Attentional control predicts pronominalization irrespective of competing referents

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Abstract

Two story-continuation experiments replicate a well-known effect whereby speakers use fewer pronouns to refer to the main character of a story when an additional character is present in the scene/discourse. This effect arises even when characters are different sex/gender and a pronoun would be unambiguous, a finding originally attributed to competition for attentional resources in the speaker's representation of the discourse (Arnold & Griffin, 2007). However earlier work did not explicitly test this account. Here we investigate the role of inhibition and attention switching on referential choice across one- and two-characters scenes in 200 participants aged 19-82. Attentional capacity did not predict pronominalization differences across scenes. Instead, our results lend support to an alternative account whereby lower pronominal use in two-character scenes reflects participants' accurate assessment that the subject is more likely to be the topic when no additional character is present.

Keywords: reference, topichood, attention, working memory, ageing

Introduction

Speakers can choose from a variety of referential forms to refer to the same entity, from semantically rich proper names, to less explicit pronouns, or physical descriptions. For example, a speaker who introduces a referent 'Sally' during a conversation might choose, in subsequent sentences, to refer back to Sally using a reduced form 'she'. This type of anaphoric reference would work well in contexts where Sally is the only referent being discussed or where the other referents are males. However, when there are multiple female referents being discussed, the use of 'she' could create ambiguity for the listener, and the more informative referential form 'Sally' may be more appropriate.

A large body of research has investigated speakers' choice of referring expressions in contexts like the one above, where referential expressions can either facilitate the sharing of information with a communicative partner or leave them guessing. One of the most widespread findings in the literature is that a speaker's choice of more or less explicit referential forms is influenced by the grammatical position of the referent. That is, speakers prefer to use pronouns when mentioning a referent that was the subject of the previous sentence or the first-mentioned entity in a recent clause, whereas they prefer to use names and descriptions for a referent that was not recently in the subject position (Fletcher, 1984; Stevenson et al., 1994; Gernsbacher et al., 1989; Gernsbacher & Hargreaves, 1988; Arnold et al., 2009; Arnold, 1998; Fukumura & van Gompel, 2010; Rohde & Kehler, 2014). However, despite this general tendency towards pronouns for recent or prominent referents, speakers' pronoun use is reduced in situations where there are multiple salient referents of the same gender (Arnold et al., 2000; Arnold, 1999; Karmiloff-Smith, 1985). This phenomenon, known as the "Gender Effect", has been widely interpreted as reflecting a speaker's sensitivity to pragmatic pressures to be optimally informative for the listener by avoiding ambiguity. Thus, referential choice is often characterized as a listener-focused process. Relatedly, studies on the effects of accessibility on referential choice often interpret a speaker's choice of a name or pronoun as reflecting assumptions about what is accessible to the listener (Ariel, 1990; Gundel et al., 1993; Chafe, 1994). That is, if a speaker assumes a referent is highly accessible

in the listener's discourse model they will use a reduced form (such as a pronoun), whereas if the speaker thinks the referent is less accessible for the listener they will use a more explicit form (such as a name).

While much of the literature on referential choice has focused on these type of pragmatic selection models (i.e. models in which speakers' referential choices are dictated by their estimate of their interlocutor's perspective), less attention has been given to speaker-internal factors that may affect referential choice. That is, rather than assuming referential choice always involves an *explicit* process of selection (as defined by Arnold, 2016) in which the prominence of a discourse referent induces preferences for particular referential forms, researchers should also consider the possibility that referential selection may be influenced by *emergent* mechanisms (e.g. what is the easiest for a speaker to produce, as proposed by Brown & Dell, 1987 and Pickering & Garrod, 2004).

This possibility was addressed in an influential study by Arnold and Griffin (2007). In the study, participants were administered a referential communication task in which the use of names and pronouns were equally unambiguous, therein removing pragmatic constraints related to ambiguity avoidance for the sake of the listener. In the task, participants were presented with two-panel vignettes featuring one or two characters and listened to a sentence about the first panel (e.g. "Mickey went for a walk (with Daisy) in the hills one day.") Participants repeated the sentence, then came up with a story continuation relating to the second panel. Of interest was whether participants used a name or pronoun to refer to the main character (i.e. the subject of the sentence in the first panel and the visually most salient referent in Panel 2), and whether the mention of/visual presence of an additional character in the panels affected participants' choice of referring expression in their description of the second panel. Importantly, when there were two characters in the panels, the characters were always different sex/gender, thus a pronoun would have been as appropriate as a name for disambiguation. Interestingly, the authors found that speakers were more likely to use pronouns in describing the main character in one-character scenes than two-character scenes, despite no clear disambiguation gains for doing so. That is, in the context of the task,

a pronoun would be perfectly felicitous—not only are pronouns generally understood to be an appropriate referential form for re-mentioning a (syntactically) prominent entity (the subject referent), in this case the gender-marked pronoun also provides sufficient disambiguating information.

The authors interpret this dispreference for pronouns in the two-character scenes as reflecting competition between entities in the speaker's mental model, unrelated to any listener-oriented strategies. Specifically, in two-character scenes, each entity competes for the speaker's attention, therein lowering the accessibility of each referent. If referent accessibility, broadly defined, is linked to reduced forms of reference like pronouns (Ariel, 1990; Arnold, 1998; Gundel et al. 1993; Levelt, 1989), the competition between referents and the concomitant lowering of each referent's respective accessibility therefore results in the use of fewer pronouns and an increase in the use of more explicit names. Arnold and Griffin view the assessment of accessibility from the speaker's point of view rather than the listener's – the one-character scene facilitates the speaker's assessment of which referent is most accessible, whereas the two-character scene complicates this assessment, but it is not a listener-oriented ambiguity avoidance strategy that is at play.

In keeping with this characterization, the authors also found that participants' mean latency to refer to the main character was shorter in the one-character than two-character context. According to the authors, this finding supports their speaker-oriented account in that participants' attentional resources may have been more heavily taxed in the two-character scenes where multiple entities are competing for attentional allocation, and that this split in attention results in a delay in reference production. In a follow-up experiment, the authors manipulated whether the secondary character was present in panel 2 and found no effect on pronominalization rates, suggesting that the effect of an additional character on referential choice can be localized to the speakers' assessment of how many characters have been mentioned in the discourse rather than their visual presence in the scene (though see Fukumara et al., 2010). Furthermore, the authors found that tense, continuity, and fluency correlated with pronominal use such that participants who produced more pronouns were also

more likely to use the same tense as in the stimulus sentence, to respond with a continuation of the stimulus sentence (rather than a new sentence), and to be less disfluent. Overall, the authors argue that these results demonstrate that in situations where there is no communicative value to using a name over a pronoun for the main character (as both forms are unambiguous), speakers' dispreference for pronouns arises from a combination of the competition between discourse entities in the speaker's mental model and the impact this competition has on their assessment of which referent is most accessible.

Nevertheless, while Arnold and Griffin offer a plausible explanation for their findings, they did not directly test whether speakers' attentional capacities predicted differences in referential choice across one- and two-character scenes. In the current study, we set out to investigate their referential accessibility account by replicating the story continuation paradigm used in Experiment 1, and by adding three measures of attentional control from the Test of Everyday Attention (Robertson et al., 1994): **sustained attention**, **inhibitory control**, and **attention switching**. Sustained attention was used as a baseline measure to ensure participants did not have severe attentional deficits (Long et al., 2018). Of interest was whether inhibitory control or attention switching predicted participants' rate of pronominal use across conditions.

