



Published in final edited form as:

Cognition. 2009 July ; 112(1): 55–80. doi:10.1016/j.cognition.2009.03.010.

Structural and semantic constraints on the resolution of pronouns and reflexives

Elsi Kaiser,

Department of Linguistics, University of Southern California, Los Angeles, CA 90089

Jeffrey T. Runner,

Department of Linguistics, University of Rochester, Rochester, NY 14627

Rachel S. Sussman, and

Department of Psychology, University of Wisconsin-Madison, Madison, WI 53706

Michael K. Tanenhaus

Department of Brain and Cognitive Sciences, University of Rochester, Rochester, NY 14627

Abstract

We present four experiments on the interpretation of pronouns and reflexives in picture noun phrases with and without possessors (e.g. *Andrew's picture of him/himself*, *the picture of him/himself*). The experiments (two off-line studies and two visual-world eye-tracking experiments) investigate how syntactic and semantic factors guide the interpretation of pronouns and reflexives and how different kinds of information are integrated during real-time reference resolution. The results show that the interpretation of pronouns and reflexives in picture NP constructions is sensitive not only to purely structural information, as is commonly assumed in syntactically-oriented theories of anaphor resolution, but also to semantic information (see Kuno, 1987; Tenny, 2003). Moreover, the results show that pronouns and reflexives differ in the degree of sensitivity they exhibit to different kinds of information. This finding indicates that the form-specific multiple-constraints approach (see Kaiser, 2003; Kaiser, 2005; Kaiser & Trueswell, 2008; Brown-Schmidt, Byron & Tanenhaus, 2005), which states that referential forms can exhibit asymmetrical sensitivities to the different constraints guiding reference resolution, also applies in the within-sentence domain.

Introduction

Successful language comprehension requires a reader or listener to rapidly interpret referential forms such as *it*, *him* and *herself*. Although these forms are extremely frequent, they are referentially underspecified. A form such as *her* can, in principle, refer to any human feminine singular referent—in other words, to any member of a very large set. As a consequence, successful comprehension of these forms requires a narrowing of the domain of potential referents. This raises the question of what constrains the referential domains for different referring forms: how do comprehenders know which entities to exclude, and which to treat as possible referents?

Send correspondence to: Elsi Kaiser, Department of Linguistics, 3601 Watt Way, GFS 301, University of Southern California, Los Angeles, CA 90089-1693, USA, Email: elsi.kaiser@usc.edu, phone: (213) 821-4151, fax: (213) 740-9306.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

For some referential forms, it has been argued that structural/syntactic information determines the choice of antecedent. For example, it is commonly assumed that the choice of referent for a reflexive like *herself* is specified by the structural configuration of the sentence (e.g. Chomsky, 1981 and many others). In contrast, for many other cases of reference resolution (especially when the referential form and its referent are in different clauses) non-structural information appears to play a crucial role. For example, many researchers have argued that semantic information influences the interpretation of pronouns with cross-clausal antecedents (e.g., see Garvey and Caramazza, 1974; McDonald & MacWhinney, 1995, Stewart et al., 2000; Koornneef & Van Berkum, 2006; Stevenson, Crawley & Kleinman, 1994; Arnold, 2001, for research on effects of implicit causality and thematic roles). Stevenson and colleagues (Stevenson et al., 1994) found that the thematic role of an entity (e.g., agent, goal, source, experiencer) influences its likelihood of being the antecedent for a subsequent pronoun (see also Arnold, 2001). In sum, existing work suggests that referential expressions tend to fall into two groups: Some are interpreted in accordance with structural principles, whereas others rely more on non-structural factors such as semantic role as well as other discourse factors (e.g., Kehler, 2002; Wolf et al., 2004).

Even though many occurrences of referentially underspecified forms fall into one of these two groups, we argue that regarding structural information and discourse/semantic information as separate aspects of reference resolution is an oversimplification. We build on and extend what we call the form-specific multiple-constraints framework, first introduced in Kaiser (2003; see also Kaiser, 2005; Kaiser & Trueswell, 2008; Brown-Schmidt, Byron & Tanenhaus, 2005). Like existing multiple-constraints approaches to reference resolution (e.g., Arnold, 1998; Ariel, 1990), the form-specific approach assumes that anaphor resolution is not determined by a single constraint but rather is the result of the interaction of multiple constraints. Crucially, the form-specific approach allows for the multiple constraints that guide reference resolution to be weighted differently for different referential forms. The approach was originally formulated on the basis of data from Finnish showing that pronouns and demonstratives, both of which can be used to refer to human antecedents mentioned in a preceding clause, do not show the same level of sensitivity to the antecedent's syntactic role and linear position (Kaiser, 2003; Kaiser & Trueswell, 2008). The asymmetrical sensitivities indicate that not all anaphoric forms are equally sensitive to the same kinds of information. This finding is also supported by cross-clausal data from Estonian (Kaiser & Hiietam, 2004; Kaiser, 2003; Kaiser & Vihman, 2006), Dutch (Kaiser & Trueswell, 2004) and English (Brown-Schmidt et al., 2005).

Most of the previous studies that found different anaphoric forms exhibiting asymmetrical sensitivities focused on cross-clausal anaphora, for which it is not surprising that non-structural (discourse/semantic) factors are relevant. One of our main aims here is to investigate whether the form-specific multiple-constraints approach also applies in the domain of within-clause reference resolution. In the clause-internal domain, many anaphor-antecedent dependencies are in structural configurations that are considered to be constrained by structural factors (e.g. the large body of work on Chomskyan Binding Theory, though see Gordon & Hendrick 1997), and the role of non-structural factors has received less attention than in the cross-clausal domain. Moreover, although existing work within the form-specific framework indicates that anaphoric forms differ in their sensitivity to different kinds of information, it does not make specific predictions regarding the range of variation that will occur for different anaphoric forms within and across languages. The ultimate goal of the form-specific approach is to develop detailed testable hypotheses about the conditions of use and weightings of constraints for each anaphoric form. This will require more research on different anaphoric forms in different languages. This paper aims to contribute to that goal.

We present four experiments investigating the processing of pronouns and reflexives in picture noun phrases (PNPs) with and without possessors (e.g. *Andrew's picture of him/himself, the*

picture of him/himself). The picture NP construction is widely acknowledged to represent a stumbling block for existing structure-driven approaches of within-clause reference resolution. Since this construction has been hypothesized to be influenced by both syntactic factors and discourse/semantic factors (see for example Kuno, 1987; Pollard & Sag, 1992; Reinhart & Reuland, 1993; Tenny, 1996; Tenny, 2003), it is a useful tool for investigating how structural and non-structural information interact during within-sentence anaphor resolution. When discussing the effects of non-structural factors, we will refer to them as ‘semantic factors’ for ease of exposition. However, we leave open the question of whether the source/perceiver manipulation (described below) is best regarded as a semantic, thematic role manipulation or a discourse-level/pragmatic manipulation (e.g., having to do with perspective-taking).

We demonstrate that in picture NPs, pronouns and reflexives differ in the degree of sensitivity they exhibit to structural and non-structural information, and that these differences emerge very early during processing. Our findings are compatible with the form-specific multiple-constraints framework, but not with multiple-constraints approaches in which the relative weights of structural and semantic constraints are the same for reflexives as for pronouns, nor with approaches that propose an initial structure-only stage of processing.

Background

The picture NP (PNP) construction has long been acknowledged to be problematic for standard structural accounts of within-clause reference resolution, such as classic Chomskyan Binding Theory (e.g., Chomsky, 1981) because picture NPs do not exhibit the complementary distribution of pronouns and reflexives that is the cornerstone of most of these approaches. As a result, some researchers have suggested that reflexives and pronouns in PNPs are exempt from structural principles, such as Binding Theory, and are resolved in accordance with semantic and pragmatic constraints (e.g. Pollard & Sag, 1992; see also Reinhart & Reuland, 1993; Safir, 1999 for related claims).

Despite the acknowledged shortcomings of structural accounts in general and Binding Theory in particular, we begin this section with a brief overview of the predictions that Binding Theory makes regarding pronouns and reflexives in PNPs. This is partly for historical reasons: Structurally-based accounts of reference resolution have had an enormous impact on syntactic research and there exists a large body of work on PNP constructions within Binding Theory that ought to be acknowledged. Furthermore, as will become clear later, even though structural constraints may not be *sufficient* to explain the referential properties of pronouns and reflexives in PNPs, our results indicate that they are nevertheless *necessary*.

To understand the predictions that Binding Theory makes for PNPs, we first consider sentences without PNPs. In most contexts, pronouns are in complementary distribution with reflexives. As illustrated in (1), the pronoun *her* cannot refer to Julianna, the subject of the clause containing the pronoun, whereas the reflexive *herself* must be interpreted as referring to the subject. (Subscripted indices are used to mark coreference, with a star * indicating that coreference with the indexed referent is not acceptable.)

(1) Julie_i said that Julianna_j tickled her_{i/*j}/herself_{*i/j}.

Principles A and B of traditional Binding Theory provide a structural account of this complementarity. According to Principle A, a reflexive must be bound in a local domain. In other words, the noun phrase that a reflexive refers to (is “bound by”) – its antecedent – must be sufficiently close to the reflexive itself (in this case, in the same clause) and must stand in a particular relation of structural superiority to the reflexive. Thus, in (1), the reflexive *herself* can only refer to the subject of the same clause, namely Julianna. Principle B, conversely, states that a pronoun must be free in a local domain, i.e., its antecedent cannot be

in a position of structural superiority in the local domain. Thus, in (1), *her* cannot refer to the local subject, Julianna, but can be coreferential with Julie, as Julie is not in the local domain.

For PNPs in sentences like (2), the Binding Theory principles presented in Chomsky (1981) predict similar complementary patterns. The indices in (2) show the coreference relations that classic Binding Theory predicts to be possible, as well as those which are predicted to be impossible (marked with *).

(2a) Peter_i saw the picture of himself_i/him_{*i}. [possessorless PNP]

(2b) Mary_i saw Lisa_j's picture of her_{i/*j}/herself_{*i/j}. [possessed PNP]

Recall that according to Principle A, reflexives need to be bound by an antecedent in the local domain. According to Binding Theory, the relevant local domain in a **possessorless PNP**, as in (2a), is the entire clause. As a result, the reflexive *himself* in the PNP construction must be bound by (i.e., coreferential with) the subject of the clause (Peter). For pronouns, Principle B states that local antecedents are not allowed, and thus the pronoun *him* in (2a) cannot refer to the subject of the clause. (Instead, *him* refers to some third person not mentioned in the local domain.)

In the **possessed PNP** in (2b), the presence of a possessor limits the local domain to the picture NP. As a result, the reflexive *herself* (which needs an antecedent in the local domain, according to Principle A) must refer to the possessor Lisa. The pronoun *her* (which cannot have an antecedent in the local domain, according to Principle B) cannot refer to the possessor, but can refer to the subject of the sentence (Mary) because the subject is outside the local domain.

In sum, Principles A and B of classic Binding Theory predict there to be no overlap in the antecedents of pronouns and reflexives in possessed and possessorless PNPs. However, it is now well-established that the pattern in (2a–b) does not fully reflect people's interpretations, especially for possessorless PNPs. A number of researchers, including Jackendoff (1972), Chomsky (1986), Williams (1987), Reinhart and Reuland (1993), Keller and Asudeh (2001) and Tenny (2004, 2003), have observed that pronouns in **possessorless PNPs** can – at least in certain contexts – refer to the subject of the sentence, just like reflexives.

More recent work has tested whether reflexives and pronouns in **possessed PNPs** show a similar breakdown in complementarity. Keller and Asudeh (2001) and Runner, Sussman and Tanenhaus (2003) found, using magnitude estimation and visual-world eye-tracking respectively, that reflexives in possessed PNPs can refer to the subject of the sentence, contrary to the predictions of the structural approach (see also Jaeger, 2004). Runner et al. present eye movement data showing that it is not the case that these Binding-theory-incompatible interpretations arise later, after an initial stage of processing during which Binding theory is strictly followed. Rather, the eye movements show the same time course for structurally expected and unexpected interpretations of reflexives. These results, as well as more recent work by Runner et al. (2006) and self-paced reading data from Badecker & Straub (2002), argue against previous claims that there exists an early processing stage of purely Binding-Theory-compatible processing (e.g., Nicol & Swinney, 1989; Sturt, 2003, see also Clifton, Kennison & Albrecht, 1997).

In sum, a range of studies suggest that a structural account along the lines of standard Binding Theory is not sufficient to capture the referential properties of pronouns and reflexives. These kinds of findings led researchers to adopt one of two main approaches: (i) augment Binding Theory in order to maintain a primarily structural account of the distribution of pronouns and reflexives (e.g., Chomsky, 1986 and many others), or (ii) treat some anaphors (especially reflexives in possessorless PNPs) as being exempt from Binding Theory altogether (e.g. Pollard & Sag 1992) and guided by semantic and discourse constraints.

Semantic and discourse factors

Research regarding the effects of semantic and discourse constraints on the interpretation of pronouns and reflexives (e.g. Cantrall, 1974; Kuno, 1987; Zribi-Hertz, 1989; Pollard & Sag, 1992; Reinhart & Reuland, 1993, Tenny, 1996; Tenny, 2003) has focused primarily on possessorless PNPs, and has led to contrasting claims for reflexives and pronouns.

Reflexives in possessorless PNPs have been argued to be sensitive to factors such as the potential antecedents' point of view, degree of awareness and semantic role (e.g., Pollard & Sag, 1992; Kuno, 1987). In this paper, we focus on the notion of 'source of information', which is based on Kuno's observation that in a sentence like (3a) the reflexive can felicitously refer to Mary because she is the one who provides John with the information. This contrasts with example (3b), where Mary is not the source of information. We will examine the hypothesis in (4). (Our use of the term 'source' draws on Sells (1987)'s definition of *source* as the one who is the intentional agent of the communication.)

(3a) John heard from Mary about a damaging rumor about herself that was going around.
(Kuno, 1987:175)

(3b) John told Mary about a damaging rumor about ^{??}herself that was going around.

(4) **Source hypothesis:**

Reflexives in PNPs prefer antecedents that are sources of information.

The source hypothesis for reflexives provides an interesting counterpart to claims that have been made regarding **pronouns** in possessorless PNPs. Tenny (2003, 2004) observes that pronouns, which she argues are sensitive to point of view, have a preference for antecedents that are perceivers of information. She notes that "verbs that provide a sentient, perceiving antecedent are especially conducive to SDPs" (Tenny, 2003:14). The abbreviation SDP refers to short-distance pronouns, i.e., pronouns that, contrary to the requirements of the standard Binding Theory, have antecedents in the local domain. The effect of perceiver status is illustrated by the examples in (5). Example (5a) (from Reinhart & Reuland, 1993), has a perceiving subject and sounds better than (5b), which has a subject that is not a perceiver (see also Chomsky, 1986:166–167, Bhatt & Pancheva, 2006). So, for pronouns, the hypothesis in (6) can be formulated.

(5a) Max_i heard the story about him_i. (Reinhart & Reuland, 1993:685)

(5b) *Max_i told the story about him_i. (Reinhart & Reuland, 1993:685)

(6) **Perceiver hypothesis:**

Pronouns in PNPs prefer antecedents that are perceivers of information.

The question of whether pronouns and reflexives in **possessed PNPs** are also influenced by non-structural information has not received as much attention in the literature. Jaeger (2004) uses evidence from a magnitude estimation experiment to claim that pronouns in possessed PNPs cannot refer to agentive subjects—more specifically, cannot refer to the creator of the picture. For example, a sentence such as *Manray_i burned Mary's photo of him_i* is judged to be less acceptable than *Mary_i burned Manray's photo of her_i*. Jaeger attributes this to the creator/agent status of Manray, who is a famous photographer. However, it is not yet known whether the claims made by Kuno and Tenny (see hypotheses (4) and (6) above) also apply to possessed PNPs.

In sum, in light of the observation that pronouns and reflexives in PNPs are not in complementary distribution, it seems that a purely structural approach is insufficient to capture their referential properties, especially in possessorless PNPs. Existing research suggests that

semantic properties of the antecedent, such as source and perceiver, play a role in guiding the interpretation of pronouns and reflexives.

General aims of this paper

Our research tests how structural and semantic constraints influence participants' final interpretations of pronouns and reflexives in PNPs, and also investigates the time course with which different constraints influence the processing of these forms. We aim to complement and extend existing work by testing whether the **source and perceiver hypotheses** in (4) and (6) are supported by experimental data for the on-line interpretation of possessorless PNPs as well as possessed PNPs. This research will (i) enable us to test whether the asymmetrical sensitivity that the form-specific multiple-constraints approach permits also applies to the within-sentence domain, and will (ii) shed light on whether structural and semantic constraints show qualitatively different behavior during real-time processing.

We conducted a series of comprehension experiments in which we used the verb to manipulate the source/perceiver status of the subject and object in sentences with PNPs. Compare, for example, the possessorless picture NPs in (7a) and (7b):

(7a) Peter **told** John about the picture of himself/him on the wall

(7b) Peter **heard** from John about the picture of himself/him on the wall.

In (7a), Peter is the subject and the source, and John is the object and the perceiver. In contrast, in (7b) Peter is the subject and the perceiver, and John is the object and the source. The verb manipulation allows us to create situations in which structural constraints and non-structural (source/perceiver) constraints are pitted against each other as well as situations in which they are aligned and favor the same antecedent.

From a purely structural perspective – e.g., the structural constraints articulated in classic Binding Theory – the verb manipulation should not affect reference resolution. According to this classic view, the subject noun phrase is the NP that the reflexive should be bound by and that the pronoun should be free from. We refer to the constraint that the reflexive be bound by the subject as the *subject constraint*, and the constraint that the pronoun be free from the subject as the *anti-subject constraint*. Crucially, the structural preferences of reflexives and pronouns are predicted to be unaffected by the verb manipulation.

