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Abstract

We report three eye-movement experiments and an offline task investigating structural constraints on pronoun resolution in different contexts. This included 'coargument' contexts in which a pronoun was the direct object of a verb ('The surgeon remembered that Jonathan had noticed him'), so-called picture noun phrases ('The surgeon remembered that Jonathan had a picture of him') and picture noun phrases with a possessor ('The surgeon remembered about Jonathan's picture of him'). In each eye-movement experiment, we observed longer reading times when the nonlocal antecedent ('the surgeon') mismatched in stereotypical gender with the pronoun, but little evidence of the gender of the local antecedent ('Jonathan') influencing reading times. The offline task suggested readers occasionally interpret pronouns as referring to local antecedents, especially in non-coargument contexts. These results suggest that structural constraints constitute more highly weighted cues to antecedent retrieval than gender congruency during the initial stages of memory retrieval during pronoun resolution.

Keywords: Anaphora resolution; memory retrieval; eye movements; reading

Introduction

The ability to link pronouns to their antecedents is an essential prerequisite of successful language comprehension. As pronouns and their antecedents may be separated by several words or sentences, resolving pronouns will involve accessing a representation of the antecedent from memory. As such, anaphora resolution has played an increasingly important role in the study of the memory architecture that subserves language comprehension. A growing body of research has investigated how structural constraints on antecedent retrieval interact with agreement features during pronoun resolution. While some studies have claimed that syntactic constraints are more highly weighted cues to antecedent retrieval than gender/number agreement (e.g. Chow, Lewis, & Phillips, 2014; Cunnings & Sturt, 2014; Dillon, Mishler, Sloggett, & Phillips, 2013; Nicol & Swinney, 1989; Parker & Phillips, 2017; Patterson, Trompelt, & Felser, 2014; Sturt, 2003; Xiang, Dillon, & Phillips, 2009), the extent to which syntactic constraints on anaphora resolution are violated during processing is contested (e.g. Badecker & Straub, 2002; Clackson & Heyer, 2014; Cunnings & Felser, 2013; Patil, Vasishth, & Lewis, 2016).

To date, the majority of research that has investigated the interaction of syntactic constraints and agreement features during anaphora resolution has examined the processing of reflexives. Fewer studies have investigated the resolution of pronouns, and most existing research has only investigated pronouns in a narrow set of syntactic contexts. The aim of the current study was to investigate the time-course of pronoun resolution in different syntactic contexts. We were particularly interested in so-called picture noun phrases, as these have been important in formulating theoretical characterisations of syntactic constraints on anaphora resolution in the linguistics literature (e.g. Pollard & Sag, 1992; Reinhart & Reuland, 1993). We begin by discussing theoretical accounts of anaphora resolution, before

discussing previous research that has investigated the time-course of antecedent retrieval during processing.

Coargumenthood and Binding Constraints

Syntactic constraints on anaphora resolution have traditionally been characterised by binding theory (Chomsky, 1981). Binding Principles A and B provide a theoretical account of the interpretive preferences for reflexives and pronouns in sentences as in (1).

(1a) Ben explained that David had injured himself in the park.

(1b) Ben explained that David had injured him in the park.

Binding Principle A states that a reflexive must be bound by an antecedent in the local syntactic domain, while Binding Principle B states that a pronoun must be free within this local domain. As such, binding theory predicts that in (1a) the reflexive must be bound by a *local* antecedent in the same clause, in this case 'David'. In (1b), the pronoun must be free from this local antecedent, but can refer to the *nonlocal* antecedent 'Ben'. We will refer to antecedents that are predicted to be preferred according to binding theory as *accessible* antecedents and those that should be dispreferred as *inaccessible* antecedents. Thus, in (1b) for example, the nonlocal antecedent 'Ben' is accessible according to binding theory, while the local antecedent 'David' is inaccessible.

One prediction of binding theory is that interpretive preferences for reflexives and pronouns should be in complementary distribution. Thus 'himself' in (2a) can refer to 'Ben' but 'him' cannot. This complimentarity however appears to break-down, or is at least intuitively weaker, in other constructions, such as (2b).

(2a) Ben injured himself / him.

(2b) Ben found a picture of himself / him.

(2b) contains a so-called 'referential' or picture noun phrase (henceforth PNP). The apparent lack of complementarity in such constructions led some researchers to reformulate the binding constraints (Pollard & Sag, 1992; Reinhart & Reuland, 1993; Reuland, 2001, 2011). Although the exact nature of these theories differs, the notion of *coargumenthood* is important in explaining the differences between (2a) and (2b). In sentences like (2a), where the predictions of binding theory appear to hold, the reflexive/pronoun and antecedent are both core coarguments (subject and object) of the same verbal predicate. In sentences like (2b), where the PNP is argued to form a nominal predicate, the reflexive/pronoun has no coarguments within this local domain (the nominal PNP predicate) by which it can be bound. In this case, binding constraints are argued to not apply. Thus, coargumenthood is argued to be a pre-requisite to the application of binding constraints.

However, despite claims that PNP contexts are exempt from binding theory, Keller and Asudeh (2001) reported that sentences similar to (2b) are more acceptable when they contain a reflexive than a pronoun. This difference in acceptability might be unexpected if PNP contexts are completely exempt from binding theory, as in this case both reflexives and pronouns should be equally acceptable. Kaiser, Runner, Sussman and Tanenhaus (2009) also reported different interpretive preferences for reflexives and pronouns in PNPs. Taken together, these results suggest there is a local antecedent preference for reflexives, and a complimentary anti-local antecedent preference for pronouns, in PNPs which may be weaker, or more violable, than is observed in coargument contexts.

A related construction is the possessed picture noun phrase (PPNP), as in (3).

(3) Ben's picture of himself / him.

In contrast to PNPs, most researchers in the linguistics literature have assumed that PPNPs are restricted by binding theory. In this case, the reflexive must be bound by the possessor and a pronoun must be free from it (Pollard & Sag, 1992; Reinhart & Reuland, 1993). Pollard and Sag argue that, if PNPs form nominal predicates, an antecedent within this predicate (the possessor) must bind the reflexive, and be free from a pronoun, in much the same way as in standard coargument contexts like (2a).

However, results from offline measures indicate that reflexives can take antecedents other than the possessor in PPNP contexts (Cunnings & Sturt, 2014; Keller and Asudeh, 2001; Runner et al., 2003, 2006; but see Kaiser et al., 2009). Offline interpretations indicate pronouns do prefer non-local antecedents in such contexts (Kaiser et al., 2009, 2006; Runner et al., 2003, 2006), although Keller and Asudeh (2001) reported that it was more acceptable for a pronoun to refer to a local antecedent in PPNP than coargument contexts. Taken together, similar to what has been observed for PNPs, these results suggest there is a local antecedent preference for reflexives, and an anti-local antecedent preferences for pronouns, in PPNPs that is weaker or more violable than is observed in coargument contexts.

Anaphora resolution and memory retrieval

According to cue-based parsing models, language comprehension is subserved by a content-addressable memory system that is accessed via direct access retrieval (for review see Jäger, Engelmann & Vasishth, 2017; Lewis, Vasishth, & Van Dyke, 2006; Van Dyke & Johns, 2012). In cue-based models, memory retrieval involves matching a set of retrieval cues against all items in memory in parallel. Items that match the retrieval cues become activated, and the item that provides the best cue-match, and is thus most highly activated, is retrieved.

As all items that (partially) match the set of retrieval cues become activated, this leads to the possibility of similarity-based interference, when a partially matching but ultimately incorrect item is retrieved from memory (see e.g. Van Dyke, 2007; Van Dyke & McElree, 2006, 2011).

An important issue for cue-based parsing is the nature of the set of cues that restrict retrieval. Across different linguistic dependencies, different sources of information could act as cues to retrieval. For anaphora, cues could include gender/number agreement, discourse prominence and syntactic constraints, amongst others. The clearest evidence of agreement cueing memory retrieval comes from subject-verb agreement (e.g. Pearlmutter, Garnsey, & Bock, 1999; Wagers, Lau, & Phillips, 2009). Consider (4), taken from Wagers et al. (2009).

(4a) The key to the cell(s) unsurprisingly was rusty from many years of disuse.

