given in context, or it needs to be accommodated. The reduced relative clause provides a partitioning of the set of businessmen (i.e., those that loaned money at low interest versus those that did not) that provides an appropriate domain for the *only*-operator. Sedivy (2002) complemented this result by testing the same sentences in

contexts that provide explicitly the domain on which *only* applies (e.g., by previously introducing businessmen and accountants). As expected, this renders the partitioning of the set of businessmen unwarranted, and the garden-path effect reappears. These results indicate that the contrast set of *only* in sentences like (6b) is created incrementally and that context is taken into account on-line. But in sentences like (6b) *only* always associates with the subject noun phrase in English (see Footnote 3). Thus, although *only*-resolution was incremental in this case, it is still an open question whether it would be incremental in sentences where *only* adjoins to the verb phrase and prosodic stress disambiguates which element the operator associates with.

Paterson et al. (2007) compared reading times for dative sentences (and also double object constructions) where the position of the focus particle varied between a pre-direct object position (e.g., *Jane passed only the salt to her mother*) and a pre-indirect-object position (e.g., *Jane passed the salt to only her mother*). Assuming that participants would associate *only* with the immediately adjacent noun phrase, they used congruous vs. incongruous replacives as continuations to the utterances (such as *but not the pepper / but not her father*) to determine whether participants are sensitive to the placement of the focus particle when creating contrasts. They found that the position of *only* evoked the expected focus effect on-line (see also Filik, Paterson, & Liversedge, 2009). This, however, manifested itself in longer reading times for the postreplacive region, rather than the replacive region itself. Paterson et al. suggested that ‘the delay was attributable to the operation of inferential processes to evaluate the congruency of the supplied contrast with the focus structure of the utterance’ (Paterson et al., 2007, p. 1440). Although these results clearly point towards relatively early integration of focus information in sentences with *only*, there are two aspects of this study that necessitate further investigations. First, by its nature, a reading study cannot reveal participants’ sensitivities to the disambiguating potential of stress placement. Second, the focus effect is measured by participants’ sensitivity to the (in)congruity of the replacive (in actual fact, only in the post-replacive region), and not where it occurs (i.e., at the point of the respective *only*-phrases).

Gennari et al.’s (2005) study gives a more refined picture of the incremental processing of focus in *only*-sentences. They measured response times and overall fixation patterns in the context of a visual setup involving three people: for instance, a woman, a man and a boy. In the picture, the boy had a glass of milk in front of him, the man had a glass of milk and a cup of coffee. The woman, standing in the background, was holding a tray with a milk carton and a teapot. Participants heard utterances either with neutral stress on the indirect object (like 7a) or with marked stress on the direct object (7b) in a picture verification task.

- | | | | | |
|-----|----|--|----------------|-------|
| (7) | a. | The mother only gave some milk to the <i>boy</i> . | Neutral stress | FALSE |
| | b. | The mother only gave some milk to the boy. | Marked stress | TRUE |

Gennari et al. (2005, p. 250) claimed that “marked stress is used immediately by the parser to decide which noun phrase bears the semantic focus and, therefore, which contrast set should be invoked for sentence interpretation”. They reached this conclusion based on their findings that in the Neutral Stress condition, there were fewer correct responses than in the Marked Stress condition (MS: proportion of correct responses 0.84, SD 0.18; NS: 0.70, SD 0.19) and that the response time in the Neutral Stress condition was numerically higher, although this was not statistically significant (MS: 2178ms, SD 859ms; NS: 2465ms, SD 1170ms; Gennari et al., 2005, p. 254). Note, however, that the expected responses diverged in the two conditions (MS: TRUE, NS: FALSE). It is possible that this influenced response times. There was also a qualitative difference between the phonetic salience of neutral and marked stress, which may have boosted participants’ performance in the Marked Stress condition.

Gennari et al. only report the overall proportion of looks on the various entities. They found that the ‘boy’s milk’ draws a significantly higher proportion of looks when it bears

contrastive stress (i.e., MS) compared to when it does not (i.e., NS). They further report that significantly more looks target what they labelled ‘contrast entities’, namely “the man’s coffee (as well as on the set of contrasting elements such as the teapot taken as a whole)” (Gennari et al., 2005, p. 256), in MS than in NS. This is unexpected in the light of the semantics outlined above (see examples 3-5), since neither the man’s coffee nor the woman’s teapot play any role in either the nonfocal or the focal meaning component in the Marked Stress condition. For establishing the truth value of the sentence *The mother only gave some milk to the boy*, only the boy’s possessions are relevant. Unfortunately, Gennari et al. do not report looks to ‘the man’s milk’, which is a crucial object for determining the truth value of the sentence *The mother only gave some milk to the boy*. To sum up, Gennari et al. found that the number of correct responses was higher in the Marked Stress condition. They also found that entities bearing contrastive focus and so-called ‘contrast entities’ are targeted more by eye gaze. However, to fully determine how focal computation in utterances with different stress patterns proceeds in real time, it is crucial to know not only the overall fixation patterns, but also how the eye movements progress as the sentence unfolds.

In this paper we report on three picture verification studies involving *alleen* ‘only’ and early or late stress. In Experiment 1 the divergent expected responses (Early Stress: YES; Late Stress: NO) corresponded to the Gennari et al. study to maximise chances of comparison. We report the first experiment in section 2. In Experiment 2, reported in section 3, the visual stimulus was adapted in such a way that the expected response was YES in both conditions. In Experiment 3, in section 4, the visual stimuli were changed to trigger NO responses in both conditions. Section 5 concludes the paper.

2 Experiment 1

2.1 Methods

2.1.1 Participants. 20 adult participants were recruited from the UiL OTS participant pool, which is largely made up of undergraduate students from Utrecht University. All participants were non-dyslectic native speakers of Dutch. Participants were unaware of the purpose of the experiment, and were paid 5 euros for their participation. The mean age of the participants was 22;8 years (range: 19 – 29); 18 participants were females; 17 were right-handed.

2.1.2 Materials. Sixteen items were constructed in two conditions. Figure 1 shows an example scene for both conditions. There are three persons in the picture, a diver, a doctor and a fireman. They all hold large plates on their left and right side. Some of the plates are empty and some contain a celery or a corn cob. In particular, the diver has a plate with a celery and one with a corn cob, while the fireman has a plate with a celery and an empty plate. The corresponding audio stimuli are in (8). The full items list is in Table 3 in the Appendix.

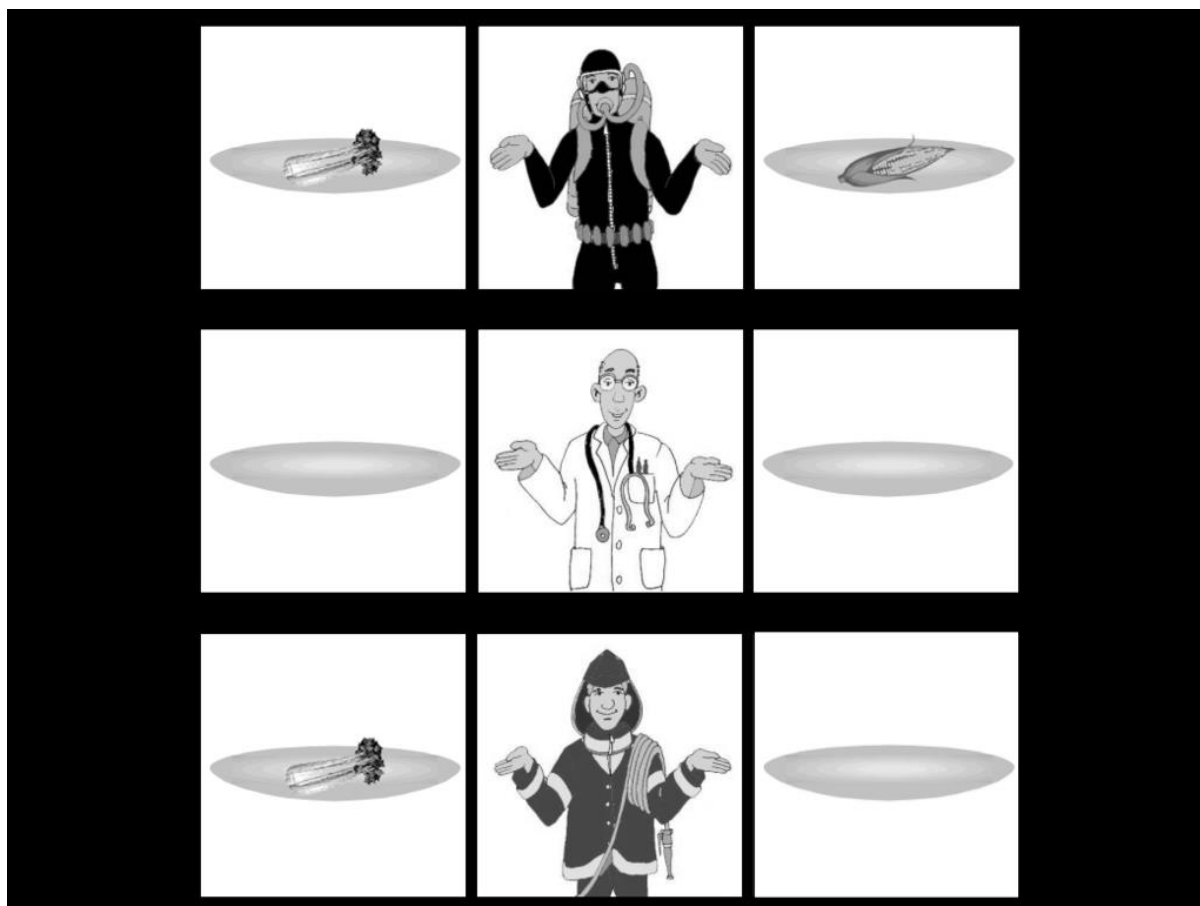


Figure 1. Example of visual stimulus for Experiment 1.