Inhibition and attention switching play an important role in regulating cognitive control, as outlined in Braver's (2012) influential dual-mechanisms of control framework. According to this framework, the ability to coordinate, regulate, and maintain goal-directed behavior is operationalized through the dynamic use of two semi-independent yet complementary modes of cognitive control: a proactive mode that optimally biases attention to a given goal (which can be viewed as an "early selection" mechanism and an index of **inhibitory control**), and a reactive mode in which a response is triggered after interference is detected (which can be viewed as a "late correction" mechanism and an index of **attention switching**). Applying Braver's framework to Arnold and Griffin's referent accessibility account, if your goal as an interlocutor is to prioritize attention to the subject of the sentence, and you prefer a proactive mode of control, then upon hearing the subject mentioned, your attention is biased towards

that referent in a goal-driven manner; subsequently, less attention is given to the mention of the secondary character. If, however, you prefer a reactive mode of control, then attention would be allocated to each referent mentioned, and as a late corrective mechanism, the secondary character would need to be inhibited at the second panel and attention would be refocused to the subject. In sum, the proactive mode (i.e. **inhibitory control**) relies on prevention of interference before it occurs whereas the reactive mode (i.e. **attention switching**) relies upon the resolution of interference after it has been detected. While each mode of control involves its own distinct flow of processes, and different individuals may favor different modes of control, ultimately the same predictions can be made for both with regards to referent accessibility.

That is, speakers with lower inhibitory control are less likely to allocate attention to the subject in two-character scenes, making it less accessible; this should result in more explicit forms of reference (names) for the subject. The same prediction can be made for those with lower attention switching skills: more names should be used for the subject in two-character scenes, in this case due to a reduced capacity to refocus attention from the secondary character back to the subject. Conversely, those with higher inhibitory control should display a similar rate of pronominal use across one- and two-character scenes as attention is biased towards the subject regardless of the number of characters, thus making the subject highly accessible. Likewise, those with higher switching skills should use pronouns at similar rates across both types of scenes, in this case due to the ability to successfully refocus attention to the subject when necessary. Thus, overall, the predictions from Arnold and Griffin associate better attentional skills with reduced impact of a competing character on participants' use of pronouns. Such an account is based on the posited link between accessibility and referential form, and it predicts an interaction between attentional capacities and the presence/absence of a competing character.

This link between accessibility and referential form has been the subject of more scrutiny in recent years, particularly the question of how to pin down broad notions like 'accessibility', 'prominence', and 'salience' (e.g., Kehler & Rohde, 2013; Rosa & Arnold, 2017;

von Heusinger & Schumacher, 2019). In rich narrative contexts, the salience of a referent may vary along multiple dimensions – its semantic relevance, its syntactic position, its status as given/new, even its visual primacy – and these measures can be absolute or relative. One proposal is that referential form is specifically tied to prominence as determined by the information-structural packaging of a sentence and the status of elements within the syntactic structure (e.g., Grosz et al., 1995; Gordon et al., 1993). The intuition is that the surface packaging of a sentence helps convey which element is topical (what the sentence is about) and what is predicated of the topic (what is new about the given topic; Strawson, 1964; Kuno, 1972; Gundel, 1974; Reinhart, 1981; Lambrecht, 1994). In that view, the general understanding is that the central function of pronouns is to signal that the speaker is continuing to refer to the current topic. With this in mind, Arnold and Griffin's finding that pronominalization is reduced in two-character scenes need not be taken to reflect participant difficulty in assessing the accessibility of competing referents; rather, the pronominalization reduction can be recast as participants' downweighting of the topicality of the subject referent in a discourse-appropriate way. Because a discourse topic can sometimes appear in a non-subject position, the presence of the second non-subject character creates a viable topic alternative and therefore ought to reduce participants' use of pronouns for the subject referent in the two-character scenes. Such an effect would arise not through attentional competition but in keeping with production biases that are determined by grammatical and information-structural factors. As such, this is a different sort of explanation than the one put forward by Arnold and Griffin because it is tied specifically to the speaker's access to the topicality status of referents in the discourse representation, as opposed to the speaker's allocation of attention across characters more generally. Crucially, the two accounts make competing predictions regarding the role of attentional capacities.

Whereas Arnold and Griffin's account can be taken to predict an interaction between measures of speakers' attentional capacities and the one- versus two-character scenes, the predictions of the topicality account are tied to the construction and consultation of the discourse representation. Under the topicality account, the reduction in pronouns for the

subject in two-character scenes is not a symptom of cognitive difficulty but the result of an appropriate assessment of the status of the subject as no longer necessarily the discourse topic. Therefore, no interaction is specifically predicted between cognitive capacity and number of characters. Under the topicality account, cognitive capacities might come into play but in a more general way, not specific to one-vs-two-character scenes. If participants vary in how well they construct or consult their discourse representation, then those participants who more successfully encode the topicality status of the subject (either as the only candidate topic or as the more likely topic among two possible candidate topics) would be expected to use more pronouns for the subject across the board than those participants whose discourse representation was less successfully encoded.

What would this successful encoding entail? It likely would require the participant to update their discourse representation when topicality information is made available at Panel 1, i.e., when the main character is mentioned in subject position. In theory, this process would involve listening to the sentence and deciphering who the subject is (i.e. the main character in both one and two-character scenes), then shifting attention to that referent to encode it as the subject. Now that the discourse representation has been updated, the participant must hold this representation in mind so that they can consult it for future utterances in order to decide whether a pronoun is an appropriate form to use to refer to the subject. The topichood account thus makes the following predictions: Speakers with high attention switching capacity and high verbal working memory should be more likely to have successfully updated their discourse representation at Panel 1, and to successfully remember that representation when deciding which referential form to use for the main character. Thus results should reveal a main effect of attentional switching and verbal working memory whereby strong skills in updating and holding the discourse representation in mind favor pronominalization of the subject.

In addition to testing the predictions from Arnold and Griffin's referential accessibility account and the alternative topicality account (Rohde & Kehler 2014), we further extended the study by not only targeting younger adults, but also middle-aged and elderly adults. Previous studies have shown that with increasing age, adults show greater variability in cognitive

abilities and referential speech patterns. For example, older adults are more prone to age-related cognitive decline (Celsis et al., 1997), and are more likely to produce pronouns than younger adults, even when pronominal use leads to ambiguity (Hendricks et al., 2014). A possible explanation for this, in line with the topichood account proposed by Rohde & Kehler (2014), is that older adults with low memory struggle to hold discourse representations in mind that would help them to determine and subsequently remember a referent's prominence. Supporting this theory is a recent study which found that while elderly adults used names more frequently when reintroducing a character than when maintaining reference to a character, they still used more pronouns than younger adults in both situations (Hendricks et al., 2014). The use of a pronoun to reintroduce a character may be indicative of an incorrect estimate of the discourse prominence of the referent. Thus, elderly speakers with low memory may resort to a more economical pronoun when failing to decide whether a name is necessary. Another possibility is that elderly adults with low memory are more likely to forget the names of the referents and simply resort to pronouns. However, if this effect were found in the current task, it is unlikely that it would be due to participants forgetting the names of the animal characters as the animals were always visible to the speaker and the names of the animals were only slightly different from the animal they represented (e.g. the horse was called Horsey).

A similar effect has been found in clinical populations: Alzheimer's patients have been found to over-use pronouns (Almor, 1999), which could also be indicative of a memory deficit in retrieving discourse representations. Furthermore, a recent study found that speakers use more pronouns under cognitive load (specifically, after having to complete a memory task) (Vogels et al., 2015). Moreover, developmental studies have shown that children with lower working memory tend to overuse pronouns when reintroducing discourse referents (Hendriks, 2016). Taken together, these results suggest that a decrease in working memory could result in higher pronominal use.

On the other hand, those with higher working memory skills may be more likely to use pronouns to refer back to the subject referent because they are better able to hold on to and subsequently consult their discourse representation to decide the appropriate referential form

to use depending on the grammatical position in which a referent was last mentioned. As such, two very different predictions can be made with regards to the influence of working memory on referential choice: those with low working memory may default to pronouns more because they struggle to hold on to discourse representations to determine a referent's prominence, whereas those with higher working memory may use pronouns more because they are better at deciphering a referent's prominence and later consulting that discourse representation when deciding which referential form to use. Given that variability in cognitive control increases with age (Zelazo et al., 2004; Logie & Morris, 2014), it may be difficult to tease apart the potential effects of verbal working memory on pronominalization rates for older adults, as similar predictions can be made for those with low and high working memory.