(4b) The key to the cell(s) unsurprisingly were rusty from many years of disuse.

Wagers et al. reported longer reading times for ungrammatical sentences like (4b) compared to grammatical sentences like (4a). However, the size of the ungrammatically effect was reliably attenuated in (4b) when the local 'distractor' noun was plural ('cells'), matching the number properties of the (ungrammatical) verb 'were'. These results suggest that when the (grammatical) subject head noun does not fully match the retrieval cues of the verb, which cue for a number-matching head noun, grammatically illicit but number matching constituents may sometimes be retrieved. We will refer to this pattern of results as partial-match *facilitatory* interference, as reading times for *ungrammatical* sentences are facilitated when an ungrammatical 'distractor' constituent partially matches the cues to retrieval.

The extent to which anaphora resolution is subject to interference has been widely debated. Most existing research examining the interaction between syntactic binding

constraints and agreement during antecedent retrieval has investigated reflexives. A number of studies have failed to observe significant *facilitatory* interference effects for reflexives (Cunnings & Sturt, 2014; Dillon et al., 2013; Sturt, 2003; Xiang et al., 2009; but see Patil et al., 2016). These studies typically manipulated *either* number *or* gender congruence between a reflexive and two potential antecedents, and reported processing difficulty when the reflexive mismatched in number or gender with an accessible antecedent, while effects of the number or gender of an inaccessible antecedent have been elusive. A recent study by Parker and Phillips (2017) did report facilitatory interference effects in reflexive processing, similar to those observed in subject-verb agreement, but only when the reflexive mismatched in *both* number and gender with an accessible antecedent. Although the extent to which binding constraints on reflexives are violable is debated (e.g. Badecker & Straub, 2003; Clackson & Heyer, 2014; Cunnings & Felser, 2013; Dillon et al., 2013; Patil et al. 2016; Parker & Phillips, 2017; Sturt, 2003), these results suggest that syntactic binding constraints constitute more highly weighted cues to antecedent retrieval than gender/number agreement, at least in coargument contexts.

Cunnings and Sturt (2014) investigated reflexives in coargument, PNP and PPNP contexts similar to (5).

(5a) Jonathan/Jennifer heard that the soldier had positioned himself/herself in the middle of the mess hall.

(5b) Jonathan/Jennifer heard that the soldier had a picture of himself/herself in the middle of the mess hall.

(5c) Jonathan/Jennifer heard about the soldier's picture of himself/herself in the middle of the mess hall.

They reported longer reading times when the reflexive mismatched in stereotypical gender with the local antecedent compared to when it matched, both for coargument reflexives and for those in PNP/PPNP contexts. They did not report any significant facilitatory interference effects, suggesting that participants initially preferred to retrieve the local antecedent only. However, participants were more likely to interpret PNP and PPNP reflexives as referring to the non-local antecedent than coargument reflexives in an offline task. These results suggest that, at least when a reflexive mismatches in only a single morpho-syntactic feature with a local antecedent, this local antecedent is initially retrieved in coargument and non-coargument contexts, but that this initial preference may be overridden in subsequent stages of processing (see also Sturt, 2003), especially in non-coargument contexts.

Fewer studies have investigated antecedent retrieval during the processing of pronouns. All existing studies that have manipulated the gender of a grammatically accessible antecedent have reported longer reading times following pronouns that mismatch in gender with the accessible antecedent, as in (6b) from Badecker and Straub (2002), than when the pronoun matches, as in (6a) (Badecker & Straub, 2002; Chow et al., 2014; Patterson et al., 2014). However, we are unaware of any existing studies that have shown significant *facilitatory* interference effects for pronouns (Badecker and Straub, 2002; Chow et al., 2014).

(6a) John thought that Bill/Beth owed him another chance to solve the problem.

(6b) Jane thought that Bill/Beth owed him another chance to solve the problem.

Badecker and Straub (2002) did report a different type of interference for grammatical sentences like (6a). Here, reading times were longer in *multiple-match* sentences when both antecedents matched the gender of the pronoun compared to the condition when only the

accessible, nonlocal antecedent matched. They interpreted this effect as indexing competition between referents when multiple antecedents matched the gender of the reflexive. We will refer to this type of effect as *inhibitory* interference, as reading times in grammatical sentences are inhibited when multiple items partially match a set of retrieval cues.

In a visual world paradigm study, Clackson, Felser and Clahsen (2011) manipulated the gender congruence between a local, inaccessible antecedent and a critical pronoun, using a manipulation similar to (6a). They reported more looks to the local antecedent shortly after the pronoun was heard when both antecedents matched the gender of the pronoun compared to when only the nonlocal antecedent matched. This can be considered analogous to the inhibitory interference observed in reading studies and is suggestive of competition between both gender-matching antecedents. However, both Chow et al. (2014) and Patterson et al. (2014) failed to find significant *inhibitory* multiple-match effects in their reading studies. The lack of clear interference effects across studies in pronoun resolution suggests that, similar to reflexives, syntactic binding constraints constitute more highly weighted cues to antecedent retrieval than gender agreement.

Few studies have investigated pronouns outside of coargument contexts. Patterson et al. (2014) examined a non-coargument context containing prepositional phrases in sentences such as ‘Barry saw Gavin place a gun near him on the ground with great care’. They manipulated gender congruence between the pronoun and both antecedents, and reported reading time evidence that the local antecedent was retrieved as an antecedent for the pronoun. Note that in this construction, although it may be difficult to construct semantically felicitous contexts, it is possible for an antecedent to appear in a syntactically even more local position to the pronoun. Consider, for example, the sentence ‘The sergeant saw the policeman place the prisoner near him into one of the cells’. Intuitively here, it is only ‘the prisoner’ that is ruled out as an antecedent for the pronoun by Principle B. Although the semantic contexts

in which only this local binding is ruled out may be limited, examples such as this question exactly what constitutes the relevant local domain for binding constraints in prepositional phrases. It might be that the relevant binding domain for which a pronoun's antecedent is restricted in prepositional phrases is syntactically more local than the contexts tested by Patterson et al. (2014). Further research is required here to tease apart how binding constraints in prepositional phrases are to be characterised. Note that irrespective of these issues in how locality is defined for binding in prepositional phrases, it is clearly not possible in picture noun phrases to place an antecedent syntactically more local to the pronoun than 'Ben' in examples (2) and (3).

We are aware of only one study to have investigated pronouns in PNP contexts. Kaiser et al. (2009) examined sentences such as (7) using the visual world paradigm.

(7a) Peter told Andrew about the picture of himself / him on the wall.

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

According to classic binding theory, the subject 'Peter' is the only antecedent that can bind the reflexive in (7), and so the pronoun must be free from this antecedent (but can refer to 'Andrew'). Additionally, in (7a), 'Peter' is a 'source' of information while 'Andrew' is a 'perceiver'. These roles are reversed in (7b). Although the pronoun must be free from the subject ('Peter') according to standard binding theory, pronouns are known to prefer 'perceivers' of information (Kuno, 1987). Kaiser et al. examined how these syntactic and pragmatic factors interacted during processing. In offline measures, they found that participants preferred the syntactic object ('Andrew') as an antecedent for the pronoun in (7a) but chose either antecedent in (7b). Participants' eye-movements suggested participants quickly looked towards the object ('Andrew') in (7a), when it was a perceiver of information,

but looked to it less in (7b), when the subject was the perceiver. Kaiser et al. interpreted these results as indicating that syntactic and pragmatic constraints interact to guide pronoun resolution.

Runner et al. (2003, 2006) used the visual world paradigm to examine pronouns in PPNPs. Participants acted out instructions like (8) while their eye-movements were monitored.

(8) Look at Ken. Have Joe touch Harry's picture of him.

