

# EXPLORING THE EFFECT OF COGNITIVE LOAD ON CHILDREN'S SENSITIVITY TO PRINCIPLE B AND PRINCIPLE C OF CHOMSKY'S BINDING THEORY (1981)

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**Abstract:** This study explores the effect of cognitive load on children's sensitivity to Principle B and Principle C of Chomsky's Binding Theory (1981). The study aimed to further investigate a processing-based account for why children show greater understanding of Principle C than Principle B across previous studies in child language. Processing-based accounts suggest that children show greater sensitivity to Principle C than Principle B because Principle C-violating interpretations of sentences are immediately blocked. However, this does not apply for Principle B-violating interpretations, as these require filtering. If this is the case, children's performance with Principle B may be influenced by processing demands within a task, but not their performance with Principle C. To investigate this further, I conducted two experiments. In Experiment 1, 39 children and an adult control group participated in a Truth-Value Judgement Task under either a low or high cognitive load condition. In Experiment 2, a subset of child participants completed the TVJT in the alternative load condition two weeks later. Children's performance on the TVJT with Principle B and Principle C trial items was compared across cognitive load conditions. Experiment 1 showed that children consistently performed better on Principle C trials than Principle B trials, however the findings and results of a mixed-effects logistic regression revealed no significant effect of cognitive load on children's performance with either principle. Experiment 2 supported this finding, suggesting individual differences in children did not notably affect results. These results do not actively support a processing-based explanation for children's different application of Principle B and Principle C. Instead, they potentially lend support to a more pragmatic-based approach. However, the study concludes processing-based accounts cannot yet be ruled out and require further investigation.

**Keywords:** Binding Theory, Principle B, Principle C, TVJT, high/low cognitive load, processing, pragmatic, child language development, regression.

**Supervisor(s):** Dr Rebecca Woods

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# **Exploring the effect of cognitive load on children's sensitivity to Principle B and Principle C of Chomsky's Binding Theory (1981)**

## **1. Introduction**

Previous research has suggested that children have difficulty acquiring Principle B of Chomsky's Binding Theory (1981) (Wexler and Chien 1985) but have notably greater ease acquiring Principle C (Crain and Mckee 1986). Many studies have attempted to explain such differences in acquisition, with some focussing on a pragmatic account (Thornton and Wexler 1999) and others proposing a structural account (Tavakolian 1978). In the present study, I build on a processing-based explanation for the differences (Conroy et al. 2009), by exploring the effect of cognitive load on children's sensitivity to Principle B and Principle C.

Section 2 firstly provides a background into Chomsky's Binding Theory, defining the notions of Principle B and Principle C (2.1). Following this, it reviews previous studies which explore children's performance with both principles (2.2) and finally assesses potential explanations for children's generally poorer performance with Principle B in comparison to Principle C (2.3-2.7), concluding that a processing-based explanation may be most suitable. Section 3 describes the methods employed for the present study's investigation, which requires all participants to complete a TVJT in either a low cognitive or high cognitive load condition (Experiment 1), with a subset of participants completing the TVJT again two weeks later in the alternative load condition (Experiment 2). The study's findings are presented in (4) and a mixed-effects logistic regression is conducted to analyse any significant effects on children's sensitivity to the constraints. The results found that cognitive load does not significantly affect children's sensitivity to Principle B or Principle C. Section 5 discusses these findings, arguing that while the results do not offer direct support for a processing-based explanation, further research is required before it can be ruled out. This is due to limitations

of the study and the complexity of assessing processing effects. Section 6 concludes the study, providing a summary.

## **2. Literature Review**

### **2.1. Binding Theory**

Chomsky's Binding Theory (1981) addresses the conditions under which two DP's in a sentence can refer to the same person or entity. There are three types of DP's distinguished in Binding Theory, which are defined and exemplified below (1a-1c).

- (1) (a) Anaphors: These are reflexives (e.g. *herself*) or reciprocals (e.g. *each other*).
- (b) Pronominals: These are non-reflexive pronouns (e.g. *her* and *you*).
- (c) R-expressions: These are referential expressions (e.g. proper names: *Tom*).

(Amended from Poole 2011: 104)

Each DP is subject to a distinct constraint under Binding Theory. Principle A governs anaphors, Principle B governs pronominals and Principle C governs R-expressions. The 3 principles of Chomsky's Binding Theory (1981) are given below (2a-2c).

- (2) (a) Principle A: An anaphor must be bound in its governing category.
- (b) Principle B: A pronoun must be free in its governing category.
- (c) Principle C: An R-expression must be free.

(Amended from Poole 2011: 118-119)

As the present study focuses on children's sensitivity to Principle B and Principle C, the following sections discuss these two principles in further detail (2.1.1-2.1.2).

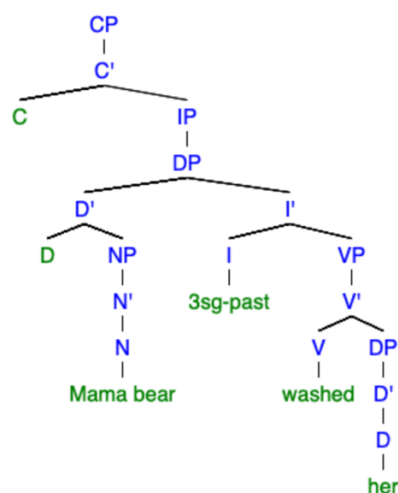
### 2.1.1. Principle B of Binding Theory

Chomsky (1981) argues that for a pronoun to be free in its governing category, satisfying Principle B (2b), it cannot be bound. This means that a pronoun cannot have a local antecedent in the same clause. For example, in (3a), the pronoun *her* cannot refer to *Mama bear* and must instead refer to a different individual outside of the clause.

- (3) (a) *Mama bear<sub>i</sub> washed her<sub>j</sub>/\*<sub>i</sub>.* (Amended from Conroy et al. 2009: 1)

This is because a pronoun is bound in its governing category if it is c-commanded by a co-indexed antecedent within the same IP. C-command means that the first branching node dominating A (the antecedent) also dominates B (the pronoun) (Chomsky 1981). As shown in (3b), *Mama bear* c-commands *her* in the same IP, so co-reference would result in a Principle B violation.

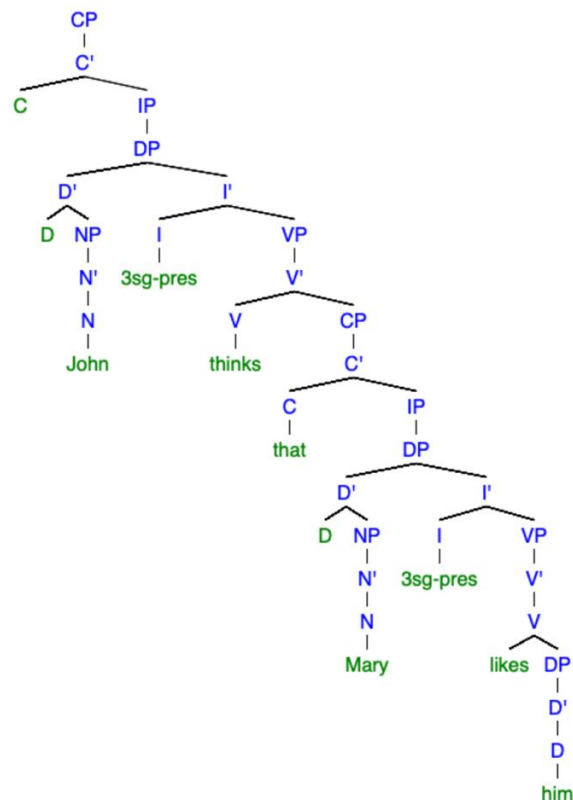
(b)



It is acceptable for a pronoun to have no antecedent at all, or a c-commanding antecedent outside of the IP (governing category). For instance, in (4), *him* can refer to the antecedent *John*, as they are in separate IP's.

(4) (a) *John<sub>i</sub> thinks that Mary<sub>j</sub> likes him<sub>i/k</sub>* (Poole 2011: 115)

(b)



Having established what Principle B of Chomsky's Binding Theory entails, the following section introduces Principle C and illustrates the differences between both principles.

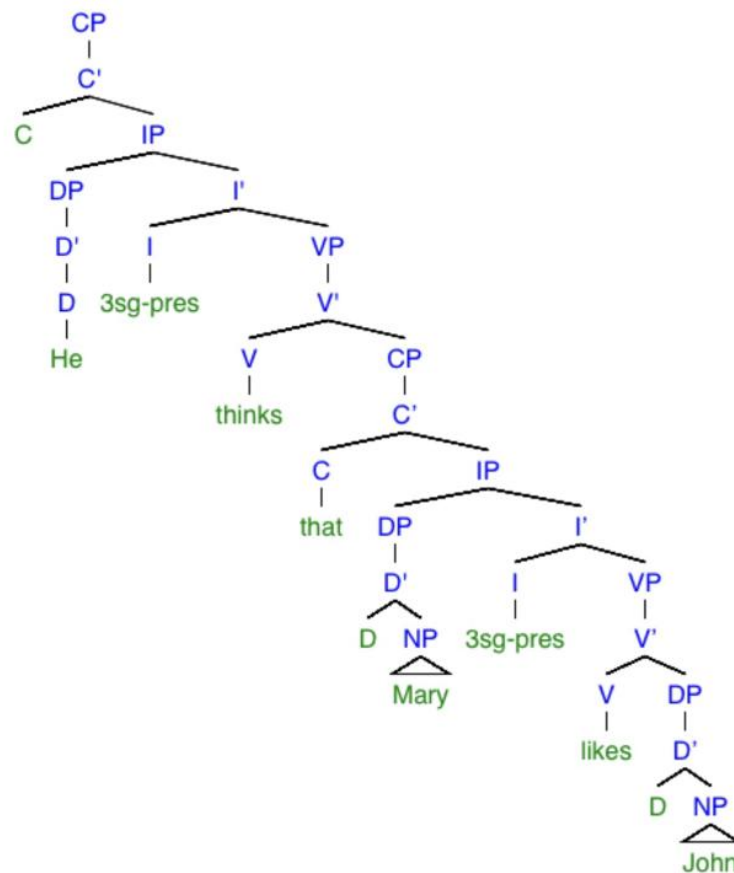
### 2.1.2. Principle C of Binding Theory

For an R-expression to be free, it cannot be bound anywhere (Chomsky 1981). This differs slightly to Principle B, as Principle B only prohibits local binding. For instance, in (5), the R-

expression *John* and the antecedent *He* cannot refer to the same entity. Otherwise, there is a Principle C violation, with *He* c-commanding *John*.