- (8) a. Late Stress condition (LS): *Expected answer: NO*
 Ik heb alleen selderij aan de brandweerman gegeven
I have only celery to the fireman given
 ‘I only gave celery to the fireman.’
- b. Early Stress condition (ES): *Expected answer: YES*
 Ik heb alleen selderij aan de brandweerman gegeven
I have only celery to the fireman given
 ‘I only gave celery to the fireman.’

The visual scenes were designed differently from the more realistic scenes found in the Gennari et al. study. In our 3 x 3 grid design, the distance between any two objects would be identical and would be sufficiently large to be well-suited for eye-tracking evaluation. The pairs of objects in the pictures – ‘corn’ and ‘celery’ in Figure 1 - were chosen to match in size, shape and grey value, to make sure participants shift their gaze to them and not identify them parafoveally while looking at the person in the middle.

For practical reasons, the experiment was performed in Dutch. Dutch prosody is sufficiently similar to English prosody to allow comparison with previous work in English. Both languages mark contrastive focal accent by enhanced duration and H*L pitch accent. Stress placement within an utterance is free to match the focus within the syntactic scope of the semantic operator.

Verbal stimuli were pre-recorded by a female native speaker of Dutch. They were checked for the placement of pitch accents using PRAAT (Boersma & Weenink, 2006). The names of target objects and people that were used in the sentences were matched in length.

They were all at least three syllables long. There were no significant differences between conditions in the overall lengths of the audio stimuli ($t(16) = 0.95$, $p = .925$).

Although the utterances as a whole do not differ in length in the two conditions, there are slight differences in length between conditions in certain auditory segments: the direct object segment was slightly longer when it was stressed (in the Early Stress condition), as was the indirect object segment in the Late Stress condition. These differences cancelled each other out overall, since each condition contains exactly one segment with marked stress.

98 filler items were constructed including various quantifiers (e.g., *niet iedereen* ‘not everybody’). The fillers were balanced for YES/NO expected responses. To match our test items, the fillers either involved early marked stress on the direct object or late marked stress on the indirect object. The fillers included a set of 32 control items involving *alleen*, 16 with early and 16 with late stress, where the expected response was different from the expected response of the corresponding test condition. This would discourage people from developing a strategy relating the position of the accent to the expected response in the test items (i.e., Early Stress=YES; Late Stress=NO). Finally, half of these control items referred to the ‘doctor’ (i.e., to the person in the middle in the visual stimulus), so that participants do not disregard the middle person in the picture in general. A list of the type of fillers used is in Table 1 in the Appendix.

Furthermore, we controlled for potential confounds caused by the spatial location of objects in the picture by varying their positions on the top-down and the left-right axes. The falsifying entity for the Early Stress condition (the ‘diver’s celery’ in Figure 1) appeared in four different positions: in four items it was located in the top left-hand corner of the picture (as in Figure 1); four times it appeared in the top right; four times in the bottom right; and four times in the bottom left.

2.1.3 Procedure. The participants were tested individually in a sound-treated booth. Prior to the experiment, they read an instruction sheet, which included the setting of the experiment. This provided a context in which both utterances with Early stress and utterances with Late stress would be pragmatically felicitous. The participants’ task was to indicate whether the sentence matched the visual scene by pressing a button on a button box.

The experiment was programmed in FEP (Veenker, 2005). Eye movements of the participants’ right eye were recorded with an EyeLink 1000 eye tracker in remote mode using a target sticker to track head movements, at a 500Hz sampling rate. Participants were seated at a distance of 600-650mm from the screen where the visual image was presented; the height of the participants’ chair was adjusted to get an optimal image of the eye.

After the experimenter had ensured a clear image of the pupil, corneal reflection, and target sticker, the experimenter left the participant booth and a 13-point calibration and validation procedure was initiated from the control room. These were repeated until the experimenter was satisfied that they were successful. Every stimulus was preceded by a fixation target in the middle of a blank screen. An automatic drift check was applied as the participant fixated this fixation target and a recalibration initiated if the drift check indicated a drift of more than 20 pixels. Participants were allowed 1000ms to explore the visual scene before the utterance was presented. The whole procedure, including instruction and calibration, took about 20 minutes for each participant.

After successful calibration, the participants were exposed to a practise block of 12 practise items (fillers, 2 of those resembling experimental items), to familiarize them with the task. The practise block was followed by a small pause in which the participants could ask questions about the task (if necessary). After this, the experiment would start. The remaining

118 trials (32 test items, 32 controls, 54 fillers) were presented in two blocks; each block was preceded by a calibration.

All the names of the persons and objects involved in the experimental items were mentioned in the first 16 filler trials (including the practice block), to ensure that the participants had seen them and knew what they were called.

All participants saw all the test items in both conditions. The items and fillers were presented to the participants in a pseudo-randomized order where an experimental item never directly followed another experimental item in any condition; of the (experimental or filler) items involving *alleen* ‘only’, the trials with late stress never followed a trial with early stress or vice versa; and experimental items never followed a filler involving *alleen* ‘only’ with any stress pattern. No more than three trials with the same stress pattern occurred successively.

2.2 Predictions

Applying Rooth’s (1992) semantics to the specific example from our experiment we obtain the following meaning components:

- (9) *Early Stress condition*:
- a. Example in English: I only gave celery to the fireman
 - b. Non-focal meaning: I gave celery to the fireman
 - c. Focal meaning: I did not give anything else to the fireman
- (10) *Late Stress condition*:
- a. Example in English: I only gave celery to the fireman
 - b. Non-focal meaning: I gave celery to the fireman
 - c. Focal meaning: I did not give celery to anyone else

Given the basic linking hypothesis that auditory input guides visual attention, one would expect looks to target the entities mentioned in the utterances, i.e., the fireman and any celery when these words are heard. Looks to these entities could also reflect verification of the non-focal meaning component, which directly corresponds to the utterance without *only*.⁴

As far as looks required for verifying the focal components are concerned, let us take the Early Stress condition first. In order to verify *I didn’t give anything else to the fireman*, looks need not shift away from the fireman and his plates. In contrast, in the Late Stress condition, the focal meaning component is *I didn’t give celery to anyone else*. Verification of this proposition requires looking at the doctor and the diver and their plates. Since in our specific example the doctor’s plates are empty, we may hypothesise that looks would target the diver and his possessions, i.e., the diver, the diver’s celery and the diver’s corn. Since the presence of the diver’s celery in the picture is the reason why the utterance does not match the picture, i.e., this is the falsifying entity, we may expect looks to concentrate on this entity. We may also expect participants to look at the diver’s corn. While the diver’s corn is irrelevant for the focal meaning component, participants may need to look at it to verify that it is not celery.

Concerning the time course of the expected looks as the sentence unfolds, the following predictions hold. The earliest point at which the focal meaning components can be verified is at the point that the indirect object is heard. This is because the sentence final verb *gegeven*

⁴ We remain agnostic as to whether participants would actually verify the truth of the non-focal meaning component. Kim (2008) found that presuppositional meaning is sometimes verified, and sometimes not depending on the task and the saliency of the entities and the grammatical encoding of the elements. Note that if the focal meaning *is* verified, the verification can only take place after the indirect object has been heard.

‘given’ is predictable in our experiment. In the Early Stress condition, marked stress and thus focus can be identified earlier: at the point when the direct object is heard. But note that the focal meaning components cannot yet be computed at this point. When the participant hears *I only gave CELERY to the...* the sentence could end in two different ways. Either the indirect object turns out to be *the fireman*, as in our actual example, in which case the utterance matches the picture, or the indirect object could turn out to be *the diver*, in which case the utterance would not match the picture. (In principle, the utterance could also end with the indirect object *the doctor*, but this would constitute an infelicitous utterance. Since the doctor has no celery in the picture, the non-focal meaning component would not be true.)

To sum up, our hypothesis is that looks will target the fireman and any celeries at the moment they are mentioned, as the audio stimulus guides visual attention. Once participants proceed to verify the focal component, we expect that looks will diverge across the two conditions. In particular, we predict that in the Early Stress condition looks will stay on the fireman and the fireman’s celery, while in the Late Stress condition, looks will shift to the diver, the diver’s celery and to a lesser extent to the diver’s corn. This should take place during the sentence final verb *gegeven* and after the utterance offset. If looks diverge in the predicted way, we would take that to be evidence for early, incremental integration of prosodic focus information.