Although participants' offline performance was largely in line with the predictions of binding theory, with the local possessor ('Harry') rarely being chosen, during processing participants' eye-movements indicated looks to the possessor shortly after the pronoun was heard. Runner et al. interpreted these results as indicating that both local and nonlocal antecedents were initially considered as antecedents for pronouns in PPNPs. Kaiser et al. (2009) also reported early looks to a possessor antecedent following pronouns in sentences similar to (7) but including PPNPs (e.g. 'Peter told / heard from Andrew about Greg's picture of him'), even though the possessor was rarely chosen as the antecedent for the pronoun in an offline task, which again might suggest both local and nonlocal antecedents were initially being considered. Note however that one complicating factor in interpreting these results for PPNPs, is that looks to the local, possessor antecedent shortly after the pronoun is heard may index continued, spillover looks to the possessor as a result of it being the last-mentioned referent depicted in the visual scene, rather than necessarily implicating its active consideration as a potential antecedent for the pronoun during memory retrieval.

In sum, existing studies investigating pronoun resolution in coargument contexts suggest binding constraints constitute highly weighted cues to antecedent retrieval (Chow et

al., 2014; Nicol & Swinney, 1989; Patterson et al., 2014). Results for pronouns in PNP and PPNP contexts may suggest consideration of local antecedents during early stages of processing (Kaiser et al., 2009; Runner et al., 2003, 2006), although the interpretation of some of these results is open to debate.

The present study

Against this background, the aim of the current study was to investigate how syntactic constraints and gender congruency interact to cue antecedent retrieval for pronouns in different contexts. We report three eye-movement experiments investigating pronouns in coargument contexts (Experiment 1), PNPs (Experiment 2) and PPNPs (Experiment 3). We also conducted an offline task (Experiment 4), to examine the extent to which local and nonlocal antecedents are considered as antecedents for pronouns in different contexts. We are unaware of any previous study that has compared pronouns in coargument, PNP and PPNP contexts with maximally similar materials. In contrast to previous studies on the time-course of pronoun resolution in (P)PNPs (Kaiser et al., 2009; Runner et al., 2003, 2006), we adopted a reading paradigm and utilised gender (mis)match effects (Cunnings & Sturt, 2014; Sturt, 2003) to investigate the time-course of anaphora resolution.

Experiment 1

The aim of Experiment 1 was to examine pronoun resolution in coargument contexts to compare with pronouns inside picture noun phrases in Experiments 2 and 3. Participants read texts, which manipulated gender congruence between a pronoun and two referents as in (9), while there eye-movements were monitored.

(9) The staff canteen was busy.

(a) *Nonlocal antecedent match, Local antecedent match*

The surgeon remembered that Jonathan had noticed him near the back of the lunch queue.

(b) *Nonlocal antecedent match, Local antecedent mismatch*

The surgeon remembered that Jennifer had noticed him near the back of the lunch queue.

(c) *Nonlocal antecedent mismatch, Local antecedent match*

The nurse remembered that Jonathan had noticed him near the back of the lunch queue.

(d) *Nonlocal antecedent mismatch, Local antecedent mismatch*

The nurse remembered that Jennifer had noticed him near the back of the lunch queue.

It wasn't long before everyone had to go back to work.

In (9a-d), the nonlocal antecedent *the surgeon/nurse* is the only accessible antecedent according to binding constraints (Chomsky, 1981; Pollard & Sag, 1992; Reinhart & Reuland, 1993). The local antecedent, *Jonathan/Jennifer*, should be inaccessible as it appears in the same local domain as the pronoun. In (9a,b) the nonlocal antecedent matches in stereotypical gender with the pronoun, while it mismatches in (9c,d). The gender of the local antecedent has also been manipulated, and matches the gender of the pronoun in (9a,c) but not (9b,d).

If syntactic constraints constitute more highly weighted cues to antecedent retrieval than gender agreement, we should observe reliable effects of the gender of the nonlocal antecedent only (Chow et al., 2014). In this case, reading times should be longer in (9c,d),

when the nonlocal antecedent mismatches in stereotypical gender with the pronoun, in comparison to (9a,b), when there is a gender match. The gender of the local antecedent should not affect reading times. Alternatively, we might find evidence of *facilitatory* interference. In this case, we should observe a reliable attenuation of the nonlocal antecedent gender mismatch effect when the local antecedent matches the gender of the pronoun, with reading times in (9c) being shorter than (9d). This would be compatible with the claim that binding constraints and gender agreement are equally weighted cues to antecedent retrieval. Additionally, multiple-match *inhibitory* interference effects might be observed in the nonlocal antecedent match conditions, with longer reading times in multiple match condition (9a) compared to local antecedent mismatch condition (9b). If syntactic constraints restrict the initial retrieval but may subsequently be violated (Cunnings & Sturt, 2014; Sturt, 2003), any interference effects should be comparatively delayed compared to main effects of the gender of the nonlocal antecedent.

Method

Participants

40 native English speakers (16 males, mean age 21) were paid to participate in the experiment. All participants had normal or corrected to normal vision and were recruited from the University of Edinburgh community.

Materials

32 sets of experimental items were constructed as in (9). Gender congruence between the pronoun and nonlocal antecedent used gender biased nouns, all of which had been rated for gender stereotypicality in previous studies (Cunnings & Felser, 2013; Kennison & Trofe, 2003; Kreiner, Sturt, & Garrod, 2008). The local antecedent's gender was manipulated using

proper names. Each item began with a single introduction sentence. The critical sentence included the nonlocal and local antecedents, and the critical pronoun. A final third sentence was included to avoid any end-of-trial artefacts from affecting reading times of the critical sentence. The masculine pronoun 'him' was used in all items to avoid the temporary ambiguity of the feminine pronoun 'her' (Clifton, Kennison, & Albrecht, 1997). The full set of experimental items is provided online as supplementary materials.

In addition to the experimental items, 64 filler texts were also constructed. These included items that were structurally similar to the experimental items but did not contain pronouns, and others that included other types of masculine and feminine pronouns.

Procedure

The experimental and filler items were pseudo-randomised such that no two experimental items were adjacent to each other. Four presentation lists were constructed in a Latin-square design, and the experiment was divided into four blocks between which participants could take a break if required. Forward and reverse orders of items within each block were constructed, and the ordering of blocks was different for each participant. Eight practice items were included before the main experiment to familiarize participants with the procedure. Each item was presented in Consolas fixed width font and displayed across up to three lines of text onscreen.

Eye-movements were recorded at a rate of 1000Hz using the EYELINK 2000 system. Although viewing was binocular, eye-movements were recorded from the right eye only. An experimental session began with calibration of the eye-tracker on a nine-point grid. Any drift in calibration was compensated for via recalibration between trials if required. Before each trial, a fixation marker was shown onscreen above the first word of the text to be displayed. Once participants fixated upon this marker, the trial text appeared. Participants were

instructed to read each text silently at their normal reading rate, and to press a button on a control pad once completed. Content questions requiring a yes-no push-button response were presented after each critical item and half the fillers. The entire experiment lasted approximately 30-45 minutes in total.

Data analysis

We report analysis for two regions of text. The *pronoun region* consisted of the critical pronoun, while the *spillover region* contained the following three words. We calculated three reading time measures at each region. *First pass reading time* is the summed duration of fixations within a region during its first inspection, until it is exited to the left or right, while *regression path duration* is calculated by summing the duration of each fixation, starting with the first fixation when a region is entered from the left, up until but not including the first fixation in a region to the right. In addition to these two *first-pass* processing measures, we also calculated *second pass times*, which included all fixations within a region *after* it has been exited following the first-pass.

All trials in which track loss occurred were discarded before any further analysis. Regions which were initially skipped were treated as missing data in the two first-pass measures. To increase the probability of a first pass fixation at the critical pronoun region, a leftward-shifting procedure was used in calculation of the first pass and regression path times at the pronoun. If the pronoun was skipped during the first pass, a leftward-shifting procedure was used, in which the region boundary was iteratively extended to the left of the pronoun, up to a maximum of 4 character positions, until a fixation was detected, and the duration of that fixation was returned as the first-pass value for that trial. If a fixation was still not found when the region boundary was extended four characters to the left, the trial was counted as missing data (see Sturt 2003: 548). For second pass times, trials in which a region was not

fixated following the first-pass contributed a second pass time of zero to the calculation of averages. Prior to the calculation of reading times, fixations shorter than 80ms that were within one character of another fixation were merged. All other fixations below 80ms, as well as those above 800ms, were removed before further analysis.

Results

Overall accuracy to the comprehension questions was 93% (all above 78%), indicating participants paid attention to the content of the sentences. Track loss accounted for 0.23% of the data. The skipping rates for the pronoun region (after leftward-shifting) and spillover region were 8%, and 4% respectively.