(5) (a)  $He_i$  thinks that  $Mary_j$  likes  $John_{k/*i}$  (Poole 2011: 117)

(b)



Having discussed the notions of both Principle B and Principle C, the following sections explore children's sensitivity to both principles.

## 2.2. The Delay in Principle B Effect

It is widely accepted in previous literature that children have difficulty acquiring Principle B. Chien and Wexler (1990) suggest children struggle with Principle B until around the age of 6, while other studies suggest these difficulties persist “well after the age of 6” (White 1998: 425) and may extend to ages 7-8 (Rooryck and Wyngaerd 2015). This is referred to as the Delay in Principle B Effect (DPBE) (Conroy et al. 2009). However, in contrast to this, children appear to acquire Principle C much earlier, with evidence indicating mastery by approximately age 4 (Crain and Mckee 1986).

### **2.2.1. Children’s acquisition of Principle B**

Children’s difficulty with Principle B revolves around their tendency to allow Principle B-violating interpretations in which a pronoun has a local c-commanding antecedent (Wexler and Chien 1985). For example, children frequently accept interpretations like (6), in which *her* and *John’s mother* are the same person.

(6)            \**John’s mother<sub>i</sub>* washed *her<sub>i</sub>*            (Amended from Wexler and Chien 1985: 139)

The viable interpretation of this sentence is provided in (7), where *her* is referring to someone else, who is not featured within the clause.

(7)            *John’s mother<sub>i</sub>* washed *her<sub>j</sub>*            (Amended from Wexler and Chien 1985: 139)

Claims surrounding children’s struggles with Principle B are supported by empirical findings. For example, Wexler and Chien (1985) found a DPBE in their study. In this study, they conducted three experiments with English-speaking children between the ages 2;6-6;6. Experiment 1 was a Picture Selection Task (129 participants), Experiment 2 was another Picture Selection Task (124 participants) and Experiment 3 was an Act Out Task (156

participants). Across these experiments, children did not show sufficient knowledge of Principle B, with minimal improvement via age groups, except the oldest age group who respected Principle B in their interpretations 70% of the time. However, with chance performance at 50%, this performance is still unstable.

Similarly, Solan (1987) also found a DPBE in a study of 37 English-speaking children aged 4-7. These children participated in an Act Out Task. The results of this experiment showed that children interpreted the pronoun incorrectly quite frequently, with their interpretations violating Principle B 57% of the time.

Even higher rates of Principle B-violating interpretations have been witnessed when testing English speaking-children's knowledge of Principle B in a Truth-Value Judgement Task (TVJT) (McKee 1992). In this study, the author found that children between the ages 2;6-5;3 accepted Principle B violating interpretations 82% of the time.

While children have demonstrated a lack of understanding for Principle B across a range of experiments, which have employed various methods of testing, such as Act Out Tasks (Wexler and Chien 1985, Solan 1987), Picture Verification Tasks (Wexler and Chien 1985) and TVJT's (McKee 1992), children often exhibit greater competency with Principle C across experiments, such as TVJT's (Crain and McKee 1986), Act Out Tasks and Imitation Tasks (Lust et al. 1980).

### **2.2.2. Children's acquisition of Principle C**

Crain and McKee (1986) tested 62 children's knowledge of Principle C (mean age=4;2). The authors conducted a TVJT in which children judged sentences that were either ruled out by Principle C, such as (8) and (9), or not ruled out by Principle C (10).

- (8) \**He<sub>i</sub>* washed *Luke Skywalker<sub>i</sub>*
- (9) \**He<sub>i</sub>* ate the hamburger when the *Smurf<sub>i</sub>* was in the fence
- (10) When *he<sub>i</sub>* stole the chickens, the *lion<sub>i</sub>* was in the box.

(Amended from Crain and Mckee 1986: 104-106)

The children had to judge whether the sentence correctly matched what had been acted out to them. Children only accepted Principle C-violating interpretations for the trial item, like those in (8) and (9) 12% of the time. In contrast, their acceptance rate for coreferential interpretations when Principle C was not blocked, like in (10) was 73%. This suggests children know when the constraint is relevant and how to accurately apply it.

Similarly, in Lust et al. (1980), 82 children aged 3;5-7;5 performed well with Principle C overall. In this study, children's comprehension of Principle C was tested through an Act Out Task and production of it through an Imitation Task. The authors reported that Principle C-violations were minimal, with only 14.5% of Principle C-violating interpretations. They suggested there were significantly less coreferential interpretations when Principle C applied, than when it did not. This supports the notion that children can apply the constraint.

Having established that the general pattern in previous literature suggests children are more sensitive to Principle C than Principle B, the following sections provide potential explanations for why this may be, proposed in previous research.

### **2.3. A structural account for the DPBE**

Earlier research has implied that children perform poorly with binding constraints because their understanding of grammar does not initially rely on sentence structure to determine when coreference is allowed between two DP's. Instead, they decide when coreference is permitted based on the linear order of the two DP's (Tavakolian 1978). The results of an experiment conducted with 3-5-year-olds in Tavakolian (1978) indicated that children dislike backwards anaphora, so do not allow an R-expression to refer to a previous antecedent, meaning Principle C is in turn obeyed. Since this notion does not apply to Principle B, a potential explanation is provided for why more violations are encountered in experiments testing Principle B than Principle C. However, more recent evidence has indicated that children do not have a dispreference for backwards anaphora (Crain and Mckee 1986) (Section 2.2.2) and any dispreference is only witnessed when Principle C applies. Therefore, many authors have turned to a pragmatic account for the DPBE.

#### **2.4. A pragmatic account for the DPBE**

Thornton and Wexler (1999) argue that the DPBE is due to children's lack of pragmatic knowledge. The authors suggest that in certain a-typical circumstances, unlike an R-expression, a pronoun may have an anaphoric interpretation, which appears to violate Principle B. To acknowledge that this is an unusual situation, the pronoun would receive added stress. This would show to an adult that the situation is peculiar, alongside the context. However, the authors argue children do not have enough world knowledge to understand that these cues indicate an a-typical situation. Therefore, children accept coreferential interpretations of pronouns because they cannot distinguish unique contexts like (11a) from ordinary ones (11b) (*stress is indicated through capital letters*).

- (11)        (a) Mama bear is washing HER  
              (b) Mama bear is washing her

(Thornton and Wexler 1999: 94)

While this account is feasible, I argue there is a core problem across the structural (2.3) and pragmatic (2.4) accounts for the DPBE. This is that while there is a consensus that children struggle more with Principle B (2.2.1) there is a lot of variability in the strength of the DPBE across studies. As noted by Conroy et al. (2009), Principle B-violating response rates range from around 15%-82%. If there is an inherent misunderstanding of Principle B, for syntactic or pragmatic reasons, it raises the question as to why children's sensitivity to it varies so notably across experiments. The notion of the Quantificational Asymmetry (QA) may provide reason for this.

## 2.5. The Quantificational Asymmetry

The QA argues that the DPBE is not uniform across all antecedents. This notion is supported by Chien and Wexler (1990), who argue that children are more susceptible to Principle B-violating interpretations when the antecedent is referential than when the antecedent is quantificational. For example, children are more likely to accept coreference in (12) over (13).

- (12) \**Mama Bear*<sub>i</sub> washed *her*<sub>i</sub> (Amended from Conroy et al 2009: 1)
- (13) \**Every bear*<sub>i</sub> washed *her*<sub>i</sub> (Amended from Conroy et al 2009: 1)

subjects. However, the idea does not explain why children typically perform better with Principle C. This is because the same pragmatic rule in referential conditions should also apply to Principle C contexts, but children still consistently demonstrate understanding of this principle (Conroy et al. 2009). Therefore, I argue a processing-based explanation is the most suitable explanation for children's differences in sensitivity to Principle B and Principle C. This processing-based explanation is proposed by Conroy et al. (2009) following their experiments.

## **2.6. A processing-based account for the DPBE**

Conroy et al. (2009) conducted 3 experiments with 16 English-speaking children aged 4-5;6 years and an adult control group. All experiments were TVJT's and aimed to test children's understanding of Principle B and whether their performance was impacted by the subject of the sentence (referential or quantificational). Their study was motivated by Elbourne's claim that the QA is a methodological artifact and that in a properly controlled experiment, where certain characters are not salient in TVJT scenarios and correct interpretations are readily available, the DPBE would appear for all antecedents (2005).