However, the verb manipulation presented above introduces an additional difference between sentences (7a) and (7b); namely, the object of *hear from* is preceded by a preposition whereas the object of *tell* is not. One might expect the presence of the preposition to render the object of *hear from* ('John' in (7b)) incapable of binding the reflexive inside the PNP, due to the object being syntactically more deeply embedded in (7b) than in (7a). However, according to Pollard and Sag (1992) and Jackendoff (1990), this is not the case. They show that objects inside prepositional phrase arguments of verbs such as *hear* (e.g., 'John' in (7b)) have the same binding abilities as the direct objects of verbs such as *tell* (e.g., 'John' in (7a), see also Runner, 1998). In other words, if one regards the object as a potential antecedent, it is an *equally possible antecedent* with *tell* and with *hear*. In sum, according to Pollard and Sag (1992) and Jackendoff (1990), the presence/absence of the preposition does not have an effect on the object's ability to act as an antecedent for a reflexive. Thus, comparing *tell* to *hear from* is not problematic.

Furthermore, as will become clear later, our results show that the object of *hear from* is actually a *better* antecedent for a reflexive inside the PNP than the object of *tell* is – which is exactly the opposite of what one would expect if the preposition were interfering with the binding abilities of the object.

Nature of relation between structural and semantic constraints

So far, we have considered the interpretation of pronouns and reflexives in possessorless PNPs from a purely structural perspective. However, as we discussed earlier, existing research suggests that semantic constraints are also at play. If both syntactic and semantic constraints play a role, we are faced with the question of how they interact. One fundamental question concerns the relative weights of syntactic and semantic information: How much of an influence does semantic information exert on the interpretation of pronouns and reflexives, as compared to the influence of syntactic information?

This formulation of the question presupposes that whatever the relative weights of structural and semantic constraints are, these weights are the same for pronouns and reflexives. Let us consider what predictions follow from this plausible starting point. If both syntactic and semantic constraints play a role, and if their relative weights are the same for pronouns as for reflexives, then we predict that in sentences like (7a) and (7b),

- i. *with pronouns*, there will be more subject interpretations with *hear* than with *tell* (based on the perceiver-preference hypothesis in (6)).
- ii. *with reflexives*, there will be more object interpretations with *hear* than with *tell* (based on the source preference hypothesis in (4)), and
- iii. if the relative weights of structural and semantic information are the same for pronouns and reflexives, the proportion of subject and object choices triggered by one form should be ‘mirrored’ by the proportion of subject and object choices triggered by the other form. In other words, whatever levels of sensitivity reflexives show to structural and to semantic information, pronouns will show the same levels of sensitivity.

However, in light of existing results revealing form-specific effects in cross-clausal reference resolution (e.g., Kaiser, 2003; Kaiser & Trueswell, 2008; Brown-Schmidt et al., 2005), one should also consider the possibility that syntactic and semantic constraints are *not* weighted equally for pronouns and reflexives. If the form-specific approach applies to pronouns and reflexives in possessorless PNPs as in (7), then it could be the case that one form is guided by a relatively more powerful syntactic constraint, perhaps modulated by a weaker semantic constraint (or vice versa), while the other form might have the reverse situation or might perhaps be guided by more evenly weighted structural and semantic constraints. Thus, while we would still expect to see effects of perceiver status for pronouns and source status for reflexives (assuming that the semantic constraints are not so weak as to be undetectable), the *magnitude of the effects* could be different for pronouns and reflexives, thus ruling out the state of affairs outlined in (iii) above.

To further clarify how semantic constraints interact with structural constraints, we also investigate possessed PNPs (e.g. *Lisa’s picture of herself/her*). Due to the presence of the possessor phrase, possessed PNPs are subject to additional structural constraints which affect reflexives and pronouns. Most structural binding theories include a structural constraint penalizing coreference between a pronoun and the possessor, as well as a structural constraint requiring coreference between a reflexive and the possessor in possessed PNPs (e.g., Chomsky 1981; Pollard & Sag, 1992). We will refer to these constraints as the *anti-possessor constraint* (for pronouns) and the *possessor constraint* (for reflexives). (We follow existing work in assuming that constraints that make reference to syntactic/grammatical roles such as ‘subject’, ‘object’ and ‘possessor’ are structural constraints, but acknowledge that these structural roles are also connected to semantic and/or discourse-level properties.)

By examining both possessorless and possessed PNPs, we can investigate the relative strengths of different structural constraints, and compare their impact to that of semantic constraints.

This allows us to see whether the relative weighting of a constraint is determined by its linguistic properties (structural vs. semantic, such that all constraints of a particular linguistic type are predicted to be equally weighted) or whether different structural constraints can have distinct weights – a question which has implications for our view of the syntax-semantics interface.

The experiments presented in this paper investigate these issues not only by looking at comprehenders' final choices, but also by probing the time-course of what referents comprehenders consider over time, before converging on their final choice. A large body of recent research suggests that real-time language processing is continuously guided by multiple weighted constraints (e.g. MacDonald, Pearlmutter & Seidenberg, 1994; Trueswell, Tanenhaus & Garnsey, 1994; see also Badecker & Straub, 2002), and thus we expect to see early effects of both structural and semantic constraints and can observe *when* potential asymmetries in the constraint weights for pronouns and reflexives emerge during real-time processing. This contrasts with two-stage models of processing (e.g., Sturt, 2003 in the real-time processing of reflexives, see also Frazier & Fodor, 1978; Nicol & Swinney, 1989) which predict that effects of the source/perceiver verb manipulation will not emerge until after an initial stage of processing guided only by syntactic information.

We present four experiments. The first three experiments (Experiments 1, 2a and 2b) investigate possessorless PNPs, and the last experiment (Experiment 3) examines possessed PNPs. Experiment 1 is a picture verification task that tests whether the judgments predicted by the source and perceiver hypotheses can be confirmed experimentally. Experiments 2a and 2b aim to shed more light on the detailed time-course of the source/perceiver effects. Experiment 2a is an off-line study that pilots the picture-choosing methodology used in Experiment 2b, which is an eye-tracking study. Experiment 3 is an eye-tracking experiment that probes the sensitivity of pronouns and reflexives in possessed PNPs to the source/perceiver manipulation. By using eye-tracking, we can gain insights into the on-line process of reference resolution and thus investigate *when* different constraints play a role in the comprehension process.

Experiment 1: Picture verification

Method

Participants—Twenty-four native English speakers from the University of Rochester community participated in this experiment in exchange for \$7.50.

Materials—The visual stimuli consisted of displays depicting two characters and a framed picture of one of the characters (see Figure 1). The images were generated from a large repository of purchased clip-art images and were arranged and edited using Adobe Photoshop. There were five male and five female characters. Before the start of the experiment, participants were familiarized with the names of the characters. The sound files that participants heard while viewing the visual displays were recorded using Praat speech software (Boersma & Weenink, Institute of Phonetics Sciences, University of Amsterdam) on an iMac G4 computer. The same female English speaker's voice was used for all sound files, and the sentences were spoken with neutral intonation.

A total of 32 target items (display-sentence pairs) and 32 filler items were constructed. The target displays always contained two characters, one on each side of the display, and a framed picture of one of the pictured characters in the middle (see Figure 1). The filler displays also had two characters and a picture in the same positions as the targets, but the picture depicted a third character. While viewing the displays, participants heard sentences with picture NPs without possessors, as shown in (8). For the target items, we crossed verb type (*told/heard*),

anaphoric form (*himself/him*), and visual display (*picture of subject/picture of object*) to create eight conditions. Filler sentences had the same structure and used the same verbs, but contained no pronouns or reflexives.

(8) Peter {told/heard from} Andrew about the picture of {him/himself} on the wall.

With *told*, the subject of the sentence is the source of information and the object is the perceiver, whereas with *heard*, this pattern is reversed.

Eight presentation lists were constructed by combining the 32 target items with the 32 filler items. Within a presentation list, a participant saw 16 target trials with *told* and 16 with *heard*. Eight of the *told* items appeared with a pronoun and eight with a reflexive. Similarly, eight of the *heard* items appeared with a pronoun and eight with a reflexive. Half of the pronoun items were paired with a display showing a picture of the object of the sentence and half were paired with a display showing the picture of the subject. The same was done for the reflexives. This resulted in eight presentation lists in total. Overall, half of the items on any given presentation list contained two male referents and half contained two female referents. The pictures were counterbalanced for position of subject (left/right) and position of the source-of-information (left/right).

Procedure—Participants listened to pre-recorded sentences while looking at displays on a computer screen. The participants' task was to indicate whether or not the sentence they heard matched the visual display, by pressing 'y' or 'n' on the computer keyboard. The displays were presented on an eMac G4 using Psyscope (Cohen, MacWhinney, Flatt & Provost, 1993), which was also used to record participants' responses. The sound files were played over external speakers.

Predictions—If structural constraints (the *subject constraint* for reflexives and the *anti-subject constraint* for pronouns) fully determine reference resolution, differences in verb semantics should not lead to differences in anaphor resolution in picture NPs. Thus, the preferred antecedents for pronouns and reflexives should remain the same regardless of whether the sentence contains *hear* or *tell*. However, if semantic constraints modulate the effects of structural constraints for both pronouns and reflexives, as predicted by the source and perceiver hypotheses ((4) and (6)), a main effect of the verb manipulation is predicted. Reflexives are predicted to result in more structurally-dispreferred object choices with *hear* (object=source) than with *tell*, and pronouns are predicted to result in more structurally dispreferred subject choices with *hear* (subject=perceiver) than with *tell*. In other words, whereas the structural and semantic constraints converge in the *tell* conditions, they conflict in the *hear* conditions.

Crucially, the magnitude of the verb effect depends on the relative weights of the structural and semantic constraints. If the weights of structural and semantic constraints (whatever these relative weights turn out to be) are the same for pronouns as they are for reflexives, the prediction is that the magnitude of the verb effect will be the same for reflexives and pronouns. In other words, the proportion of subject and object choices in the reflexive conditions will be paralleled by the proportion of object and subject choices triggered in the pronoun condition: Whatever levels of sensitivity reflexives show to structural and to semantic information, pronouns are predicted to show the same levels.

However, if the form-specific multiple-constraints approach applies in the within-clause domain, the syntactic and semantic constraints might not be weighted equally for pronouns and reflexives. If the weightings for these two forms are different, one form could be subject to a powerful syntactic constraint and a weaker semantic constraint (or vice versa), whereas for the other form, the weights of the constraints might be the same or perhaps reversed. We

do not have specific hypotheses regarding the directions of these effects, but want to emphasize that the form-specific approach allows for a situation in which the effects for pronouns and reflexives are asymmetrical, contrary to the ‘equally weighted’ approach sketched above.

Results and Discussion—We first provide a general overview of the results and then report in more detail the statistical outcomes of mixed-effects logistic regression models. As can be seen in Figure 2, in the **reflexive conditions**, there was a general preference to interpret the reflexive as referring to the subject: overall, collapsing across verb types, there were more *yes* answers when the subject was pictured (91%) than when the object was pictured (32%). However, the proportion of subject and object choices was modulated by the verb manipulation. When the object was pictured, there were 37.5% *yes* answers with reflexives when the object was the source-of-information (with *hear*), and 27% *yes* answers when the object was the perceiver-of-information (with *told*). When the subject was pictured, there were 93.7% *yes* answers when the subject was the source and 87.5% *yes* answers when it was the perceiver.

In the **pronoun conditions**, there was a general preference to interpret the pronoun as referring to the object: collapsing across verbs, there were more *yes* answers when the object was pictured (78%) than when the subject was pictured (43%). The verb manipulation also influenced participants’ choices. When presented with a picture of the subject, participants gave 55.2% *yes* responses when the subject was the perceiver of information (with *heard*) and 30% *yes* responses when the subject was the source of information (with *told*). When presented with a picture of the object, participants gave 86.5% *yes* responses when the object was the perceiver of information and 69.8% *yes* responses when it was the source.

We used a mixed-effects regression model to analyze the proportion of *yes* answers as a function of anaphor type (pronoun vs. reflexive), verb (*hear* vs. *tell*) and picture (subject vs. object), with participant and item as random effects. The variable ‘picture’ refers to whether the subject or the object was pictured, i.e., whether participants were being asked to judge a subject-referring interpretation or an object-referring interpretation. The independent variables were centered in order to avoid collinearity in the interaction terms (see Jaeger, 2008 and others).

The analyses reveal a significant main effect of picture ($\beta = -0.82$, Wald $Z = -3.9$, $p < .001$), as well as a significant picture \times anaphor interaction ($\beta = 5.52$, Wald $Z = 12.94$, $p < .001$), but no main effect of anaphor ($p > .1$). Here and in the rest of the paper, β is used to denote the estimated regression coefficient. Wald’s z-score (Wald, 1943) is calculated by dividing β by the estimate for its standard error and is a measure of how far the estimated regression coefficient is from zero in terms of its standard error. If this distance is great enough – i.e., the coefficient is judged to be significantly different from zero – the factor is considered to contribute significantly to the model (see Jaeger, 2008 for further details).

Further analyses show that in the pronoun conditions, a picture of the object was significantly more likely to be accepted than a picture of the subject ($\beta = 1.89$, Wald $Z = 7.44$, $p < .001$). In the reflexive conditions, a picture of the subject was significantly more likely to be accepted than a picture of the object ($\beta = -3.50$, Wald $Z = -10.5$, $p < .001$). Thus, we find a significant structural preference with both pronouns and reflexives, but in opposite directions: pronouns prefer (pictures of) object antecedents and reflexives prefer (pictures of) subject antecedents.

In addition, we also see a significant picture \times anaphor \times verb interaction ($\beta = 3.84$, Wald $Z = 4.6$, $p < .001$). Further analyses show that in the pronoun conditions, there is a significant picture \times verb interaction ($\beta = 2.35$, Wald $Z = 4.62$, $p < .001$): with a picture of the object, there were more ‘yes’ answers with *tell* than *hear*, but when a picture of the subject was shown, there were more ‘yes’ answers with *hear* than *tell*. There is a weaker, but still significant picture \times verb

interaction in the reflexive conditions ($\beta = -1.36$, Wald $Z = -2.08$, $p < .05$): with a picture of the object, there were more ‘yes’ responses with *hear* than *tell*, but when a picture of the subject was shown, the verb manipulation did not have a very strong effect (Fig 2). In sum, the likelihood of *yes* responses in both the pronoun and the reflexive conditions depends not only on whether the picture shows the subject or the object but also on the verb used. The preference that pronouns and reflexives exhibit for objects and subjects respectively was significantly influenced by the source/perceiver status of the subject/object.

In order to compare the sensitivity of pronouns vs. reflexives to the *verb manipulation* more directly, we also fitted a model in which the dependent variable was the proportion of structurally-expected vs. structurally-unexpected responses. For reflexives, according to the subject constraint, responding ‘yes’ to a picture of the subject is a structurally-expected response (responding ‘no’ is unexpected), and responding ‘no’ to a picture of the object is also a structurally-expected response (responding ‘yes’ is unexpected). For pronouns, according to the object constraint, responding ‘yes’ to a picture of the object is a structurally-expected response, and responding ‘no’ to a picture of the subject is also a structurally-expected response. As before, the independent variables were centered to avoid collinearity. This approach makes it possible to evaluate the reflexive and pronoun conditions uniformly by allowing us to compare directly the strength of the (different) structural preferences of pronouns and reflexives, as well as how strongly these preferences are influenced by the verb manipulation

This analysis reveals a significant main effect of anaphor ($\beta = -0.80$, Wald $Z = -3.92$, $p < .001$), signaling an asymmetrical sensitivity to structural information: Pronouns resulted in more structurally-unexpected responses (acceptance of a subject antecedent) than reflexives (acceptance of an object antecedent). We also see a significant main effect of verb ($\beta = 0.95$, Wald $Z = 4.62$, $p < .001$), due to *hear* triggering more structurally-unexpected responses than *tell*. This fits with the hypothesis that reflexives are subject to a source constraint (and thus objects are more likely to be accepted with *hear* than *tell*) and pronouns to a perceiver constraint (and thus subjects are more likely to be accepted with *hear* than *tell*).

In addition, there is a significant anaphor-picture interaction ($\beta = 2.97$, Wald $Z = 7.18$, $p < .001$), showing that reflexives are more sensitive to the structural subject/object distinction than pronouns. However, there is no significant anaphor-verb interaction ($p > .2$), indicating that there is no significant difference in how sensitive pronouns and reflexives are to the verb manipulation.

Further analyses reveal a strong effect of the verb manipulation for pronouns ($\beta = 1.23$, Wald $Z = 4.74$, $p < .001$). The reflexive conditions show a weaker but nevertheless significant verb effect as well ($\beta = 0.88$, Wald $Z = 2.41$, $p < .05$). Thus, semantic constraints have a significant effect on both forms.

Overall, the results of the picture-verification task used in Experiment 1 revealed a significant effect of structure, with pronouns preferring objects and reflexives preferring subjects. The verb manipulation also had an effect on both anaphoric forms, with reflexives preferring sources and pronouns preferring perceivers – as predicted by the hypotheses in (4) and (6). However, there was a difference in the strength of the effects, with reflexives being more strongly guided by structural information than pronouns. This asymmetry supports a model such as the form-specific multiple-constraints approach, in which multiple constraints of differing types and strengths interact and can be differently weighted for different anaphoric forms. In particular, we see that in the case of reflexives in PNPs, the structural subject constraint is weighted more heavily than the semantic source constraint – although the semantic constraint still has a modulating influence. In contrast, pronouns in PNPs exhibit more evenly-matched competition between the structural anti-subject constraint and the semantic perceiver

constraint. This pattern of data is compatible with the form-specific multiple-constraints framework, but not an approach in which the relative weights of the structural and semantic constraints are the same for both pronouns and reflexives. This finding is also consistent with Runner et al. (2003) who found that a simple discourse manipulation had a much greater effect on pronouns than on reflexives.

Experiments 2a and 2b. Picture choosing and eye-tracking

Even though the results of Experiment 1 shed light on how structural and semantic constraints influence the interpretation of pronouns and reflexives in picture NPs, yes/no answers reflect participants' final choices and do not tell us about other interpretations participants may have considered before reaching a final choice. In order to learn about what entities participants consider as potential referents for pronouns and reflexives in picture NPs, and how these choices emerge and/or change over time, we use the visual-world eye-tracking paradigm (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995).