2.3 Results

For the response data, two experimental trials belonging to the same participant were removed because the answer had already been given before onset of the indirect object. In addition, one filler trial was removed because the answer had been given before sentence onset.

2.3.1 Number of correct responses. The percentage of correct responses for the Late Stress condition was 98%, for the Early Stress condition 99%. The difference was not significant ($F_1(1,19)=2.923$, $p=.104$, $\eta_p^2=.133$; $F_2(1,15)=1.364$, $p=.261$, $\eta_p^2=.083$; $\text{min}F'(1,28)=.93$, $p=.34$). The overall correct response rate for the experiment was 98%.

2.3.2 Response time. The overall mean response time from utterance onset for the Late Stress condition was 3034ms, while it was 3048ms for the Early Stress condition. The difference is not significant ($F_1(1,19)=.027$, $p=.871$; $F_2(1,15)=.045$; $p=.835$; $\text{min}F'(1,33)=.017$, $p=.90$). So, we did not find a significant effect in response time or accuracy across the conditions.

2.3.3 Eye gaze patterns. The coding and analysis was performed as follows. Each picture was divided into 9 Areas of Interest, using the 3 x 3 grid format. See Figure 1. Fixations were assigned to the AoI they occurred on. For ease of reference, we refer to the AoIs with the content of the example stimulus in Figure 1; the data and plots that we give are calculated over all items and participants, so when for instance we say ‘fireman’, we mean ‘the person in the picture who is part of the non-focal proposition in all the items’.

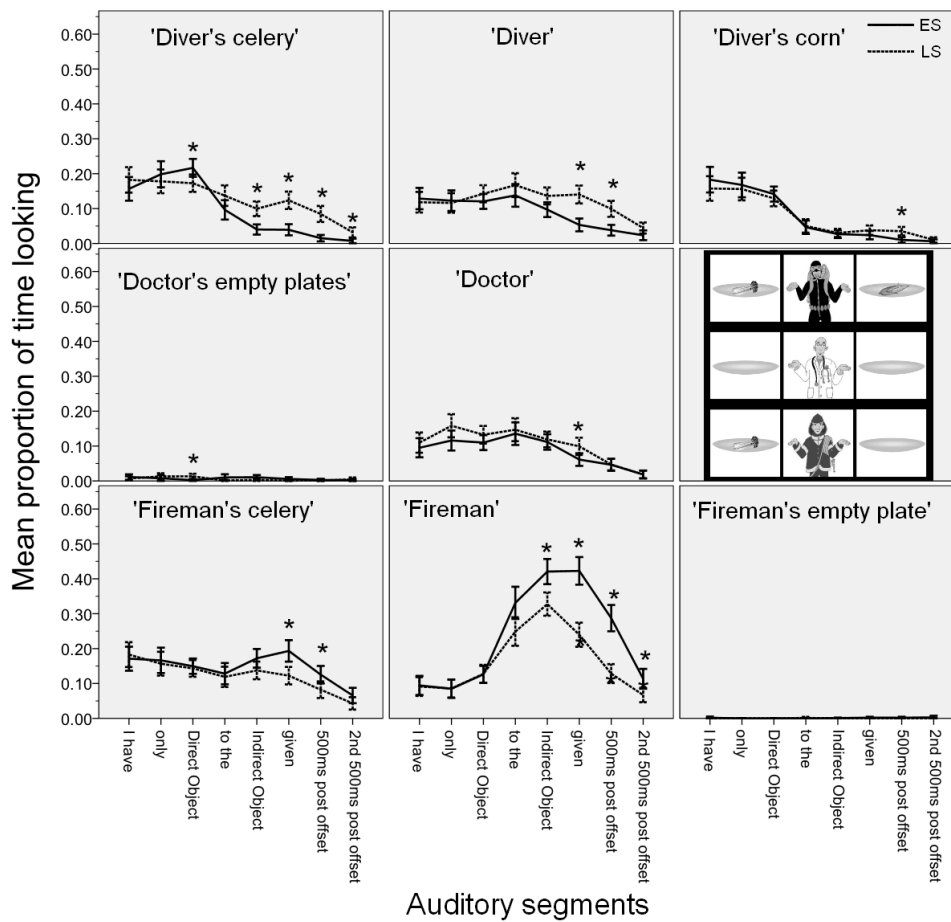
For the fine-grained analysis of eye movements over time, we divided the utterances into relevant audio segments, and determined the onset of each segment using PRAAT. The sentence segments are: *ik heb* ‘I have’; *alleen* ‘only’; *selderij/ selderij* ‘celery/ celery’; *aan de* ‘to the’; *brandweerman/ brandweerman* ‘fireman/ fireman’; *gegeven* ‘given’. For each segment, we analysed the fixation samples falling between 200ms after segment onset, and 200ms after the offset of that auditory segment, to take into account that it takes 200ms to launch a saccade driven by linguistic input (cf. Altmann & Kamide, 2004). The final three segments comprise the interval starting at 200ms after the onset of the verb *gegeven* ‘given’ and ending 1500ms later. This was divided into three segments of identical length. For ease of

reference we call these the auditory segment *gegeven* ‘given’, the ‘first 500ms interval after offset’ and the ‘second 500ms interval after offset’. The auditory segments and their average onsets are in Table 2 in the Appendix.

For each experimental trial, we computed the proportion of time the participant spent fixating each area of interest in each auditory segment. We averaged these proportions over participants and over items, and analysed the differences between conditions using SPSS repeated-measures GLM⁵. For all the eye movement data, we only discuss effects that are significant by participants (F_1) and by items (F_2). We also provide $\min F'$ values (Clark, 1973; Raaijmakers, Schrijnemakers, & Gremmen, 1999). We report mean proportion of fixation time per AoI for the auditory segments and statistical analyses for the factor Condition in tables.

Figure 2 gives the time course of the mean fixation time proportions for the items in the visual stimulus for Experiment 1. The figure contains 8 plots corresponding to the 9 AoIs in our visual scene (the ‘doctor’s empty plates’ are plotted together). In each plot we give the mean proportion of time spent looking at that AoI (e.g., the ‘fireman’ etc.) during each auditory segment in the two conditions (Early Stress vs. Late Stress). The error bars indicate ± 2 standard error. Significant differences between conditions are indicated with stars.

⁵ We tested the data for each of the AoI-auditory segment combination for normality, and found that the data was not normally distributed in the AoI-auditory segment combinations that attract only very few fixations (such as the empty plates, and after utterance offset). We attempted to normalize the data by performing an arcsine transformation on the proportion measures, but since this did not normalize the distributions, we performed the analyses on the proportion data as they are. Non-parametric Wilcoxon signed-rank test were performed post hoc, which gave the same significant results as we report here.



Error Bars: +/- 2 SE

Figure 2. Time course of the mean fixation proportions for the items in the visual stimulus for Experiment 1.

Table 1 gives the mean proportion of time spent fixating each AoI for the auditory segments and analyses of variance between the conditions for Experiment 1 where the differences were statistically significant.

Table 1

Proportions of time spent fixating each of the relevant people and objects in Early Stress (ES) and Late Stress (LS) condition for each auditory segment, and analysis of variance between proportions for Experiment 1

Auditory segment	Person/ Object	prop time	prop time	F1(1,19)	p	η_p^2
		looking ES	looking LS			
DO	Diver's celery	0.22	0.17	6.366	.021	.251
	Doctor's empty plates	0.00	0.01	7.134	.015	.273
IO	Diver's celery	0.04	0.10	15.540	.001	.450
	Fireman	0.42	0.33	14.756	.001	.437
given	Diver	0.05	0.14	29.426	.000	.608
	Diver's celery	0.04	0.12	13.907	.001	.423
	Doctor	0.06	0.10	5.105	.036	.212
	Fireman	0.42	0.24	83.212	.000	.814
	Fireman's celery	0.19	0.12	9.824	.005	.341
0-500ms after offset	Diver	0.04	0.10	14.356	.001	.430
	Diver's celery	0.02	0.08	25.298	.000	.571
	Diver's corn	0.01	0.04	8.803	.008	.317
	Fireman	0.29	0.13	20.688	.000	.521
	Fireman's celery	0.13	0.08	6.946	.016	.268
501-1000ms after offset	Diver's celery	0.01	0.03	6.136	.023	.244
	Fireman	0.11	0.07	4.680	.043	.198

Table 1 Continued.