Conroy et al.'s (2009) results found that children's performance with Principle B did not differ notably across antecedents, with an acceptance rate of 11% for Principle B-violating interpretations when the subject was referential and 14% when the subject was quantificational. However, their results did not support the suggestion that a DPBE would appear for all antecedents. Children appear to consistently avoid anaphoric interpretations and display an adult-like application of Principle B. Regarding the DPBE, Conroy et al conclude from these findings that it may be less pervasive than suggested. However, they do acknowledge that children's performance is typically better with Principle C. The authors suggest that this is likely due to how these constraints impact real time language processing (Conroy et al. 2009).

### **2.6.1. Empirical evidence for a processing-based account**

Adult psycholinguistic studies have suggested that Principle C acts as an initial filter on the processing of pronouns (Kazanina et al. 2007). This means that adults do not attempt to make a link between an R-expression and the pronoun that c-commands it. In Kazanina et al. (2007) adults participated in a self-paced reading experiment. When Principle C permitted coreference, readers slowed down when reading sentences where the pronoun and R-expression did not match in gender. However, when Principle C blocked coreference, the readers did not slow down. This suggests Principle C-violating interpretations are immediately blocked, so there is no need to check gender. This differs to how real time language processing impacts Principle B.

Badecker and Straub (2002) provide evidence which suggests Principle B is a late filter. This means Principle B-violating interpretations are temporarily considered before exclusion. In Badecker and Straub (2002), adults participated in self-paced reading tests. They investigated what guides pronoun and anaphora interpretations. The findings suggest that readers use multiple resources to figure out the referent of a pronoun. Although syntax is one of these resources, they still initially consider Principle B-violating interpretations. This was indicated by their slowed down reading pace when searching for an antecedent, even in prohibited contexts.

These findings suggest that Principle B and Principle C operate differently in real-time processing, with adults seemingly considering Principle B-violating interpretations, but not Principle C-violating interpretations. If children, as suggested by Conroy et al. (2009), encounter difficulty revising initial misinterpretations, Principle B being a late filter may account for the apparent DPBE witnessed across studies. This is because if children commit to the Principle B-violating interpretation when it is available to them, they may fail to recover. Principle B being a late filter may also account for variability across experiments testing this principle, as different methods of testing have different processing demands (McDaniel et al. 1998), so filtering out incorrect interpretations may be easier in some experiments than others. Adopting this processing-based account for the DPBE, I consider

how the cognitive demands of a task may impact performance with Principle B differently to Principle C.

## **2.7. Cognitive Load Theory**

The cognitive load construct takes into account the demand that a certain task imposes on an individual. If a task has an extraneous cognitive load, Sweller argues working-memory capacity can be affected negatively (1988). When this happens, it makes it harder to use schemas and complete the task effectively.

When testing children's knowledge of Principle C, conducting an experiment which requires the children to participate under a high cognitive load would likely not affect performance. This is because if Principle C-violating interpretations are blocked immediately, there is no real task at hand for the child, as they are blind to incorrect interpretations.

However, when testing children's knowledge of Principle B, an experiment with high cognitive load may affect performance. This is because children need to actively consider whether the pronoun can refer locally. Increased cognitive load may impact their working-memory capacity and in turn their ability to apply Principle B.

Previous research has supported the notion that cognitive load impacts children's performance with Principle B (Van Rij et al. 2010). In this study, the authors conducted a TVJT. 75 Dutch children participated aged 4;1-6;3 in two conditions. In one condition the test sentences for the TVJT were read to them at a normal pace, but in the other condition the speech rate was slowed down. This slowed down speech rate was a method of decreasing cognitive load. The results of this study found that, if a child shows the DPBE, a slowed-down speech rate has a positive effect on their performance with Principle B. Children's performance with Principle C in different conditions was not tested in their experiment.

In the present study, I explore the effect of increased cognitive load on children's sensitivity to both Principle B and Principle C, investigating a processing-based account for the DPBE further.

## **2.8. Research Questions and Hypotheses**

*Research Question 1:* Does increased cognitive load impact children's acceptance of Principle B-violating interpretations?

*Hypothesis 1:* Cognitive load will have an effect. Under high cognitive load, children will show a higher rate of acceptance for Principle B-violating interpretations in comparison to the low load condition.

*Research Question 2:* Does increased cognitive load impact children's acceptance of Principle C-violating interpretations?

*Hypothesis 2:* Cognitive load will not have an effect. Children will show similar amounts of Principle C-violating interpretations in the high cognitive load and low cognitive load condition.

## **3. Methodology**

To explore the effect of cognitive load on children's sensitivity to Principle B and Principle C, I conducted two experiments in the present study. Both experiments employed the same TVJT as a method for testing children's sensitivity to Principle B and Principle C. This is a well-established method, often considered one of the most "illuminating methods" for revealing children's linguistic competence (Gordon 1998: 211). While there are other methods available, a TVJT appeared most suitable for the present study, as it can be designed to support for memory and attentional demands (Gordon 1998). Since there were two conditions in my study (a low cognitive load condition and a high cognitive load

condition), it was important to ensure any external demands were minimal in the low load condition to then be manipulated for the high load condition.

### **3.1. Experiment 1**

Experiment 1 is a between-subjects experiment, where participants were randomly assigned to either the low cognitive load condition or the high cognitive load condition of the TVJT. In the following section, I discuss the design of the TVJT across both conditions.

#### **3.1.1. Methods and Materials**

All participants completed a TVJT. Participants in the low cognitive load condition of the TVJT completed only the TVJT. However, participants in the high load condition completed the TVJT and a visual memory task simultaneously. Firstly, I describe the design of the TVJT, which was presented to all participants (3.1.2).

#### **3.1.2. TVJT Design**

In the present study's TVJT, participants were presented with a static image on a computer screen depicting a short scenario. After the participant had observed this scenario, a puppet made a statement about the scenario, which I read out loud while the image was still visible on the computer screen. The participant was then asked whether the puppet's statement accurately described the scenario, to which they responded "yes" or "no" (Gordon 1998).

The TVJT consisted of 8 target scenarios. Each scenario was compatible with both a Principle B and a Principle C test sentence. The 8 scenarios were assigned to two lists of items using a Latin Square design (Conroy et al. 2009). This meant that each participant saw all 8

scenarios, paired with 4 Principle B and 4 Principle C test sentences. Across participants, each scenario appeared equally often with Principle B and Principle C test sentences.

Of the 8 target scenarios, 4 scenarios are classed as true items and 4 as false items. For the 4 true items, the test sentences accurately described the image. For the 4 false items, the test sentences inaccurately described the image. Truth values were balanced across Principle B and Principle C conditions, such that for each principle 2 test sentences were true and 2 were false. Examples of a true target item (14) and false target item (15) are given below.

(14) True Target Item

Figure 1: Image taken from the present study of George Pig wiping Pedro Pony.



Principle B test sentence: George Pig wiped him.

Principle C test sentence: He wiped Pedro Pony.

(15) False Target Item

Figure 2: Image taken from the present study of Daddy Pig painting himself and Grandpa Rabbit standing next to him.



Principle B test sentence: Daddy Pig painted him.

Principle C test sentence: He painted Daddy Pig.

In addition to the 8 target items, 8 filler items were included in the study to test children's overall understanding of the task. Similarly to the target items, 4 of these fillers were true and 4 were false, ensuring the amount of true/false items overall is even. Examples of a true filler item (16) and a false filler item (17) are provided below.

(16) True Filler Item

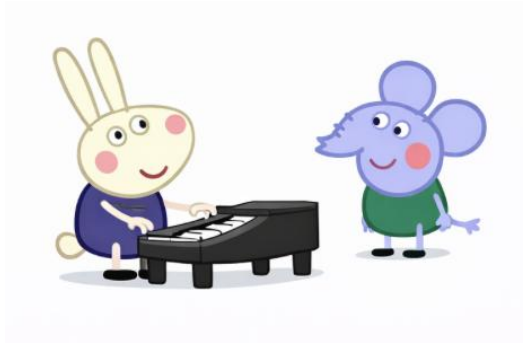
Figure 3: Image taken from the present study of Simon squirrel kicking a ball. Rohan Rhino is next to him.



Test Sentence: Simon Squirrel kicked the ball.

(17) False Filler Item

Figure 4: Image taken from the present study of Richard rabbit playing the piano. Edmund elephant is stood near him.



Test Sentence: Edmund Elephant played the piano.

Overall, 16 scenarios were presented to participants. All 16 scenarios were created using AI to control image design. It was important for the characters in the images to be approximately the same size and style to avoid saliency effects (Elbourne 2005) and that all images had a white background to minimise distractions. See Appendix A for further discussion on prompts given to AI.

Each image contained two Peppa Pig characters of the same gender. This was done to avoid bias toward a deictic interpretation due to gender mismatch. Character gender is clearly indicated in names and if participants are unfamiliar with the show, characters are also identifiable by their animal labels. For example, *Suzy Sheep*. The two characters in the image were always different animals.

In each image, one character was either doing something to the other character in the image or to themselves. Actions were transitive verbs and always available to do to another person (See (14)) or to oneself (See (15)) without seeming unnatural. For instance, verbs

such as “hugged” were avoided, as it may seem peculiar to hug oneself and therefore bias toward a deictic interpretation, masking true grammatical competence.

See Appendix B for the target and filler stimulus in List 1 and List 2. See Appendix C for the target and filler scenarios test sentences were paired with.

As mentioned previously, if the participant is assigned to the low load condition of the experiment, this TVJT is the only task they complete. However, children in the high load condition have an additional visual memory task. Short term recall tasks have often been employed as a secondary task in studies (Potter and Lombardi 1990), with dual task designs often showing that holding visual items in one’s working memory, while completing a task, can influence aspects of performance (Xin and Li 2019). In the next section, I will discuss how a memory task is implemented in the TVJT to increase the cognitive load of a task.