In order for eye movements to provide meaningful information about which referents participants are considering as potential antecedents, the visual display presented to participants must include at least two pictures – in this case a picture of the subject and a picture of the object. While such displays can easily be designed, they represent a departure from the picture verification task because the picture-choosing task forces participants to choose between two directly competing interpretations. This differs from the picture verification task, in which participants are asked whether a particular sentence matches a particular display. Thus, the picture-choosing task asks participants to choose the best interpretation out of two possibilities, whereas the picture verification task asks participants whether a particular interpretation is possible. *A priori*, we might expect these tasks to generate slightly different results, especially for interpretations that are possible but dispreferred.

As a preliminary step towards our aim of using eye-tracking to investigate the on-line processes leading to participants' final interpretations of pronouns and reflexives in picture NPs, we first conducted an off-line picture choosing experiment to investigate the effects of a design switch from picture verification to picture choice (Experiment 2a), followed by a visual-world eye-tracking study (Experiment 2b).

Experiment 2a. Picture-choosing

Experiment 2a investigates whether the effects of the source/perceiver verb manipulation persist in a context where people need to choose between two directly competing interpretations. If both the structurally-preferred and the structurally-dispreferred interpretation are visually salient, will we still see effects of the semantic constraints? To test this question, we used the same kinds of auditorily-presented sentences as Experiment 1, but instead of being shown a computer display consisting of the two mentioned characters and a picture of one of the characters, participants saw (on a sheet of paper) a display with two characters and a picture of each character (Fig 3). The task was to select one of the pictures by circling it.

Method

Participants—Twenty-four native English speakers (who did not participate in the other experiments) from the University of Rochester community took part in this experiment. They received \$7.50 for their participation.

Materials—The visual stimuli consisted of displays showing two characters and a framed picture of each of the two characters (see Figure 3). There were 20 critical items, and half

contained two male characters and half contained two female characters. The characters were the same as in Experiment 1. The auditory stimuli consisted of sentences like the one shown in (9). The sound files were recorded using Praat speech software on an iMac G4. As in Experiment 1, all sentences were spoken with neutral intonation.

(9) Peter {told/heard from} Andrew about the picture of {him/himself} on the wall.

Each participant saw ten target trials with *told* and ten with *heard*. Five of the *told* items appeared with a pronoun and five with a reflexive, and similarly five of the *heard* items appeared with a pronoun and five with a reflexive. The resulting four presentation lists were reversed to control for trial order, creating a total of eight presentation lists. Overall, half of the items on any given presentation list contained two male referents and half contained two female referents. The pictures were counterbalanced for position of subject (left/right) and position of source-of-information (left/right).

Procedure—Participants listened to pre-recorded sentences while looking at displays that contained two characters and a picture of each character (see Figure 3). The pictures were printed on 8.5 × 11" sheets of paper, and participants were instructed to mark (by circling one of the pictures) which of the pictures was mentioned in the sentence. The sound files were played on a Macintosh computer over external speakers.

Predictions—The predictions are essentially the same as for Experiment 1, except that now we are not measuring likelihood of yes/no answers but rather choice of subject picture vs. choice of object picture. In light of the results of Experiment 1, we predict that (i) the interpretation of reflexives will be guided by a strong subject constraint, modulated by a relatively weaker source constraint, and that (ii) the interpretation of pronouns is guided by two more evenly-matched constraints, i.e., the anti-subject constraint and the perceiver constraint. In the reflexive conditions, participants are predicted to generally choose the subject picture over the object picture, but to choose the object picture more often with *hear* than *tell*. In the pronoun conditions, participants are predicted to show a general object picture preference, which is predicted to be stronger with *tell* (where the object is the perceiver) than with *hear*. The proportion of structurally-unexpected responses is predicted to be higher with pronouns than with reflexives, as in Experiment 1.

Results and Discussion—Figure 4 shows the percentage of subject and object choices for each condition. With reflexives, we again see a strong preference to interpret the reflexive as referring to the subject (overall, 89.6% subject choices). The rate of object choices was 14% with *heard* and 7% with *told*. As in Experiment 1, pronouns do not share the subject-preference of reflexives and trigger 55% object choices overall. With pronouns, the rate of subject choices was 31.7% with *told* and 58% with *heard*.

We evaluated the effects of anaphor type (pronoun vs. reflexive) and verb (hear vs. tell) using a mixed-effects regression model in which the dependent variable was the proportion of object responses for pronouns and the proportion of subject responses for reflexives. (Using the proportion of subject choices as the dependent variable for both pronouns and reflexives would have resulted in the statistics being harder to interpret, given that we are primarily interested in measuring and comparing the effect of non-structural information on pronouns and reflexives. Using the proportion of subject choices as the dependent variable for both pronouns and reflexives is best suited for testing whether pronouns and reflexives differ in how likely they are to refer to the subject—something that is often assumed to be the case and also confirmed by the results of Experiment 1.) Participant and item were included as random effects. As in the analyses of Experiment 1, the independent variables were centered in order to avoid collinearity in the interaction terms.

The two main effects are highly significant. There is a main effect of anaphor ($\beta = -2.22$, Wald $Z = -7.99$, $p < .001$), with reflexives triggering more structurally-expected choices than pronouns. We also see a main effect of verb ($\beta = 1.09$, Wald $Z = 3.96$, $p < .001$), showing that the source/perceiver manipulation influences participants' picture choices. However, there is no significant anaphor-verb interaction ($\beta = 0.39$, Wald $Z = .72$, $p = .47$), indicating that the degree of sensitivity to the verb manipulation does not differ for the two anaphor types.

Further analyses show that in the **pronoun conditions**, participants' choice of subject vs. object was strongly influenced by the verb ($\beta = 1.52$, Wald $Z = 4.80$, $p < .001$). In the pronoun conditions, *tell* triggers significantly more object choices than *hear*, as predicted by the perceiver constraint. The **reflexive conditions** show a marginal effect of verb ($\beta = 0.82$, Wald $Z = 1.822$, $p = .069$), with *tell* triggering more subject choices than *hear* – as predicted by the source constraint for reflexives.

As a whole, the results of Experiment 2a show that when the two interpretations (subject vs. object) are visually salient (and thus competing with each other more explicitly than in Experiment 1), we see a significant effect of verb type for pronouns and marginal effect for reflexives in the predicted direction. The differences between the results for the reflexives in Experiment 1 (significant verb effect) and Experiment 2a (marginal verb effect) suggest that (i) use of a forced-choice task can make it harder to detect, at least in off-line measures like picture choice, the effects of the source/perceiver manipulation, whereas (ii) in a one-picture verification task, source/perceiver effects can be detected more easily even in off-line picture verification responses. This should be kept in mind when evaluating the picture choice data from Experiment 2b, an eye-tracking experiment which necessarily has to include pictures of both referents.

Taken together, Experiments 1 and 2a suggest that, for reflexives, the structural subject constraint is weighted more heavily than the semantic source constraint, but with pronouns the structural anti-subject constraint and the semantic perceiver constraint are more evenly weighted. In addition, the pronoun results suggest that neither the source constraint nor the anti-subject constraint entirely determine pronoun reference. Participants are still willing to consider the subject as an antecedent for a pronoun when the verb is *tell*, i.e., the subject is the source (over 30% subject choices). In contrast, with reflexives, there are only 7% choices that go against both structural and semantic constraints (object choices with *tell*). This suggests that for pronouns, even though the perceiver constraint and the anti-subject constraint have significant effects, their influence is not absolute.

On the whole, the results of Experiment 2a corroborate the findings of Experiment 1, and are compatible with the form-specific multiple-constraints framework, but not with approaches that assume structural and semantic constraints to be weighted the same for pronouns and for reflexives.

Experiment 2b. Eye-tracking of possessorless PNP processing

The methodologies used in Experiments 1 and 2a cannot address questions about the time course with which structural and semantic information are used in processing. To investigate time-course we used a light-weight head-mounted eye-tracker (ISCAN EC-501) to record participants' eye movements in real time as they saw two-picture displays displayed on a computer monitor and listened to pre-recorded sentences similar to those in Experiments 1 and 2a. The participants' task was to click (using the computer mouse) on the picture mentioned in the sentence. Existing research demonstrates that eye movements to objects in a display are closely time-locked to the potential referents that a listener is considering as language unfolds over time (Cooper 1974; Tanenhaus et al. 1995; for a review see Tanenhaus & Trueswell, 2006). Thus we can use looks to pictures to shed light on what participants consider as potential

referents for pronouns and reflexives in picture NPs as the sentence unfolds in real time. In addition to tracking any changes in the proportion of looks to the subject and object pictures over time, we can also conduct action-contingent analyses by looking at participants' eye movements relative to the final interpretations they assign to a particular anaphoric form.

Method

Participants—Sixteen native English speakers from the University of Rochester community, who had not participated in the earlier experiments, took part in exchange for \$7.50.

Materials—The visual materials for this experiment were similar to those used in Experiment 2a, the picture-choosing experiment. Each display – presented on a computer screen – contained two characters and two framed pictures (see Figure 5), and the same male and female characters were used as in the previous experiments. The sound files that participants heard while viewing the displays were recorded using Praat speech software on an iMac G4 computer. As before, the same female English speaker's voice was used for all items, and the sentences were spoken with neutral intonation.

Each participant saw 12 target items and 78 filler items. The fillers, like the target items, contained two characters, one on each side of the display, and two framed pictures. In the targets, the framed pictures depicted the characters in the display. In filler items, some framed pictures depicted characters in the display, and some depicted other characters. The displays were counterbalanced for position of subject (left/right) and position of source-of-information (left/right). Half of the items contained two female characters and half contained two male characters.

While viewing the displays, participants heard sentences like (9). Verb type (*told/heard*) and anaphoric form (*himself/him*) were manipulated. Filler sentences had the same structure and used *hear* and *tell* as well as other similar verbs, and some fillers contained pronouns and reflexives. As in Experiments 1 and 2a, the verb manipulation allows us to manipulate the source/perceiver roles: With *told*, the subject of the sentence is the source of information and the object is the perceiver, whereas with *heard*, this pattern is reversed.

(9) Peter {told/heard from} Andrew about the picture of {him/himself} on the wall.

Each participant saw six target trials with *told* and six with *heard*. Three of the *told* items appeared with a pronoun and three with a reflexive; similarly, three of the *heard* items appeared with a pronoun and three with a reflexive. The four presentation lists were also reversed to control for trial order, which created eight presentation lists in total.

Procedure—Participants listened to pre-recorded sentences while looking at displays presented on a computer monitor. The participants' task was to click (using the computer mouse) on the picture mentioned in the sentence they heard. As in the other experiments, participants were familiarized with the characters' names during a training phrase. The displays were presented on a Macintosh eMac G4 using Psyscope, which was also used to record participants' responses. The sound files were played over external speakers. A light-weight head-mounted eye-tracker (ISCAN EC-501) was used to record participants' eye movements.

Data analysis—Using a SONY DSR-30 digital VCR with jog-shuttle control, a trained research assistant listened to the audio portion of the videotape and determined the onset of critical target sentences, marking the frame at which they occurred. The time between the sentence onset and the onset of the anaphor was measured using Praat software (Paul Boersma and David Weenink, Institute of Phonetic Sciences, University of Amsterdam) and this was used to calculate where in the video record the onset of the pronoun or reflexive occurred. The

video record was analyzed frame-by-frame (without sound) starting 30 frames (one second) before the onset of the pronoun or reflexive and continuing for 90 frames (three seconds). Coding consisted of recording frame-by-frame whether the participant was looking to the left character, right character, left picture, right picture or elsewhere. Because the audio was turned off, the coder was blind to experimental condition. These data were then used to determine which regions had been fixated over time.¹

Predictions

Predictions for picture-choice data—The picture choice results are predicted to be the same as Experiment 2a. We predict that pronouns will show significant sensitivity to a structural anti-subject constraint as well as a semantic perceiver constraint, and that reflexives will be sensitive primarily to a structural subject constraint, with weaker effects of a semantic source constraint.

Predictions for eye movement patterns—Our expectation is that eye movement patterns in both the reflexive conditions and the pronoun conditions will show significant sensitivity to the subject/object distinction and also to the source/perceiver distinction, due to eye-movements being a more sensitive measure than off-line responses.

Existing approaches to sentence processing make different predictions regarding the time-course of the source/perceiver effects. If we extend two-stage, syntax-first theories of processing (e.g. Frazier & Fodor, 1978) directly to picture NPs, the prediction is that the initial stages of processing for both pronouns and reflexives will be guided only by structural information. If this claim is combined with the results of Experiments 1 and 2a, the prediction is that eye movements will reveal an initial stage where pronoun interpretation is driven only by the anti-subject constraint and reflexive interpretation only by the subject constraint. The effects of the source constraint for reflexives and the perceiver constraint for pronouns are predicted to be delayed until a later stage of processing. Other research focusing specifically on Binding Theory, in particular Nicol & Swinney (1989) and Sturt (2003), also argues for early effects of structural (specifically Binding Theoretic) constraints (but see Badecker & Straub, 2002). However, given claims that possessorless picture NPs are outside the purview of Binding Theory (e.g. Pollard & Sag, 1992), it is not clear whether these particular theories apply to the sentences we tested.

However, if we combine the results of Experiments 1 and 2b with the sizeable body of recent research showing that real-time language processing is continuously guided by multiple weighted constraints (e.g. MacDonald, Pearlmutter & Seidenberg, 1994; Trueswell, Tanenhaus & Garnsey, 1994; see also Badecker & Straub, 2002 on Binding Theory in particular), it seems likely that we will see early effects of structural and semantic constraints guiding the resolution of both pronouns and reflexives. The off-line data from Experiments 1 and 2a indicate that reflexives and pronouns exhibit an asymmetrical sensitivity to structural and semantic information, which leaves open at least two possibilities for the real-time interpretation of these forms: (i) The asymmetrical sensitivity is a fundamental property of reflexives and pronouns that emerges early during processing or (ii) the asymmetry is a late effect, and the initial processing of pronouns and reflexives is fundamentally alike, guided by structural and semantic information to equal degrees.

¹Double-coding was used to determine the reliability of the eye gaze coding for Experiments 2b and 3. In Experiment 2b, the first 2500ms of the video record of three participants were fully double coded. The two scorers were in agreement on over 96% of the video record. In Experiment 3, the video record of three participants was fully double coded. The two scorers were in agreement on over 95% of the video record.

Results and discussion

Picture choices—As Figure 6 shows, the picture choice results resemble the data from Experiment 2a. With reflexives, there were 6.25% object choices with *told* and 12.5% object choices with *heard*. With pronouns, there were 62.5% subject choices with *heard* and 16.67% subject choices with *told*. (Although the proportion of subject choices in the *tell-pronoun* conditions in this experiment (16.67%) may seem low when compared to the proportion observed in Experiment 2a (31.67%), an unpaired t-test reveals that the proportions are not significantly different ($t(38)=1.66, p=.1$)).

We evaluated the effects of anaphor type (pronoun vs. reflexive) and verb (hear vs. tell) using a mixed-effects regression model in which the dependent variable was the proportion of object responses for pronouns and the proportion of subject responses for reflexives. The analysis was conducted in the same way as the Experiment 2a analysis.

We see a significant main effect of anaphor ($\beta = -2.02$, Wald $Z = -4.22$, $p < .001$); the subject preference for reflexives is significantly stronger than the object preference for pronouns. This indicates an asymmetrical sensitivity to structural constraints: pronouns trigger more structurally-unexpected picture choices than reflexives. There is also a significant main effect of the verb manipulation ($\beta = 1.69$, Wald $Z = 3.14$, $p < .01$); as in Experiment 2a, *hear* triggers more subject choices than *tell*. However, this effect is modulated by hints of a marginal anaphor-verb interaction ($\beta = 1.67$, Wald $Z = 1.74$, $p = .082$), indicating that pronouns are somewhat more sensitive to the verb manipulation than reflexives. In fact, further analyses reveal significant verb effects for pronouns ($\beta = 2.47$, Wald $Z = 4.39$, $p < .001$) but not reflexives ($p > .2$). So, although pronouns prefer perceivers over sources, the weak numerical preference of reflexives for sources over perceivers is not significant. This confirms the conclusions we drew on the basis of the difference between Experiment 1 and Experiment 2a, namely that a forced-choice task (Experiments 2a, 2b) can make it harder to detect subtle effects that are captured by a picture-verification task (Experiment 1).

Summary of eye movement patterns—The eye movement data from 0 ms to 1800 ms after the onset of the anaphor are shown in Figures 7a,b, plotted in terms of subject-picture advantage. The subject-picture advantage score is calculated by subtracting the proportion of looks to the picture of the object from the proportion of looks to the picture of the subject. Thus, a positive subject-picture advantage score means a higher proportion of looks at the picture of the subject than the picture of the object, whereas a negative subject-picture advantage score means that there was a higher proportion of looks at the picture of the object than that of the subject. The first graph plots the data for reflexives and the second for pronouns, split by verb. We first provide a brief overview of the eye-movement patterns and then present more detailed statistical analyses.

As Figure 7a shows, in reflexive conditions there is a general subject picture preference: participants look more at the picture of the subject than the picture of the object (both lines are above zero). However, the subject picture advantage score is generally higher with *tell* than *hear*; reflecting a higher proportion of looks to the picture of the subject when it is the source (with *tell*) than when it is the perceiver (with *hear*). This source preference begins to emerge at around 200–250ms after the onset of the anaphor. In our reflexive conditions, the early source preference weakens temporarily approximately 600ms after the onset of the anaphor, but returns as a strong pattern at around 1200ms. The eye movement patterns suggest that reflexives show a source preference, even during the earliest moments of processing.

Pronouns, as Figure 7b illustrates, pattern in an almost opposite manner. There was no overarching preference for the subject picture or the object picture. Overall, the subject advantage score is higher with *hear* (where the subject is a perceiver) than with *tell* (where the

subject is a source). The verb conditions begin to separate within 200ms of anaphor onset, indicating early sensitivity to the source/perceiver manipulation. Note also that with *tell*, the subject picture advantage score quickly becomes negative, meaning that *tell* triggers more looks to the picture of the object (the perceiver) than the picture of the subject (the source). The opposite pattern arises with *hear*, indicating a verb-driven perceiver preference. This preference weakens at around 600ms post-onset—at around the same time that the source preference in the reflexive conditions weakens—but strengthens again afterwards.