Auditory segment	Person/ Object	F2(1,15)	p	η_p^2	df2	minF' (1,df2)	p
DO	Diver's celery	6.190	.025	.292	33	3.138	.086
	Doctor's empty plates	8.735	.010	.368	34	3.927	.056
IO	Diver's celery	24.143	.000	.617	34	9.454	.004
	Fireman	12.524	.003	.455	33	6.774	.014
given	Diver	48.663	.000	.764	33	18.338	.000
	Diver's celery	43.559	.000	.744	29	10.541	.003
	Doctor	5.703	.031	.275	34	2.694	.110
	Fireman	51.522	.000	.775	30	31.820	.000
	Fireman's celery	17.345	.001	.536	33	6.272	.017
	0-500ms after offset	Diver	21.019	.000	.584	34	8.530
	Diver's celery	25.221	.000	.627	34	12.630	.001
	Diver's corn	9.183	.008	.380	34	4.494	.041
	Fireman	51.106	.000	.773	31	14.727	.001
	Fireman's celery	7.561	.015	.335	34	3.620	.066
501-1000ms after offset	Diver's celery	14.487	.002	.491	31	4.310	.046
	Fireman	10.507	.005	.412	32	3.238	.081

The targeted AoIs during each auditory segment were as follows. Comparing the two conditions, looking patterns start to systematically diverge during the indirect object. At this audio segment, participants spent a significantly higher proportion of time looking at the 'diver's celery' in the Late Stress condition than in the Early Stress condition, and they also spent a significantly higher proportion of time looking at the 'fireman' in the Early Stress condition than in the Late Stress condition. During the sentence final verb *gegeven* 'given', more time was spent looking at the 'diver', the 'diver's celery' and the 'doctor' in the Late Stress condition than in the Early Stress condition, while more time was spent on looking at the 'fireman' and the 'fireman's celery' in the Early Stress condition compared to the Late Stress condition. Essentially the same pattern of looks continued during the first and second 500ms intervals after the sentence offset. During the first of these segments, there were also significantly more looks to the 'diver's corn' in the Late Stress condition than in the Early Stress condition.

Earlier on in the sentence, a higher proportion of time was spent looking at the ‘diver’s celery’ during the direct object audio segment in the Early Stress condition. During the same audio segment, more time was spent looking at the ‘doctor’s empty plates’ in the Late Stress condition.

2.4 Discussion

2.4.1 Behavioural measures. We found a high number of correct responses in both conditions and no significant difference in the number of correct judgments between the conditions. We speculate that the reason why we got a higher number of correct responses than Gennari et al. (2005) may have been because their experiment involved a more realistic and more complex visual scene, while ours was a stylised 3-by-3 design, and because we provided an overall context story, while participants in the Gennari et al. study heard items without context. Finally, in our experiment there was no phonetic difference between Early and Late Stress, thus no corresponding facilitation effect was expected for Early Stress.

Like Gennari et al., we did not find any significant differences in response times between the conditions. Importantly, this result may have been influenced by the difference in expected responses (ES: YES, LS: NO), as in the original Gennari et al. study. It is possible that it takes longer (or shorter) to find a falsifying entity in a picture than it takes to scan the picture and verify that there is no falsifying entity present. It could also be the case that a negative judgment takes longer (or shorter) than a positive one. In order to control for these factors, we performed Experiment 2, where the expected response in both conditions was YES. In Experiment 3, the expected response was NO in both conditions.

2.4.2 Eye gaze patterns. The most important finding from Experiment 1 is that looks diverged across conditions in the predicted way at the indirect object, at the sentence-final verb *gegeven* ‘given’ and after the utterance offset: participants’ looks target the ‘fireman’ and the ‘fireman’s celery’ more in the Early Stress condition, while looks target the ‘diver’, the ‘diver’s celery’, the ‘doctor’, and somewhat later also the ‘diver’s corn’ in the Late Stress condition. First of all, this provides evidence that participants have computed the focal meaning component by this stage. This is because the observed divergent looks correspond to the participants’ attempt at verifying the focal meaning component of the utterance, which is different in the two conditions (see (9c) and (10c) above).

Second, this finding also constitutes evidence that the verification process corresponds to the semantics associated with the utterance (see Rooth, 1992 and discussion above). In principle, one may imagine that instead of looks corresponding directly to the focal meaning component participants could engage in heuristic strategies. For argument’s sake, one may hypothesise for instance that in order to verify an utterance involving *only* it would be enough to look for the falsifying entity. So, in *I only gave celery to the fireman* looks could target any celery in the picture that does not belong to the fireman. The participant could legitimately reject the utterance without having verified that this offending celery in fact belongs to the ‘diver’. In other words, looks to the falsifying entity are logically necessary for falsification, but looks to the possessor of that falsifying entity are not. The fact that we do find looks targeting the ‘diver’ supports the expectation that sentence verification follows the proposition-based semantics associated with *only*-sentences. Participants do not simply look for an offending object, they seem to verify the relevant proposition of the focal meaning component, *I didn’t give celery to anyone else*, falsified by the proposition *I gave celery to the diver*.

Our expectation that looks follow the logic of the semantically determined focal meaning component is further supported by the relative absence of looks to irrelevant entities. While

participants do look at the (potentially) falsifying entities (the ‘fireman’s celery’ in the Early Stress condition; the ‘diver’s celery’ in the Late Stress condition), they do not target Gennari et al.’s (2005) ‘contrast entities’ (the ‘diver’s corn’) in the Early Stress condition in our experiment. At no auditory segment are looking proportions to this entity higher in the Early Stress condition than in the Late Stress condition.

In addition, there was a brief, but significant difference in looks targeting the ‘diver’s celery’ during the direct object segment (i.e., ES>LS). We take this to be a direct effect of marked stress on the word *selderij* ‘celery’ in the same way as was found by Eberhard et al. (1995). This is a referential look: participants target the image corresponding to the entity just heard. They do so more, if the word bears marked stress. This effect is brief. Note that there is in fact another celery in the visual scene, but there is no statistically significant difference in looks targeting that celery. The significantly smaller proportion of time spent looking at the ‘doctor’s empty plates’ in the Early Stress condition was unexpected. Note though that the looking time proportion was just over 1% in the Late Stress condition, and under 1% in the Early Stress condition.

Overall, we believe that our findings are consistent with early and incremental focus identification and association with *only*, consolidating earlier results by Paterson et al (2007) and Gennari et al. (2005). No facilitation was found for response times. However, this may have been due to the fact that the two conditions had divergent expected responses in Experiment 1. We investigate this issue further in Experiment 2.

As noted, there is a predicted difference between time spent on the ‘fireman’ in the Early and the Late Stress conditions, which is significant from the indirect object segment onwards. We were surprised to see that this effect actually reaches significance in the participant analysis already one auditory segment before, during *aan de* ‘to the’, i.e., before participants have actually heard *de brandweerman* ‘the fireman’ ($F_1(1,19)=6.006$, $p=.024$, $\eta_p^2=.240$; $F_2(1,15)=3.609$, $p=.077$, $\eta_p^2=.194$; $\text{minF}'(1,30)=2.254$, $p=.144$). We interpret the earliness of the effect as the participants’ anticipating the continuation of the utterance to be *de brandweerman* ‘the fireman’ at the point when they have heard *Ik heb alleen SELDERIJ aan de...* ‘I only (gave) CELERY to the...’. We tested this hypothesis in Experiment 3.

3 Experiment 2

3.1 Method

3.1.1 Participants. 20 non-dyslexic native Dutch speakers were recruited from the UiL OTS participant pool. Participants were unaware of the purpose of the experiment, and were paid 5 euros for their participation. The mean age of the participants was 24;3 years (range: 19-46); 19 females and 1 male; 17 participants were right-handed.

3.1.2 Materials. Like in Experiment 1, sixteen items were constructed in two conditions. The auditory stimuli were identical to the ones used in Experiment 1. The visual stimuli of Experiment 1 were changed in such a way that the expected responses were YES in both conditions. In particular, the ‘diver’ had a plate with a ‘corn cob’ and an empty plate, while the ‘fireman’ had a plate with a ‘celery’ and an empty plate. See Figure 3 for an example.