### **3.1.3. Cognitive load manipulation: Visual Memory Task Design**

For each of the 16 trials (8 target/ 8 filler) in the TVJT, a memory task was paired with each one. This memory task means that before each scenario, the participant was presented with an image of 3 things, which were all from different pragmatic categories. The participant was told to keep this image in their mind. Keeping this image in mind, they completed the TVJT trial. After this trial, the child was shown a picture of three things again. This was either the same three things as before, or one thing had changed to an entirely different thing. The child was asked whether they believed the picture was of the same three things, or if they thought something had changed, to which they replied “same” or “different”. See Figure 5, for an example of an initial image in the picture memory task and see Figure 6 for how this picture then changed.

Figure 5: Image taken from the present study of three items used in the picture memory task.



Figure 6: Modification of the 3 items in figure 5.



Like the images used in the TVJT, the images used in the picture memory task were also created using AI for similar reasons, such as controlling for size and style of images.

For the high load condition, across the 8 target items, 4 images changed and 4 images remained the same. Image change was counterbalanced with truth value (True/False items) and principle (Principle B/Principle C). For the 8 filler trials, 4 images remained the same and 4 changed, with image change also counterbalanced with truth value. This meant that across all 16 items, 8 images remained and 8 changed. See Appendix D.

Having outlined the design of the TVJT, and the visual memory task for the high load condition, the following section describes the participants and experimental procedure.

#### **3.1.4. Participants**

39 native English-speaking children participated in this experiment, ranging in age from 3;3-6;4 years (*mean age=4;8 years*), as this is the age range in which the DPBE is typically prevalent (Conroy et al. 2009). All child participants were recruited from Nunthorpe Primary Academy and written parental consent was obtained through school communication channels. See Appendix E for the information sheet and Appendix F for the consent form sent to parents.

15 adult controls also participated and were recruited through snowball sampling. All adult controls were native speakers of English aged 18+, not vulnerable in any way and non-linguistic students. See Appendix G for the adult consent form.

### **3.1.5. Procedure**

Before conducting the experiment, participants were randomly assigned as evenly as possible to either the low or high cognitive load condition of the TVJT and to one of the two stimulus lists (List 1 or List 2), with list assignment counterbalanced across cognitive load conditions.

The participants were then collected from their classroom and taken to a quiet room to complete the task individually with the experimenter. Upon arrival, the child's consent to the task was sought verbally. Participants firstly completed the digit span task to test for working memory (Appendix H). Following this, the requirements of the TVJT were explained to the participant. Participants then completed two practice trials to ensure understanding of the task. These two trial items were counterbalanced with a true/false scenario and Principle B/ Principle C test sentence to familiarise the child with the two types of sentences and scenarios they should expect, following advised protocol (Gordon 1998). For those in the high load condition, the practice trials were accompanied with one changing picture memory task and one remaining.

All participants proceeded to complete the experiment. In the low cognitive load condition, participants completed the TVJT in one testing session which lasted around 7-10 minutes across participants. In the high cognitive load condition, participants completed the TVJT and visual memory task in one testing session which lasted around 13-22 minutes across participants.

After conducting the experiment, 3 children were excluded from analysis. 2 children were excluded from the low cognitive load condition for answering more than 2/8 fillers incorrectly, showing lack of understanding for the task. 1 child was excluded from the high cognitive load condition for failing on more than 4/16 of the memory tasks, as lack of engagement with the memory task indicates sufficient cognitive load may not have been added.

### **3.1.6. Final dataset**

The final sample size was 36 child participants (mean age=4;8) and 15 adult controls. See Table 1 for the distribution of child participants across cognitive load (low load mean age=4;9, high load mean age=4;7) and list conditions of the TVJT and Table 2 for the adult distribution.

Table 1: Child participant distribution table across Load and List.

| Child participants distribution | Low Load | High Load |
|---------------------------------|----------|-----------|
| List 1                          | 9        | 9         |
| List 2                          | 9        | 9         |
| Total                           | 18       | 18        |

Table 2: Adult participant distribution table across Load and List.

| Adult participants distribution | Low Load | High Load |
|---------------------------------|----------|-----------|
| List 1                          | 4        | 4         |
| List 2                          | 4        | 3         |
| Total                           | 8        | 7         |

This meant that there were 288 target responses produced by children to code and 120 target responses for adults. In the following section, I discuss how these responses were coded to extract meaningful results.

### **3.1.7. Data coding**

Responses to the TJVT in the final dataset were coded as either an incorrect anaphoric interpretation or a correct deictic interpretation of the test sentence. An anaphoric interpretation violates Principles B and C by allowing the pronoun or R-expression to corefer with a local antecedent. A deictic interpretation disallows local coreference and assumes the pronoun or R-expression refers to an entity outside of the clause.

For false trials, “yes” responses indicate an anaphoric interpretation, while “no” responses indicate a deictic interpretation (18). For true trials, “yes” responses indicate a deictic interpretation, whereas “no” suggests an anaphoric interpretation (19).

(18) False Trial

Scenario: Danny Dog is stamping himself. Freddy Fox is stood next to him.

Principle B test sentence: Danny Dog stamped him.

A “yes” response suggests the child has interpreted *him=Danny Dog*, while a “no” response shows understanding that these two DP’s cannot corefer under Principle B.

Principle C test sentence: He stamped Danny Dog.

A “yes” response suggests the child thinks *He=Danny Dog*, while a “no” response acknowledges that coreference is not permitted by Principle C.

(19) True trial

Scenario: Suzy Sheep sprayed Zoe Zebra with a water gun.

Principle B test sentence: Suzy sheep sprayed her.

A “yes” response indicates understanding that *her=Zoe Zebra*, while a “no” response indicates that the child thinks *her=Suzy Sheep*.

Principle C test sentence: She sprayed Zoe Zebra.

A “yes” response shows understanding that *She=Suzy Sheep*, whereas a “no” response suggests the child has interpreted *She=Zoe Zebra*.

Some children offered an explanation for their “yes”/”no” judgement. In cases where the explanation contradicted their “yes”/”no” judgement, their response was coded based on their “yes”/”no” judgement. This decision was made because, unlike in Conroy et al. (2009), verbal explanations were not obtained for all trials/ participants, so relying on explanations would result in an inconsistent dataset.

After coding all responses, the number of anaphoric interpretations were counted. The number of anaphoric interpretations for each principle across each load condition is presented in Experiment 1’s descriptive results section (4.1). This section also considers any list effects and truth-value effects, as these were calculated design choices. A mixed effects logistic regression is then conducted to see if cognitive load had a significant effect on

anaphoric response rate for either principle and whether any other factors played a role in the rate of anaphoric interpretations (4.2).

Before presenting the results of Experiment 1, I discuss how Experiment 2 is used to help interpret these results.

### **3.2. Experiment 2**

Experiment 2 was designed as a small follow-up to Experiment 1 to assess whether the observed effects of cognitive load were robust to individual differences in children. Experiment 2 involved re-testing a subset of child participants from Experiment 1. Participants completed the exact same TVJT as in Experiment 1, but in the opposite cognitive load condition to which they were previously assigned. This re-testing took place two weeks after Experiment 1 was conducted.

#### **3.2.1. Participants**

Participants retested in Experiment 2 were selected from children who had successfully completed the first experiment. There were 15 participants ranging in age from 3;5-6;4 (mean age= 4;2). Participants were evenly distributed between cognitive load conditions (low load condition mean age= 4;4, high load condition mean age= 4). Each participant remained in the same list as they were assigned to in Experiment 1 and lists are counterbalanced across load conditions. See table 3.

Table 3: Participant distribution table across Load and List.

| Participant distribution | Low Load | High Load |
|--------------------------|----------|-----------|
| List 1                   | 4        | 3         |

List 2

4

4

Data from Experiment 2 was coded in the same way as Experiment 1. Results from Experiment 2 are presented descriptively in (4.3) of the results section, as supporting analysis for Experiment 1's results.

## 4. Results

### 4.1. Experiment 1 Results

#### 4.1.1. Descriptive results

Table 4 presents the descriptive results of this study's analysis. All child participant's results have been treated as a collective. The child's chronological age is treated as a continuous factor in the statistical test, where any effects of age can be made clear.

Table 4: Acceptance rates for anaphoric interpretations of pronouns (Principle B) and R-expressions (Principle C) under low and high cognitive load.

| % Accept binding/ coreference | Low Load |     | High Load |     |
|-------------------------------|----------|-----|-----------|-----|
| <i>Children</i>               |          |     |           |     |
| Principle B                   | 25/72    | 35% | 32/72     | 44% |
| Principle C                   | 10/72    | 14% | 7/72      | 10% |
| <i>Adults</i>                 |          |     |           |     |
|                               | 2/32     | 6%  | 0/28      | 0%  |