Statistical analysis of eye movement patterns—We conducted ANOVAs on five 400 ms time-slices, starting at 200 ms before the onset of the anaphor and continuing for 1800 ms post-onset. We chose to use ANOVAs rather than logistic regression because there are unresolved issues about how to apply mixed effect models to visual world eye-tracking data (e.g., Tanenhaus, Frank, Salverda, Jaeger & Masharov, 2008). As in the previous experiments, the analyses were conducted on *the proportion of looks to the subject picture for reflexives and object picture for pronouns* (rather than subject picture for both forms) because this provides a uniform way of evaluating both the pronoun and the reflexive conditions in terms of their respective structural biases. Participant means of the proportion of looks to subject picture for reflexives and to object picture for pronouns were entered into an ANOVA with four factors: Anaphor (pronoun or reflexive), Verb (hear or tell), Order (forward or reverse list) and List (four levels).²

During the time slice from **−200ms pre-anaphor to 200ms post-anaphor**, there are no significant effects of anaphor ($F(1,8)=.15$, $p=.71$) or verb ($F(1,8)=.029$, $p=.87$), and no anaphor-verb interaction ($F(1,8)=.934$, $p=.36$). Sub-analyses conducted on two smaller time-slices (0–100ms and 100–200ms post anaphor) also revealed no significant effects of anaphor or verb and no anaphor-verb interaction (F 's < 1.5, p 's > .2), and planned comparisons for the pronoun and reflexive conditions similarly revealed no significant verb effects for either form in either subsegment (F 's < 1.2, p 's > .3).

During the time slice from **200ms to 600ms post-anaphor**, there is a significant main effect of verb ($F(1,8)=8.08$, $p<.05$), a marginal main effect of anaphor ($F(1,8)=3.58$, $p=.095$), but no verb-anaphor interaction ($F(1,8)=.99$, $p=.35$). Planned comparisons reveal significant verb effects in the pronoun conditions, in the predicted direction ($F(1,8)=6.39$, $p<.05$). However, in the reflexive conditions, the proportion of looks to the subject picture shows no significant verb effects ($p=.526$). However, a further analysis reveals that in the reflexive conditions, the proportion of looks to the (structurally-dispreferred) object picture is affected by the verb manipulation: an ANOVA on the proportion of looks to the object picture reveals that there are more looks to the structurally-dispreferred object picture in the reflexive conditions with *heard* (when the object is the source) than with *told* ($F(1,8)=6.44$, $p<.05$). Thus, the statistical analyses support the strong perceiver preference for pronouns and the source preference for reflexives that we observed in Figures 7a,b, with the verb effects emerging as the anaphor is being recognized.

From **600ms to 1000ms post-anaphor**, there are no significant effects of anaphor ($F(1,8)=1.176$, $p=.31$) or verb ($F(1,8)=.028$, $p=.872$), and no anaphor-verb interaction ($F(1,8)=2.4$, $p=.16$). From **1000ms to 1400ms post-anaphor**, we see a marginal effect of anaphor ($F(1,8)=3.78$, $p=.088$), but no main effect of verb ($F(1,8)=.65$, $p=.44$) and no anaphor-verb interaction ($F(1,8)=2.49$, $p=.15$). However, in the fourth time slice, planned comparisons reveal a marginal

²The analyses were computed using participants as a random variable. The items in our experiments are very similar to each other because they have the same structure (illustrated in ex.(8) for possessorless PNPs and ex.(11) for possessed PNPs) and use the same set of five male and five female characters. Furthermore, pictures and sentences were counter-balanced for location of subject/object and source/perceiver, and for the frequency with which each character occupied these roles (see Raaijmakers, Schrijnemakers & Gremmen, 1999; Raaijmakers, 2003).

verb effect in the pronoun conditions ($F(1,8)=4.29, p=.072$). As we saw in Figure 7b, in the pronoun conditions *hear* and *tell* tend to trigger looks to the subject picture and the object picture respectively. From **1400ms to 1800ms post-anaphor**, there is a significant main effect of verb ($F(1,8)=14.68, p<.01$), a marginal main effect of anaphor ($F(1,8)=3.98, p=.081$) but no anaphor-verb interaction ($F(1,8)=0.72, p=.42$). As Figures 7a,b show, there was a perceiver preference in the pronoun conditions and a source preference in the reflexive conditions, and planned comparisons reveal significant verb effects in both the pronoun conditions ($F(1,8)=29.67, p=.001$) and reflexive conditions ($F(1,8)=7.65, p<.05$).

In sum, the eye movements show an initial early sensitivity to the source-perceiver manipulation for both pronouns and reflexives, beginning 200ms after anaphor onset, followed by a subsequent strengthening of these effects. Moreover, the marginal main effect of anaphor – which starts to emerge as early as 200ms post-anaphor and indicates that the subject preference with reflexives is stronger than the object preference with pronouns – shows that the pronoun-reflexive asymmetry emerges early on during processing.

When considering the timing of these effects, combined with the fact that it takes about 150–200ms to program and execute an eye movement (see Matin et al., 1993), it is worth noting that although one might think of the pronouns (*her, him*) as being equivalent to the first syllable of the reflexives (*herself, himself*), existing phonetic work indicates that monosyllabic words are realized differently when they are free-standing words compared to when they are embedded in a carrier word. For example, Salverda, Dahan & McQueen (2003) and Salverda, Dahan et al. (2007) found that listeners were able to distinguish monosyllabic words (e.g., *ham*) from disyllabic words (e.g., *hamster*) even before the end of first vowel, due to cues such as length (i.e., *ham* is longer when it is realized as a free-standing word than when it is a subpart of another word).

In our target stimuli, echoing the length distinction investigated by Salverda et al. (2003), free-standing pronouns (*him, her*) had an average duration of 278ms, whereas first syllable of reflexives (*himself, herself*) had an average duration of only 158ms, which is significantly shorter than the free-standing pronoun ($t(46)=-14.48, p<.0001$). The average duration of entire reflexive was 520ms. In addition, the phrase ‘picture of’ was realized with reliably shorter duration in the reflexive conditions than in the pronoun conditions (401m vs. 444ms, $t(46)=5.81, p<.0001$). Thus, the relatively early emergence of the verb effects in the pronoun vs. reflexive conditions (significant in the 200–600ms time slice) is not surprising, given that the acoustic stimuli presumably contained early probabilistic cues to the pronoun/reflexive distinction. Crucially, since our predictions concern not in the absolute but rather the relative timing of the effects, the presence of early probabilistic cues regarding the pronoun reflexive distinction does not compromise our hypotheses and conclusions.

Action-contingent analyses—One of the benefits of visual world eye-tracking is that it allows for action-contingent analyses (see Runner et al. 2003, Tanenhaus & Trueswell 2006), which enable us to focus on participants’ eye movements contingent on their final interpretation of the pronoun or reflexive. This allows us to distinguish between the following two hypotheses regarding the role of semantic constraints:

Hypothesis (i): Semantic constraints, specifically source/perceiver information, only exert an influence when participants violate the structural requirements of a particular anaphoric form, i.e., the semantic constraints act as a type of repair strategy to license structurally-dispreferred interpretations.

Hypothesis (ii): Semantic constraints influence participants' eye movements regardless of the final interpretation; the source/perceiver effects are not a repair strategy for structurally-dispreferred interpretations.

We can distinguish between these two hypotheses by investigating participants' eye movements contingent on their final choices. (Due to uneven sample sizes resulting from the action-contingent nature of the data, we follow Runner et al. 2003 and Brown-Schmidt et al. 2005 and focus on descriptive analyses.) Figure 8a shows the subject-picture advantage score for reflexives when the (structurally-preferred) subject was chosen, and Figure 8b shows the subject-picture advantage score for pronouns when the (structurally-preferred) object was chosen. In both cases, we see effects of the verb manipulation. For reflexives, the subject-picture advantage is stronger with *tell* than with *hear*, showing a source preference even when the structurally-preferred referent is chosen. Conversely, with pronouns, we see a perceiver preference (a stronger subject-picture preference) with *hear* than *tell* even when the object picture was chosen. These patterns argue against Hypothesis (i), and demonstrate that the nonstructural source/perceiver effects are present even when the participant chooses the structurally preferred interpretation.

Taken as a whole, Experiment 2b provides further support for the view that pronouns and reflexives are guided by differently-weighted constraints. The results of the picture-choosing component of Experiment 2b closely resemble the findings of Experiment 2a. The picture choices in both experiments revealed a strong perceiver preference for pronouns. For picture choices in the reflexive conditions, we saw a marginal verb effect in Experiment 2a, and no significant effect in Experiment 2b. The absence of a significant verb effect for reflexives fits with our view that a forced-choice design can make it harder to detect an effect that is more evident in a picture verification task (Experiment 1).

Eye-tracking provides a more sensitive measure of participants' interpretations and therefore helps to minimize the problem of an effect being masked by the forced-choice situation. The eye movement data from Experiment 2b reveal that both pronouns and reflexives are immediately influenced by semantic information. Moreover, the action-contingent analyses show that the source/perceiver sensitivity should not be regarded as a repair strategy that listeners apply only when structural preferences are violated; rather, there are effects of source for reflexives and effects of perceiver for pronouns even when participants select the picture of the structurally-preferred antecedent.

Taken together, the results support our claim that the referential properties of pronouns and reflexives in picture NPs are guided by differently-weighted structural and semantic constraints. More specifically, reflexives exhibit primary sensitivity to a structural subject constraint, modulated by a weaker semantic source constraint. The interpretation of pronouns, on the other hand, shows signs of a more evenly-matched competition between a structural anti-subject constraint and a semantic source constraint. As mentioned earlier, these two constraints have a significant effect on pronoun interpretation but it seems that they do not determine it fully; there are some subject interpretations even when the two constraints align in favor of the object referent (when subject is the source, with *tell*). In sum, the eye-tracking results, like the picture choice results, are compatible with an approach which allows pronouns and reflexives to be differentially sensitive to semantic and structural information, but do not fit with an approach that assumes the relative weights of syntactic and semantic constraints to be the same for reflexives as they are for pronouns.

Experiment 3. Eye-tracking of possessed PNP processing

The results of Experiments 1 and 2 revealed that reflexives and pronouns in PNPs lacking possessors have asymmetrical sensitivities to structural and semantic information: Reflexives

are more strongly influenced by the structural subject constraint than the semantic source constraint, whereas pronouns are influenced by a structural anti-subject constraint and a semantic perceiver constraint to more comparable degrees. In Experiment 3 we take a closer look at the relation between structural and semantic information by asking whether other structural constraints are weighted the same as the syntactic constraints we considered in Experiments 1 and 2. More generally, does the linguistic status of a constraint (structural vs. semantic) determine its weight, such that all syntactic constraints that influence a particular form are weighted the same? We investigated this question by testing possessed PNPs, e.g. *Peter's picture of himself*, a configuration in which pronouns and reflexives are subject to additional structural constraints. The question of whether the linguistic status of a constraint determines its weight has implications for our view of the architecture of the language processing system. If the language processing system is a modular system and treats structural and semantic factors as fundamentally different from each other, one might expect all structural constraints to have the same weight which differs from that of semantic constraints. However, if the interface between syntax and semantics is more fluid, it seems likely that structural and semantic constraints may be intermixed in terms of their relative weights. Finally, as discussed earlier, whereas anaphors in possessorless PNPs are sometimes considered to be exempt from Binding Theory, that is not the case for PNPs with possessors because the possessor is usually analyzed as the subject of the NP (Chomsky, 1981; Pollard & Sag, 1992; Reinhart & Reuland, 1993; inter alia).

According to the structural principles of Binding Theory, in a possessed PNP the reflexive must refer to the possessor of the picture. Thus, in (10a,b), Binding theory states that *himself* refers to Andrew. We will refer to this as the *possessor constraint* for reflexives. According to the structural principles of Binding Theory, a pronoun cannot refer to the possessor but is free to refer to either the subject or the object (in (10a,b), either Peter or John). We will call this the *anti-possessor constraint* for pronouns. From a purely structural standpoint, changing the verb from *hear* to *tell* is predicted to have no effect on the referential preferences of reflexives or pronouns.

(10a) Peter told John about Andrew's picture of himself/him.

(10b) Peter heard from John about Andrew's picture of himself/him.

The aim of Experiment 3 is to see whether the weighting of these additional structural constraints relative to semantic constraints is the same as what we observed in Experiments 1 and 2. Finding that different structural constraints can differ in weight would mean that structural constraints do not pattern as a uniform block, and that the linguistic status of a constraint does not determine its weight. This would be evidence compatible with a multiple-constraints approach but not an approach treating all structural factors as equal.

Method

Participants—Sixteen native English speakers from the University of Rochester community participated in this experiment in exchange for \$7.50.

Materials—The visual materials for this experiment were similar to those used in Experiment 2b, except that now each display contained three characters and a framed picture of each character (see Figure 9). Thus, the level of visual complexity is greater in this experiment since there were six entities in each display, compared with only four in Experiment 2b. As in Experiment 2b, the sound files were recorded using Praat software on a Macintosh computer, and the same female English speaker's voice was used for all sound files. A total of 16 target items and 104 filler items were constructed. The filler displays, like the target displays, contained three characters as well as three framed pictures.

In the experimental items, participants viewed the displays while hearing sentences containing possessed picture NPs, as in (11). As before, we manipulated verb type (*told/heard*) and anaphoric form (*himself/him*). Before the start of the experiment, participants were told that the middle character owns all three pictures shown in the display, and the experiment was preceded by a short training phase to familiarize participants with the task, the characters, and the nature of picture ownership within the experiment. Filler sentences used *told* and *heard* and other similar communication verbs, and some fillers contained pronouns and reflexives. Those fillers that used unambiguous full nouns were designed such that the location of the mentioned picture was distributed between left, right and middle. Displays were counterbalanced for position of subject (left/right) and position of source-of-information (left/right). Half of the items contained three female characters and half contained three male characters. Due to the increased length of the sentences (stemming from the presence of the possessor), the prepositional phrase ‘on the wall’ was not used in Experiment 3.

(11) Peter {told/heard from} Andrew about Greg’s picture of {him/himself}.

Each participant saw eight target trials with *told* and eight with *heard*. Four of the *told* items appeared with a pronoun and four with a reflexive; similarly, four of the *heard* items appeared with a pronoun and four with a reflexive. The four presentation lists were also reversed to control for trial order, which created a total of eight presentation lists.

Procedure—The procedure and equipment were the same as for Experiment 2b. Participants listened to pre-recorded sentences while looking at displays presented on a computer monitor, and their task was to click on the picture mentioned in the sentence.

Data analysis—The data analysis methods were the same as for Experiment 2b. The video record was analyzed frame-by-frame (without sound) starting 20 frames before the onset of the pronoun or reflexive and continuing for 80 frames.

Predictions—The results of Experiments 1 and 2 showed that for **reflexives**, structural constraints outweigh semantic constraints, although both influence the interpretation of reflexives. In Experiment 3, we tested whether this also holds when another structural constraint – the possessor constraint – becomes relevant.

Let us first consider the predictions for picture choices in the reflexive conditions. According to Binding Theory, the possessor constraint is the only one that matters for reflexives in possessed PNPs (the subject constraint and the source constraint are irrelevant), and thus participants are predicted to consistently choose the picture of the possessor, never the subject or the object. However, existing research (e.g. Runner et al., 2003, 2006) suggests that this is unlikely to be the case.

If the possessor constraint is weighted equal to the subject constraint (i.e., both structural constraints are weighted equally and outweigh the source constraint), the prediction is that the pattern we saw in Experiment 2 (mainly subject choices but some object choices as well, especially with *hear*) will be replaced by roughly comparable rates of possessor and subject choices (perhaps slightly more subject choices with *tell*), and again a significant effect of the verb manipulation (more object choices with *hear* than *tell*).

Finally, if the possessor constraint outweighs the subject constraint – a prediction that receives support from existing work showing that reflexives in possessed PNPs have a strong (but not absolute) possessor preference, e.g., Runner et al. 2003; 2006 – the prediction is that participants’ interpretations of reflexives will show a clear possessor preference, perhaps accompanied by a small number of subject choices triggered by the less-powerful subject constraint, but perhaps no significant verb effects. This is because the presence of a strong

possessor constraint, coupled with a weaker subject constraint, may render effects of a subtle source constraint harder to detect. In fact, if the possessor preference is strong enough, reflexives are predicted to show minimal sensitivity to the verb manipulation.

In Experiments 1 and 2 we saw that **pronouns** are relatively more sensitive to semantics, such that both the perceiver constraint and the anti-subject constraint have clear effects. In possessed PNPs, if the anti-possessor constraint and the anti-subject constraint are equally weighted, then – given that the anti-subject constraint is not so powerful as to rule out subject choices entirely, even with *tell* (see Figs 4 and 6) – we predict that pronouns in possessed PNPs will have an overall object preference, modulated by a perceiver preference, but will also trigger roughly equal (but smaller) numbers of subject choices and possessor choices.

However, if the anti-possessor constraint outweighs the anti-subject constraint, the prediction is that we will see very few if any possessor choices regardless of verb, but that the rate of subject and object choices can still be influenced by the anti-subject constraint and the perceiver constraint, similar to Experiments 1 and 2.

As in Experiment 2b, we expect that potentially subtle effects – in particular, effects of the verb manipulation – can be detected more reliably in eye-movement patterns than in participants' off-line choices. In the **pronoun conditions**, eye-movement patterns are expected to show significant sensitivity to the verb manipulation (a perceiver preference) regardless of whether the two structural constraints are weighted equally, as discussed above for picture choices. In the **reflexive conditions**, if the subject constraint and the possessor constraint are weighted equally (and the source constraint is less powerful but nevertheless present, as indicated by the results of Experiments 1 and 2), then the prediction is that participants will show an early preference for subjects and possessors over objects, but that objects will nevertheless receive more consideration when they are sources (with *tell*) than when they are perceivers (with *hear*) – i.e., a significant verb effect, as in Experiment 2. However, if structural constraints can be weighted differently from each other such that the possessor constraint is more powerful than the subject constraint, we expect to see a strong early possessor preference in the reflexive conditions, which may well render any effects of the weaker source preference non-detectable. Thus, the absence of a verb effect, especially when combined with a strong possessor preference, is compatible with an approach where different structural constraints can be weighted differently, but harder to explain if both the subject constraint and the possessor constraint are equally weighted.