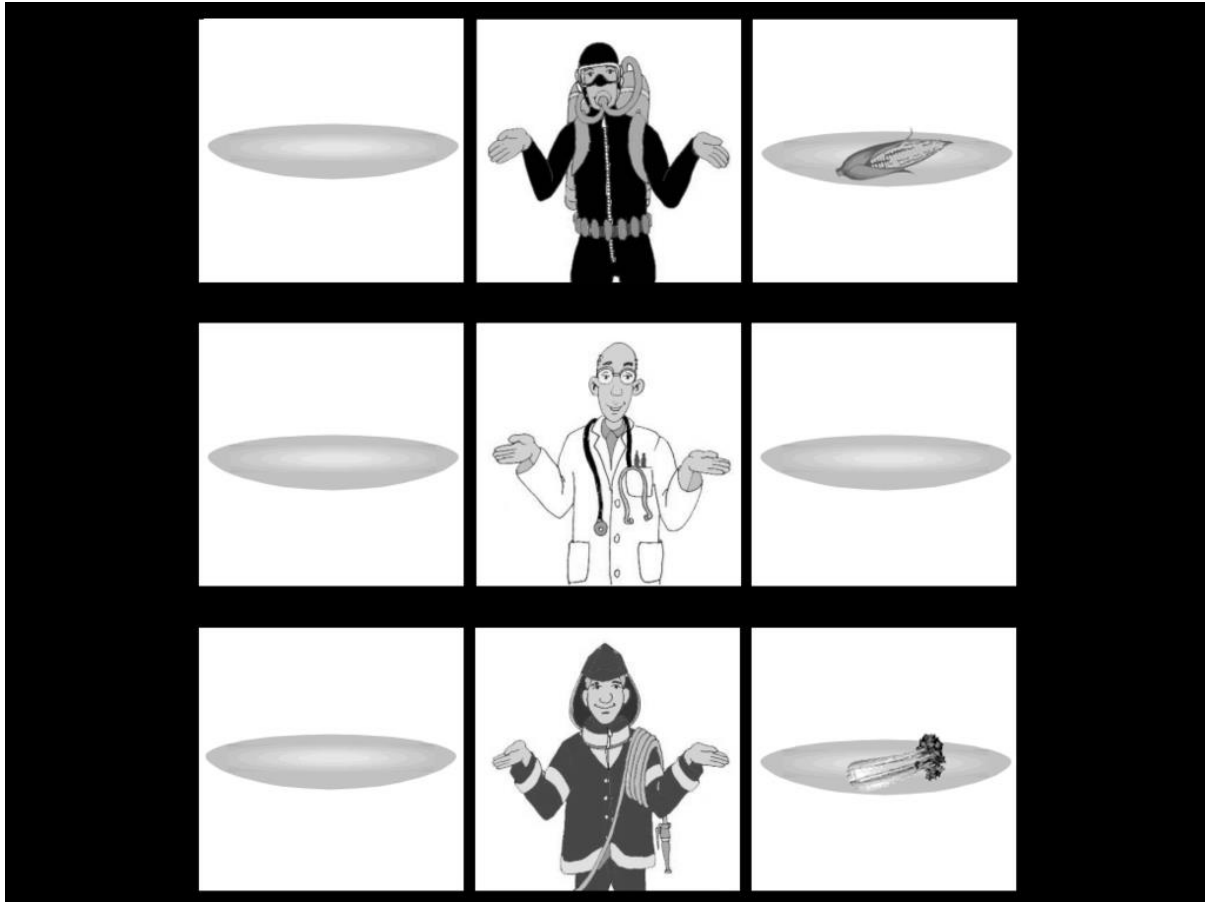


Figure 3. Example of visual stimulus for Experiment 2stimulus.

The 64 unrelated fillers from Experiment 1 were included alongside the test items. In addition 32 controls involving *alleen* ‘only’ were created, 16 with early stress, 16 with late stress, with half of the items referring to the ‘doctor’. The expected response for the controls was NO, to counterbalance the YES bias introduced by the test items.

3.1.3 Procedure. The procedure was identical to that of Experiment 1.

3.1.4 Predictions. We were interested to see if there was a facilitatory effect of early stress resulting in shorter response times in the Early Stress condition compared to the Late Stress condition. Regarding eye movement patterns, our predictions were the same as in Experiment 1 except that since both conditions are true in the pictures, there is no falsifying entity in the picture.

3.2 Results

From the response data, two trials from different experimental participants were removed because they responded before the indirect object segment.

3.2.1 Number of correct responses. The percentage of correct responses for the Late Stress condition was 100%, for the Early Stress condition 99%. The difference was not significant ($F_1(1,19)=.322$, $p=.577$, $\eta_p^2=.017$; $F_2(1,15)=.190$, $p=.669$, $\eta_p^2=.012$; $\text{minF}'(1,30)=.119$, $p=.73$). The overall correct response rate for the experiment as a whole was 98%.

3.2.2 Response time. The overall mean response time from utterance onset for the Late Stress condition was 2843ms, while it was 2868ms for the Early Stress condition. The difference is not significant ($F_1(1,19)=.147$, $p=.706$, $\eta_p^2=.008$; $F_2(1,15)=.225$; $p=.642$, $\eta_p^2=.015$; $\text{minF}'(1,34)=.089$, $p=.77$).

3.3.3 Eye gaze patterns. Coding and analysis was identical to that in Experiment 1. Figure 4 gives the mean proportion of looking time for the items in the visual stimulus for each auditory segment.

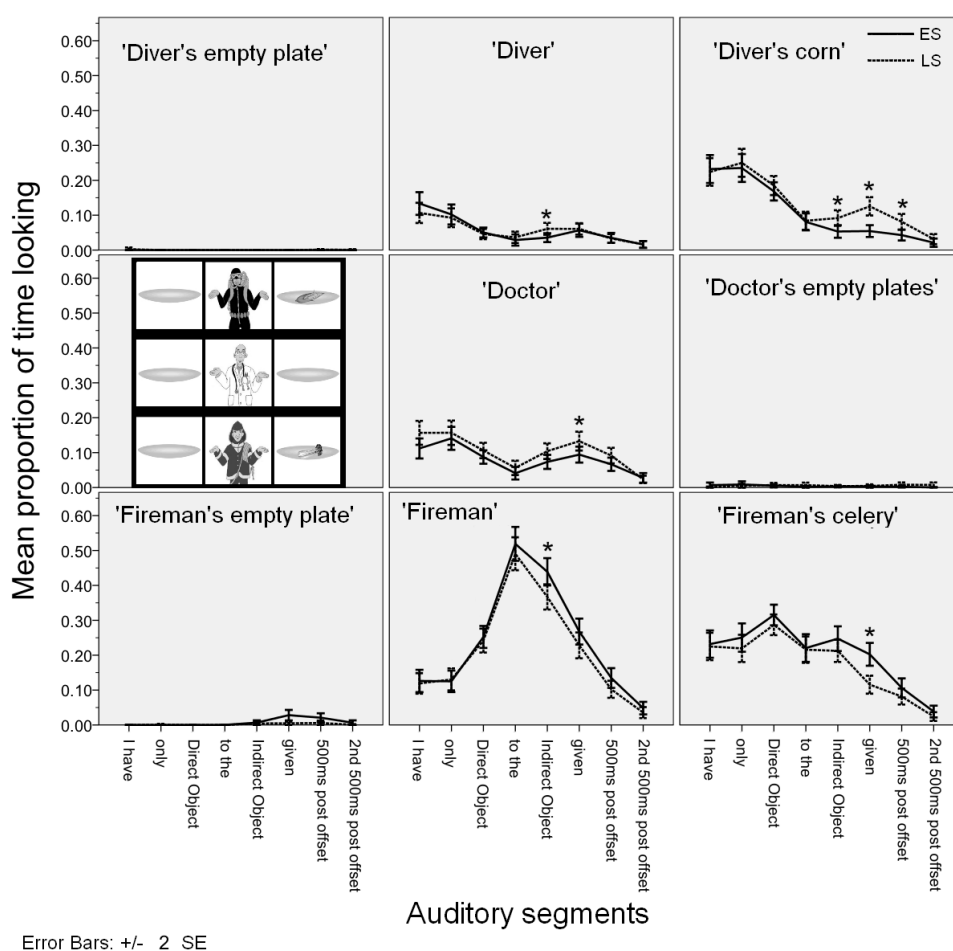


Figure 4. Time course of the mean fixation proportions for the items in the visual stimulus for Experiment 2.

Table 2

Table 2 gives the mean proportion of time spent looking at each AoI for the auditory segments and analyses of variance between the conditions.

Auditory segment	Person/ Object	prop time looking ES	prop time looking LS	F1 (1,19)	p	η_p^2
IO	Diver	0.04	0.06	5.878	.025	.236
	Diver's corn	0.05	0.09	6.777	.017	.263
	Fireman	0.44	0.37	8.070	.010	.298
Given	Diver's corn	0.05	0.13	17.702	.000	.482
	Doctor	0.09	0.13	4.852	.040	.203
	Fireman's celery	0.20	0.12	22.323	.000	.540
0-500ms after offset	Diver's corn	0.04	0.08	9.169	.007	.326

Table 2 Continued

Auditory segment	Person/ Object	F2 (1,15)	p	η_p^2	df2	minF' (1,df2)	p
IO	Diver	6.796	.020	.312	34	3.152	.085
	Diver's corn	6.084	.026	.289	33	3.206	.083
	Fireman	6.181	.025	.292	32	3.500	.071
Given	Diver's corn	16.129	.001	.518	33	8.439	.007
	Doctor	5.233	.037	.259	34	2.518	.122
	Fireman's celery	36.090	.000	.706	34	13.792	.001
0-500ms after offset	Diver's corn	10.071	.006	.402	34	4.799	.035

Looks started systematically diverging across conditions during the indirect object auditory segment, where more time was spent looking at the 'diver' and the 'diver's corn' in the Late Stress condition, and more time was spent looking at the 'fireman' in the Early Stress condition. On the 'diver's corn' the effect continued during the auditory segments corresponding to the verb, and the first 500ms intervals after utterance offset. During the utterance final verb *gegeven* 'given', there was also significantly more time spent targeting the 'doctor' in the Late Stress condition and the 'fireman's celery' in the Early Stress condition.