Analysis was conducted using linear mixed-effects models (see Baayen, 2008; Baayen, Davidson, & Bates, 2008) with the lme4 package in R. In contrast to previous work in which each measure at each region is analysed independently, which may lead to an increased false positive discovery rate (von der Malsburg & Angele, 2017), to minimise the number of comparisons across regions we conducted a single analysis for each reading time measure that included both analysis regions, but which treated region as a fixed effect. We believe this method has several benefits over analysing each region separately. Firstly, it maximises power to observe effects that may be consistent, but not significant, across regions. Secondly, it provides a way to explicitly test time-course effects. Many previous studies have drawn conclusions about time-course based on finding a particular reading time pattern at, for example, the critical region and a different pattern at the spillover region. Typically the reliability of such time-course effects has not directly been tested statistically. Including region as a fixed effect allows us to explicitly test potential time-course effects across regions.

For each measure, a mixed-effects model was fit with sum-coded (-0.5, 0.5) fixed main effects of 'region' (pronoun region vs. spillover region), 'nonlocal antecedent' (match vs. mismatch), 'local antecedent' (match vs. mismatch) and their interactions. Subject and item random intercepts and random slopes for each fixed effect were fitted using a 'maximal' random effects structure (Barr, Levy, Scheepers, & Tily, 2013). By including 'region' as a fixed effect, our analysis includes two datapoints from each trial that are non-independent. To account for this, we additionally included random effects for trial, defined as the unique subject and item pairing that constituted a particular individual trial in the experiment. We included a random intercept for trial and a random slope for 'region'. As the factor 'region' is the only repeated measure at the level of the trial, we did not include additional random slopes by trial (see Barr, 2013).

If the maximal model did not converge, the random correlation parameters were removed and the model refit. If this model still did not converge, we iteratively removed the random effects parameters that accounted for the least amount of variance in the data until convergence was achieved. For each fixed effect, *p* values were calculated using an upper bound of the *t* statistic (Baayen, 2008: 248). We do not discuss main effects of region below, given that these merely reflect the different lexical material between the pronoun and spillover regions. Significant interactions between either antecedent and region provide insight into the time-course of processing.

Summaries of the reading time data and statistical analysis for Experiment 1 are presented in Tables 1 and 2 respectively.[1]

(TABLE 1 ABOUT HERE)

[1] Data and analysis code for the four experiments reported in this paper can be found at the first author's OSF website (https://osf.io/v93wg/).

In first-pass reading times there was a significant main effect of the nonlocal antecedent, with longer reading times when the nonlocal antecedent mismatched in stereotypical gender with the pronoun compared to when there was a gender match. A similar pattern was also observed in regression path times, with significantly longer reading times when there was a stereotypical gender mismatch. No further main effects or interactions were significant in any measure.

(TABLE 2 ABOUT HERE)

Discussion

Reading times at and after the pronoun were significantly affected by the stereotypical gender of the nonlocal antecedent but not the gender of the local antecedent. In both first-pass times and regression path times, reading times were longer when the nonlocal antecedent mismatched in stereotypical gender with the pronoun. We did not observe any significant effects of the local antecedent, either in terms of facilitatory or inhibitory interference, in any reading time measure. This suggests that upon encountering the pronoun, participants preferentially retrieved the nonlocal antecedent. These results are compatible with Chow et al. (2014) and suggest that binding constraints constitute highly weighted cues to antecedent retrieval during pronoun resolution, at least in coargument contexts. Experiments 2 and 3 further investigate antecedent retrieval for pronouns in other contexts.

Experiment 2

In Experiment 2, we examined pronouns in PNPs. The items used were identical to those in Experiment 1, except that the pronoun now appeared inside a picture noun phrase. The items from Experiment 1 were adapted as in (10), which shows the critical second sentence only.

(10a) *Nonlocal antecedent match, Local antecedent match*

The surgeon remembered that Jonathan left a picture of him near the back of the lunch queue.

(10b) *Nonlocal antecedent match, Local antecedent mismatch*

The surgeon remembered that Jennifer left a picture of him near the back of the lunch queue.

(10c) *Nonlocal antecedent mismatch, Local antecedent match*

The nurse remembered that Jonathan left a picture of him near the back of the lunch queue.

(10d) *Nonlocal antecedent mismatch, Local antecedent mismatch*

The nurse remembered that Jennifer left a picture of him near the back of the lunch queue.

As in Experiment 1, *the doctor/nurse* is the only antecedent that is accessible according to standard binding theory, as the pronoun should be free from the local antecedent *Jonathan/Jennifer* (Chomsky, 1981, 1986). In this case, and if binding constraints restrict antecedent retrieval, we should observe significant main effects of the nonlocal antecedent only in Experiment 2, with reading times being longer following stereotypical gender mismatches in (10c,d) compared to gender matches in (10a,b). The gender of the local antecedent should not have a significant effect on reading times.

Alternatively, if pronouns in PNPs are exempt from binding theory (Pollard & Sag, 1992), we might observe that the local antecedent is retrieved some proportion of the time. In this case, we may observe *facilitatory* or *inhibitory* effects during processing. That is, we may observe a significant attenuation of the stereotypical gender mismatch effect in condition (10c), when the local antecedent matches the gender of the pronoun, compared to (10d), when the local antecedent mismatches. We might also observe evidence of multiple-match effects, with reading times in the stereotypical gender match conditions being longer in (10a), when both antecedents match the gender of the pronoun, compared to (10b), when only the nonlocal antecedent matches. Finally, if binding constraints restrict the initial retrieval but are violable (Cunnings & Sturt, 2014; Sturt, 2003), any interference effects should be comparatively delayed compared to effects of the nonlocal antecedent.

Method

Participants

28 native English speakers (6 males, mean age 22), none of whom took part in Experiment 1, were paid to participate. All had normal or corrected to normal vision and were recruited from the University of Edinburgh community.

Materials

The 32 sets of experimental items from Experiment 1 were adapted as in (10). All sentences were identical to those used in Experiment 1 except that the pronoun now appeared inside a PNP. All items appeared with identical introduction and wrap-up sentences as in Experiment 1. The full set of experimental items can be found in the supplementary materials online. 64 filler texts were also included which included distractor items that were structurally similar to the experimental items but did not contain pronouns.

Procedure and Data Analysis

The procedure and data analysis was the same as in Experiment 1.

Results

Overall accuracy to the comprehension questions was 92% (all above 81%), indicating that participants paid attention to the content of the sentences. There was no track loss, and skipping rates for the pronoun and spillover region were 11% and 9% respectively. Summaries of the reading time data and statistical analysis are presented in Tables 3 and 4 respectively.

(TABLE 3 ABOUT HERE)

No significant effects were observed in first-pass reading time. In regression path times, there was a marginally significant main effect of the non-local antecedent and a marginal interaction between region and the nonlocal antecedent. Although only marginally significant, the pattern of results here suggests a nonlocal antecedent stereotypical gender mismatch effect at the spillover region but not the pronoun region. Indeed, analysis of each region separately revealed that regression path times at the pronoun region did not differ significantly as a result of the stereotypical gender of the nonlocal antecedent (estimate = 3, SE = 21, t = 0.15, p =.879), but were significantly longer for nonlocal antecedent stereotypical gender mismatch than match conditions at the spillover region (estimate = 57, SE = 28, t = 2.02, p = .044). In second path times there was a significant main effect of the nonlocal antecedent, with longer reading times when the nonlocal antecedent mismatched in stereotypical gender with the pronoun. There was also a marginal interaction between region

and non-local antecedent, which suggested numerically larger nonlocal antecedent gender mismatch effects at the spillover region. There was also a marginal 3-way interaction, however analysis of each region separately indicated significant main effects of the nonlocal antecedent only (for the pronoun region, estimate = 31, SE = 14, t = 2.25, p = .025; for the spillover region, estimate = 62, SE = 19, t = 3.30, p = .001), in the absence of any other significant effects (all $t < 1.25$, all $p > .213$).