Results

Picture choices—Figure 10 illustrates the proportion of subject picture, object picture and possessor picture choices. In the **pronoun conditions**, with *hear* the subject (the perceiver) was chosen over 79% of the time, and with *tell* the object (the perceiver) was chosen 77% of the time. There were very few possessor choices in the pronoun conditions (2% with *tell* and 1.5% with *hear*). In the **reflexive conditions**, participants' responses showed an overwhelming preference for the possessor with both *hear* and *tell* (92% and 90% respectively). There were very few object choices (0.4% with *tell* and 0% with *hear*), but there were 7.8% subject choices with *hear* and 9.8% with *tell*.

To further analyze the picture choice results, we investigated the effects of anaphor type (pronoun vs. reflexive) and verb (*hear* vs. *tell*) using mixed-effects regression models. We fitted models using each of the three possible picture choices (subject, object, possessor) as the dependent variable. Participant and item were included as random effects. The independent variables were centered to avoid collinearity in the interaction terms.

For the proportion of **possessor picture choices**, there is a significant effect of anaphor type ($\beta = -9.46$, Wald $Z = -6.84$, $p < 0.001$), showing that reflexives prompt a significantly higher rate of possessor picture choices than pronouns do. There is no significant effect of verb ($p > .7$) and no significant anaphor-verb interaction ($p > .6$).

The proportion of **subject picture choices** also shows a main effect of anaphor ($\beta = 2.79$, Wald $Z = 6.45$, $p < .001$), indicating that pronouns triggered significantly more subject choices than reflexives. There is also a significant verb effect ($\beta = -1.54$, Wald $Z = -3.64$, $p < .001$) and a significant verb-anaphor interaction ($\beta = -3.52$, Wald $Z = -4.15$, $p < .001$), due to pronouns resulting in significantly more subject choices than reflexives, especially in the *hear*+pronoun condition.

Figure 10 shows that the proportion of **object picture choices** is much higher for pronouns than reflexives. In fact, there are virtually no object choices in the reflexive conditions at all (none with *hear* and only 0.4% object choices with *tell*).

Further analyses reveal significant verb effects in the **pronoun conditions** for both subject choices ($\beta = -3.00$, Wald $Z = -6.51$, $p < .001$) and object choices ($\beta = 2.82$, Wald $Z = 6.29$, $p < .001$): pronouns exhibit a clear perceiver preference. Verb type has no effect on the likelihood of possessor choices in the pronoun conditions ($p > .9$). In the **reflexive conditions**, there are no significant effects of the verb manipulation on the rate of subject choices ($p > .7$), or on the rate of possessor choices ($p > .4$). The rate of object choices is extremely low regardless of verb (no object choices with *hear* and 0.4% with *tell*).

In sum, pronouns show a strong perceiver preference in possessed PNPs but reflexives show no sign of sensitivity to the verb manipulation and exhibit a strong possessor preference. However, in the reflexive conditions there are nevertheless some subject choices in both verb conditions (7.8% with *hear*, 9.8% with *tell*), as would be expected if the subject constraint is still playing some role.

Eye movement patterns—We now consider the eye movement results in order to look at the fine-grained temporal aspects of participants' interpretations of pronouns and reflexives in possessed PNPs, and in particular to assess the presence/absence of potentially subtle verb effects in the reflexive conditions. Figures 11a and 11b show the subject-picture advantage (i.e., proportion of looks to picture of subject minus proportion of looks to picture of object) for pronouns and reflexives respectively, plotted over time. A positive subject picture advantage indicates more looks to the picture of the subject than the picture of the object, and a negative subject picture advantage indicates more looks to the picture of the object than the subject. (The proportion of looks to the picture of the possessor, analyzed separately, is shown in Figure 11c.)

As Figure 11a shows, in the case of pronouns there is not much difference between *hear* and *tell* until about 1300ms after the onset of the pronoun, at which point a subject-picture preference emerges in the case of *hear* (where the subject is the perceiver) and an object-picture preference arises with *tell* (where the object is the perceiver). In the reflexive conditions, as Figure 11b illustrates, there is no clear difference between the two verbs when it comes to looks to the subject picture and looks to the object picture. In other words, there are no clear verb effects.

Figure 11c shows the proportion of looks to the picture of the possessor. Although both pronouns and reflexives initially exhibit a fairly high proportion of looks to the possessor, starting at 400ms after anaphor onset, reflexives ultimately trigger more looks to the picture of the possessor than pronouns, due to a drop in possessor looks in the pronoun conditions.

Statistical analysis of eye movements—In order to analyze the time-course of the eye movement patterns in more detail, we conducted ANOVAs on five 400ms time-slices, starting 200ms before the onset of the anaphor and continuing until 1800ms after the onset. For each time-slice, participant means of the subject picture advantage score (proportion of trials with look to subject picture minus proportion with looks to object picture) were entered into an ANOVA with four factors: Anaphor (pronoun or reflexive), Verb (*hear* or *tell*), Order (forward or reverse list) and List (four levels). We conducted these analyses on the subject picture advantage score for both pronouns and reflexives.

There are no effects of verb or anaphor type and no anaphor x verb interactions on the subject-picture advantage scores during the first four time slices (−200 to 200ms, 200 to 600ms, 600 to 1000ms, 1000 to 1400ms: F 's < 2.1, p 's > .18). However, during the time slice from **1400ms to 1800ms post-anaphor**, we see a significant effect of verb ($F(1,8)=6.72$, $p<.05$) as well as a verb-anaphor interaction ($F(1,8)=7.4$, $p<.05$), but no significant effect of anaphor ($F(1,8)=.88$, $p=.38$). As Figures 11a-c and further analyses suggest, this effect is driven by the pronoun conditions: Planned comparisons show that with reflexives, there are no significant verb effects in any time slice (F 's < 1.4, p 's > .2), whereas with pronouns, a significant verb effect arises during the last time-slice ($F(1,8)=8.31$, $p<.05$), but not during the earlier time slices (F 's < .5, p 's > .5). As Figure 11a illustrates, in the pronoun conditions there is a subject-picture preference with *hear* (where the subject is the perceiver), whereas with *tell* we see an object-picture preference (where the object is the perceiver).

ANOVAs were also conducted on the proportion of looks to the *picture of the possessor* during the same five time slices and with the same factors. These analyses reveal strong effects of anaphor type. This effect does not reach significance during the first two time slices (−200–200ms: $F(1,8)=3.59$, $p=.095$, 200–600ms: $F(1,8)=2.6$, $p=.15$), but is significant in the third time slice and persists from there onwards (600–1000ms: $F(1,8)=43.54$, $p<.001$, 1000–1400ms: $F(1,8)=72.23$, $p<.001$, 1400–1800ms: $F(1,8)=31.55$, $p=.001$). This shows that reflexives are triggering significantly more looks to the picture of the possessor than pronouns, as predicted by Binding Theory.

Discussion—The results of Experiment 3 show that the interpretation of pronouns and reflexives in *possessed* PNPs differs from their interpretation in *possessorless* PNPs.

Reflexives: In possessed PNPs reflexives are guided by a strong possessor constraint. There is no significant effect of the verb manipulation in the picture choice patterns or in the eye movements to the subject and object pictures, although there does appear to be a weak overall pull towards subjects (approx. 8–10% subject-picture choices, regardless of verb). The existence of some subject choices fits with existing work by Keller and Asudeh (2001), Jaeger (2004) and Runner et al. (2003, 2006), which all find that subjects are possible (albeit dispreferred) antecedents for reflexives in possessed PNPs. In fact, the possessor constraint and subject constraint may be related, since subjects and possessors are often regarded as occupying similar structural positions (see e.g. Szabolcsi, 1983; Stowell, 1983; Abney, 1987)—thus, reflexives could be regarded as generally preferring structurally-prominent antecedents.

As a whole, these findings do not support the idea that all structural constraints pattern as an equally-weighted block. Rather, our results show that reflexives are subject to a heavily-weighted possessor constraint, and more weakly influenced by another structural constraint—the subject constraint. The source constraint is presumably too weak, in comparison to the strong possessor constraint, to be detectable in possessed PNPs.

Pronouns: In the pronoun conditions, participants' picture choices reveal clear effects of a structural anti-possessor constraint and a semantic perceiver constraint. The low rate of possessor choices (in comparison to subject choices) supports an approach in which the anti-possessor constraint outweighs the anti-subject constraint, corroborating the findings from the reflexive conditions. Interestingly, eye movements reveal an early, transient possessor preference, followed by the predicted but surprisingly late perceiver preference. In what follows we consider this seemingly unexpected pattern in more detail.

Delayed verb effects in pronoun conditions—At first glance, and especially in light of participants' picture choice patterns, it might seem surprising that the verb effect does not reach significance in the pronoun conditions until 1400ms after pronoun onset, and that reflexives and pronouns both start off with a high proportion of looks to the picture of the possessor.

There are at least two possible explanations (perhaps working together) for the initial possessor looks in the pronoun conditions. First, it has been suggested in previous work (Runner et al., 2006) that during the earliest moments of processing, participants temporarily consider the possessor as a potential antecedent for pronouns as well as reflexives. According to this view, the early possessor looks in the pronoun conditions are due to participants temporarily considering the possessor as a potential antecedent, but then abandoning it in favor of the subject or object. However, it is also possible that the early possessor looks stem not from reference resolution-driven processes but from the visual proximity of the possessor. The possessor character has just been mentioned (...*Andrew's picture of him/himself*) and the picture of the possessor is right above the possessor character—i.e., the closest picture to the most-recently-mentioned character. In light of existing work on the effects of proximity on saccades (e.g., Findlay & Brown, 2006), it is not surprising if participants first look at the closest picture.

Crucially, in the pronoun conditions—in stark contrast to the reflexive conditions—the possessor effect is short-lived. The early looks to the possessor decline steeply in the pronoun condition around 400ms after anaphor onset. In the reflexive conditions, in contrast, the looks keep increasing. Thus, regardless of how it is interpreted, the early possessor effect does not conflict with our conclusion that the interpretation of pronouns and reflexives is guided by differently weighted structural and semantic constraints.

In the pronoun conditions, the early possessor looks are replaced by increased looks to the subject picture and the object picture. However, as Figure 11a shows, there is no clear subject/object preference or perceiver/source preference until a significant perceiver effect emerges 1400ms after anaphor onset. There are at least two possible reasons for why such a delay could occur. If participants are indeed temporarily considering the possessor as a potential antecedent, the temporal delay in looks to the perceiver could be related to the time it takes to abandon a potential antecedent in favor of another. A further factor that might be contributing to the delay is the greater referential and visual complexity of the stimuli in Experiment 3, when compared to the materials used in Experiments 1 and 2. Because Experiment 3 uses possessed PNPs, each sentence contains three referents, rather than just two, and each display contains six objects instead of four. Thus, the items are both semantically and visually more complex than in the first three experiments. In light of existing work showing that the presence of multiple alternatives results in an increase in saccadic response time (e.g. Lee, Keller & Heinen, 2005), it is not altogether unexpected to see a delay in Experiment 3 relative to Experiment 2.

As a whole, the results of Experiment 3 support our claim that the referential properties of pronouns and reflexives are guided by differently-weighted structural and semantic constraints, and show that all structural constraints are not weighted equally – a finding which is problematic for accounts that treat structural constraints as a unified class.

General discussion

In this paper, we set out to investigate how different kinds of information interact during reference resolution. Our aim was to explore the idea that treating structural information and semantic information as separate aspects of reference resolution is an oversimplification, and to investigate in the within-clause domain the claim (formulated on the basis of cross-sentential reference resolution) that reference resolution is best understood as a form-specific process driven by multiple constraints – in other words, that anaphoric forms can differ in their degree of sensitivity to structural and discourse/semantic information (Kaiser, 2003; Kaiser & Trueswell, 2008, and others). Thus, this paper contributes to the broader goal of furthering our knowledge regarding the possible range of sensitivities that different referential forms exhibit.

In the experiments presented in this paper, we used the picture NP (PNP) construction as a means to investigate how different kinds of information guide the interpretation of pronouns and reflexives. The PNP construction is well-suited for this, since existing research suggests that the use of pronouns and reflexives in PNPs is influenced by semantic information – in particular, researchers have suggested that, at least in PNPs without possessors, pronouns exhibit a preference for perceivers of information (Tenny, 2003) and reflexives for sources of information (Kuno, 1987).

Experiment 1 and Experiments 2a and 2b investigated the validity of the source/perceiver hypotheses for reflexives and pronouns in PNPs without possessors, as well as the time-course with which different kinds of information influence the processing of these forms. The results showed that (i) the interpretation of pronouns and reflexives is guided by both structural and semantic constraints and that (ii) pronouns and reflexives differ from each other in the degree of sensitivity they exhibit to structural and semantic constraints. Specifically, our results suggest the following asymmetry for pronouns and reflexives in possessorless PNPs: the interpretation of *reflexives* is guided by a structural subject constraint that is weighted more heavily than a semantic source constraint, whereas the interpretation of *pronouns* is guided by two more evenly-matched constraints; a structural anti-subject constraint and a semantic perceiver constraint. Furthermore, eye movement patterns (Experiment 2b) show that (i) both structural and semantic constraints influence processing of pronouns and reflexives very early on and (ii) semantic constraints have an effect even when participants interpret the anaphoric form in the structurally-preferred manner. In other words, the effects of semantic information cannot be relegated to the role of a repair process that only plays a role when the structurally-preferred antecedent is unavailable.

Experiment 3 used possessed PNPs to further investigate the relative weights of structural and semantic constraints, in particular how two additional structural constraints interact with the constraints we probed in Experiments 1 and 2. Experiment 3 examined whether constraints belonging to a particular linguistic class (structural vs. semantic) are all weighted the same. The results suggest that, for reflexives, the structural possessor constraint outranks both the subject constraint and the source constraint. For pronouns, although we saw fairly even competition between structural and semantic constraints in Experiments 1 and 2, Experiment 3 reveals a situation where the structural anti-possessor constraint is stronger than the semantic source constraint and the structural anti-subject constraint. These results indicate that (i) both pronouns and reflexives can be subject to powerful structural constraints, depending on the structural configuration, and (ii) different structural constraints can be weighted differently, suggesting that the linguistic status of a constraint is not what determines its weight.

Taken together, the results of Experiments 1, 2 and 3 suggest that, in order to be empirically adequate, a theory of anaphor resolution must be fine-grained enough to allow for multiple factors, weighted differently for different anaphoric forms. Thus, although the assumption that

the relative weights of syntactic and semantic constraints are the same for reflexives and pronouns seems to be a reasonable initial hypothesis, the asymmetrical behavior of pronouns and reflexives in PNPs – both in terms of participants' off-line responses and on-line processing – shows that this assumption must be abandoned. Furthermore, our data do not support a model of reference resolution in which constraints of one type (e.g. structural or semantic constraints) 'cluster' together, as Experiment 3 made clear. Rather, if we order the constraints according to their strength, the result is a complex interaction between structural and semantic constraints for both reflexives and pronouns. These results fit with the form-specific multiple-constraints approach, but not with an approach that posits a general, form-independent weighting of structural vs. semantic constraints.

It is worth keeping in mind that the present research investigated the influence of structural and semantic constraints on the interpretation of pronouns and reflexives in picture NPs, as our main aim was to learn more about how, whether, and when different anaphoric forms show sensitivity to different constraints. The results presented here do not aim to make specific claims regarding pronouns' and reflexives' interpretation preferences in all possible contexts, or the real-time application of Binding Theoretic constraints in all structural configurations (see e.g. Badecker & Straub, 2002; Sturt, 2003 regarding pronouns and reflexives in object position).

As mentioned earlier, some researchers have argued that picture NPs (in particular possessorless picture NPs) are exempt from Binding Theory and subject to semantic and discourse constraints, whereas anaphors in other syntactic configurations (e.g. direct object position) are subject to Binding constraints. However, our results show that pronouns and reflexives in PNPs are sensitive to both structural and semantic constraints. Thus, regardless of whether or not PNPs are regarded as being exempt from the structural constraints of Binding theory, it nevertheless seems that some kind of structural constraints are necessary to capture the referential properties of pronouns and reflexives in picture NPs.

Although our results suggest that anaphor resolution is guided by multiple factors which are weighted differently for different anaphoric forms, we leave open the question of how this is realized in the processing system. At least two different possibilities suggest themselves, perhaps best conceptualized as two ends of a continuum. If we approach this question from a retrieval- or memory-based perspective, the retrieval processes activated by different anaphoric forms might differ in the extent to which they are sensitive to various syntactic and semantic constraints. For example, the asymmetrical sensitivity to structural and semantic factors that we observed for pronouns and reflexives would result from the two forms activating retrieval cues that vary in their syntactic and semantic properties and weights. Alternatively, the asymmetrical sensitivities of pronouns and reflexives might be coded as expectations within a forward-looking expectancy-based perspective (e.g., Arnold & Tanenhaus, 2007; Elman, 1990; Levy, 2008; Tabor & Tanenhaus, 1999). If we assume that comprehenders have expectations about what entities are likely to be mentioned next and, crucially, what form is likely to be used to refer to them, then the asymmetrical sensitivities of pronouns and reflexives could be regarded as a consequence of form-specific expectations. For example, if a particular entity is likely to be mentioned in the following discourse, participants' expectation about the likelihood of, say, a reflexive (or a pronoun) being used to refer to that entity will be conditioned by syntactic and semantic properties of the antecedent. It also seems plausible that the system might include a mix of retrieval and expectancy-based processes. A deeper understanding of how the form-based multiple-constraints approach is represented in the language processing system is an important question for future work.