Experiment 1: Replication of Experiment 1 from Arnold & Griffin (2007)

Participants

A total of 104 adults were recruited from the University of Edinburgh volunteer panel, the university careers services website, and local community groups. All correspondence was done via email which ensured that everyone who registered was computer literate. Written informed consent was obtained from all participants and the study was approved by the University of Edinburgh Linguistics and English Language ethics committee. Prior to analysis, we excluded 4 participants: 3 non-native English speakers and 1 with abnormally low attentional scores. We thus report results from 100 native English speakers aged 19-82 with normal vision and hearing.

Materials/Procedures

Story continuation task

Participants took part in a story continuation task based on Experiment 1 in Arnold and Griffin (2007). The task included twenty critical trials, each consisting of two-panel vignettes featuring one or two animal characters carrying out actions (see Fig 1.). A total of ten possible characters, five male, five female, were randomly combined to create the displays (Males: Birdie, Doggie, Froggy, Horsey, Piggy, Females: Bunny, Duckie, Goosey, Kitty, Mousey). Females were depicted with long eyelashes and usually wore dresses and bows, whereas

males wore trousers and ties. Critical trials consisted of one-character trials ($n=10$) and two-character trials ($n=10$). In addition to critical trials, filler trials ($n=40$) were randomly interspersed in the trial sequence, as in Arnold and Griffin (2007). Fillers were a hybrid of one- and two-character trials such that the number of characters varied from panel 1 to panel 2, with a transition from one to two characters ($n=20$) or two to one character ($n=20$). The same ten characters featured in critical were also featured in filler trials.

Figure 1. Sample one and two-character trials.

At the beginning of each trial, a preview of both panels appeared for two seconds, then the first panel remained in the top half of the computer screen. Participants heard a recorded sentence describing the first panel and they repeated it (for full list of sentences see Appendix A); then the second panel appeared beneath the first and participants constructed a story continuation. For two-character trials, both characters were depicted as the same size in panel

1. The main character (i.e. the subject of the sentence in panel 1) was always shown carrying out an action worthy of narration in panel 2 (eating rice with a spoon in Figure 1, panel 2). To further encourage participants to refer to the main character, the secondary character was depicted as relatively inactive and smaller than the main character in panel 2. To create the one-character trials, we simply removed the secondary character so only the main character was present in the two panels. Main characters were rotated such that each of the ten characters was featured as the main character in two critical trials. Sentences were presented in the past tense, and when a secondary character was present, the character was mentioned in a “with” phrase (e.g. Doggie cooked rice {with Mousey} for dinner).

Of interest was the way in which participants referred to the main character (i.e. a pronoun or a name) in describing panel 2 and whether the referential form varied depending on the presence or absence of a secondary character in the scene. Importantly, in two-character trials, the characters were always different sex/gender so the use of a pronoun would be unambiguous.

At the start of the task, participants were introduced to the ten animal characters by name and were then asked to identify each of them on their own. To ensure participants of all ages could remember the ten names, we chose names based on the animal name (e.g. the mouse character was named Mousey). Participants were told to imagine that they were telling stories for a five-year-old child and to refrain from adding extra humor. After the character familiarization phase, participants were given two practice trials before beginning the task. Participants’ responses were audio recorded for transcription and coding purposes.

Practice trials and filler trials were not included in the analysis. Using the same criteria outlined in Arnold and Griffin (2007), we only included responses that referred to the main character as the subject of the sentence and preceded any mention of another character. As such, we excluded cases in which the referring expression denoted more than one character (e.g. *they*, *both of them*, *Doggie and Mousey*, etc) or was possessive (e.g. *Birdie’s ball*, *her ball*, etc.). We also excluded cases of naming errors (for both character and gender), though self-corrections were not excluded. Furthermore, we excluded cases where the referring

expression was elliptical (e.g. *...and went to the park*), as well as cases where the response started with a quote from one of the characters (e.g. *'Mmm this rice is delicious.'*). Finally, we excluded cases where the referring expression was part of a subordinate clause (e.g. *When Goosey [main character] dosed off, Doggie [secondary character] went for a walk.*) unless the referring expression in the subordinate clause did not differ from that in the matrix clause (e.g. *When he [main character] got to work, he [main character] was still feeling ill.*). A total of 199 responses (out of 2000) were excluded, thus around 10% of the data.

Cognitive tasks

Test of Everyday Attention

Participants' attentional skills were measured via the Test of Everyday Attention (TEA) (Robertson et al., 1994), a clinical test based on Posner and Peterson's (1990) multi-system attentional model. The test offers a fine-grained method of assessing an individual's cognitive resources by separating attention into theoretically distinct factors through the use of three auditory subtests: attention switching, inhibition, and sustained attention. The test is sensitive enough to detect subtle differences in attention and has been standardized through a normative sample of healthy adults aged 18-80 (Robertson et al., 1996). More recently it has been used in a variety of linguistic studies, from language learning (Vega-Mendoza, 2015) and bilingualism (Hindle et al., 2015; Ooi et al., 2018) to perspective-taking (Long et al., 2018) and referential communication (Long et al., under review).

For each of the measures (referred to as the elevator tasks), participants are asked to envision that they have entered an elevator on the ground floor. The floor light indicator does not work, so in order to know which floor they are on they must count the tones they hear. After each trial they are asked which floor they are on. Performance on each subtest is measured as the percentage of trials with correct responses (0-100).

Elevator Task (sustained attention, n=7 trials): Participants are presented with tones of the same pitch at irregular intervals and must keep track of the count. As healthy individuals are expected to perform near ceiling, this task was used as a baseline measure.

Elevator Task with Distraction (selective attention/inhibition n=10 trials):

Participants are presented with low and high tones. They must selectively attend to and count the low tones only while ignoring interspersed high tones. Performing well requires inhibiting high tones while counting low tones or selectively attending to low tones only.

Elevator Task with Reversal (attention switching, n=10 trials): Participants are presented with low, medium, and high tones in random order. They must count medium tones only. Low tones indicate the elevator will move down with the subsequent medium tones, while high tones indicate the elevator will move up with subsequent medium tones. Performing well requires inhibiting low and high tones from the count while efficiently disengaging inhibition and refocusing attention upon hearing a middle tone.

Reading Span

Verbal working memory (VWM) capacity was assessed using an automated reading span task (Scholman, 2019) adapted from Waters et al. (1987) and Waters & Caplan (1996). Participants were presented with a total of 56 sentences varying in length from 8 to 11 words and were asked to judge the acceptability of each sentence by clicking “acceptable” or “unacceptable” on a computer screen (see Appendix B for full list of sentences). Four different sentence types were presented, with varying levels of complexity to see how well people could remember the content. Half of the sentences contained a verb that required an animate subject while the other half contained a verb that required an animate object. Furthermore, half of the sentences were grammatically acceptable and the other half were made unacceptable by reversing the animacy of the subject and object noun phrases (e.g. *It was the boy that the hat bought*).

After a set of two to five sentences (recommended by Conway et al., 2005), participants were asked to recall the last word of each sentence in the order in which it was presented by typing the words on the computer. Sets were presented in random order so participants could not anticipate how many words they would be asked to recall. Before beginning the task, participants were given a practice phase in which they judged the acceptability of eight sentences. Reaction times were measured for each of the practice trials.

A participant's average reaction time during the practice trials plus two standard deviations was used as a time-out during the task to ensure participants went at their own pace but were not taking extra time to rehearse the words (cf. von der Malsburg & Vasishth, 2013; Unsworth et al., 2005). Participants were also given a practice phase for the recall portion of the task. In the practice phase, participants judged sentences and recalled the last words for a block of three sentences and a block of five sentences. Practice trials were not used in the analysis.

Working memory was calculated using the partial-credit unit scoring procedure where the partial-credit unit represents the mean proportion of words within a set that were recalled correctly (Conway et al., 2005; Friedman & Miyake, 2005). Typos were accounted for by allowing a one-character difference between the target word and response.