Discussion

The only significant effects we observed in Experiment 2 were a result of the stereotypical gender of the nonlocal antecedent. This was most clearly observed in second pass times, where reading times were longer when the nonlocal antecedent mismatch the gender of the pronoun. There was also suggestive evidence of a gender mismatch effect in regression path times especially at the spillover region. Effects of the local antecedent, either in terms of facilitatory or inhibitory interference, did not reach significance in any measure. This pattern of results suggests that the nonlocal antecedent was preferentially retrieved when readers encountered the pronoun.

These results are similar to Experiment 1 in that they suggest that the pronoun preferentially triggered retrieval of the nonlocal antecedent. This might be unexpected under the hypothesis that PNPs are fully exempt from binding constraints (Pollard & Sag, 1992), but is compatible with the hypothesis that pronouns in PNPs prefer nonlocal antecedents (Chomsky, 1981, 1986; Keller & Asudeh, 2001). We now turn to Experiment 3, which examined pronouns in PPNPs.

Experiment 3

In Experiment 3, we adapted the materials from Experiments 1 and 2 to investigate pronouns in PNPs with a possessor. The items were adapted as in (11).

(11a) *Nonlocal antecedent match, Local antecedent match*

The surgeon remembered about Jonathan's picture of him near the back of the lunch queue.

(11b) *Nonlocal antecedent match, Local antecedent mismatch*

The surgeon remembered about Jennifer's picture of him near the back of the lunch queue.

(11c) *Nonlocal antecedent mismatch, Local antecedent match*

The nurse remembered about Jonathan's picture of him near the back of the lunch queue.

(11d) *Nonlocal antecedent mismatch, Local antecedent mismatch*

The nurse remembered about Jennifer's picture of him near the back of the lunch queue.

As in Experiments 1 and 2, *the surgeon/nurse* is the only antecedent accessible according to standard binding theory (Chomsky, 1981, 1986), whereas *Jonathan/Jennifer* should be inaccessible. The same predictions also hold for revised theories (Pollard & Sag, 1992; Reinhart & Reuland, 1993) under the assumption that PPNPs form nominal predicates which require the pronoun to be free from the local possessor (Pollard & Sag, 1992; Reinhart & Reuland, 1993). If pronouns cue retrieval of the nonlocal antecedent, we should find effects of the stereotypical gender of the nonlocal antecedent only, with reading times being longer in conditions (11c,d) in comparison to (11a,b).

A different pattern of results can be predicted if PPNP reflexives are exempt from binding theory (Runner et al, 2003, 2006). In this case, we may observe that pronoun resolution is guided more by gender agreement, in which case we should observe *facilitatory* interference effects during processing. That is, we would predict a significant attenuation of the stereotypical gender mismatch effect in condition (11c), when the local antecedent matches the gender of the pronoun, compared to (11d), when the local antecedent mismatches. We might also observe *inhibitory* interference, with reading times in the nonlocal antecedent gender match conditions being longer in (11a), when both antecedents match the gender of the pronoun, compared to (11b), when only the nonlocal antecedent matches. As in Experiments 1 and 2, if binding constraints restrict an initial retrieval but may subsequently be violated, interference effects should be comparatively delayed compared to effects of the nonlocal antecedent.

Method

Participants

28 native English speakers (11 males, mean age 21) with normal or corrected to normal vision from the University of Edinburgh community were paid to participate. None had taken part in either Experiments 1 or 2.

Materials

The 32 sets of experimental items were adapted as in (11), with the pronoun now appearing inside a PPNP. All other aspects of the experimental items, including the introduction and wrap-up sentences, were identical to Experiments 1 and 2 (see online supplementary materials). Note that in this experiment, as a result of our manipulation that keeps the surface word order as similar as possible across experiments, the nonlocal antecedent is now in the

same clause as the local antecedent and pronoun. 64 fillers were also included, as in Experiments 1 and 2.

Procedure and Data Analysis

The procedure and data analysis was the same as in Experiment 1.

Results

Overall accuracy to the comprehension questions was 91% (all above 82%), indicating that participants paid attention to the content of the sentences. There was no track loss. Skipping rates for the pronoun and spillover regions were both 3%. Summaries of the reading time data and statistical analysis for Experiment 3 are presented in Tables 5 and 6 respectively.

(TABLE 5 ABOUT HERE)

In first pass times, there was a significant region by local antecedent interaction. Analysis of each region separately indicated that first pass times at the pronoun region did not differ significantly as a result of the gender of the local antecedent (estimate = 6, SE = 8, t = 0.770, p = .442). However, there was a significant effect of the local antecedent at the spillover region (estimate = 33, SE = 16, t = 2.13, p = .034), with longer reading times when it mismatched the gender of the pronoun compared to when there was a gender match. In both regression path and second pass times there was a significant main effect of the nonlocal antecedent only. In both measures, reading times were longer when the nonlocal antecedent mismatched the stereotypical gender of the nonlocal antecedent. No other main effects or interactions were significant.

(TABLE 6 ABOUT HERE)

Discussion

In Experiment 3, regression path times and second pass times were influenced by the stereotypical gender of the nonlocal antecedent only. In both measures, reading times across the pronoun and spillover regions were significantly longer when the nonlocal antecedent mismatched the gender of the pronoun. We did also observe a significant effect of the local antecedent, although this was restricted to first-pass reading time at the spillover region only. Here, we observed neither partial-match facilitatory interference, nor multiple-match inhibitory interference, as would be expected if gender was a highly weighted cue to antecedent retrieval. Instead, reading times were longer when the local antecedent mismatched the gender of the pronoun, which may suggest the local antecedent was occasionally retrieved irrespective of its gender. This effect however, which appeared in only one measure, appeared delayed until the spillover region, while effects of the nonlocal antecedent were observed in both regression path and second pass times across both regions. We argue that this pattern of results suggest that the nonlocal antecedent was preferentially retrieved upon encountering the pronoun.[2]

[2] An anonymous reviewer queried this interpretation of our results. As the nonlocal antecedent effect was calculated across both regions, it might be that there is no significant effect of the nonlocal antecedent at the pronoun region itself, which would complicate our interpretation of the time-course of nonlocal and local antecedent effects. Even though the region by nonlocal antecedent interaction was not significant, we conducted an additional analysis of the regression path times at each region separately to address this issue. This yielded significant main effects of the gender of the nonlocal antecedent at both regions (for the pronoun region, estimate = 28, SE = 13, t = 2.20, p = .028; for the spillover region,

We thus maintain that the results here suggest, as in Experiments 1 and 2, that the pronoun initially triggered retrieval of the nonlocal antecedent. In Experiment 4, we further investigate the extent to which these preferences may be ultimately overridden, by testing offline interpretive preferences for pronouns in the three contexts tested in Experiments 1-3.

Experiment 4

To investigate the interpretation ultimately preferred for pronouns in different contexts, we conducted an antecedent choice task in which participants had to choose their favoured antecedent for a pronoun. This experiment tested a subset of six conditions from Experiments 1-3, as in (12).

(12a) *Coargument pronoun, Nonlocal antecedent match*

The surgeon remembered that Jonathan had noticed him near the back of the lunch queue.

(12b) *Coargument pronoun, Nonlocal antecedent mismatch*

The nurse remembered that Jonathan had noticed him near the back of the lunch queue.

(12c) *PNP pronoun, Nonlocal antecedent match*

The surgeon remembered that Jonathan left a picture of him near the back of the lunch queue.

(12d) *PNP pronoun, Nonlocal antecedent mismatch*

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estimate = 80, SE = 38, t = 2.10, p = .036), in the absence of any other significant effects (all t < 1.17, all p > .245). We thus maintain that these results are consistent with our interpretation of the time-course of nonlocal and local antecedent effects.

The nurse remembered that Jonathan left a picture of him near the back of the lunch queue.

(12e) *PPNP pronoun, Nonlocal antecedent match*

The surgeon remembered about Jonathan's picture of him near the back of the lunch queue.

(12f) *PPNP pronoun, Nonlocal antecedent mismatch*

The nurse remembered about Jonathan's picture of him near the back of the lunch queue.

In Experiment 4, the local antecedent always matched the gender of the pronoun, while we manipulated the gender of the nonlocal antecedent such that it matched in (12a,c,e) but not (12b,d,f). We tested pronouns in coargument (12a,b), PNP (12c,d) and PPNP (12e,f) contexts to gauge the extent to which local and nonlocal antecedents are preferred for pronouns in different contexts.