It is worth noting that in our investigation of the interaction of structural and semantic information, we focused on the impact of source and perceiver, basing our hypotheses on Kuno (1987) and Tenny (2004, 2003). It is possible that source and perceiver could be correlated

with, or potentially even derived from, other semantic or pragmatic notions. For example, one could hypothesize that what matters is agentivity (see Jaeger, 2004:284, fn 29). If one is willing to treat the subject of *tell* and the object of *hear* as agentive, the effects seen here could be explained in terms of pronouns having an anti-agentivity preference (see Jaeger (2004)'s agentivity hypothesis) and reflexives having an agentivity preference. It may also be possible to connect the source vs. perceiver effects to the notion of point-of-view, something that has been argued to play a crucial role in guiding the use and interpretation of reflexives (e.g. Zribi-Hertz 1989) as well as pronouns (Tenny 2003, see also Cantrall 1974) in PNPs. However, because our primary focus in this paper is to shed light on the relative strengths of structural and non-structural constraints for reflexives and pronouns, in particular their asymmetrical sensitivities, the precise semantic properties of the non-structural constraints do not directly impact our claims as they have been formulated here. Nonetheless the semantic properties are of central importance for further development of the form-specific framework and thus constitute an important question for future work.

Our finding that pronouns are less strictly governed by structural information than reflexives and often more influenced by semantic information has interesting echoes in cross-clausal reference resolution. It is well-known that pronouns are used as discourse anaphors in free/non-bound positions (e.g. *Lisa called Alice yesterday. She wanted to ask if Alice could help her with something*), where their interpretation has been found to be guided by discourse salience (e.g., Ariel, 1990; Givón, 1983; Gundel, Hedberg & Zacharski, 1993), coherence relations between sentences (e.g., Kehler, 2002; Wolf et al., 2004), verb semantics (e.g., Stevenson, Crawley & Kleinman, 1994) as well as other factors. Thus, our finding that pronouns are susceptible to semantic factors in picture NP contexts fits well with the observation that pronouns are guided by discourse/semantic information in cross-clausal usage. In fact, the perceiver preference we observed fits with work by Stevenson et al. (1994) and Arnold (2001) which finds that across sentences, pronouns prefer antecedents whose thematic role is 'goal' (i.e., antecedents who are receiving something) over antecedents whose thematic role is 'source.'

In closing, it is important to note that preliminary cross-linguistic work with possessorless PNPs corroborates the patterns we found for English. Off-line experiments on PNPs in German and Dutch reveal striking parallels with English: Reflexives are subject to a strong subject preference, modulated by a weaker source preference, whereas pronouns show a stronger sensitivity to perceiver of information (Kaiser & Runner, 2008). Research on a typologically different non-Indo-European language, Finnish, similarly finds that pronouns are guided by an anti-subject constraint and a perceiver constraint (Kaiser et al., 2005), although the patterns are slightly less clear with reflexives. As a whole, these results indicate that not only the particular structural and semantic constraints under investigation, but also their asymmetrical weightings for pronouns and reflexives, generalize beyond English and provide an indication of the complex interplay of structural and semantic information during language processing.

Acknowledgments

Preliminary analyses of some of the data reported here were presented at OnLI (Conference On Linguistic Interfaces, Ulster, June 2007), the 43rd Annual Meeting of the Chicago Linguistic Society (Chicago, May 2007), the 20th Annual CUNY Conference on Human Sentence Processing (San Diego, March 2007), the 37th Meeting of the North East Linguistic Society (UIUC, October 2006), and the Western Conference on Linguistics (USC, November 2004). Thanks to audience members for comments and feedback. We gratefully acknowledge Rebekka Puderbaugh, Sasha Eloi, Katie McEldoon and Colleen Griffin for help with stimulus preparation and coding. Thanks also to members of the language processing community at the University of Rochester for useful feedback and comments. This research was partially supported by NSF grants BCS-010776 and BCS-0518842, and NIH grant HD-27206.

References

- Abney, S. Ph.D thesis. MIT; 1987. The English Noun Phrase in Its Sentential Aspect.
- Ariel, M. Accessing NP antecedents. London, UK: Routledge, Croom Helm; 1990.
- Arnold, J. Reference form and discourse patterns. Stanford University; Stanford, CA: 1998. Unpublished Ph.D. dissertation
- Arnold JE. The effects of thematic roles on pronoun use and frequency of reference. *Discourse Processes* 2001;31:137–162.
- Arnold, JE.; Tanenhaus, MK. Disfluency effects in comprehension: How new information can become accessible. In: Gibson, E.; Perlmutter, N., editors. *The processing and acquisition of reference*. Cambridge, MA: MIT Press; 2007.
- Badecker W, Straub K. The processing role of structural constraints on the interpretation of pronouns and anaphors. *Journal of Experimental Psychology: Learning, Memory and Cognition* 2002;28:748–769.
- Bhatt, R.; Pancheva, R. *The Blackwell Companion to Syntax*. Vol. II. Oxford, UK: Blackwell Publishers; 2006. *Implicit Arguments*; p. 554-584.
- Brown-Schmidt S, Byron DK, Tanenhaus MK. Beyond salience: Interpretation of personal and demonstrative pronouns. *Journal of Memory and Language* 2005;53:292–313.
- Cantrall, WR. *Viewpoint, Reflexives, and the Nature of Noun Phrases*. The Hague: Mouton; 1974.
- Chomsky, N. *Lectures on Government and Binding*. Dordrecht: Foris; 1981.
- Chomsky, N. *Barriers*. Cambridge, MA: MIT Press; 1986.
- Clifton C Jr, Kennison S, Albrecht J. Reading the words her, his, him: Implications for parsing principles based on frequency and structure. *Journal of Memory and Language* 1997;36:276–292.
- Cohen JD, MacWhinney B, Flatt M, Provost J. PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers* 1993;25(2):257–271.
- Cooper RM. The control of eye fixation by the meaning of spoken language: a new methodology for the real-time investigation of speech perception, memory and language processing. *Cognitive Psychology* 1974;6:84–107.
- Salverda AP, Dahan D, Tanenhaus MK, Crosswhite K, Masharov M, McDonough J. Effects of prosodically modulated sub-phonetic variation on lexical competition. *Cognition* 2007;105 (2):466–476. [PubMed: 17141751]
- Elman JL. Finding structure in time. *Cognitive Science* 1990;14:179–211.
- Findlay D, Brown V. Eye scanning of multi-element displays: I. Scanpath planning. *Vision Research* 2006;46:179–195. [PubMed: 16054669]
- Frazier L, Fodor JD. The Sausage Machine: A new two-stage parsing model. *Cognition* 1978;6:1–34.
- Garvey C, Caramazza A. Implicit causality in verbs. *Linguistic Inquiry* 1974;5:459–464.
- Givón, T. *Topic continuity in discourse: A quantitative cross-language study*. Amsterdam: John Benjamins; 1983.
- Gordon PC, Hendrick R. Intuitive knowledge of linguistic co-reference. *Cognition* 1997;62:325–370. [PubMed: 9187062]
- Gundel JK, Hedberg N, Zacharski R. Cognitive status and the form of referring expressions in discourse. *Language* 1993;69:274–307.
- Jackendoff, RS. *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press; 1972.
- Jackendoff RS. On Larson’s treatment of the double object construction. *Linguistic Inquiry* 1990;21:427–456.
- Jaeger, TF. *Proceedings of the LFG04 Conference*. Stanford, CA: CSLI Publications; 2004. *Binding in picture NPs revisited: Evidence for a semantic principle of Extended Argumenthood*.
- Jaeger TF. Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language* 2008;59:434–446.
- Kaiser, E. *The quest for a referent: A crosslinguistic look at reference resolution*. University of Pennsylvania; Philadelphia, PA: 2003. Ph.D. dissertation

- Kaiser, E. When salience isn't enough: Pronouns, demonstratives and the quest for an antecedent. In: Laury, R., editor. *Minimal reference in Finnic: The use and interpretation of pronouns and zero in Finnish and Estonian discourse*. Helsinki, Finland: Suomalaisen Kirjallisuuden Seura; 2005. p. 135-162.
- Kaiser, E.; Hiietam, K. A Typological Comparison of Third Person Pronouns in Finnish and Estonian. In: Dahl, A.; Bentzen, K.; Svenonius, P., editors. *Nordlyd; Proceedings of the Workshop on Generative Approaches to Finnic Languages*; 2004. p. 654-667.
- Kaiser, E.; Runner, JT. Intensifiers in German and Dutch anaphor resolution. In: Natasha, Abner; Jason, Bishop, editors. *Proceedings of the 27th West Coast Conference on Formal Linguistics*; Somerville, MA: Cascadilla Proceedings Project; 2008. p. 265-273.
- Kaiser, E.; Runner, JT.; Sussman, RS.; Tanenhaus, MK. Reference resolution for reflexives and pronouns in Finnish. Poster presented at the 18th Annual CUNY Conference on Human Sentence Processing; University of Arizona; 2005.
- Kaiser, E.; Trueswell, J. The referential properties of Dutch pronouns and demonstratives: Is salience enough?. In: Meier, C.; Weisgerber, M., editors. *Proceedings of the Conference sub8 Sinn und Bedeutung*; Konstanz, Germany: Universität Konstanz; 2004. p. 137-149. Arbeitspapier Nr.177, FB Sprachwissenschaft
- Kaiser E, Trueswell J. Interpreting pronouns and demonstratives in Finnish: Evidence for a form-specific approach to reference resolution. *Language and Cognitive Processes* 2008;23(5):709–748.
- Kaiser, E.; Vihman, V-A. On the referential properties of Estonian pronouns and demonstratives. Talk presented at the 22nd Scandinavian Conference of Linguistics (Aalborg University, June 2006), To appear in the *Proceedings of the 22nd SCL*; 2006.
- Kehler, A. *Coherence, Reference and the Theory of Grammar*. Stanford, CA: CSLI Publications; 2002.
- Keller, F.; Asudeh, A. Constraints on linguistic coreference: Structural vs. pragmatic factors. In: Moore, J.; Stenning, K., editors. *Proceedings of 23rd Annual Conference of the Cognitive Science Society*; Mahwah, NJ: L. Erlbaum; 2001. p. 483-488.
- Koornneef AW, Van Berkum JJA. On the use of verb-based implicit causality in sentence comprehension: Evidence from self-paced reading and eye tracking. *Journal of Memory and Language* 2006;54:445–465.
- Kuno, S. *Functional Syntax: Anaphora, discourse & empathy*. Chicago: University of Chicago Press; 1987.
- Lee KM, Keller E, Heinen S. Properties of saccades generated as a choice response. *Experimental Brain Research* 2005;162:278–286.
- Levy R. Expectation-based syntactic comprehension. *Cognition* 2008;106(3):1126–1177. [PubMed: 17662975]
- MacDonald MC, Pearlmutter NJ, Seidenberg MS. The lexical nature of syntactic ambiguity resolution. *Psychological Review* 1994;101:676–703. [PubMed: 7984711]
- Matin E, Shao KC, Boff KR. Saccadic overhead: information processing time with and without saccades. *Perception & Psychophysics* 1993;53(4):372–380. [PubMed: 8483701]
- McDonald JL, MacWhinney B. The time course of pronoun resolution: Effects of implicit verb causality and gender. *Journal of Memory and Language* 1995;34:543–566.
- Nicol J, Swinney D. The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research* 1989;18:5–20. [PubMed: 2647962]
- Pollard C, Sag I. Anaphors in English and the scope of Binding Theory. *Linguistic Inquiry* 1992;23:261–303.
- Raaijmakers JGW. A further look at the 'language-as-fixed-effect' fallacy. *Canadian Journal of Experimental Psychology* 2003;57:141–151. [PubMed: 14596473]
- Raaijmakers JGW, Schrijnemakers JMC, Gremmen F. How to deal with the language-as-fixed-effect fallacy: Common misconceptions and alternative solutions. *Journal of Memory and Language* 1999;41:416–426.
- Reinhart T, Reuland E. Reflexivity. *Linguistic Inquiry* 1993;24:657–720.
- Runner, JT. *Noun Phrase Licensing*. New York: Garland Publications; 1998.

- Runner JT, Sussman RS, Tanenhaus MK. Assignment of reference to reflexives and pronouns in picture noun phrases: evidence from eye movements. *Cognition* 2003;89(1):B1–B13. [PubMed: 12893125]
- Runner JT, Sussman RS, Tanenhaus MK. Assigning Reference to Reflexives and Pronouns in Picture Noun Phrases. *Cognitive Science* 2006;30:1–49.
- Safir K. Vehicle change and reconstruction in a'-chains. *Linguistic Inquiry* 1999;30:587–620.
- Salverda AP, Dahan D, McQueen JM. The role of prosodic boundaries in the resolution of lexical embedding in speech comprehension. *Cognition* 2003;90:51–89. [PubMed: 14597270]
- Sells P. Aspects of Logophoricity. *Linguistic Inquiry* 1987;18(3):445–479.
- Stevenson RJ, Crawley RA, Kleinman D. Thematic roles, focus, and the representation of events. *Language and Cognitive Processes* 1994;9:519–548.
- Stewart AJ, Pickering MJ, Sanford AJ. The time course of the influence of implicit causality information: Focusing versus integration accounts. *Journal of Memory and Language* 2000;42:423–443.
- Stowell T. Subjects across categories. *The Linguistic Review* 1983;2:285–312.
- Sturt P. The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language* 2003;48:542–562.
- Szabolcsi A. The possessor that ran away from home. *The Linguistic Review* 1983;3:89–102.
- Tabor W, Tanenhaus MK. Dynamical theories of sentence processing. *Cognitive Science* 1999;23:491–515.
- Tanenhaus MK, Spivey-Knowlton MJ, Eberhard KM, Sedivy JE. Integration of visual and linguistic information in spoken language comprehension. *Science* 1995;268:1632–1634. [PubMed: 7777863]
- Tanenhaus, M.; Trueswell, J. Eye movements and spoken language comprehension. In: Traxler, M.; Gernsbacher, MA., editors. *Handbook of Psycholinguistics*. Vol. 2. Academic Press; 2006. p. 863-900.
- Tanenhaus, MK.; Frank, A.; Salverda, AP.; Jaeger, F.; Masharov, M. The Art of the State: Mixed Effects Regression Modeling in the Visual World. Talk presented at the 2008 Conference on Human Sentence Processing. University of North Carolina; Chapel Hill. March 13–18, 2008; 2008.
- Tenny C. Short distance pronouns and locational deixis. 1996LinguistList on-line conference
- Tenny, C. Short Distance Pronouns in Representational Noun Phrases and a Grammar of Sentience. 2003. Ms. (online: <http://www.linguist.org/Wiltschko-pronouns.pdf>)
- Tenny, C. Pronoun Binding and the Grammar of Sentience. Talk presented at the Workshop on Semantic Approaches to Binding Theory, held at the 16th European Summer School in Logic, Language and Information; Nancy, France. 2004.
- Trueswell JC, Tanenhaus MK, Garnsey SM. Semantic influences on parsing: use of thematic role information in syntactic disambiguation. *Journal of Memory and Language* 1994;33:285–318.
- Wald A. Test of statistical hypotheses concerning several parameters when the number of observations is large. *Transactions of the American Mathematical Society* 1943;54(3):426–482.
- Williams E. Implicit arguments, the binding theory and control. *Natural Language and Linguistic Theory* 1987;5:151–180.
- Wolf F, Gibson E, Desmet T. Discourse coherence and pronoun resolution. *Language and Cognitive Processes* 2004;19:665–675.
- Zribi-Hertz A. Anaphor Binding and Narrative Point of View English Reflexive Pronouns in Sentence and Discourse. *Language* 1989;65(4):695–727.