Statistical analysis

The alpha level for all reported tests was set to $p < .05$ and all analyses were run using R statistical software (R Core Team, 2019). As expected, participants performed at ceiling on the baseline measure of sustained attention (mean score=99.43; after the exclusion of one participant, score=57), thus this will not be considered further.

Using logistic mixed effects regression, we modelled the binary outcome variable of Pronominal Use (pronoun=1, name=0) with Number of Characters, Age, Inhibition, Switching, VWM, and their interactions as predictor variables.¹ Age, Inhibition, Switching and VWM were entered as scaled continuous predictors and deviation coding was used for Number of Characters (One-Character=-0.5, Two-Character=0.5). When possible, the model was fit with the maximal random effect structure for participants and items (Barr et al., 2013).

Results

Descriptive statistics for participants' performance on the story continuation task and cognitive tasks are reported in Tables 1 & 2.

Table 1. Rate of pronominal use on the story continuation task for all participants as well as a median age split for younger and older adults

¹ Note that this model did not test for interactions between the cognitive measures as there were no principled predictions for such interactions.

	Mean	SD	Range
One character			
All participants	.54	.50	0-1
Younger adults	.47	.50	0-1
Older adults	.61	.49	0-1
	Mean	SD	Range
Two character			
All participants	.25	.43	0-1
Younger adults	.22	.41	0-1
Older adults	.28	.45	0-1

Table 2. Performance on the cognitive tasks for all participants as well as a median age split for younger and older adults

	Mean	SD	Range
Sustained attention			
All participants	99.43	2.80	85.71-100
Younger adults	99.14	3.40	85.71-100
Older adults	99.71	2.00	85.71-100
	Mean	SD	Range
Inhibition			
All participants	86.20	21.63	0-100
Younger adults	82.80	24.51	0-100
Older adults	89.60	17.67	10-100
	Mean	SD	Range
Switching			
All participants	65.80	33.18	0-100
Younger adults	72.60	29.80	0-100
Older adults	59	34.96	0-100
	Mean	SD	Range
Verbal Working Memory			
All participants	.76	.16	.06-1
Younger adults	.79	.13	.41-1
Older adults	.73	.18	.06-.97

Notes: In the above tables, we divided our sample (n=100) based on the median age such that younger adults were between the ages of 19-50 and older adults were between the ages of 52-82.

Our results replicated Arnold & Griffin (2007): we found a main effect of Number of Characters ($p<.0001$) revealing that participants used more pronouns in the one-character condition than the two-character condition even though a pronoun would have been unambiguous in both conditions (for full model output see Appendix C). In addition, we found a main effect of Switching ($p=0.042$) revealing that participants with better switching skills used pronouns more frequently, perhaps because switching processes are involved in updating the

discourse model when the topicality of the referent is established and encoded, as would be predicted by the topicality account.

Regarding the interactions predicted by the referential accessibility account, we did not find any interactions between attentional functions and Number of Characters: There was no Switching x Number of Characters interaction ($p=.546$) nor an Inhibition x Number of Characters interaction ($p=.141$), suggesting that attentional control does not underlie differences in pronominal use across conditions. Moreover, no interaction was found between VWM and Number of Characters ($p=.78$), suggesting that VWM also does not underlie differences in pronominal use across conditions. There was however an interaction of VWM x Age ($p=.049$): for younger adults, pronoun use increased with greater VWM (see Fig 2.).

In addition to the main effects of Number of Characters and Switching, there was a main effect of age ($p<.001$): pronominal use increased with age, in keeping with prior work. To explore the possibility that this effect is in part due to age-related decline in the ability to keep track of discourse referents, we ran a linear regression model to test whether Age predicted VWM performance. Results revealed that Age did in fact predict VWM scores ($p<.001$): as age increased, VWM performance decreased, suggesting that overall differences in pronominal use between older and younger adults could be driven by age-related deficits in VWM.

Figure 2. Regression lines showing the interaction of VWM and Age. A median age split for older adults (OA) and younger adults (YA) is shown. The shaded bands around the regression lines represent a 95% confidence region for the regression fit.

Experiment 2: A Simplified Version of Experiment 1 from Arnold & Griffin (2007)

In Experiment 2, we simplified the story continuation task to test whether the absence of hybrid fillers would make the one-character and two-character distinction more salient, potentially clarifying the underlying cognitive mechanisms regulating pronominal use across the two conditions.

Participants

A total of 105 adults were recruited from the University of Edinburgh volunteer panel, the university careers services website, and local community groups. All correspondence was done via email to ensure that everyone who registered was computer literate. Written informed consent was obtained from all participants and the study was approved by the University of Edinburgh Linguistics and English Language ethics committee. Prior to analysis, we excluded 5 participants: 3 non-native English speakers, 1 participant with hearing difficulty, and 1 due to a technical malfunction. We thus report results from 100 native English speakers aged 19-81 with normal vision and hearing.

Materials/Procedures

The same materials and procedures from Experiment 1 were used in Experiment 2, with one critical difference: the 40 hybrid filler trials in the story continuation task were removed so participants were only presented with the 20 critical trials from Experiment 1 (10 trials of one character and 10 trials of two characters).

Statistical analysis

Again using logistic mixed effects regression, we modelled the binary outcome variable of Pronominal Use (pronoun=1, name=0) with Number of Characters, Age, Inhibition, Switching, and VWM and their interactions as predictor variables.² Age, Inhibition, Switching and VWM were entered as scaled continuous predictors and deviation coding was used for Number of Characters (One-Character=-0.5, Two-Character=0.5). When possible, the model was fit with the maximal random effect structure for participants and items.

Results

Descriptive statistics for participants' performance on the story continuation task and cognitive tasks are reported in Tables 3 & 4.

Table 3. Rate of pronominal use on the story continuation task for all participants as well as a median age split for younger and older adults

	Mean	SD	Range
One character			
All participants	.47	.50	0-1
Younger adults	.45	.50	0-1
Older adults	.49	.50	0-1
	Mean	SD	Range
Two character			
All participants	.13	.34	0-1
Younger adults	.13	.33	0-1
Older adults	.14	.35	0-1

Table 4. Performance on the cognitive tasks for all participants as well as a median age split for younger and older adults

² In line with Experiment 1, this model did not test for interactions between the cognitive measures as there were no principled predictions for such interactions.

	Mean	SD	Range
Sustained attention			
All participants	99	3.65	85.71-100
Younger adults	98.88	3.84	85.71-100
Older adults	99.13	3.43	85.71-100
	Mean	SD	Range
Inhibition			
All participants	79.8	23.54	10-100
Younger adults	79.02	23.63	10-100
Older adults	80.61	23.43	10-100
	Mean	SD	Range
Switching			
All participants	50.7	35.93	0-100
Younger adults	68.24	28.21	0-100
Older adults	32.45	33.98	0-100
	Mean	SD	Range
Verbal Working Memory			
All participants	.71	.17	.19-.98
Younger adults	.77	.14	.38-.98
Older adults	.65	.18	.19-.80

Notes: In the above tables, we divided our sample (n=100) by the median age such that younger adults were between the ages of 19-44 and older adults were between the ages of 45-81.

As in Experiment 1, we were able to replicate Arnold & Griffin (2007), suggesting that the effect of character number on pronominal use is robust. That is, for a second time we found a main effect of Number of Characters ($p < .0001$) in which participants used more pronouns in the one-character condition than the two-character condition (for full model output see Appendix D). Other than this main effect, there were no other main effects or interactions, including again no interactions between Number of Characters and any of the cognitive measures (all p 's $> .05$).

Additional analyses

In an effort to obtain increased statistical power, we combined the data from Experiment 1 and Experiment 2 since these items were the same across experiments. Here we modelled the binary outcome variable of Pronominal Use (pronoun=1, name=0) with Number of Characters, Age, Inhibition, Switching, VWM, and Version (with or without fillers)

and their interactions as predictor variables.³ Age, Inhibition, Switching and VWM were entered as scaled continuous predictors and deviation coding was used for Number of Characters (One-Character=-0.5, Two-Character=0.5) and Version (With fillers=-0.5, Without fillers=0.5). When possible, the model was fit with the maximal random effect structure for participants and items.