Principle B

Principle C

0/32

0%

2/28

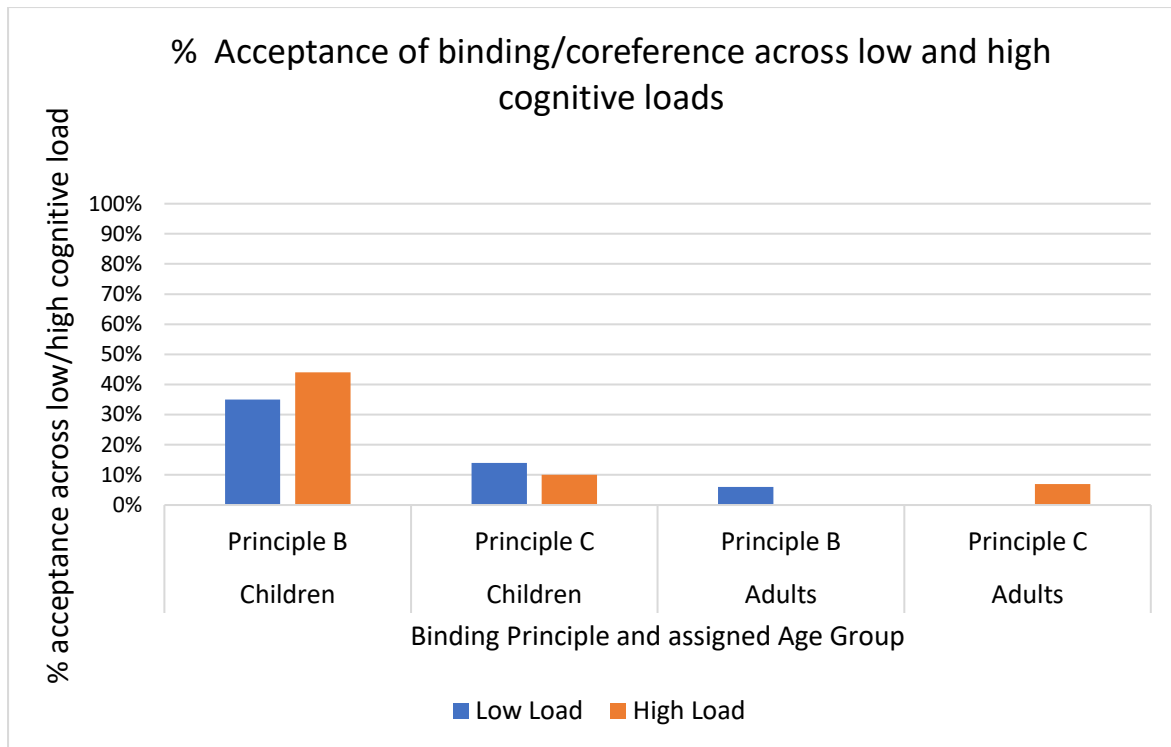
7%

For Principle B, children in the low cognitive load condition accepted anaphoric interpretations in 35% (25/72) of the trials. Children in the high load condition accepted anaphoric interpretations in 44% (32/72) of the trials, showing a higher proportion of anaphoric interpretations in the high load condition.

For Principle C trials, children's acceptance rates for anaphoric interpretations were lower overall than in Principle B trials. Children accepted anaphoric interpretations in 14% (10/72) of trials under low cognitive load and 10% (7/72) of trials under high cognitive load. There is a slight decrease in acceptance rate for anaphoric interpretations from low load to high load condition.

The adult control group showed consistently low acceptance rates for anaphoric interpretations across both conditions. For Principle B, anaphoric responses were produced in 6% (2/32) of trials under low cognitive load and 0% (0/28) under high cognitive load. For principle C, no anaphoric responses were observed in the low load condition (0/32) and only 7% (2/28) in the high load condition. Figure 1 illustrates the patterns described in Table 1 regarding children's and adult's acceptance rate for anaphoric interpretations across low cognitive load and high cognitive load conditions.

Figure 7: Graph displaying % acceptance rates for anaphoric interpretations of pronouns and R-expressions across low and high cognitive load.



In addition to the main analysis, further descriptive analyses were conducted to investigate whether other categorical factors influenced children's responses. The factors under investigation were whether the test sentence was true or false in relation to the image (Table 5 and Figure 8) and the child's assigned list (Table 6 and Figure 9).

Table 5: Acceptance rates for anaphoric interpretations of pronouns (Principle B) and R-expressions (Principle C) across true and false items.

| Anaphoric interpretations in true/false scenarios | False Item |     | True Item |     |
|---------------------------------------------------|------------|-----|-----------|-----|
|                                                   |            |     |           |     |
| Principle B                                       | 45/57      | 79% | 12/57     | 21% |
| Principle C                                       | 15/17      | 88% | 2/17      | 12% |

Figure 8: Graph displaying % acceptance rates for anaphoric interpretations of pronouns and R-expressions across true and false scenarios

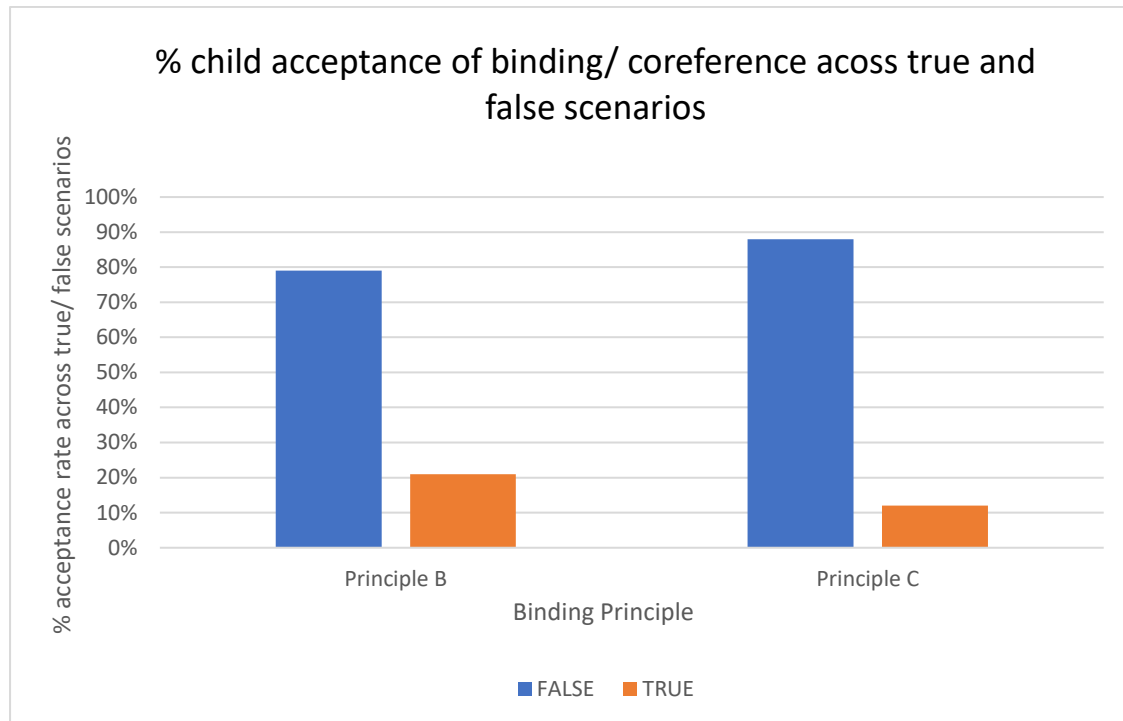


Table 5 and Figure 8 illustrate that children demonstrate a higher rate of anaphoric interpretations in false conditions than in true across both principles. For Principle B, anaphoric interpretations were seen 45/57 times (79%) in false scenarios and only 12/57 times (21%) in true scenarios. A similar pattern emerged for Principle C, with 15/17 (88%) anaphoric interpretations in false scenarios and 2/17 (12%) in true scenarios.

Table 6: Acceptance rates for anaphoric interpretations of pronouns (Principle B) and R-expressions (Principle C) across List 1 and List 2.

| Anaphoric interpretations in List 1/List 2 | List 1 |     | List 2 |     |
|--------------------------------------------|--------|-----|--------|-----|
| Principle B                                | 22/57  | 39% | 35/57  | 61% |

|             |      |     |       |     |
|-------------|------|-----|-------|-----|
| Principle C | 7/17 | 41% | 10/17 | 59% |
|-------------|------|-----|-------|-----|

Figure 9: Graph displaying % acceptance rates for anaphoric interpretations of pronouns and R-expressions across List 1 and List 2.

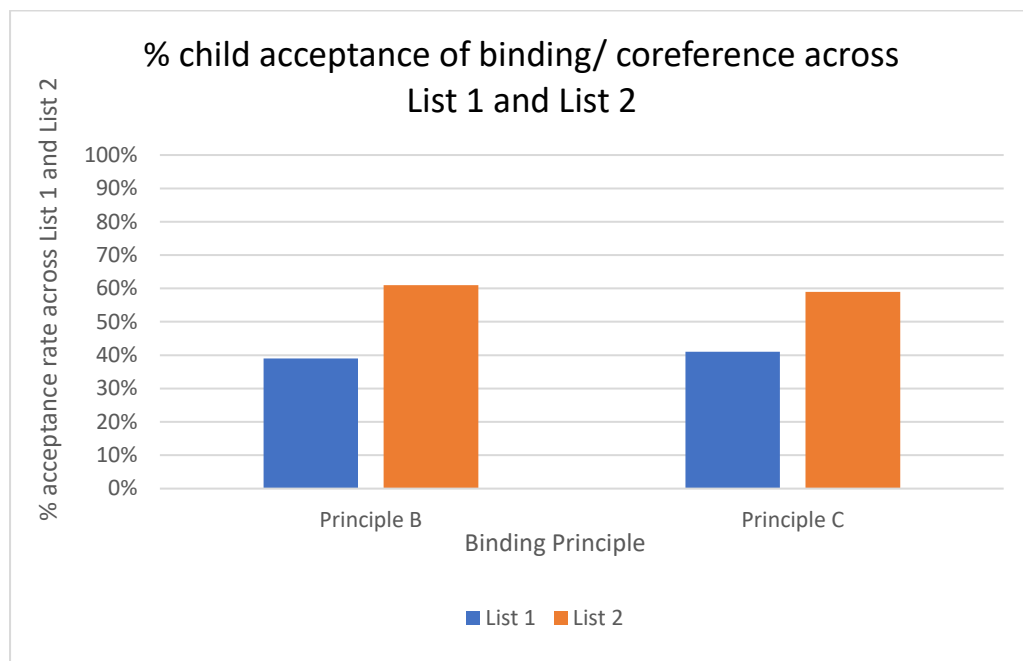


Table 6 and Figure 9 show that children assigned to List 2 exemplified more anaphoric interpretations than children assigned to List 1 across both principles. For Principle B, children in List 1 produced anaphoric responses 39% of the time (22/57) and children in List 2 61% of the time (35/57). For Principle C, children in List 1 produced anaphoric responses 41% of the time (7/17) and children in List 2 61% of the time (10/17).