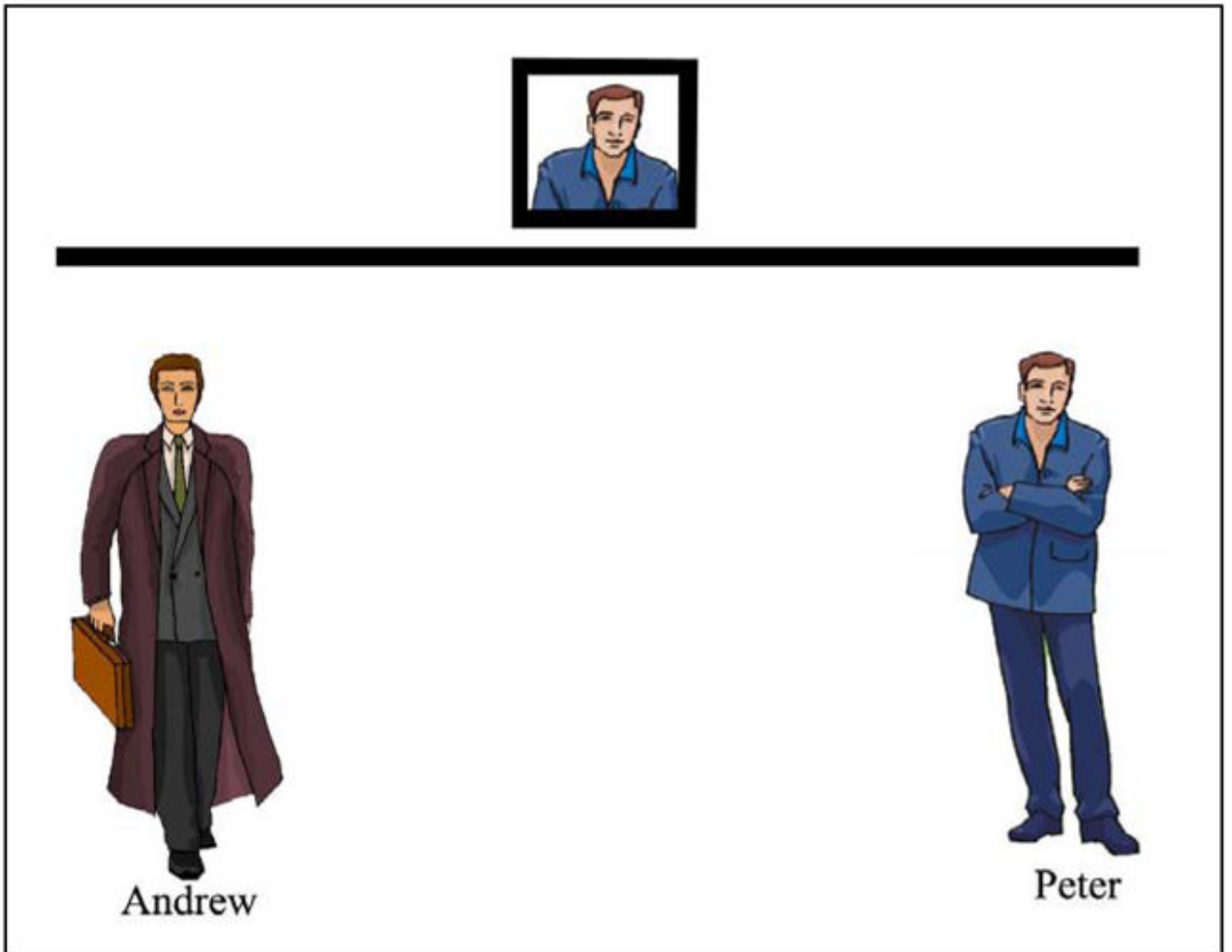


FIGURE 1.
Sample display for Experiment 1, picture-verification experiment

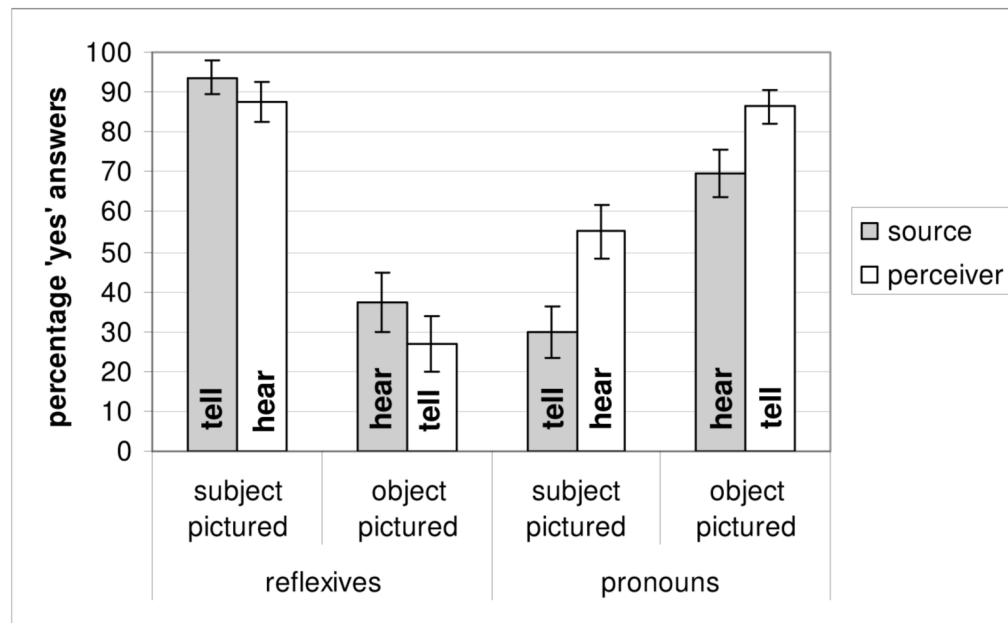


FIGURE 2. Percentage of 'yes' answers in the picture verification task in Experiment 1 (error bars represent ± 1 SE).

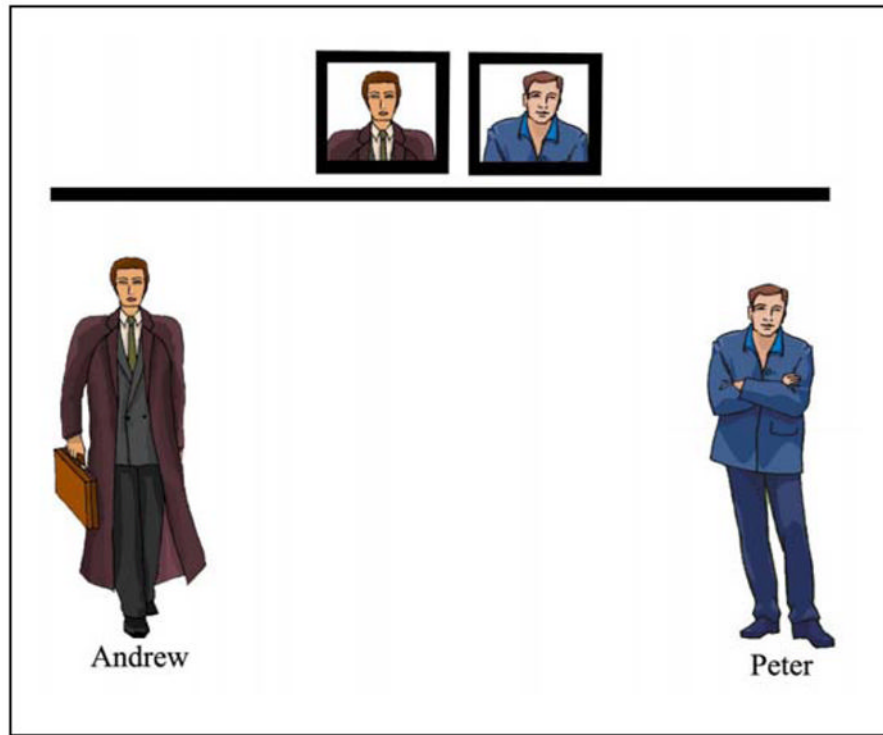


FIGURE 3.
Sample display for Experiment 2a, picture-choosing experiment

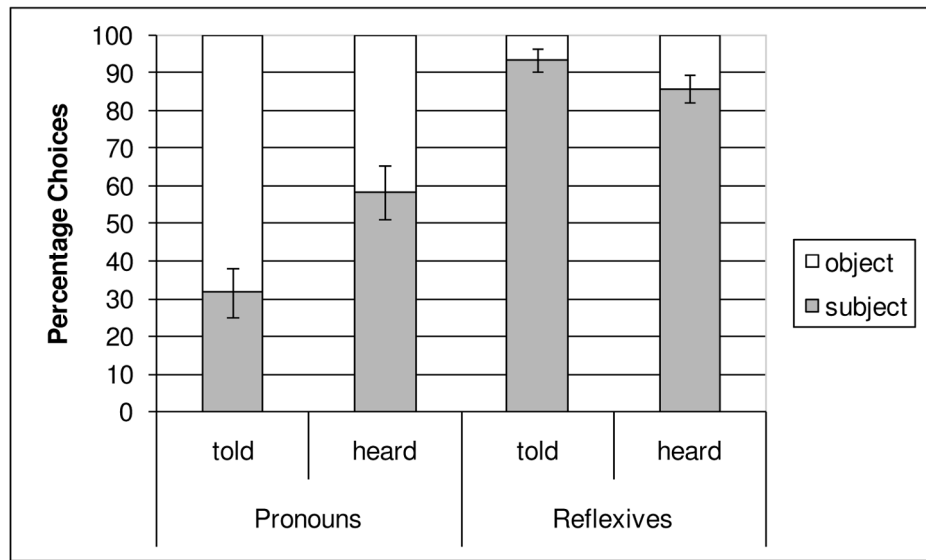


FIGURE 4. Percentage of subject-picture choices in the picture-choosing task in Experiment 2a (error bars represent ± 1 SE)

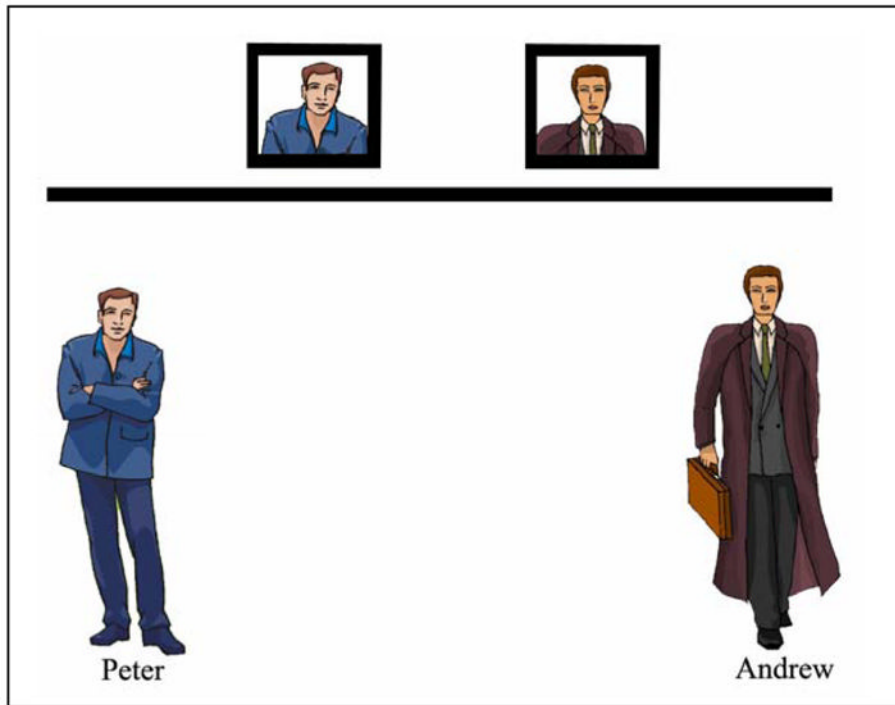


FIGURE 5.
Sample display for Experiment 2b, eye-tracking experiment

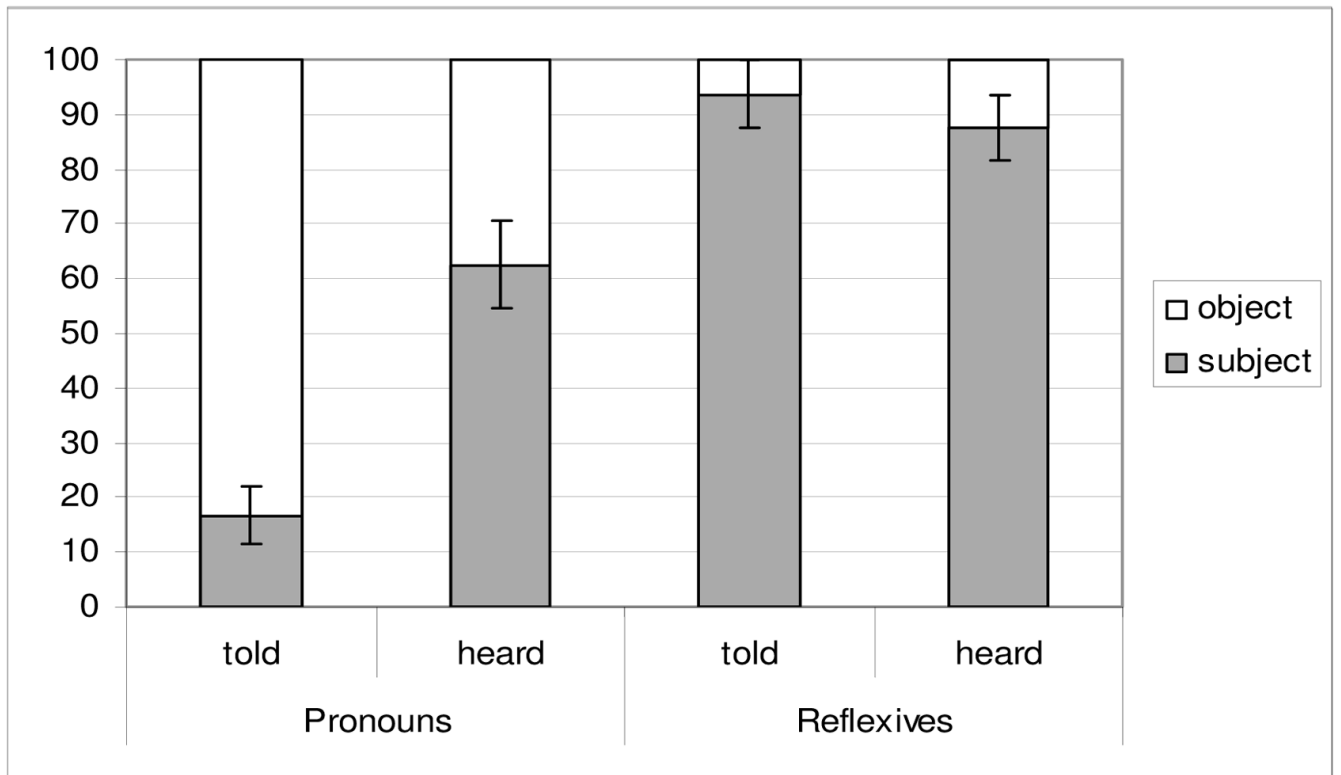


FIGURE 6. Percentage of subject-picture choices and object-picture choices in Experiment 2b (error bars represent ± 1 SE)

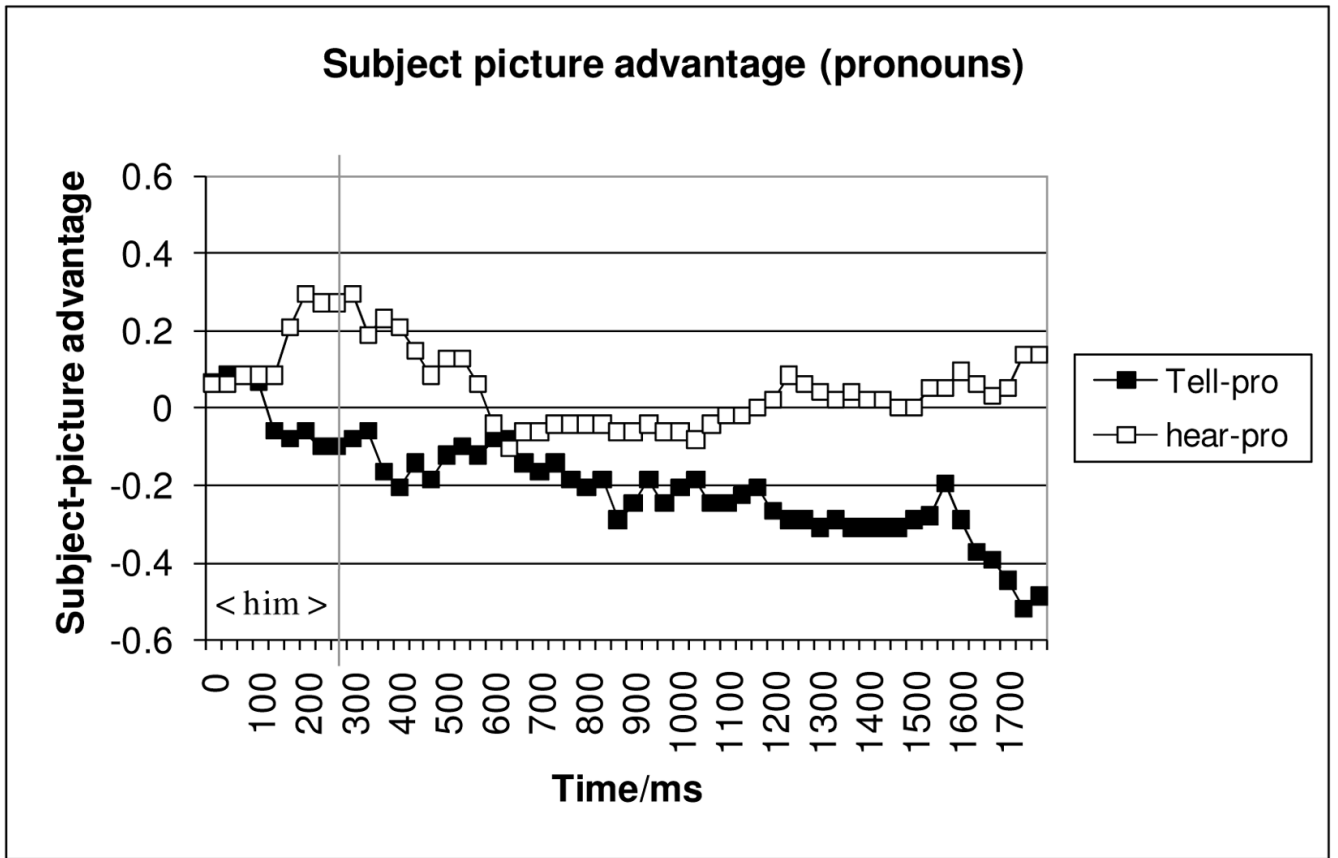
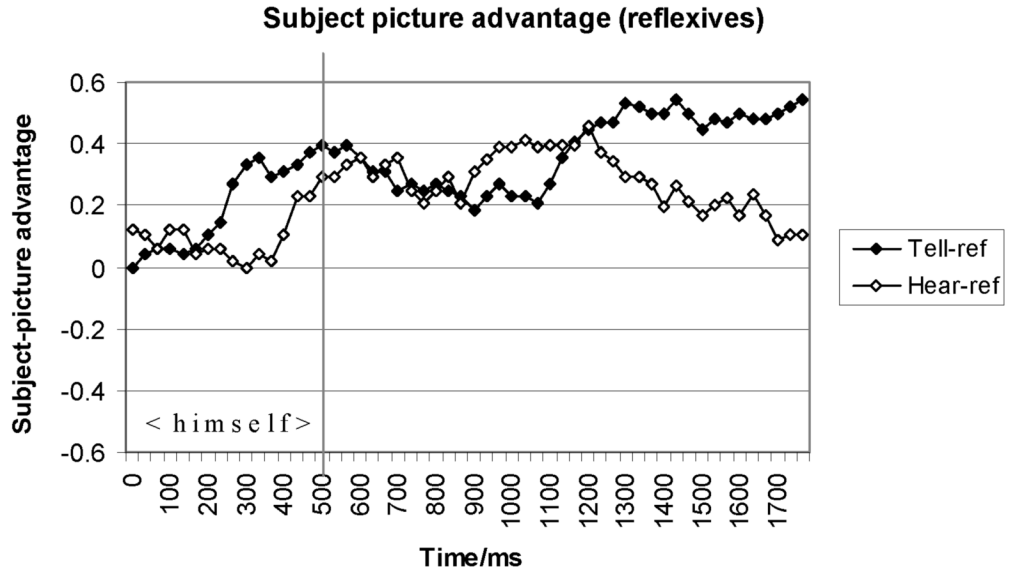


FIGURE 7. FIGURE 7a. Subject-picture advantage scores for reflexives in Experiment 2b. The subject-picture advantage score is calculated by subtracting the proportion of looks to the object picture from the proportion of looks to the subject picture. The onset of the reflexive is at 0ms. FIGURE 7b. Subject-picture advantage scores for pronouns in Experiment 2b. The onset of the pronoun is at 0ms.