Results

In the analysis of the combined data, we found similar effects observed in Experiment 1 alone: we found a main effect of Number of Characters in which participants used more pronouns in one-character than two-character scenes ($p < .0001$) (for full model output see Appendix E). We again found a main effect of Switching ($p = .016$) whereby better switching skills resulted in greater pronominal use. There was again a main effect of age ($p = .003$): older adults used more pronouns than younger adults. As in Experiment 1, we tested the possibility that this effect was due to age-related decline in the ability to keep track of discourse referents by running a regression model to test whether Age predicted VWM performance. Replicating the Experiment 1 results, Age predicted VWM scores ($p < .001$): as age increased, VWM performance decreased, suggesting that overall differences in pronominal use between older and younger adults could be driven by age-related deficits in VWM. Additionally, as in Experiment 1, we found a VWM x Age interaction ($p = .048$) (see Fig. 3) in which younger adults with better VWM were more likely to use pronouns.

³ In line with the previous models, this model did not test for interactions between the cognitive measures as there were no principled predictions for such interactions.

Figure 3. Regression lines showing the interaction of VWM and Age. A median age split for older adults (OA) and younger adults (YA) is shown. The shaded bands around the regression lines represent a 95% confidence region for the regression fit.

There was also an Age x Version interaction ($p=.013$): older adults pronominalize more in the version of the task with fillers (Version 1) than they do in the version of the task without fillers (Version 2) (see Fig 4.). Interestingly, younger adults' strategy is less affected by version. Perhaps since the number of characters varies from panel to panel in the filler trials, older adults with low VWM find it more difficult to keep track of discourse referents and opt for a strategy of pronominalization.

Figure 4. Regression lines showing the interaction of Age and Version. Version 1 includes filler trials, Version 2 does not. The shaded bands around the regression lines represent a 95% confidence region for the regression fit.

In addition to this, we found a VWM x Version interaction ($p=.027$) whereby those with higher VWM used more pronouns in the version with fillers (Version 1), but fewer pronouns in the version without fillers (Version 2) (see Fig 5.). These results support the account in which those with higher VWM capacity have the cognitive resources to keep track of the discourse status of different referents and achieve appropriate anaphoric reference (pronouns as the preferred referential form for the most topical referent) by displaying a higher rate of pronouns in the more difficult version of the task.

Figure 5. Regression lines showing the interaction of VWM and Version. Version 1 includes filler trials, Version 2 does not. The shaded bands around the regression lines represent a 95% confidence region for the regression fit.

Discussion

Analyses from two experiments and their combined data replicated the results from Arnold & Griffin (2007) in which participants' pronominal use decreased when an additional character was present in the discourse/visual scene. Nevertheless, the results provide no evidence in support of Arnold and Griffin's accessibility account which would predict that attentional capacity underlies differences in pronominal rates across one- and two-character scenes. In fact, none of the cognitive measures from any of the analyses interacted with character number to predict pronominalization rates. Although the absence of these interactions are incompatible with the accessibility account, they are fully compatible with the topichood account (Rohde & Kehler, 2014), which makes no prediction for the role of cognitive control on differences in pronominalization across scenes. Instead, the topichood account predicts that higher pronominal use in one-character scenes would reflect participants' accurate assessment that the subject is more likely to be the topic when no additional character is present.

The results from Experiment 1 support additional predictions from the topichood account, namely that participants with strong attention switching and verbal working memory

would be more likely to successfully update and remember their discourse representation when deciding which referential form to use for the main character, resulting in a higher rate of pronominalization in both one- and two-character scenes. Indeed, supporting these predictions we found a main effect of attention switching on overall pronominal use (whereby better switching resulted in a higher rate of pronouns), and that younger adults with better verbal working memory displayed a higher rate of pronominal use. While verbal working memory did not predict older adults' pronominal use, it is possible that the effect was masked by two similar predictions for those with low and high verbal working memory. According to the topichood account, those with higher working memory skills may be more likely to use pronouns to refer back to the subject referent because they are able to hold on to and subsequently consult their discourse representation, whereas those with low working memory may default to pronouns because they struggle to hold on to discourse representations. Why would the effect be masked in older but not younger adults? Descriptive statistics from Table 1 show that older adults display far greater variability in verbal working memory than younger adults (with older adults' scores ranging from .06-1 and younger adults' scores ranging from .41-1). Thus, while younger adults have a much higher baseline verbal working memory, it is clear that some of the older adults have large deficits. Perhaps those older adults at the low and high end of verbal working memory capacity are both pronominalizing (for different reasons) therein masking the effect.

Interestingly, while results from Experiment 1 support the topichood account, results from Experiment 2 revealed no effect of attention switching or verbal working memory on pronominal use. One possibility is that by removing the filler trials in Experiment 2, the story continuation task became markedly easier, therein decreasing the demands placed on cognitive control. It is important to note that the original design of the task was simple to begin with: participants repeated short, uncomplex sentences, and came up with new ones related to the following panel. Participants were facilitated by the fact that each panel showed one or two characters in stereotypical gendered clothing and their names were only slightly different from the animal they represented (e.g. the horse was called Horsey). Thus, by removing the

filler trials, in which the number of characters varied from Panel 1 to Panel 2, participants no longer had the additional pressure of integrating potentially relevant new information about topichood from Panel 1 to Panel 2, making the updating and maintenance of discourse representations easier to manage. From a methodological point of view, this finding is important: While psycholinguistic experiments typically use fillers to disguise the research question, the inclusion of fillers may also have unexpected effects on the results, such as increasing the demands placed on cognitive functions. Supporting this idea is the novel result from the combined data from Experiments 1 and 2. The combined data showed that older adults pronominalized more in the version of the task with fillers than the version of the task without fillers. Perhaps in the version with fillers older adults with low working memory found it more difficult to keep track of the topicality of discourse referents, making them more likely to default to a strategy of pronominalization. If older adults with both low and high working memory were more likely to pronominalize, that explains why verbal working memory did not predict older adults' rate of pronominalization in the version with fillers.

Overall, despite principled reasons for testing two distinct aspects of attention and their effects on pronominalization rates across one- and two- scenes, no evidence was found in favor of the accessibility account proposed by Arnold and Griffin (2007). Instead, the results are in line with predictions made by the topichood account (Rohde & Kehler) whereby differences in pronominalization across scenes reflects participants' accurate assessment that the subject is more likely to be the topic when no other character is present. Further supporting the topichood account, attention switching and verbal working memory were found to influence overall pronominalization rates. Future studies should further investigate the predictions made by the topichood account through the use of a wide range of interactive tasks on adults of all ages.

References

- Almor, A., Kempler, D., MacDonald, M. C., Andersen, E. S., & Tyler, L. K. (1999). Why do Alzheimer patients have difficulty with pronouns? Working memory, semantics, and reference in comprehension and production in Alzheimer's disease. *Brain and language*, 67(3), 202-227.
- Ariel, M. (2014). *Accessing noun-phrase antecedents (rle linguistics b: Grammar)*. Routledge.
- Arnold, J. E. (2016). Explicit and emergent mechanisms of information status. *Topics in cognitive science*, 8(4), 737-760.
- Arnold, J.E. (1999). Marking salience: The similarity of topic and focus. *Unpublished manuscript, University of Pennsylvania*.
- Arnold, J. E. (1998). Reference form and discourse patterns. (Doctoral dissertation). Stanford University.
- Arnold, J. E., Bennetto, L., & Diehl, J. J. (2009). Reference production in young speakers with and without autism: Effects of discourse status and processing constraints. *Cognition*, 110(2), 131-146.
- Arnold, J. E., & Griffin, Z. M. (2007). The effect of additional characters on choice of referring expression: Everyone counts. *Journal of memory and language*, 56(4), 521-536.
- Arnold, J. E., Losongco, A., Wasow, T., & Ginstrom, R. (2000). Heaviness vs. newness: The effects of structural complexity and discourse status on constituent ordering. *Language*, 76(1), 28-55.
- Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, 68(3), 255-278.
- Braver, T. S. (2012). The variable nature of cognitive control: a dual mechanisms framework. *Trends in cognitive sciences*, 16(2), 106-113.
- Brown, P. M., & Dell, G. S. (1987). Adapting production to comprehension: The explicit mention of instruments. *Cognitive Psychology*, 19(4), 441-472.
- Celsis, P., Agniel, A., Cardebat, D., Demonet, J. F., Ousset, P. J., & Puel, M. (1997). Age related cognitive decline: a clinical entity? A longitudinal study of cerebral blood flow and memory performance. *Journal of Neurology, Neurosurgery & Psychiatry*, 62(6), 601-608.
- Chafe, W. (1994). *Discourse, consciousness, and time: The flow and displacement of conscious experience in speaking and writing*. University of Chicago Press.
- Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic bulletin & review*, 12(5), 769-786.
- Fletcher, C. R. (1984). Markedness and topic continuity in discourse processing. *Journal of Verbal Learning and Verbal Behavior*, 23(4), 487-493.
- Fukumura, K., & Van Gompel, R. P. (2010). Choosing anaphoric expressions: Do people take into account likelihood of reference?. *Journal of Memory and Language*, 62(1), 52-66.