We expected participants to prefer the nonlocal antecedent in coargument contexts. If PNPs are exempt from binding theory (Pollard & Sag, 1992, Reinhart & Reuland, 1993), participants should choose either antecedent in PNP contexts, and may exhibit a preference for the local antecedent when the nonlocal antecedent mismatches the pronoun in stereotypical gender, as in (12d). If PPNPs form complex predicates (Pollard & Sag, 1992), interpretive preferences for pronouns in PPNPs, as in (12e,f), should be similar to those in coargument contexts (12a,b). Alternatively, if both PPNP and PNP contexts are exempt from binding theory (Runner et al., 2003, 2006), pronouns in PPNPs (12e,f) should behave similarly to pronouns in PNPs (12c,d).

Method

Participants

36 native English speakers (4 males, mean age 21) from the University of Reading community, none of whom took part in any of the eye-movement experiments, took part in Experiment 4.

Materials

The 32 experimental items from Experiments 1-3 were adapted as in (12). As 32 items do not divide equally into six conditions, four additional items were constructed to give 36 items in total (see supplementary materials). All items appeared with introduction and wrap-up sentences as in Experiments 1-3. 54 filler items were constructed that included different types of pronouns in various contexts, with either one gender-matching or multiple gender-matching potential antecedents.

Procedure

The experimental and filler items were pseudo-randomised across six lists in a Latin-square design. A forward and reverse order of the randomised lists was presented to the same number of participants. The questionnaire was administered via email as a Word document. The critical pronoun in each text appeared in a box. Below each text, two antecedents from the discourse appeared as either choices (A) or (B) (e.g. (A) Jonathan, (B) The doctor). Participants were instructed to choose who they thought the boxed pronoun most likely referred to, and were given the options to choose person (A), person (B) or either of them. Participants responded using a drop-down menu that had options for (A), (B) or 'Either'. Across items, the local and nonlocal antecedent appeared as option (A) and (B) an equal number of times.

Results

The percentage of nonlocal antecedent, local antecedent and 'either' responses for each condition are shown in Table 7.

(TABLE 7 ABOUT HERE)

The results indicate that participants mostly chose the nonlocal antecedent for pronouns in coargument and non-coargument contexts. This preference for the nonlocal antecedent does however appear slightly weaker for pronouns in PNP and PPNP contexts. For analysis purposes, we coded the data as either a response for the 'nonlocal antecedent' or 'other response', collapsing 'local antecedent' and 'either' responses into a single category. We conducted the analysis in this way as either a 'local antecedent' or an 'either' response is not expected under binding theory. The data were analysed using a mixed logit model.[3] The 3-level factor 'construction type' (coargument, PNP, PPNP) was Helmert coded, with one contrast comparing coargument pronouns to those in PNP and PPNPs lumped together, and a second contrast comparing PNP to PPNP pronouns. The 2-level fixed effect 'nonlocal antecedent' (gender match vs. mismatch) was sum coded (-0.5, 0.5).

This analysis revealed that the contrast between coargument and picture noun phrase pronouns was significant (estimate = 1.24, SE = 0.28, $z = 4.38$, $p < .001$), indicating that there were more nonlocal antecedent responses for coargument pronouns (87%) than those in either type of picture noun phrase (74%). There was a trend for more nonlocal antecedent responses for PPNP than PNP pronouns, but this contrast was only marginally significant (estimate = 0.21, SE = 0.12, $z = 1.81$, $p = .071$). Participants also tended to pick the nonlocal antecedent

[3] The model was fit using the bobyqa optimizer. The maximal model did not converge but removing the random correlation parameters led to convergence.

less often when it mismatched the stereotypical gender of the pronoun in the two picture noun phrase contexts but not the coargument context. However, both the main effect of the gender of the nonlocal antecedent (estimate = 0.46, SE = 0.27, z = 1.71, p = .088), and the interaction between it and the relevant construction type contrast (coargument vs. picture noun phrase) were marginal (estimate = 0.77, SE = 0.45, z = 1.73, p = .083). The interaction between nonlocal antecedent gender and the second construction type contrast (PNP vs. PPNP) was not significant (estimate = 0.28, SE = 0.23, z = 1.23, p = .219).

Discussion

The results of Experiment 4 indicate a general preference for the nonlocal antecedent for pronouns in coargument and picture noun phrase contexts. This preference was however weaker in the two picture noun phrase contexts than for coargument pronouns, suggesting that participants were ultimately willing to consider the local antecedent as a potential antecedent of the pronoun some percentage of the time, particularly in non-coargument contexts. We discuss these results, along with the results of Experiments 1-3, in more detail below.

General Discussion

We investigated the time-course of pronoun resolution in coargument contexts and in picture noun phrases. Across three eye-movement experiments, we found longer reading times when a nonlocal antecedent mismatched in stereotypical gender with a pronoun. These results suggest syntactic constraints restrict antecedent retrieval during pronoun resolution to nonlocal antecedents in both coargument contexts and PNPS, either with or without a possessor. Significant effects of the local antecedent were observed in only one experiment, in one eye-movement measure, and we argued appeared delayed in comparison to effects of

the nonlocal antecedent. We did however find evidence that participants are willing to sometimes consider the local antecedent as a potential antecedent for the pronoun in an offline measure in Experiment 4, especially in non-coargument contexts, although the nonlocal antecedent was generally preferred overall. We discuss the implications of these results for the time-course of memory retrieval during language comprehension, and the characterisation of syntactic constraints on pronouns in PNPs, in turn below.

Memory Retrieval During Pronoun Resolution

In the three eye-movement experiments, we observed longer reading times when the nonlocal antecedent mismatched in stereotypical gender with the pronoun. Effects of the gender of the local antecedent were more elusive, being significant in only one measure in one experiment, and appeared to be delayed to the spillover region. For pronouns in coargument contexts, our results replicate previous findings that binding constraints constitute a highly weighted cue that restricts retrieval to nonlocal antecedents (Chow et al., 2014; Patterson et al., 2014). Our results also suggest that, at least initially, pronouns also restrict retrieval to nonlocal antecedents in picture noun phrase contexts as well. These results are similar to existing studies of reflexives, and in particular Cunnings and Sturt (2014), in suggesting that binding constraints constitute more highly weighted cues to antecedent retrieval than gender agreement.

We argued that the clearest evidence for retrieval of the local antecedent would come from either partial-match facilitatory interference in nonlocal antecedent gender mismatch conditions, with shorter reading times when the local antecedent matched the gender of the pronoun, or multiple-match inhibitory interference in the nonlocal antecedent gender match conditions, with longer reading times when both antecedents matched the pronoun's gender. We did not find significant effects of either type of interference in any of the three eye-

movement experiments. The one effect we did observe in Experiment 3 was a main effect of the gender of the local antecedent, with longer reading times when it mismatched the pronoun in gender. This might be expected if the local antecedent was sometimes retrieved *irrespective* of its gender. Such results would be predicted if gender constitutes only a weak cue to antecedent retrieval, with other cues, such as antecedent animacy, referential status or discourse prominence, potentially interacting with binding constraints to occasionally cue retrieval of inaccessible antecedents irrespective of gender. We also found that comprehenders did occasionally consider local antecedents in Experiment 4, which used an offline measure, particularly in non-coargument contexts. We argue that this pattern of results and time-course of effects suggest that binding constraints initially restrict retrieval to nonlocal antecedents, but that this nonlocal preference may sometimes be overridden in subsequent stages of processing (see Cunnings & Sturt, 2014, for similar claims for reflexives).

This interpretation of our results contrasts with studies that have examined pronoun resolution in picture noun phrases using the visual world paradigm (Kaiser et al., 2009; Runner et al., 2003, 2006). In their studies on pronouns in PPNP contexts (e.g. 'Have Joe touch Harry's picture of him'), Runner et al. and Kaiser et al. found that offline antecedent preferences were largely in line with binding theory, with the possessor rarely being considered as a potential antecedent for the pronoun. In eye-movement measures however, they reported early looks to the possessor antecedent, which might be taken as evidence that it was considered as an antecedent for the pronoun. This would be unexpected based on our claim that local antecedents are initially restricted from retrieval. As we discussed in the Introduction however, it may be difficult to tease apart whether these effects from the visual world paradigm truly reflect early consideration of the possessor as a potential antecedent, or

continued looks to the possessor due to spillover processing as a result of it being the last mentioned referent depicted in the visual display.