#### 4.1.2 Mixed-effects logistic regression

In this study, the dependent variable of the logistic regression is an anaphoric interpretation. See (14) and (15) for anaphoric interpretations in true and false trials. By

conducting a logistic regression, I assess which factors influence the probability of an anaphoric interpretation occurring. While the study's primary concern is exploring whether cognitive load impacts anaphoric responses across both Principle B and C conditions, additional predictors that may impact results were included in the model to ensure that any observed effects can reliably be attributed to cognitive load if they emerge.

The factors incorporated into the mixed-effects logistic regression are listed below:

- Item
- Principle
- Cognitive load condition
- Age
- Truth value item
- List
- Digit Span score
- Interaction between principle and load

Firstly, a potential item random effect is presented in Table 7. Following this, the main findings from the logistic regression are presented in Table 8, regarding the impact of all fixed effects on anaphoric response production.

A random effect for item (the stimuli) was included in the model to account for any potential variability that may impact results. An attempt was made to include participant random effects, but this was not possible likely due to insufficient observations per participant.

Table 7: Item effects of the mixed effects logistic regression (Random effect)

| Groups Name      | Variance | Std.Dev. |
|------------------|----------|----------|
| Item (Intercept) | 0.1067   | 0.3267   |

Table 4 shows that there is some variability across items, meaning some test sentences elicited more anaphoric responses than others. However, the variability is limited (*StdDev*=0.33).

Table 8: Results of the logistic regression predicting anaphoric responses (fixed effects).

| Fixed Effects          | Baseline                | Estimate | Std.Error | Z value | P value      |
|------------------------|-------------------------|----------|-----------|---------|--------------|
| (Intercept)            |                         | 2.2494   | 1.2267    | 1.834   | 0.0667 .     |
| PrincipleC             | PrincipleB              | -2.5397  | 0.5621    | -4.519  | 6.23e-06 *** |
| LoadLow                | LoadHigh                | -0.4171  | 0.4116    | -1.013  | 0.3109       |
| Age                    | Continuous              | -0.2963  | 0.2103    | -1.409  | 0.1588       |
| TSentence              | FSentence               | -2.3350  | 0.4264    | -5.476  | 4.35e-08 *** |
| List 1                 | List 2                  | 0.5836   | 0.4012    | 1.454   | 0.1458       |
| DS                     | Continuous              | -0.1692  | 0.1219    | -1.388  | 0.1651       |
| PrincipleC:<br>LoadLow | PrincipleB:<br>LoadHigh | 1.0128   | 0.6953    | 1.457   | 0.1452       |

The primary aim of this study was to examine whether cognitive load differentially affects the acceptance rates for anaphoric interpretations in Principle B and Principle C conditions. The analysis revealed no significant interaction between principle and cognitive load ( $p=0.1452$ ). Cognitive load did not appear to significantly affect anaphoric interpretations in Principle B or Principle C trials ( $p=0.3109$ ).

Other factors which did not significantly impact the rate of anaphoric interpretations was a child's age ( $p=0.1588$ ), their DS score (*Digit Span*) ( $p=0.1651$ ) and the assigned lists ( $p=0.1458$ ).

There were two factors which significantly affected the rate of anaphoric interpretations. The first factor was Principle, with anaphoric interpretations being significantly less likely in Principle C trials than in Principle B trials ( $estimate=-2.5397$ ,  $p<.001$ ). The second factor is whether it was a true trial (T) or a false trial (F). Anaphoric responses were significantly less likely when the test sentence was true to the image, than when they were false ( $estimate=-2.34$ ,  $p<.001$ ).

#### 4.2. Results of Experiment 2 (follow-up experiment)

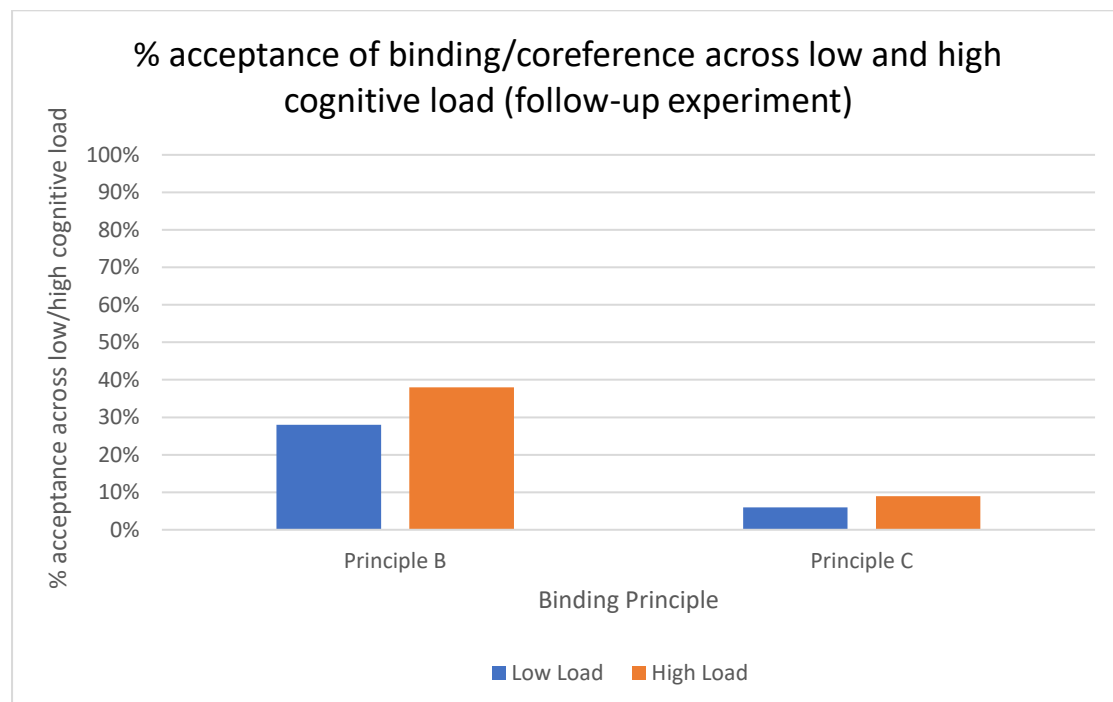
As established above, cognitive load did not significantly impact the number of anaphoric interpretations in children's responses for Principle B or Principle C test sentences. However, the between-subject experiment means individual differences are not accounted for. For example, there is a possibility that some children may be more prone to anaphoric interpretations than others irrespective of load conditions. If such children were randomly allocated to the low load condition, potential effects of cognitive load may be masked. To further investigate potential impacts of load, a subset of participants from the original experiment took part in a follow-up study, allowing for some within-subject comparison of performance between loads. Table 9 illustrates the results of this follow-up study and Figure 10 presents this visually.

Table 9: Acceptance rates for anaphoric interpretations of pronouns (Principle B) and R-expressions (Principle C) under low and high cognitive load in pilot experiment.

| % Accept binding/<br>coreference | Low Load | High Load |
|----------------------------------|----------|-----------|
|----------------------------------|----------|-----------|

|             |      |     |       |     |
|-------------|------|-----|-------|-----|
| Principle B | 9/32 | 28% | 11/28 | 39% |
| Principle C | 2/32 | 6%  | 3/28  | 10% |

Figure 10: Graph displaying % acceptance rates for anaphoric interpretations of pronouns and R-expressions across low and high cognitive load in pilot experiment.



For Principle B, children displayed anaphoric interpretations in 28% (9/32) of trials under low cognitive load and 39% (11/28) under high cognitive load. Therefore, there is a slight but not notable increase in anaphoric interpretations from low to high load in Principle B. A similar pattern emerged for Principle C, where children demonstrated anaphoric interpretations in 6% (2/32) of low load trials and 10% (3/28) of trials in the high load condition. Overall, the differences for both principles between load are minimal and the pattern is consistent with the main experiment, in which cognitive load did not significantly impact anaphoric response production. This will be discussed in detail in the following section.

## **5. Discussion**

### **5.1. Summary of findings**

#### **5.1.1. Effect of cognitive load**

This study investigated the effect of increased cognitive load on children's sensitivity to Principle B and Principle C. The study's findings suggest that increased cognitive load did not affect children's sensitivity to Principle B or Principle C. The study's main findings are drawn from Experiment 1, which constituted the main test of the research questions (5.1.1.1-5.1.1.2). The results of Experiment 2 are considered as a follow-up analysis to assess the robustness of Experiment 1's findings and to explore the potential role of individual differences (5.1.1.3).

##### **5.1.1.1. Effect of cognitive load on Principle B**

Research Question 1 asked whether increased cognitive load impacts children's acceptance rate for Principle B-violating interpretations. It was hypothesised cognitive load would have an effect and that children would show a higher rate of acceptance for Principle B-violating interpretations in the high cognitive load condition of the TVJT than children in the low load condition. However, the results of this study have not supported this hypothesis. In Experiment 1, while there was a slightly higher acceptance rate for Principle B-violating interpretations in the high load condition than in the low load condition (35% in low load, 44% in high load) the load effect was not statistically significant. This suggests increased cognitive load did not affect children's sensitivity to Principle B.