- Fukumura, K., Van Gompel, R. P., & Pickering, M. J. (2010). The use of visual context during the production of referring expressions. *The quarterly journal of experimental psychology*, 63(9), 1700-1715.
- Friedman, N. P., & Miyake, A. (2005). Comparison of four scoring methods for the reading span test. *Behavior research methods*, 37(4), 581-590.
- Gernsbacher, M. A., & Hargreaves, D. J. (1988). Accessing sentence participants: The advantage of first mention. *Journal of memory and language*, 27(6), 699-717.
- Gernsbacher, M. A., Hargreaves, D. J., & Beeman, M. (1989). Building and accessing clausal representations: The advantage of first mention versus the advantage of clause recency. *Journal of memory and language*, 28(6), 735-755.
- Gordon, P. C., Grosz, B. J., & Gilliom, L. A. (1993). Pronouns, names, and the centering of attention in discourse. *Cognitive science*, 17(3), 311-347.
- Grosz, B. J., Weinstein, S., & Joshi, A. K. (1995). Centering: A framework for modeling the local coherence of discourse. *Computational linguistics*, 21(2), 203-225.
- Gundel, J. (1974). *The role of topic and comment in linguistic theory*. University of Texas Ph. D (Doctoral dissertation).
- Gundel, J. K., Hedberg, N., & Zacharski, R. (1993). Cognitive status and the form of referring expressions in discourse. *Language*, 274-307.
- Hendriks, P. (2016). Cognitive modeling of individual variation in reference production and comprehension. *Frontiers in psychology*, 7, 506.
- Hendriks, P., Koster, C., & Hoeks, J. C. (2014). Referential choice across the lifespan: Why children and elderly adults produce ambiguous pronouns. *Language, Cognition and Neuroscience*, 29(4), 391-407.
- Hindle, J. V., Martin-Forbes, P. A., Bastable, A. J., Pye, K. L., Martyr, A., Whitaker, C. J., Craik, F.I., Bialystok, E., Thomas, E.M., Mueller Gathercole, V.C. & Clare, L. (2015). Cognitive reserve in Parkinson's Disease: the effects of Welsh-English bilingualism on executive function. *Parkinson's Disease*, 2015.
- Karmiloff-Smith, A. (1985). Language and cognitive processes from a developmental perspective. *Language and cognitive processes*, 1(1), 61-85.
- Kehler, A., & Rohde, H. (2013). A probabilistic reconciliation of coherence-driven and centering-driven theories of pronoun interpretation. *Theoretical Linguistics*, 39(1-2), 1-37.
- Kuno, S. (1972). Functional sentence perspective: A case study from Japanese and English. *Linguistic inquiry*, 3(3), 269-320.
- Lambrecht, K. (2004). On the interaction of information structure and formal structure in constructions. *Construction Grammar in a cross-language perspective*, 157-199.
- Levelt, W. J. (1993). *Speaking: From intention to articulation* (Vol. 1). MIT press.
- Logie, R. H., & Morris, R. G. (Eds.). (2014). *Working memory and ageing*. Psychology Press.

- Long, M. R., Horton, W. S., Rohde, H., & Sorace, A. (2018). Individual differences in switching and inhibition predict perspective-taking across the lifespan. *Cognition*, 170, 25-30.
- Long M. R., Rohde H, Rubio-Fernández P. The pressure to communicate efficiently continues to shape language use later in life. (Under review at *Scientific Reports*.)
- Ooi, S. H., Goh, W. D., Sorace, A., & Bak, T. H. (2018). From Bilingualism to Bilingualisms: Bilingual experience in Edinburgh and Singapore affects attentional control differently. *Bilingualism: Language and Cognition*, 21(4), 867-879.
- Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and brain sciences*, 27(2), 169-190.
- Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual review of neuroscience*, 13(1), 25-42.
- R Core Team. *R: A Language and Environment for Statistical Computing*. (R Foundation for Statistical Computing, Vienna, Austria, 2019).
- Reinhart, T. (1981). Definite NP anaphora and c-command domains. *Linguistic Inquiry*, 12(4), 605-635.
- Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The Test of Everyday Attention. *Journal of the International Neuropsychological Society*, 2(6), 525-534.
- Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1994). The test of everyday attention (TEA). *Bury St. Edmunds, UK: Thames Valley Test Company*, 197-221.
- Rohde, H., & Kehler, A. (2014). Grammatical and information-structural influences on pronoun production. *Language, Cognition and Neuroscience*, 29(8), 912-927.
- Rosa, E. C., & Arnold, J. E. (2017). Predictability affects production: Thematic roles can affect reference form selection. *Journal of Memory and Language*, 94, 43-60.
- Scholman, M. C. J. (2019). Coherence relations in discourse and cognition: Mapping approaches, annotations, and interpretations. (*Doctoral thesis*).
- Stevenson, R. J., Crawley, R. A., & Kleinman, D. (1994). Thematic roles, focus and the representation of events. *Language and Cognitive Processes*, 9(4), 519-548.
- Strawson, P. F. (1964). Intention and convention in speech acts. *The philosophical review*, 73(4), 439-460.
- Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior research methods*, 37(3), 498-505.
- Vega-Mendoza, M., West, H., Sorace, A., & Bak, T. H. (2015). The impact of late, non-balanced bilingualism on cognitive performance. *Cognition*, 137, 40-46.
- Von der Malsburg, T., & Vasisht, S. (2013). Scanpaths reveal syntactic underspecification and reanalysis strategies. *Language and Cognitive Processes*, 28(10), 1545-1578.
- Vogels, J., Krahmer, E., & Maes, A. (2015). How cognitive load influences speakers' choice of referring expressions. *Cognitive science*, 39(6), 1396-1418.

- Von Heusinger, K., & Schumacher, P. B. (2019). Discourse prominence: Definition and application. *Journal of Pragmatics*, 154, 117-127.
- Waters, G. S., & Caplan, D. (1996). The measurement of verbal working memory capacity and its relation to reading comprehension. *The Quarterly Journal of Experimental Psychology Section A*, 49(1), 51-79.
- Waters, G., Caplan, D., & Hildebrandt, N. (1987). Working memory and written sentence comprehension.
- Zelazo, P. D., Craik, F. I., & Booth, L. (2004). Executive function across the life span. *Acta psychologica*, 115(2-3), 167-183.

Appendix A:

Full list of experimental items from the story continuation task: Single- and two-character stimulus sentences (with the phrase mentioning a secondary character underlined).