Kaiser et al. (2009) also examined pronouns in PNP contexts in sentences such as 'Peter told/heard from Kevin about the picture of him', in which classic binding theory would predict 'Kevin' to be the only accessible antecedent. They found in both offline measures, and in eye-movements during processing, that participants considered the inaccessible antecedent 'Peter' as a potential antecedent for the pronoun, especially when it was a 'perceiver' of information ('Peter heard from Kevin about the picture of him'). These results related to the discourse status of antecedents (source vs. perceiver) are potentially harder to explain based on our claim that local antecedents are initially restricted from pronoun resolution, as they do not suffer from the same potential confound as in other visual world studies as discussed above. Instead, these results suggest that at least for PNP pronouns, syntactic and pragmatic constraints combine to cue retrieval. Thus, while in our experiments we argue that the pronoun initially triggered retrieval of the nonlocal antecedent in coargument, PNP and PPNP contexts, we acknowledge that we did not manipulate the pragmatic factors investigated by Kaiser et al., and it thus remains an open question whether we would find evidence of interference if we included such a manipulation. Irrespective of this potential interaction between binding constraints and pragmatics however, we maintain that our results nevertheless suggest that merely being in a picture noun phrase does not lead pronouns to readily cue retrieval of a syntactically local antecedent, as might be expected if picture noun phrases are completely exempt from binding constraints.[4]

[4] Kaiser et al. also examined PPNPs and found little evidence that the possessor was ever considered as a potential antecedent for the pronoun, irrespective of their pragmatic manipulation. This might be taken to suggest that binding constraints interact with pragmatic factors for PNP but not PPNP pronouns. Note however that in the PPNP materials tested by

Although we have claimed that pronouns preferentially cue retrieval of nonlocal antecedents, how to implement this type of syntactic (non)locality constraint in a cue-based architecture is a non-trivial problem. One issue is that binding constraints as described in the theoretical linguistics literature are inherently relational in nature, being described in terms of the relationship between two items in memory (the antecedent and reflexive/pronoun), rather than content-based features (for discussion, see Kush, 2013; Kush, Lidz & Phillips, 2015). An additional challenge for implementing Principle B in particular relates to its inherently 'negative' nature, in that the traditional characterisation of Principle B restricts which antecedents *cannot* co-refer with a pronoun, rather than providing information relating to which antecedents a pronoun *can* co-refer with. How to implement such a negative constraint in a cue-based architecture, which involves *matching* rather than *mismatching* a set of cues against items in memory, also warrants discussion.

Our study did not aim to tease apart different ways of implementing binding constraints in a cue-based architecture, but we believe one way to achieve this would be by dynamically updating the feature-based content of items in memory during incremental sentence processing (Kush, 2013; Kush et al. 2015). Kush proposed that during sentence processing, the parser keeps tracks of whether items in memory are sufficiently local by a [+LOCAL] feature encoded on constituents. When particular boundaries are passed, such as a clause (or other constituent relevant for binding domains), the [+LOCAL] feature of constituents no longer within the local domain are deactivated. This would provide one way

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Kaiser et al. ('Peter told/heard from Andrew about Greg's picture of him'), it is not possible to manipulate the interaction of pragmatic factors and binding constraints, as it is not possible to manipulate the 'perceiver' status of the possessor. Thus, it is difficult to draw any strong conclusions about potential differences in the role of pragmatic information in PNP and PPNP contexts.

of implementing Binding Principle A, as reflexives could then cue retrieval of items with the [+LOCAL] feature. To implement Principle B, it might be that items marked [+LOCAL] are inhibited, such that retrieval is restricted to items not bearing this feature. We note however that this possibility is different to how retrieval cues have typically been implemented in sentence processing, where retrieval is achieved by *matching* a set of retrieval cues against items in memory, rather than inhibiting them.[5] Another possibility is that as constituents become nonlocal, the [+LOCAL] feature is not just deactivated but also recoded as being [+NONLOCAL]. In this way, pronouns may cue retrieval of antecedents marked as [+NONLOCAL]. Both of these possibilities may provide ways of implementing Principle B as tested in our study. Although our study cannot tease these two potential accounts apart, we believe dynamic updating of features is likely key to implementing binding constraints in a cue-based architecture.[6]

Finally, we note that in a recent study on reflexive resolution, Parker and Phillips (2017) reported partial-match facilitatory interference effects in coargument contexts when an accessible antecedent mismatched the reflexive in both gender and number. This suggests that inaccessible antecedents are sometimes retrieved if the accessible antecedent provides a

[5] We thank an anonymous reviewer for highlighting the possible role of inhibition in implementing Principle B.

[6] We note that both of these accounts may have difficulty in constraining pronoun resolution in sentences such as 'The father of Kevin introduced him' or 'Kevin's father introduced him', where the accessible antecedent ('Kevin') is syntactically local but does not c-command the pronoun. Two features would be required here, one that encodes syntactic locality and one that tracks c-command, to fully account for these binding restrictions. How antecedent retrieval is constrained during processing, for either reflexives or pronouns, for these types of constructions is unknown however, and remains an avenue for future research.

particularly poor feature-match. We only examined gender agreement in our study, and thus it remains an avenue for future research if results similar to Parker and Phillips can also be observed for pronouns.

Pronouns and Binding Constraints

We now discuss how our results relate to theoretical accounts of binding constraints. We have argued that the results from the three eye-movement experiments indicate that the nonlocal antecedent was preferentially retrieved. In the offline experiment as well there was a general preference for the nonlocal antecedent across all contexts. These findings might be unexpected if picture noun phrases are completely exempt from binding constraints, as claimed by some authors (Pollard & Sag, 1992; Reinhart & Reuland, 1993). At the same time, the results of Experiment 4 indicate that pronouns in both PNPs and PPNPs are more likely to take a local antecedent than coargument pronouns. There are potentially a number of different ways to account for these findings. One possibility could be to maintain constraints akin to binding theory, but under the assumption that they only restrict the *initial* retrieval of an antecedent (see Cunnings & Sturt, 2014, for similar claims with regards to reflexives). In this way, it might be that binding constraints are more readily overridden in picture noun phrases than coargument contexts. Another possibility could be that there is no strict dichotomy between coargumenthood and non-coargumenthood, but that binding constraints apply in a graded fashion across contexts. We do not attempt to tease these accounts apart here, but merely note that the nonlocal antecedent preferences that we observed suggest there may not be a strict dichotomy between coargument and non-coargument contexts.

Irrespective of these different potential ways of accounting for the distinction between coargument and picture noun phrase pronouns, another theoretical issue that our results address relates to binding constraints in different types of picture noun phrases. A number of

researchers have claimed that PPNPs are restricted by binding theory in a similar way to coargument contexts, with only PNPs being binding theory exempt (Pollard & Sag, 1992; Reinhart & Reuland, 1993). Classic binding theory also predicts pronouns should be free form a possessor in PPNPs in the same way as they are from a local antecedent in coargument contexts (Chomsky, 1981, 1986). The results of Experiment 4 in particular are not compatible with this view, and instead suggest that both PNP and PPNP pronouns can sometimes take a local antecedent. Indeed, it was only in Experiment 3, with PPNP pronouns, that we observed any significant effects of the local antecedent during reading. Given the similarity of the results for PNP and PPNP pronouns observed in Experiment 4, we do not wish to over-interpret this potential difference between PNP and PPNP pronouns during processing, but nevertheless these results are not compatible with the claim that pronouns in PPNP contexts behave like other coargument pronouns.

In sum, however the distinction between coargument and non-coargument contexts is made, either in terms of a strict dichotomy or in a more graded fashion, our results suggest that the distinction should be made between coargument pronouns and those in picture noun phrases, irrespective of whether there is a possessor, rather than between coargument and PPNP pronouns compared to pronouns in PNPs.