3.3 Discussion

3.3.1 Behavioural measures. We found a high rate of correct responses for both test conditions. We did not find that Early Stress facilitated verification, as response times did not differ across conditions. See General discussion below for more on this.

3.3.2 *Eye gaze patterns.* The eye gaze patterns were similar to Experiment 1. The looking patterns diverged in the expected way: more looks on the ‘fireman’ and the ‘fireman’s celery’ in the Early Stress condition and on the ‘diver’, the ‘diver’s corn’ and the ‘doctor’ in the Late Stress condition. Perhaps due to the more simple nature of the visual stimulus, the effects are not as sustained over time as they are in Experiment 1.

Let us now turn to our final experiment where the expected responses were NO in both conditions.

4 Experiment 3

4.1 Motivation and predictions

Recall that in Experiment 1, we found that the difference between conditions in the looks targeting the ‘fireman’ was already significant in the participant analysis before the indirect object was heard. Although we did expect more looks targeting the ‘fireman’ in the Early Stress condition, we did not expect this to happen until after the indirect object *de brandweerman* ‘the fireman’ was actually heard. We believe that this (numerical) increase in looks targeting the ‘fireman’ is anticipatory. Our hypothesis is that in a picture verification task, participants employ an unconscious strategy when performing the task: they start out with the assumption that the utterance would match the picture.

Let us explain this in more detail using our actual example. Take the moment when participants hear the first half of the utterance *Ik heb alleen SELDERIJ ...* ‘I have only CELERY ...’ in a setting where the fireman is the only person that has only celery, as in Figure 1 from Experiment 1. At this point, there is only one continuation of this utterance that would make the sentence true in the picture, namely the actual continuation (i.e., ... *de brandweerman gegeven.* ‘...the fireman given.’). Any alternative continuation (e.g., referring to the ‘diver’) would make the sentence false. Given that there is only one way a sentence can be true in a picture and there are many ways it could be false, it would make sense for the listener to adopt a cognitive strategy that assumes that the sentence is true until proven wrong (see also Spelke 1979). In contrast, in the Late Stress condition, when participants hear *Ik heb alleen selderij ...* ‘I have only celery ...’ in a context of a picture where both the fireman and the diver has celery, as in Figure 1, there is no continuation of the utterance that can make the sentence true. So, there is no anticipatory advantage in this condition. This has the effect that participants’ eye gaze already targets the ‘fireman’ in Figure 1 numerically more in the Early Stress condition even before they have heard it (during the *aan de* ‘to the’ auditory segment) compared to the Late Stress condition.⁶ In short, we speculate that in a bi-modal verification task, participants anticipate the continuation of the sentence to be such that it makes the utterance true in the picture.

This is in line with findings of Altmann and Kamide (1999) and Kamide et al. (2005) (see also Ito & Speer, 2008). These authors found that while listening to utterances presented to them in the visual-world paradigm, participants can sometimes anticipate certain semantic properties of forthcoming lexical items based on the lexical items they have already heard. In particular, they tested utterances like *The boy will eat the cake* presented in a visual setting with a boy, a cake, a toy car, a toy train and a ball. They found that participants’ eye movements

⁶ Note that in Experiment 2, the continuation of the sentence with ‘fireman’ matches the picture in both the Early and the Late Stress condition, so our hypothesis predicts the same anticipatory looks targeting the ‘fireman’ in both conditions, with no significant difference between conditions. As can be seen in Figure 4, this expectation seems to be met.

targeted the cake already before the object noun phrase, so when they only heard *The boy will eat....* Altmann and Kamide showed that this was because the verb *eat* places a semantic restriction on the object noun phrase and the cake was the only edible object in the picture.

The goal of Experiment 3 was to investigate our anticipatory look hypothesis.

4.2 Methods

4.2.1 Participants. 23 non-dyslexic native speakers of Dutch were recruited from the UiL OTS participant pool. Data of 3 participants were discarded prior to analysis; one participant did not receive adequate instruction prior to the experiment and reread the instruction sheet repeatedly during the experiment; one experimental run suffered from an unresponsive button box; and one participant was intimately familiar with linguistic theories on stress shift. The remaining participants were unaware of the purpose of the experiment, and were paid 5 euros for their participation. The mean age of the 20 remaining participants was 22;8 years, ranging from 17-27 years; 14 females and 6 males; 18 participants were right-handed.

4.2.2 Materials. Like in Experiments 1 and 2, sixteen items were constructed in two conditions. The auditory stimuli were identical to the ones used in Experiments 1 and 2. The visual stimuli were changed in such a way that the expected responses were NO in both conditions. In particular, the ‘fireman’ had a ‘celery’ and a ‘corn cob’, while the ‘diver’ had a ‘celery’. See Figure 5 for an example.

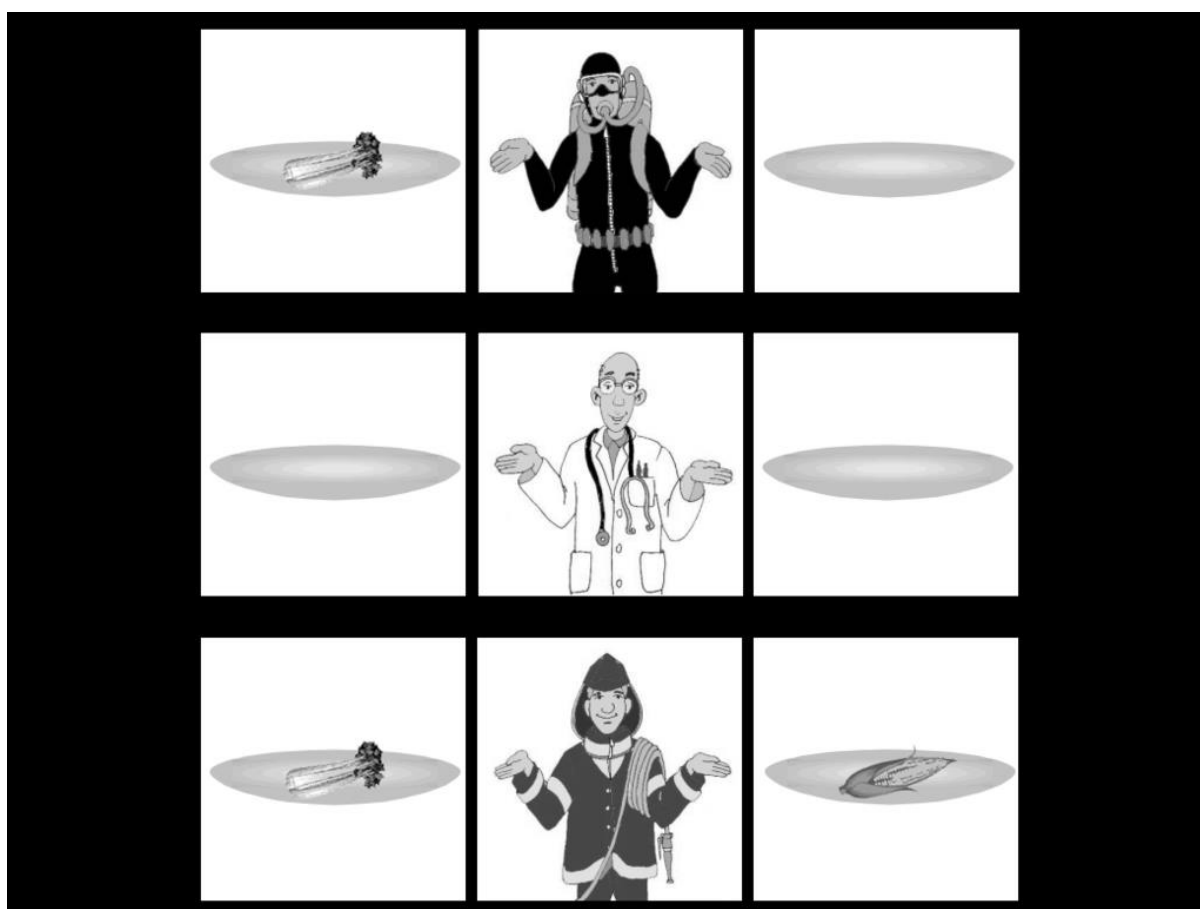


Figure 5. Example of visual stimulus for Experiment 3.

The 64 unrelated fillers from Experiments 1 and 2 were included alongside the test items. In addition 32 controls were created, 16 with early stress, 16 with late stress; half of the items

mentioning the ‘doctor’. The expected response for the controls was YES, to counterbalance the test items.

4.2.3 Procedure. The procedure was identical to that of Experiments 1 and 2.

4.2.4 Predictions. The experiment was designed to test our hypothesis that the early numerical increase in looks targeting the ‘fireman’ in Experiment 1 was anticipatory in the following sense. Participants hear *Ik heb alleen SELDERIJ...* ‘I have only CELERY...’ and anticipate that the utterance will continue in such a way that it matches the picture. In Experiment 3 the visual stimulus was changed in such a way that the only person that has only celery is ‘the diver’. See Figure 5 above. The audio stimuli were identical to that of Experiment 1. Thus, our anticipation hypothesis predicts that participants will look more at ‘the diver’ during the *aan de* ‘to the’ auditory segment in the Early Stress condition. This is because the ‘diver’ has only celery. But once they hear the indirect object *de brandweerman* ‘the fireman’, their looks are expected to shift to the ‘fireman’. So, it is expected that in Experiment 3 the anticipatory strategy ‘tricks’ participants.