Critical trials from Experiments 1 & 2:

1. Doggie (M) cooked rice with Mousey (F) for dinner.
2. Mousey (F) was out all day with Birdie (M) and came home hungry.
3. Froggy (M) decided to work on a painting with Duckie (F) at the weekend.
4. Bunny (F) wrote a song with Horsey (M) to play on the piano.
5. Birdie (M) ran out the door with Kitty (F) and forgot to turn off the bath.
6. Duckie (F) walked to the botanical gardens with Piggy (M) to look at the plants.
7. Horsey (M) was feeling ill when walking with Goosey (F) to work.
8. Kitty (F) went with Froggy (M) to buy a motorbike.
9. Piggy (M) went for a run with Bunny (F) around the park.
10. Goosey (F) sat down with Doggie (M) on the park bench.
11. Doggie (M) went with Mousey (F) to pick up the newspaper.
12. Duckie (F) took a cooking course with Piggy (M) over the summer.
13. Froggy (M) made a cake with Duckie (F) to celebrate the occasion.
14. Goosey (F) went ice skating with Doggie (M) in the city.
15. Birdie (M) ran the marathon with Kitty (F) in New York.
16. Kitty (F) went with Froggy (M) to buy a new camera.
17. Horsey (M) went to the countryside with Goosey (F) for a peaceful afternoon.
18. Mousey (F) went to the canal with Birdie (M) during lunch break.
19. Piggy (M) went with Bunny (F) to the outdoor concert.
20. Bunny (F) went with Horsey (M) to the café.

Filler trials from Experiment 1:

1. Kitty (F) just finished a quilting project. (Panel 2: Image of Kitty (F) showing Froggy (M) the quilt she made.)
2. Birdie (M) spent the evening with Bunny (F) at the dance school. (Panel 2: Image of Birdie (M) dancing.)
3. Goosey (F) wanted to try something new. (Panel 2: Image of Goosey (F) and Piggy (M) scuba diving.)
4. Bunny (F) decided to invite a friend out to lunch. (Panel 2: Image of Bunny (F) and Horsey (M) eating lunch in a restaurant.)
5. Doggie (M) played hide and seek with Mousey (F) this afternoon. (Panel 2: Image of Doggie (M) hiding behind a tree.)
6. Horsey (M) went with Bunny (F) to buy some flowers. (Panel 2: Image of Horsey (M) watering the flowers.)
7. Kitty (F) went apple-picking with Piggy (M) in the orchard. (Panel 2: Image of Kitty eating an apple.)
8. Froggy (M) had a sore ankle after running on the cobblestone. (Panel 2: Image of Goosey putting ice on Froggy's ankle.)
9. Kitty (F) needed help with the homework. (Panel 2: Image of Piggy (M) helping Kitty (F) with the homework.)
10. Doggie (M) learned how to tie a shoelace with Mousey (F) at school. (Panel 2: Image of Doggie (M) trying to tie his shoelace at home.)
11. Horsey (M) went with Bunny (F) to the chemist. (Panel 2: Image of Horsey (M) picking up a prescription.)
12. Mousey (F) was excited to go to the theme park. (Panel 2: Image of Mousey (F) and Doggie (M) riding a rollercoaster.)
13. Bunny (F) went with Birdie to the art show. (Panel 2: Image of Birdie (F) buying a painting.)

14. Froggy (M) wanted to join a community project. (Panel 2: Image of Froggy (M) and Bunny (F) building a house.)
15. Kitty (F) did some Spring cleaning with Doggie (M) at the weekend. (Panel 2: Image of Kitty dusting the mantel.)
16. Piggy (M) needed help packing for a holiday abroad. (Panel 2: Image of Piggy (M) and Mousey (F) putting clothes in a suitcase.)
17. Horsey (M) watched the sunset with Bunny (F) on the terrace. (Panel 2: Image of Horsey (M) taking a picture of the sunset.)
18. Goosey (F) went bowling with Horsey (M) after school. (Panel 2: Image of Goosey (F) knocking down the pins.)
19. Duckie (F) realized that the shirt had wrinkles. (Panel 2: Image of Duckie (F) and Piggy (M) ironing the shirt.)
20. Goosey (F) went with Birdie (M) to band practice. (Panel 2: Image of Goosey (F) playing the flute.)
21. Bunny (F) got lost when going for a walk. (Panel 2: Image of Piggy (M) finding Bunny (F) and bringing her a map.)
22. Duckie (F) went hiking with Froggy (M) and tripped on a rock. (Panel 2: Image of Duckie (F) putting on a band-aid.)
23. Goosey (F) made dinner with Horsey (M) this evening. (Panel 2: Image of Goosey (F) chopping vegetables.)
24. Froggy (M) decided to get in shape with Bunny (F) over the summer. (Panel 2: Image of Froggy (M) doing jumping jacks.)
25. Bunny (F) worked on the puzzle with Piggy (M) for ten days straight. (Panel 2: Image of Bunny (F) putting in the last piece of the puzzle.)
26. Birdie (M) decided to chop some firewood. (Panel 2: Image of Birdie (M) and Mousey (F) chopping wood.)
27. Froggy (M) decided to go for a long walk since the weather was nice. (Panel 2: Image of Froggy (M) running into Kitty (F) on the street.)
28. Goosey (F) thought that everyone forgot about the birthday party. (Panel 2: Image of Goosey (F) smiling at Birdie (M) who showed up with cake.)
29. Froggy (M) went with Kitty (F) to the lake this morning. (Panel 2: Image of Froggy (M) fishing on a boat.)
30. Duckie (F) studied for the exam with Birdie (M) yesterday. (Panel 2: Image of Duckie (F) taking the exam.)
31. Duckie (F) heard that an amazing band was in town. (Panel 2: Image of Duckie (F) and Froggy (M) watching the band.)
32. Piggy (M) got ready with Mousey (F) for the celebration. (Panel 2: Image of Piggy (M) putting on a new tie.)
33. Duckie (F) was very upset about the decision. (Panel 2: Image of Duckie (F) venting about it to Horsey (M).)
34. Kitty (F) went to play in the back garden. (Panel 2: Image of Kitty (F) and Birdie (M) on the trampoline.)
35. Duckie (F) went with Froggy (M) to the park to throw the frisbee. (Panel 2: Image of the frisbee flying past Duckie (F).)
36. Mousey (F) spent hours playing a board game with Birdie (M) last night. (Panel 2: Image of Mousey (F) getting sleepy.)
37. Kitty (F) decided to go outside and enjoy the day. (Panel 2: Image of Kitty (F) on a sailboat with Doggie (M).)
38. Horsey (M) had a craving for something sweet. (Panel 2: Image of Horsey (M) and Mousey (F) eating cookies.)
39. Doggie tried to think of something interesting to do after school. (Panel 2: Image of Doggie (M) playing video games with Goosey (F) after school.)
40. Mousey (F) forgot to make the bed this morning. (Panel 2: Image of Mousey (F) making the bed with Froggy (M).)

Appendix B:

Full list of experimental items from the reading span task

1. It was the elephant that escaped from the zoo. (Animate subj., cleft subj., acceptable.)
2. It was the professor that forgot the handout. (Animate subj., cleft subj., acceptable.)
3. It was the man that clenched the pillow. (Animate subj., cleft subj., acceptable.)
4. It was the bear that made the growling sound. (Animate subj., cleft subj., acceptable.)
5. It was the sound that made the computer. (Animate subj., cleft subj., unacceptable.)
6. It was the document that filed the librarian. (Animate subj., cleft subj., unacceptable.)
7. It was the cookie that ate the talented dancer. (Animate subj., cleft subj., unacceptable.)
8. It was the toy that fascinated the child. (Animate obj., cleft subj., acceptable.)
9. It was the porcelain doll that scared the little girl. (Animate obj., cleft subj., acceptable.)
10. It was the bike that hit the news reporter. (Animate obj., cleft subj., acceptable.)
11. It was the building that impressed the architect. (Animate obj., cleft subj., acceptable.)
12. It was the sulky teenager that bored the book. (Animate obj., cleft subj., unacceptable.)
13. It was the florist that astonished the bouquet. (Animate obj., cleft subj., unacceptable.)
14. It was the family that shocked the revelation. (Animate obj., cleft subj., unacceptable.)
15. It was the teddy bear that the child wanted. (Animate subj., cleft obj., acceptable.)
16. It was the Polish bread that the family liked to eat. (Animate subj., cleft obj., acceptable.)
17. It was the upbeat pop song that the grandfather hated. (Animate subj., cleft obj., acceptable.)
18. It was the young man that the engagement ring bought. (Animate subj., cleft obj., G. Experimental items working memory study, Chapter 8 213 unacceptable.)
19. It was the CEO that the enormous file requested. (Animate subj., cleft obj., unacceptable.)
20. It was the owner of the house that the light fixed. (Animate subj., cleft obj., unacceptable.)
21. It was the model that the cheeseburger ate. (Animate subj., cleft obj., unacceptable.)
22. It was the older man that the speech offended. (Animate obj., cleft obj., acceptable.)
23. It was the widow that the vivid dream tormented. (Animate obj., cleft obj., acceptable.)
24. It was the innocent people that the restrictions affected. (Animate obj., cleft obj., acceptable.)
25. It was the berry that the amateur hunter poisoned. (Animate obj., cleft obj., unacceptable.)
26. It was the memory that the heartbroken girl haunted. (Animate obj., cleft obj., unacceptable.)
27. It was the embroidery that the young girl calmed down. (Animate obj., cleft obj., unacceptable.)
28. It was the amulet that the innocent children hypnotized. (Animate obj., cleft obj., unacceptable.)
29. The boy envied the friend that bought a new game. (Animate subj., obj.-subj., acceptable.)
30. The girl played with the friend that injured her foot. (Animate subj., obj.-subj., acceptable.)
31. The athlete hired the manager that applied for the position. (Animate subj., obj.-subj., acceptable.)
32. The scarf loved the designer that kept the model warm. (Animate subj., obj.-subj., unacceptable.)
33. The milk drank the lawyer that turned sour. (Animate subj., obj.-subj., unacceptable.)
34. The castle hated the man that interested all tourists. (Animate subj., obj.-subj., unacceptable.)
35. The sound listened to the man that came from the basement. (Animate subj., obj.-subj., unacceptable.)
36. The artwork fascinated the girl that loved to paint. (Animate obj., obj.-subj., acceptable.)
37. The drug worried the pharmacist that worked with patients. (Animate obj., obj.-subj., acceptable.)

38. The book inspired the young girl that admired strong women. (Animate obj., obj.-subj., acceptable.)
39. The flower field charmed the lady that had always lived in the city. (Animate obj., obj.-subj., acceptable.)
40. The woman bothered the rain that had straightened her hair. (Animate obj., obj.-subj., unacceptable.)
41. The police officer puzzled the evidence that investigated the case. (Animate obj., obj.- G. Experimental items working memory study, Chapter 8 214 subj., unacceptable.)
42. The gardener pleased the good weather that worked outside. (Animate obj., obj.-subj., unacceptable.)
43. The employee that the boss fired yelled at her supervisor. (Animate subj., subj.-obj., acceptable.)
44. The singer that everybody loved hated rock music. (Animate subj., subj.-obj., acceptable.)
45. The actress that the audience booed at called her manager. (Animate subj., subj.-obj., acceptable.)
46. The man that the painter loved despised his parents. (Animate subj., subj.-obj., acceptable.)
47. The door that nobody trusted pushed the doctor open. (Animate subj., subj.-obj., unacceptable.)
48. The secrets that the woman was seeing betrayed her psychologist. (Animate subj., subj.-obj., unacceptable.)
49. The knee that the coach trained injured his gymnast. (Animate subj., subj.-obj., unacceptable.)
50. The meat that the butcher cut delighted the customer. (Animate obj., subj.-obj., acceptable.)
51. The pen that the teacher brought splashed ink on the children. (Animate obj., subj.- obj., acceptable.)
52. The song that the mother played comforted the sad daughter. (Animate obj., subj.-obj., acceptable.)
53. The man that the doctor recommended helped the exercises. (Animate obj., subj.-obj., unacceptable.)
54. The man that the plumber didn't fix annoyed the leaking shower. (Animate obj., subj.-obj., unacceptable.)
55. The customers that the woman made impressed the bracelet. (Animate obj., subj.-obj., unacceptable.)
56. The audience that the acrobats performed astonished the trick. (Animate obj., subj.- obj., unacceptable.)

Appendix C:

Model output for pronominal use in Experiment 1

Fixed effect	Coefficient	SE	P-value
VWM	.61779	.38644	.10990
Switching	.80504	.39619	.04216
Inhibition	-.44708	.37424	.23224
Number of Characters	-2.98339	.31549	<.0001
Age	1.33382	.38141	.00047
VWM x Number of Characters	.08512	.30516	.78030
Switching x Number of Characters	-.17361	.28720	.54551
Inhibition x Number of Characters	.49252	.33452	.14093
VWM x Age	-.76921	.39120	.04927
Switching x Age	-.59165	.42276	.16167
Inhibition x Age	.13145	.35535	.71144
Age x Number of Characters	-.19585	.32995	.55279
VWM x Age x Number of Characters	.11346	.30099	.70621
Switching x Age x Number of Characters	.11754	.32563	.71812
Inhibition x Age x Number of Characters	.03701	.27779	.89400

Notes: Significant main effects and interactions are shaded.

Appendix D:*Model output for pronominal use in Experiment 2*

Fixed effect	Coefficient	SE	P-value
VWM	-.64658	.46328	.163
Switching	.67862	.52618	.197
Inhibition	-.20517	.44993	.648
Number of Characters	-4.59830	.65846	<.0001
Age	.22216	.47826	.642
VWM x Number of Characters	.74664	.42513	.079
Switching x Number of Characters	-.32744	.44732	.464
Inhibition x Number of Characters	-.27327	.41105	.506
VWM x Age	-.37659	.45059	.403
Switching x Age	.38417	.51447	.455
Inhibition x Age	-.39391	.46266	.395
Age x Number of Characters	.04574	.42438	.914
VWM x Age x Number of Characters	-.57905	.40216	.150
Switching x Age x Number of Characters	-.22149	-.509	.611
Inhibition x Age x Number of Characters	-.38578	.43340	.373

Notes: Significant main effects and interactions are shaded.

Appendix E:

Model output for pronominal use of the combined data from Experiments 1 and 2

Fixed effect	Coefficient	SE	P-value
VWM	-.187843	.38696	.85699
Switching	.79506	.32927	.01575
Inhibition	-.32213	.29086	.26808
Number of Characters	-3.63489	.34722	<.0001
Age	.94772	.31862	.00293
Version	-.44732	.62783	.47616
VWM x Number of Characters	.34981	.25099	.16340
Switching x Number of Characters	-.26665	.25211	.29021
Inhibition x Number of Characters	.14920	.25931	.56502
VWM x Age	-.60016	.30346	.04796
Switching x Age	-.18122	.34036	.59422
Inhibition x Age	-.07961	.29564	.78770
Age x Number of Characters	-.18163	.25539	.47697
VWM x Version	-1.34090	.60560	.02682
Switching x Version	-.26053	.65567	.69111
Inhibition x Version	.32923	.58129	.57114
Number of Characters x Version	-1.12074	.62288	.07198
Age x Version	-1.57740	.63537	.01304
VWM x Age x Number of Characters	-.18448	.24402	.44964
Switching x Age x Number of Characters	.01720	.26204	.94767
Inhibition x Age x Number of Characters	-.18398	.24474	.45221
VWM x Number of Characters x Version	.60055	.50365	.23311
Switching x Number of Characters x Version	-.07647	.50629	.87994
Inhibition x Number of Characters x Version	-.75460	.49952	.13088
VWM x Age x Version	.57926	.60465	.33806
Switching x Age x Version	.106744	.68133	.11718
Inhibition x Age x Version	-.52146	.58127	.36966
Number of Characters x Age x Version	.14299	.53170	.78798
VWM x Number of Characters x Age x Version	-.63599	.49048	.19474
Switching x Number of Characters x Age x Version	-.34106	.53724	.52488
Inhibition x Number of Characters x Age x Version	-.36555	.50270	.46712

Notes: Significant main effects and interactions are shaded.