##### **5.1.1.2. Effect of cognitive load on Principle C**

Research Question 2 asked whether increased cognitive load impacts children's acceptance of Principle C-violating interpretations. It was hypothesised that increased cognitive load would not have an effect and that children would show similar rates of Principle C-violating interpretations across both cognitive load conditions. The results of Experiment 1 support this hypothesis. There were slightly more principle C-violating interpretations in the low load condition (14%) than in the high load condition (10%), however the effect of cognitive load held no statistical significance. This suggests increased cognitive load did not affect children's sensitivity to Principle C.

#### **5.1.1.3. Support from Experiment 2**

The results of Experiment 2 further support the absence of a cognitive load effect for both principles. For Principle B, acceptance rates for violating interpretations remained comparable across low (28%) and high (39%) cognitive load conditions, with a similar pattern observed for Principle C (6% in low load and 10% in high load). These results are similar to those in Experiment 1, despite participants being tested under the opposite load condition. This consistency suggests the findings from Experiment 1 regarding cognitive load effects are robust and not driven by individual differences between participants. Reversing the cognitive load manipulation for participants did not seem to alter their responses, reinforcing the idea that cognitive load did not have an impact on children's sensitivity to Principle B or Principle C.

#### **5.1.1.4. Theoretical implications**

The contrasting hypotheses for Principle B (Hypothesis 1) and Principle C (Hypothesis 2) were motivated by previous literature suggesting that Principle B and Principle C differ in how they interact with real-time processing. Conroy et al. (2009) proposed that Principle B-violating interpretations may be momentarily available when interpreting a sentence and

therefore require filtering out. However, Principle C-violating interpretations are immediately blocked, so not available for consideration. Based on this suggestion, which has support from adult psycholinguistic studies (Kazanina et al. 2007, Badecker and Straub 2002), I predicted that acceptance rates for Principle B-violating interpretations would be higher in the high cognitive load condition of the TVJT, as the task has been made more challenging, making it more difficult to filter out anaphoric interpretations. Whereas the acceptance rate for Principle C-violating interpretations would be similar across load conditions, as no filtering was required. Since the present findings suggest that children perform similarly across both load conditions for both principles, a processing-based account for the DPBE is not directly supported. However, a clear asymmetry between children's performance between Principle B and Principle C was observed.

### **5.1.2. Effect of Principle**

While increased cognitive load did not have a significant effect on anaphoric response rate in Principle B or Principle C trials, the principle itself did. Children demonstrated significantly more anaphoric interpretations in Principle B trials than in Principle C trials, across both conditions. In the main experiment (Experiment 1), for Principle B trial items, there was a 35% acceptance rate for anaphoric interpretations in the low load condition and 44% acceptance rate in the high load condition. Whereas, for Principle C, anaphoric interpretations were only accepted 14% of the time in the low load condition and 10% of the time in the high load condition. This finding appears to support the notion of the DPBE widely recognised in previous literature (2.2.1). In the following section, I revisit possible explanations for the DPBE, considering what explanation the results best support.

#### **5.1.2.1. Theoretical implications**

The asymmetry in children's performance with Principle B and Principle C suggests a clear difference in how children apply both principles. However, since increased cognitive load

did not significantly influence children's performance with Principle B or Principle C, this study's findings indicate that attributing children's difficulties with Principle B to simply processing reasons may be too limited an explanation. While the lack of cognitive load effect for Principle C is unsurprising under a processing-based account for children's performance, the lack of cognitive load effect on Principle B is surprising. With poor performance on Principle B trials across both conditions, I consider whether children's difficulty with the principle may arise from syntactic or pragmatic deficiencies.

As previously discussed, Tavakolian (1978) present a potential account for the DPBE. This account focusses on the idea that children lack knowledge on the structural restrictions binding constraints impose. Their difficulty with Principle B arises from this, but their dispreference for backwards anaphora means the same difficulties are not displayed for Principle C. Based on the present study's results alone, this account could potentially offer a reasonable explanation for the DPBE, with children consistently performing poorly with Principle B, in comparison to Principle C. However, since the proposal of this account (Tavakolian 1978), evidence has emerged to suggest children do not actually have a dispreference for backwards anaphora (Crain and Mckee 1986). Without testing neutralised Principle C contexts in this study, I therefore argue it would be unjustified to adopt a syntactic deficit account for the DPBE from my findings.

A more compatible account for my findings is arguably a pragmatic account for the DPBE (Thornton and Wexler 1999). If a child thinks that a Principle B-violating interpretation of a pronoun is permitted, after being exposed to atypical circumstances where a pronoun co-refers with a local antecedent (Thornton and Wexler 1999) (See 2.4), then they would likely fail to recognise violations. Adopting this approach would mean that a lack of cognitive load effect on Principle B-violating interpretations is unsurprising in the present study. This is because there is no task of filtering out an incorrect interpretation, when the child does not yet realise there is one. However, despite the present findings lending support for this notion, a processing-based account for the DPBE cannot yet be discarded. There are various reasons as to why a processing-based explanation is still viable, which will be outlined and discussed in the following sections.

### **5.1.3. Why a processing-based account cannot yet be ruled out**

As highlighted in (2.4), the strength of the DPBE is not consistent across studies, with some children showing no DPBE at all in previous research (Conroy et al. 2009) and some showing an extreme one (McKee 1992). With children sometimes succeeding with Principle B, a purely pragmatic account is hard to maintain, even when the present findings may point toward it. This is because the account predicts relatively stable difficulty for all children, but variability in the DPBE across studies suggests performance is influenced by task demands, which indicates something processing-related is interfering with performance.

In previous research, a processing-based account of the DPBE has received support (Van Rij et al. 2010). When cognitive load was decreased in this study, by slowing down the speech rate of the TVJT, children performed better with Principle B, if they originally showed a DPBE. This indicates that at least part of children's difficulty with Principle B arises from real time processing constraints.

While the results of the present study do not show support for a processing-based account, in contrast to (Van Rij et al. 2010), the results do not necessarily undermine such account. There is the possibility that the task design reduced observable effects of cognitive load (5.2).

## **5.2. Limitations of the study**

### **5.2.1. The TVJT**

This study employed a TVJT as the method for testing children's linguistic competency with Principle B and Principle C. As previously discussed, the TVJT was chosen as it can be

designed to minimise certain processing demands, by presenting children with clear scenarios to make judgements on, which are entertaining through the inclusion of familiar figures in children's culture (Gordon 1998), such as Peppa Pig characters. This was important, as it meant children's role in the low cognitive load condition was made as simple as possible for an effective comparison with performance in the high cognitive load. However, the TVJT method does have limitations which may have influenced results, meaning findings which may appear to not support a processing-based explanation should be treated with caution.

#### **5.2.1.1. Positive bias in TVJTs**

The first limitation that I note of the TVJT is that results often reflect a positivity bias. This refers to the idea that people find it easier to confirm the truth of a statement rather than to reject falsehood (Watson 1961). In a TVJT children must make a true/ false judgement about a statement. As suggested by Gordon (1998), if children exhibit a similar bias, they may focus on recognising what is true than what is not true in a statement, creating a positive response bias. This notion may impact the validity of the present study's findings.

In the present study, a "yes" response (indicating that the child believes the statement to be true) to false items is taken to reflect an anaphoric interpretation (17). However, it may instead reflect a preference to accept statements as true. Similarly, while a "yes" response to true items is taken to reflect a deictic interpretation, children may be conforming to the truth rather than applying a grammatical principle. To minimise the influence of a potential positivity bias, the study included an equal number of true and false items across Principle B and Principle C conditions. This counterbalancing ensures the findings come from a pattern of positive and negative responses, rather than a single response type (Gordon 1998).

However, despite this counterbalancing, the findings did reveal a statistically significant effect of truth value in items ( $p < .001$ ) on performance with both principles, which may

reflect a positivity bias. Children accepted much more anaphoric interpretations for false items than for true items. While this may be expected, as false items require active rejection of violations and true items reflect compliance with non-violating interpretations, the potential interference of a positivity bias should be noted.

If violations are elevated due to a positivity bias, this may provide a potential explanation for a lack of cognitive load effect. This is because if a child's answer defaults to "yes", they may be less sensitive to task manipulations, such as cognitive load increases. This response bias could therefore reduce variability in performance across cognitive load conditions, as children's responses may be influenced by both conformity with the truth and the application of grammatical principles, rather than solely grammatical knowledge. Therefore, the predicted difference in how Principle B and Principle C interact with real-time processing may not be accurately reflected in the cognitive load findings. One other notable factor in my TVJT, which I argue could have masked true cognitive load effects, is part of my design choice (5.2.1.2).

#### **5.2.1.2. Plausible deniability in TVJT's**

As discussed in the methods section, the scenarios presented to participants in the TVJT were in the form of static images. While this is an established method in TVJT's and often considered most suitable for a single experimenter (Gordon 1998), it has been argued that it restricts plausible deniability in a TVJT (Crain et al. 1996).

Plausible deniability refers to the notion that in TVJT tests for binding constraints, the deictic interpretation must always be possible in the scenario (Conroy et al. 2009). For instance, in this study's false items, where the correct response is false ("no") (deictic interpretation) and incorrect response is true ("yes") (anaphoric interpretation), the deictic interpretation must be a true possibility. If the child does not view the deictic interpretation as available, this may bias them toward an incorrect anaphoric response.

An attempt was made in the present study to make both deictic interpretations and anaphoric interpretations available. This was done by ensuring there were 2 characters of the same gender in the scenario and the verb could be either done to oneself, or the other character (See 3.1.2). However, it has been argued that the availability of a deictic interpretation in false trials is satisfied by making the deictic interpretation of the sentence almost happen (Conroy et al. 2009). This cannot happen in a static picture, as there is no motion.