In addition, we expected that the predictions of Experiment 1 (and 2) about divergent looks between the two conditions would be replicated, except potentially, due to the potential hindering effect of the anticipatory looks, somewhat delayed.

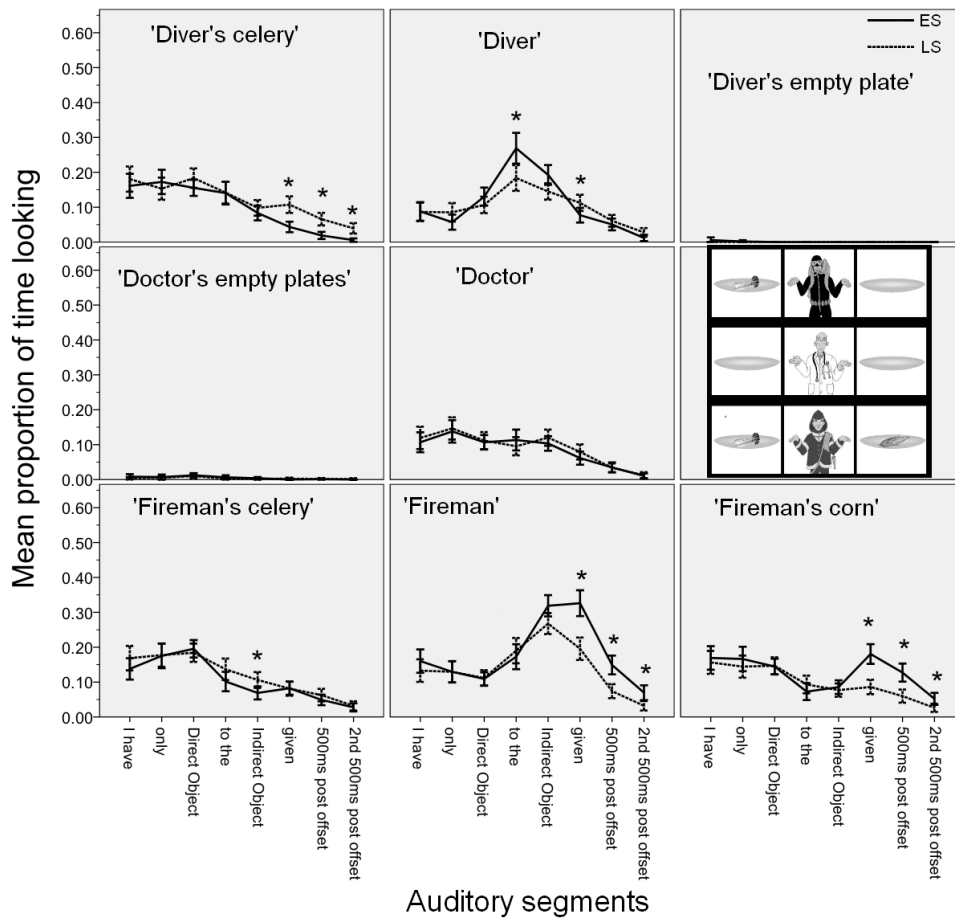
4.3 Results

11 trials (6 experimental) were removed from analysis of the response data because the response had already been given before the onset of the indirect object (6 experimental and 4 filler items) or utterance onset (1 filler).

4.3.1 Number of correct responses. The percentage of correct responses for the Late Stress condition was 97.2%, for the Early Stress condition 98.4%. The difference was not significant ($F_1(1,19)=1.353$, $p=.259$, $\eta_p^2=.066$; $F_2(1,15)=1.184$, $p=.294$, $\eta_p^2=.073$; $\text{min}F'(1,33)=.631$, $p=.433$). The overall correct response rate for Experiment 3 was 97.1%.

4.3.2 Response time. The overall mean response time from utterance onset for the Late Stress condition was 2875ms, while it was 2909ms for the Early Stress condition. The difference is not significant ($F_1(1,19)=.418$, $p=.526$, $\eta_p^2=.022$; $F_2(1,15)=.244$; $p=.628$, $\eta_p^2=.016$; $\text{min}F'(1,30)=.154$, $p=.697$).

4.3.3 Eye gaze patterns. Coding and analysis was identical to that in Experiments 1 and 2. Figure 6 gives the mean proportion of looks for the items in the visual stimulus for each auditory segment.



Error Bars: +/- 2 SE

Figure 6. Time course of the mean fixation proportions for the items in the visual stimulus for Experiment 3.

Table 3 gives the mean proportion of looking time on each AoI for the auditory segments and analyses of variance between the conditions.

Table 3

Proportions of time spent fixating each of the relevant people and objects in Early Stress (ES) and Late Stress (LS) condition for each auditory segment, and analysis of variance between proportions for Experiment 3.

Auditory segment	Person/ Object	prop time looking ES	prop time looking LS	F1 (1,19)	p	η_p^2
To the	Diver	0.27	0.18	7.518	.013	.284
IO	Fireman's celery	0.07	0.11	8.288	.010	.304
Given	Diver	0.08	0.11	6.576	.019	.257
	Diver's celery	0.04	0.11	15.733	.001	.453
	Fireman	0.33	0.20	28.690	.000	.602
	Fireman's corn	0.18	0.09	21.543	.000	.531
0-500ms after offset	Diver's celery	0.02	0.07	19.961	.000	.512
	Fireman	0.15	0.07	13.266	.002	.411
	Fireman's corn	0.13	0.06	16.140	.001	.459
501-1000ms after offset	Diver's celery	0.01	0.04	14.628	.001	.435
	Fireman	0.07	0.03	5.289	.033	.218
	Fireman's corn	0.05	0.03	5.300	.021	.249

Table 3 Continued

Auditory segment	Person/ Object	F2 (1,15)	p	η_p^2	df2	minF' (1,df2)	p
To the	Diver	16.519	.001	0.524	32	5.167	.030
IO	Fireman's celery	5.316	.036	0.262	31	3.239	.082
Given	Diver	9.188	.008	0.380	34	3.833	.059
	Diver's celery	36.636	.000	0.710	31	11.006	.002
	Fireman	17.601	.001	0.540	30	10.909	.002
	Fireman's corn	19.365	.001	0.564	33	10.198	.003
0-500ms after offset	Diver's celery	22.901	.000	0.604	34	10.665	.002
	Fireman	14.691	.002	0.495	34	6.971	.012
	Fireman's corn	14.915	.002	0.499	33	7.752	.009
501-1000ms after offset	Diver's celery	12.077	.003	0.446	33	6.615	.015
	Fireman	7.778	.014	0.341	34	3.148	.085
	Fireman's corn	7.676	.014	0.338	34	3.135	.086

Looking at differences between the conditions, we found that a significantly higher proportion of time was spent looking at the 'diver' in the Early Stress condition during *aan de* 'to the'. A significantly higher proportion of time was spent looking at the 'fireman' and the 'fireman's corn' during *gegeven* 'given' and the two subsequent 500ms intervals after offset in the Early Stress condition. There was also a significantly higher proportion of time spent looking at the 'fireman's celery' in the Late Stress condition during the indirect object auditory segment. In addition, significantly more time was spent looking at the 'diver' and the 'diver's celery' in the Late Stress condition during the verb *gegeven* 'given'. For the 'diver's celery', this effect persisted during the two 500ms intervals after utterance offset.

4.4 Discussion of Experiment 3 and general discussion

4.4.1 Behavioural measures. Overall, in none of the experiments was there any facilitatory effect of early stress in terms of shorter response times or a higher accuracy rate for the Early Stress condition. We think that this is because even though participants may use early stress to anticipate the continuation of the utterance, they still have to wait until the sentence is actually finished until they can establish the meaning components based on the actual continuation. So, overall, even if accentual information is presented earlier in the Early Stress condition, leading to early identification of focus, this cannot facilitate computation of the meaning components associated with *only* overall, due to the propositional nature of these meaning components. The verification task is complex and involves several inferential steps. By the time participants perform this, the potential advantage of early stress disappears.

4.4.2 Eye tracking patterns. The visual stimulus in Experiment 3 was designed to test our hypothesis that participants anticipate the continuation of the utterance when they hear *Ik heb alleen SELDERIJ ...* ‘I have only CELERY ...’ in the Early Stress condition. If the sentence would continue with *de duiker* ‘the diver’, it would match the picture; and in the Early Stress condition we do indeed find more time is being spent looking at the ‘diver’ than in the Late Stress condition, right before the indirect object is heard. So, we can confirm our anticipation hypothesis.