Conclusion

In three eye-movement experiments, we found that readers preferred to resolve a pronoun as referring to a structurally nonlocal antecedent. In an offline antecedent choice task, participants did occasionally consider local antecedents for pronouns, especially when they were in picture noun phrases. We argue that our results suggest pronouns in both coargument and picture noun phrase contexts, irrespective of whether the picture noun phrase contains a possessor, preferentially cue retrieval of nonlocal antecedents, but that this preference may be

overridden, especially in non-coargument contexts. Our results suggest that local antecedents are not as readily retrieved upon encountering a pronoun in non-coargument contexts as might be predicted by theories which assume PNPs are exempt from binding theory (Pollard & Sag, 1992; Reinhart & Reuland, 1993). As has previously been argued for reflexives (Cunnings & Sturt, 2014), our results suggest binding constraints constitute more highly weighted cues to antecedent retrieval than gender congruency during pronoun resolution in both coargument and non-coargument contexts.

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Table 1. *Reading times in Experiment 1 (Standard Errors in parentheses)*

	First Pass Reading Time	Regression Path Time	Second Pass Time
Pronoun Region			
Nonlocal Match, Local Match	231 (5)	268 (10)	109 (10)
Nonlocal Match, Local Mismatch	239 (6)	285 (12)	119 (11)
Nonlocal Mismatch, Local Match	251 (7)	322 (13)	120 (11)
Nonlocal Mismatch, Local Mismatch	245 (6)	323 (17)	138 (12)
Spillover Region			
Nonlocal Match, Local Match	365 (14)	490 (23)	273 (19)
Nonlocal Match, Local Mismatch	352 (13)	479 (24)	309 (23)
Nonlocal Mismatch, Local Match	375 (12)	509 (23)	306 (22)
Nonlocal Mismatch, Local Mismatch	370 (13)	516 (25)	308 (24)

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent

Table 2. *Summary of the statistical analysis in Experiment 1*

	Estimate		*t*	*p*
First Pass Reading Time				
Region	122	(18)	6.71	< .001
Nonlocal	14	(7)	2.08	.038
Local	3	(6)	0.48	.633
Region * Nonlocal	5	(13)	0.39	.697
Region * Local	10	(14)	0.72	.469
Nonlocal * Local	1	(13)	0.07	.943
Region * Nonlocal * Local	24	(30)	0.81	.421
Regression Path Time				
Region	198	(25)	7.85	< .001
Nonlocal	37	(19)	2.02	.044
Local	4	(13)	0.27	.787
Region * Nonlocal	15	(26)	0.59	.556
Region * Local	7	(26)	0.25	.800
Nonlocal * Local	1	(27)	0.03	.974
Region * Nonlocal * Local	34	(50)	0.67	.505
Second Pass Time				
Region	178	24	7.43	< .001
Nonlocal	15	15	1.00	.319
Local	17	14	1.20	.229
Region * Nonlocal	1	21	0.03	.978
Region * Local	6	19	0.29	.770
Nonlocal * Local	13	28	0.48	.632
Region * Nonlocal * Local	43	40	1.06	.289

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent
Estimate = Model Estimate (Standard Error in brackets).

Table 3. *Reading times in Experiment 2 (Standard Errors in parentheses)*

	First Pass Reading Time	Regression Path Time	Second Pass Time
Pronoun Region			
Nonlocal Match, Local Match	239 (7)	307 (20)	79 (10)
Nonlocal Match, Local Mismatch	237 (7)	278 (11)	66 (9)
Nonlocal Mismatch, Local Match	245 (7)	299 (19)	103 (13)
Nonlocal Mismatch, Local Mismatch	235 (7)	294 (19)	103 (12)
Spillover Region			
Nonlocal Match, Local Match	290 (11)	329 (17)	160 (16)
Nonlocal Match, Local Mismatch	314 (16)	363 (19)	198 (18)
Nonlocal Mismatch, Local Match	297 (13)	392 (29)	245 (22)
Nonlocal Mismatch, Local Mismatch	294 (11)	414 (31)	236 (21)

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent

Table 4. *Summary of the statistical analysis in Experiment 2*

	Estimate		*t*	*p*
First Pass Reading Time				
Region	59	(16)	3.72	< .001
Nonlocal	1	(9)	0.15	.883
Local	3	(8)	0.42	.677
Region * Nonlocal	7	(14)	0.53	.597
Region * Local	13	(17)	0.78	.434
Nonlocal * Local	17	(13)	1.36	.173
Region * Nonlocal * Local	24	(26)	0.94	.347
Regression Path Time				
Region	81	(23)	3.50	< .001
Nonlocal	31	(18)	1.69	.092
Local	7	(15)	0.47	.641
Region * Nonlocal	53	(28)	1.92	.055
Region * Local	39	(26)	1.51	.133
Nonlocal * Local	6	(31)	0.20	.843
Region * Nonlocal * Local	47	(51)	0.92	.357
Second Pass Time				
Region	123	(18)	6.68	< .001
Nonlocal	46	(14)	3.34	< .001
Local	4	(12)	0.33	.741
Region * Nonlocal	31	(17)	1.79	.074
Region * Local	20	(17)	1.18	.240
Nonlocal * Local	17	(24)	0.68	.495
Region * Nonlocal * Local	60	(35)	1.69	.090

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent
Estimate = Model Estimate (Standard Error in brackets).

Table 5. *Reading times in Experiment 3 (Standard Errors in parentheses)*

	First Pass Reading Time	Regression Path Time	Second Pass Time
Pronoun Region			
Nonlocal Match, Local Match	246 (9)	282 (15)	79 (10)
Nonlocal Match, Local Mismatch	232 (7)	254 (9)	64 (10)
Nonlocal Mismatch, Local Match	250 (7)	291 (13)	95 (14)
Nonlocal Mismatch, Local Mismatch	251 (7)	299 (14)	111 (13)
Spillover Region			
Nonlocal Match, Local Match	369 (15)	459 (34)	221 (23)
Nonlocal Match, Local Mismatch	422 (18)	450 (20)	189 (20)
Nonlocal Mismatch, Local Match	403 (15)	514 (28)	261 (26)
Nonlocal Mismatch, Local Mismatch	418 (17)	557 (36)	254 (27)

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent

Table 6. *Summary of the statistical analysis in Experiment 3*

	Estimate		*t*	*p*
First Pass Reading Time				
Region	155	(25)	6.14	< .001
Nonlocal	13	(8)	1.61	.109
Local	14	(8)	1.64	.101
Region * Nonlocal	4	(16)	0.26	.795
Region * Local	41	(18)	2.29	.022
Nonlocal * Local	12	(17)	0.72	.470
Region * Nonlocal * Local	56	(35)	1.60	.110
Regression Path Time				
Region	211	(26)	8.19	< .001
Nonlocal	54	(20)	2.71	.007
Local	3	(19)	0.17	.865
Region * Nonlocal	54	(33)	1.64	.102
Region * Local	28	(31)	0.90	.370
Nonlocal * Local	45	(37)	1.22	.225
Region * Nonlocal * Local	13	(64)	0.20	.841
Second Pass Time				
Region	144	(21)	6.97	< .001
Nonlocal	42	(15)	2.80	.005
Local	10	(15)	0.64	.521
Region * Nonlocal	21	(20)	1.02	.308
Region * Local	21	(22)	0.92	.356
Nonlocal * Local	28	(31)	0.90	.367
Region * Nonlocal * Local	5	(40)	0.13	.897

Nonlocal = Nonlocal Antecedent, Local = Local Antecedent
Estimate = Model Estimate (Standard Error in brackets).

Table 7. Percentage of responses in six conditions in Experiment 4

	Coargument Pronouns		PNP Pronouns		PPNP Pronouns	
	Nonlocal Antecedent Match	Nonlocal Antecedent Mismatch	Nonlocal Antecedent Match	Nonlocal Antecedent Mismatch	Nonlocal Antecedent Match	Nonlocal Antecedent Mismatch
Percentage of nonlocal antecedent responses	86.6	88.0	77.3	65.3	79.2	73.1
Percentage of local antecedent responses	5.6	4.6	6.0	15.3	6.0	7.9
Percentage of either antecedent responses	7.9	7.4	16.7	19.4	14.8	19.0