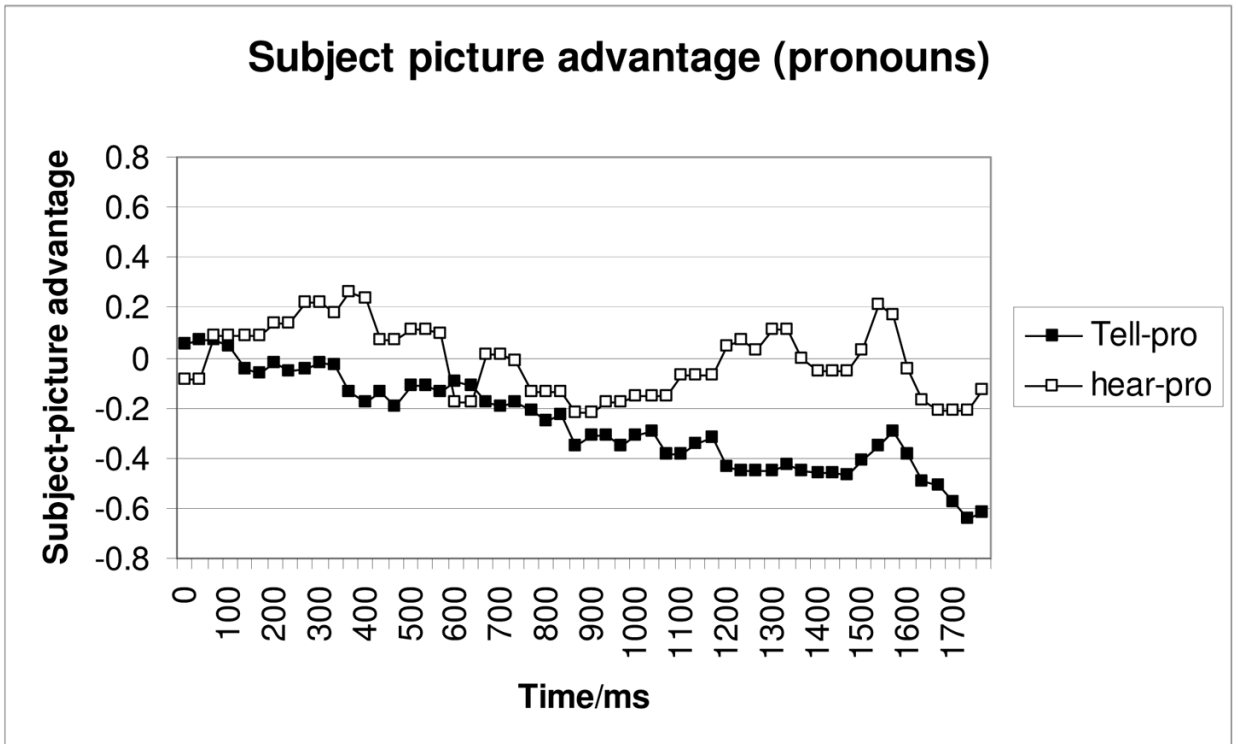
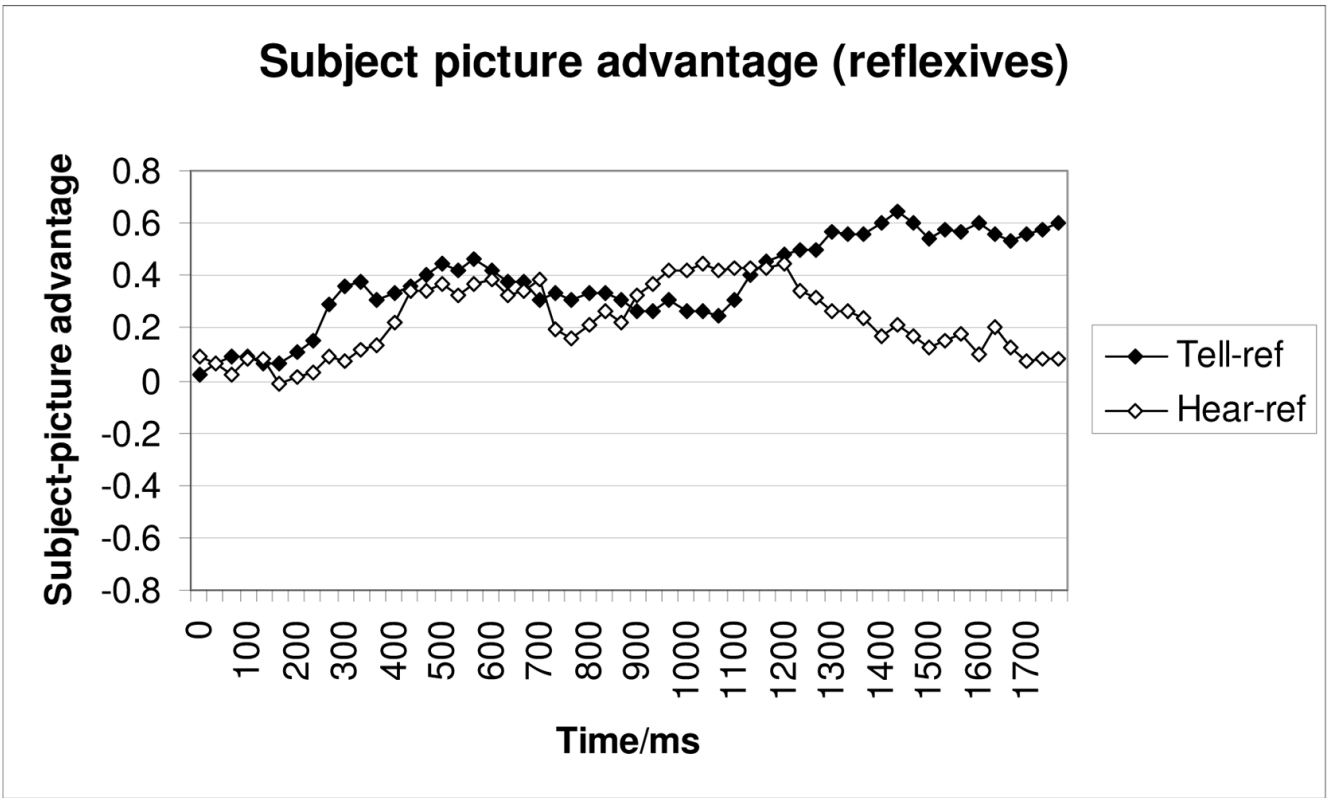


FIGURE 8.

FIGURE 8a. Subject-picture advantage scores for reflexives in Experiment 2b on trials where the subject picture was chosen.
FIGURE 8b. Subject-picture advantage scores for pronouns in Experiment 2b on trials where the object picture was chosen

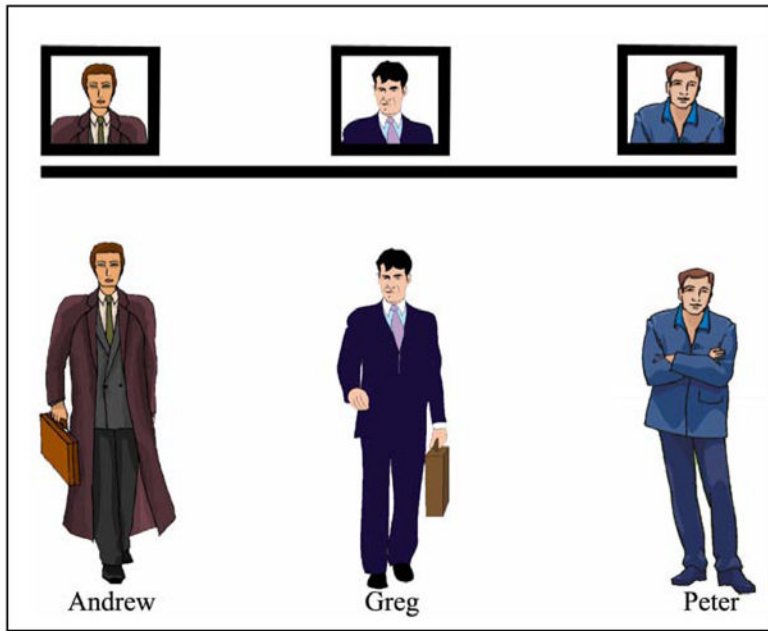


FIGURE 9.
Sample display for Experiment 3, eye-tracking experiment

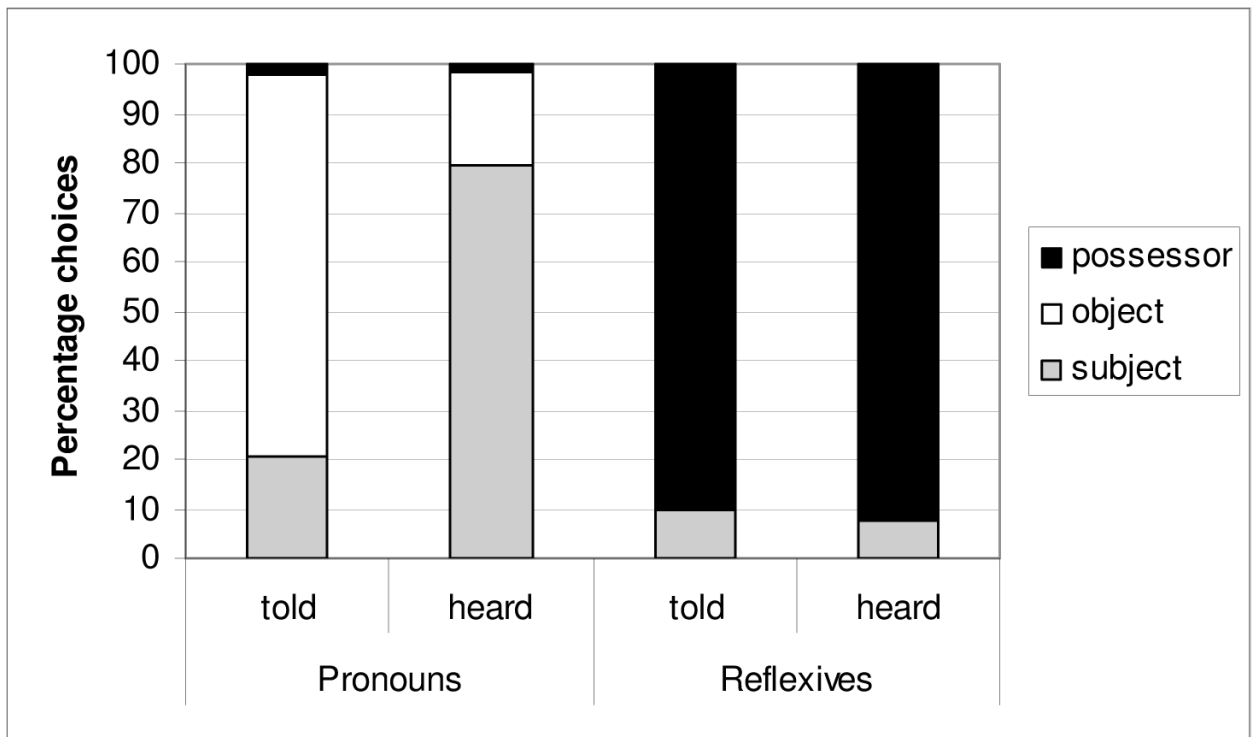
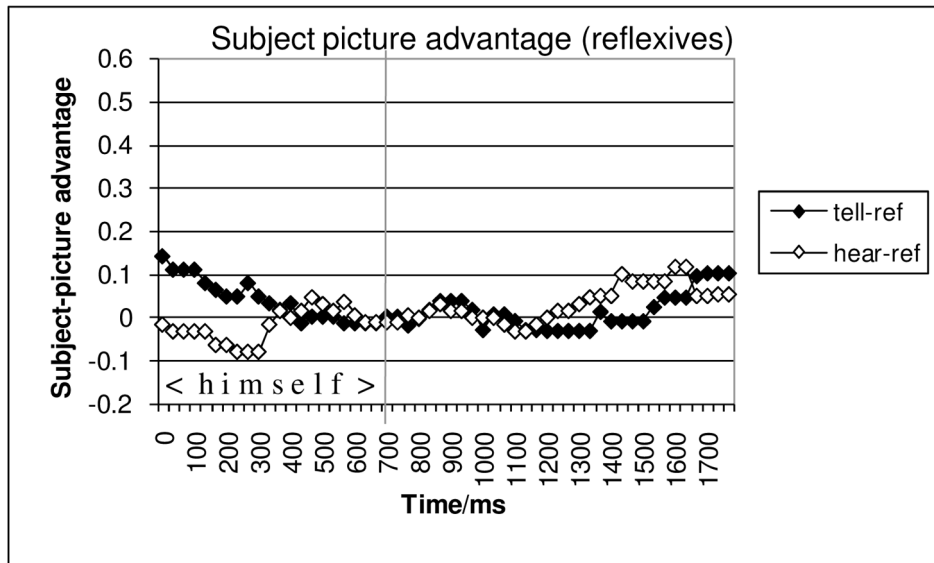
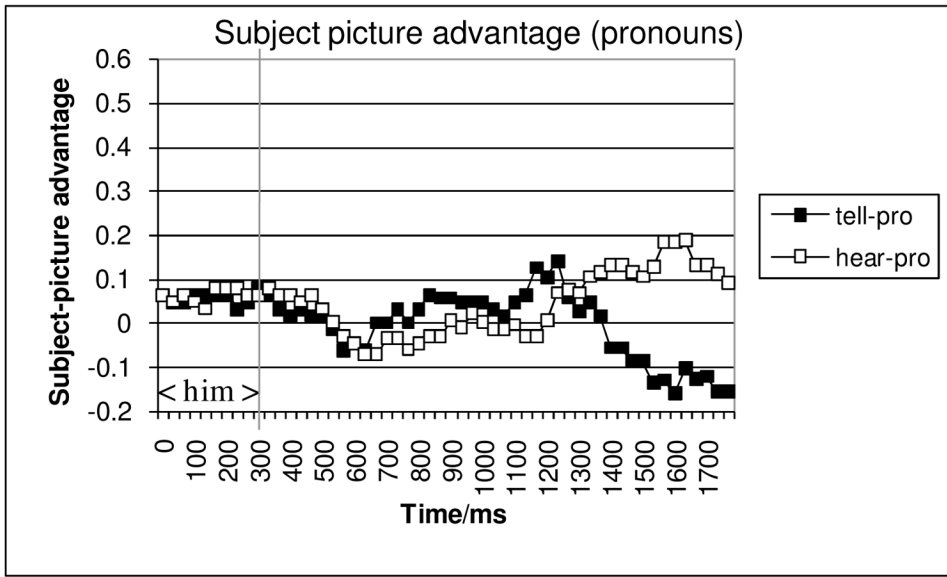


FIGURE 10. Percentage of subject-picture choices, object-picture choices and possessor-picture choices in Experiment 3



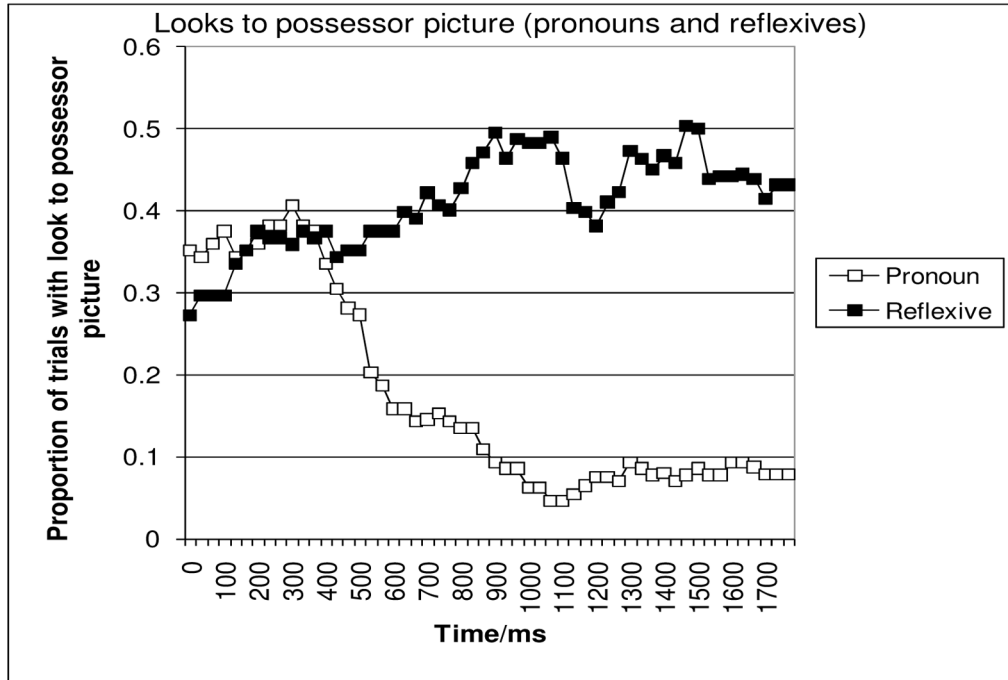


FIGURE 11.
 FIGURE 11a. Subject-picture advantage scores as a function of time for pronouns in Experiment 3. The subject-picture advantage score is calculated by subtracting the proportion of looks to the picture of the object from the proportion of looks to the picture of the subject. The onset of the pronoun is at 0ms.
 FIGURE 11b. Subject-picture advantage scores as a function of time for reflexives in Experiment 3. The onset of the reflexive is at 0ms.
 FIGURE 11c. Proportion of trials with a look to the picture of the possessor as a function of time. The onset of the anaphor is at 0ms.