But, the actual continuation of the utterance turns out to be *de brandweerman* ‘the fireman’. So, the utterance ends up being false. As predicted (and already found in Experiments 1 and 2), once the indirect object has been heard, looks shift to the ‘fireman’ and his possessions in the Early Stress condition and to the ‘diver’ and his celery in the Late Stress condition. The effects are somewhat delayed compared to Experiment 1, presumably due to the hindering effect of the anticipation strategy. In particular, during the sentence final verb, there are more looks targeting the ‘fireman’ and the ‘fireman’s corn’ in the Early Stress condition and more looks targeting the ‘diver’ and the ‘diver’s celery’ in the Late Stress condition. On the ‘fireman’, the ‘fireman’s celery’ and the ‘diver’s celery’, these effects continue throughout the first and second 500ms intervals after utterance offset

In the Late Stress condition, we did not expect to find any particular anticipatory looks, since there is no possible continuation that would make *Ik heb alleen selderij ...* ‘I have only celery ...’, without marked stress on the direct object, true in the picture. One indication that anticipatory looks may be going on in the Late Stress condition, though, may be that during the indirect object auditory segment, we find more looks on the ‘fireman’s celery’, which would be the falsifying object if the sentence would continue with ‘diver’. The ‘fireman’s celery’ is of course also part of the non-focal meaning of the sentence, so it is difficult to interpret this effect.

Overall, we found that sentence verification starts early. In fact, perhaps unexpectedly, it starts already before the whole utterance is heard. Participants anticipate the continuation of the utterance assuming that the utterance will turn out to match the picture. Crucially, prosodic focus on the direct object was found to be relevant for guiding anticipatory looks already at the next sound segment, during *aan de* ‘to the’ (see Experiment 3). This gives evidence of incremental prosodic focus processing.

In all three experiments, we found that utterance verification proceeds according to the semantics of *only*-sentences (Rooth, 1992). Participants’ looks diverge already during the sentence final verb *gegeven* ‘given’ in the two conditions, as they verify the different focal meaning components associated with Early and Late Stress. So, we found evidence that participants’ looks not only target the falsifying entity in the picture, but rather the falsifying proposition was established. This provides support for the psychological reality of proposition-based semantics for prosodic focus association with *only*.

5 Conclusion

Our results show incremental focus processing and thus fall in line with earlier results (Gennari et al., 2005; Paterson et al., 2007). Investigating the time course of looks accompanying the computation of *only*-sentences allowed us to tap into how participants process focal differences marked prosodically. We found that people process prosodic focus incrementally: there is evidence of participants verifying the focal meaning component already during the indirect object. We also found that participants make anticipatory looks in this picture verification task taking into account the prosodic focus of the utterance, providing further indirect evidence of

incremental focus computation at the earliest possible point, at the point where the direct object with or without prosodic focus is heard.

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Appendix

Table 1: Test items, fillers and expected answers

Conditions	Example	Number of items and expected response
Late Stress	Ik heb alleen worteltjes aan de Eskimo gegeven. I have only carrots to the Eskimo given 'I only gave carrots to the Eskimo.'	16 items Experiment 1: NO Experiment 2: YES Experiment 3: NO
Early Stress	Ik heb alleen worteltjes aan de Eskimo gegeven. I have only carrots to the Eskimo given 'I only gave carrots to the Eskimo.'	16 items Experiment 1: YES Experiment 2: YES Experiment 3: NO
Control with Early Stress 1	Ik heb alleen komkommer aan de dokter gegeven. I have only cucumber to the doctor given 'I only gave cucumber to the doctor.'	8 items Experiment 1: NO Experiment 2: NO Experiment 3: YES
Control with Early Stress 2	Ik heb alleen aardbeien aan de politieman gegeven. I have only strawberries to the police officer given 'I only gave strawberries to the police officer.'	8 items Experiment 1: NO Experiment 2: NO Experiment 3: YES
Control with Late Stress 1	Ik heb alleen sla aan de indiaan gegeven. I have only lettuce to the Indian given 'I only gave lettuce to the Indian.'	8 items Experiment 1: YES Experiment 2: NO Experiment 3: YES
Control with Late Stress 2	Ik heb alleen champagne aan de koningin gegeven. I have only champagne to the queen given 'I only gave champagne to the queen.'	8 items Experiment 1: YES Experiment 2: NO Experiment 3: YES
ENDE_filler	De matroos en de astronaut hebben aardappels. 'The sailor and the astronaut have potatoes.'	16 items; 8 'YES', 8 'NO'
GEEN_filler	Ik heb geen sla aan de clown gegeven. I have no lettuce to the clown given 'I didn't give any lettuce to the clown.'	16 items; 8 'YES', 8 'NO'
NIED_filler	Ik heb niet aan iedereen broccoli gegeven. I have not to everyone broccoli given	16 items; 8 'YES', 8 'NO'

	‘I didn’t give broccoli to everyone.’	
NIEM_filler	Niemand heeft groene kool gekregen. Noone has green cabbage got ‘Noone got green cabbage.’	16 items; 8 ‘YES’, 8 ‘NO’

Table 2: Durations of auditory segments in milliseconds

Segment	Average Duration	Longest Duration	Shortest Duration
Ik heb <i>I have</i>	268	307	168
Alleen <i>Only</i>	279	318	226
Direct Object (DO)	600	765	400
aan de <i>to the</i>	257	319	173
Indirect Object (IO)	548	677	354
Gegeven <i>given</i>	608	693	544

Table 3: Item list

Late stress condition:

- 1 Ik heb alleen worteltjes aan de ESKIMO gegeven.
I only gave carrots to the Eskimo.
- 2 Ik heb alleen groene kool aan de ESKIMO gegeven.
I only gave green cabbage to the Eskimo.
- 3 Ik heb alleen broccoli aan de AFRIKAAN gegeven.
I only gave broccoli to the African guy.
- 4 Ik heb alleen appeltaart aan de BRANDWEERMAN gegeven.
I only gave apple pie to the fireman.
- 5 Ik heb alleen paprika aan het JONGETJE gegeven.
I only gave peppers to the little boy.
- 6 Ik heb alleen champignons aan het JONGETJE gegeven.
I only gave mushrooms to the little boy.
- 7 Ik heb alleen selderij aan de BRANDWEERMAN gegeven.
I only gave celery to the fireman.
- 8 Ik heb alleen radijsjes aan de ASTRONAUT gegeven.
I only gave raddishes to the astronaut.
- 9 Ik heb alleen perziken aan de KONINGIN gegeven.
I only gave peaches to the queen.
- 10 Ik heb alleen champagne aan de KONINGIN gegeven.
I only gave champagne to the queen.
- 11 Ik heb alleen bananen aan de ASTRONAUT gegeven.
I only gave bananas to the astronaut.
- 12 Ik heb alleen limonade aan de BRANDWEERMAN gegeven.
I only gave lemonade to the fireman.
- 13 Ik heb alleen aardbeien aan de POLITIEMAN gegeven.
I only gave strawberries to the policeman.

- 14 Ik heb alleen ananas aan de POLITIEMAN gegeven.
I only gave pineapple to the policeman.
- 15 Ik heb alleen sinaasappel aan de AFRIKAAN gegeven.
I only gave oranges to the African guy.
- 16 Ik heb alleen cappuccino aan de ASTRONAUT gegeven.
I only gave a cappuccino to the astronaut.

Early stress condition:

- 1 Ik heb alleen WORTELJES aan de eskimo gegeven.
I only gave carrots to the Eskimo.
- 2 Ik heb alleen GROENE KOOL aan de eskimo gegeven.
I only gave green cabbage to the Eskimo.
- 3 Ik heb alleen BROCCOLI aan de afrikaan gegeven.
I only gave broccoli to the African guy.
- 4 Ik heb alleen APPELTAART aan de brandweerman gegeven.
I only gave apple pie to the fireman.
- 5 Ik heb alleen PAPRIKA aan het jongetje gegeven.
I only gave peppers to the little boy.
- 6 Ik heb alleen CHAMPIGNONS aan het jongetje gegeven.
I only gave mushrooms to the little boy.
- 7 Ik heb alleen SELDERIJ aan de brandweerman gegeven.
I only gave celery to the fireman.
- 8 Ik heb alleen RADIJSJES aan de astronaut gegeven.
I only gave radishes to the astronaut.
- 9 Ik heb alleen PERZIKEN aan de koningin gegeven.
I only gave peaches to the queen.
- 10 Ik heb alleen CHAMPAGNE aan de koningin gegeven.
I only gave champagne to the queen.
- 11 Ik heb alleen BANANEN aan de astronaut gegeven.
I only gave bananas to the astronaut.
- 12 Ik heb alleen LIMONADE aan de brandweerman gegeven.
I only gave lemonade to the fireman.
- 13 Ik heb alleen AARDBEIEN aan de politieman gegeven.
I only gave strawberries to the policeman.
- 14 Ik heb alleen ANANAS aan de politieman gegeven.
I only gave pineapple to the policeman.
- 15 Ik heb alleen SINAASAPPEL aan de afrikaan gegeven.
I only gave oranges to the African guy.
- 16 Ik heb alleen CAPPUCCHINO aan de astronaut gegeven.
I only gave a cappuccino to the astronaut.