This means that, in false trials, there is the potential that children may have been pressured toward an anaphoric interpretation, as they did not see deictic interpretations as an option. If these interpretations were not an option, there was no task of choosing between two interpretations, but rather just choosing whether the interpretation available was sufficient. This may mean that the participants have greater ease responding to the scenario, despite their response potentially being incorrect. An absence of a cognitive load effect may be partially attributed to this, as if the task was too easy for children, even an increased cognitive load may not add sufficient demands for real time processing to be affected.

Overall, the present findings do not provide evidence that increased cognitive load influences children's performance with either Principle B or Principle C. However, while this may appear to challenge processing-based accounts for the DPBE and support a more pragmatic approach (Thornton and Wexler 1999), there is not yet enough evidence to discredit a processing-based account. Instead, the absence of a cognitive load effect may reflect methodological constraints within the present study's TVJT design (5.2.1.1-5.2.1.2) which make it difficult for an effect to emerge. In the following sections, I discuss the need for future research assessing processing-based accounts for the DPBE.

### **5.3. Areas for future research**

### **5.3.1. Methodological triangulation**

The limitations of the present study discussed in (5.2) highlight the importance of interpreting null cognitive load effects with caution when only a single testing method has been employed, with methodological artifacts and choices potentially influencing findings.

To gauge a better understanding of the potential role of processing on children's performance with binding constraints, such as Principle B and Principle C, it is necessary to triangulate methods. This is because assessing effects of processing demands can be complex. While one method of increasing cognitive load may target a child's short-term working memory (a visual memory task), others may target other aspects of processing, which impact principles more directly. Until various studies have been conducted, a true understanding of processing-based accounts cannot be achieved.

The contrasting results of the present study and previous work by Van Rij et al. (2010) further supports the need for methodological triangulation. While increased cognitive load did not influence children's performance with Principle B negatively in the present study, decreasing cognitive load influenced it positively in Van Rij et al (2010). With both studies employing similar TVJT's with picture-based scenarios, it suggests that different cognitive manipulations may influence different aspects of processing and therefore impacting Principle B performance in different ways.

In the following sections, I present some ideas for future research.

### **5.3.2. Picture selection tasks and eye-tracking**

One method that could be employed in future studies is a Picture Selection Task (Gerken and Shady 1998) with combined eye-tracking (Sedivy 2010). In Picture Selection tasks, children are presented with a sentence and asked to choose from a set of pictures which one best corresponds to it (Gerken and Shady 1998). When testing binding constraints,

Picture Selection tasks may avoid methodological confounds, discussed in (5.2.1.2), where children may bias toward a certain incorrect interpretation, as both interpretations are presented clearly to them. By tracking the children's eye movements during this task, researchers can observe real time processing. For instance, in adult psycholinguistic studies testing Principle B (Badecker and Straub 2002) and Principle C (Kazanina et al. 2007) reading pace can indicate whether an adult considered certain interpretations. In a child acquisition studies, using a Picture Selection Task, how long a child looks at a picture for may indicate how readily available that interpretation was. This may shed light on whether Principle B is a late filter and Principle C an initial filter for children.

### **5.3.3. Puppet based TVJT designs**

Another method which could be used is a puppet-based TVJT, where puppets act out a scenario for the child to make a judgement on. As suggested by Conroy et al. (2009), this method can ensure there is no bias toward an incorrect interpretation, as the correct interpretation can be made available by the action almost happening. One may then conduct a similar study to the present one, by increasing cognitive load in one condition, or like Van Rij et al. (2010) by decreasing it in one condition. However, rather than basing whether cognitive load had an effect purely on responses, a researcher may also want to time responses, perhaps gauging a clearer perspective on whether Principle C is an initial filter and Principle B a late one for children.

## **6. Conclusion**

The present study has explored the effect of cognitive load on children's sensitivity to Principle B and Principle C of Chomsky's Binding Theory (1981). The study hypothesised that cognitive load would affect children's sensitivity to Principle B, such that in high cognitive load conditions children would accept more Principle-B violating interpretations. In contrast to this, the study predicted that cognitive load would not affect children's sensitivity to

Principle C, expecting children to accept a similar amount of Principle C-violating interpretations across conditions. This study's findings suggest cognitive load did not have a significant effect on children's sensitivity to either principle.

The study's hypotheses were based on a processing-based account for the DPBE (Conroy et al. 2009). This account suggests that children's difficulties with Principle B arise due to the constraint's interaction with real time processing, with adult psycholinguistic studies (Badecker and Straub 2002) suggesting Principle B-violating interpretations require filtering out. On the other hand, children perform well with Principle C because Principle C-violating interpretations are immediately blocked (Kazanina et al. 2007). With no evidence of a cognitive load effect on children's sensitivity to Principle B and Principle C, the study presents potential challenges to a processing-based explanation.

However, in line with previous research (Chien and Wexler 1985), a DPBE did emerge in this study. This raises questions about why children do have difficulty with Principle B and not Principle C. I suggest the study's findings may best align with a pragmatic account for the DPBE (Thornton and Wexler 1999), which suggests children allow Principle-B violating interpretations, because adults allow coreference between a pronoun and its local antecedent in atypical circumstances. While adults add stress to the pronoun to indicate that the situation is atypical, children do not yet possess enough world knowledge to understand what this stress means.

However, while findings may be most compatible with this explanation, I acknowledge that a lack of cognitive load effect in the present study does not provide enough evidence to yet rule out processing-based explanations, despite not lending direct support to them.

Previous studies (Van Rij et al. 2010) have shown that decreased cognitive load can positively impact children's performance with Principle B, highlighting the complexities of assessing processing effects, with some studies illuminating them and others not. In (5.2), I

acknowledge potential methodological artifacts in the present study, which may have masked cognitive load affects and highlight the need to study processing-based explanations of the DPBE further.

In (5.3), I have offered some potential methods for further research, highlighting the importance of triangulation of methods to reach the fairest conclusion on the validity of a processing-based explanation for the DPBE.

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## Appendix A: Prompts given to AI.

### Prompts given to AI.

For AI to generate appropriate pictures, certain prompts were given.

Firstly, I had to find pictures of all Peppa Pig characters on a Wikipedia fan page. I transferred images of each character to a word document and labelled each character by its name. I put these word documents into AI. This meant AI generated pictures of the characters accurately. Without this prompt, it created characters which did not accurately represent Peppa Pig characters.

I then asked AI to generate me 8 target pictures with these characters, which represented either a deictic interpretation of the test sentence, or an anaphoric interpretation of the test sentence. I also asked it to generate me 8 filler pictures with these characters. I specified which characters I wanted in each picture and which character was doing the action.

I instructed AI to make all characters the same size and child friendly. I requested for the background to be white.

AI generated all pictures as requested, however it sometimes required additional reminders of what the characters should look like and to maintain white background across all images.

Appendix B: Target and filler test sentences across List 1 and List 2. Target scenarios and filler scenarios.

The two item lists a participant could be assigned to.

|                | List 1                                        | List 2                                         |
|----------------|-----------------------------------------------|------------------------------------------------|
| Target Trial 1 | Miss Rabbit washed her<br>(Principle B, True) | She washed Peppa Pig<br>(Principle C, True)    |
| Filler Trial 1 | Mrs crocodile watered the plant<br>(False)    | Mrs crocodile watered the plant<br>(False)     |
| Target Trial 2 | He touched Grandpa Pig<br>(Principle C, True) | Grandad dog touched him<br>(Principle B, True) |
| Filler Trial 2 | Daddy Giraffe ate a cake<br>(True)            | Daddy Giraffe ate a cake<br>(True)             |
| Target Trial 3 | He painted Daddy Pig<br>(Principle C, False)  | Daddy pig painted him<br>(Principle B, False)  |
| Filler Trial 3 | Madame Gazelle pushed the<br>pram (True)      | Madame Gazelle pushed the<br>pram (True)       |
| Target Trial 4 | Suzy Sheep sprayed her<br>(Principle B, True) | She sprayed Zoe Zebra<br>(Principle C, True)   |
| Filler Trial 4 | Mr Badger drank the water<br>(False)          | Mr Badger drank the water<br>(False)           |
| Target Trial 5 | She licked Candy Cat<br>(Principle C, False)  | Candy Cat licked her<br>(Principle B, False)   |
| Filler Trial 5 | Kylie kangaroo read a book<br>(True)          | Kylie kangaroo read a book<br>(True)           |
| Target Trial 6 | Danny Dog stamped him<br>(Principle B, False) | He stamped Danny Dog<br>(Principle C, False)   |
| Filler Trial 6 | Edmund Elephant played the<br>piano (False)   | Edmund Elephant played the<br>piano (False)    |

|                |                                                     |                                                     |
|----------------|-----------------------------------------------------|-----------------------------------------------------|
| Target Trial 7 | Delphine Donkey brushed her<br>(Principle B, False) | She brushed Delphine Donkey<br>(Principle C, False) |
| Filler Trial 7 | Simon squirrel kicked the ball<br>(True)            | Simon squirrel kicked the ball<br>(True)            |
| Target Trial 8 | He wiped Pedro Pony<br>(Principle C, True)          | George Pig wiped him<br>(Principle B, True)         |
| Filler Trial 8 | Belinda bear climbed the tree<br>(False)            | Belinda bear climbed the tree<br>(False)            |

---

## Appendix C: Target scenarios and filler scenarios.

Target scenario 1:



Filler scenario 1:



Target scenario 2:



Filler scenario 2:



Target scenario 3:



Filler scenario 3:



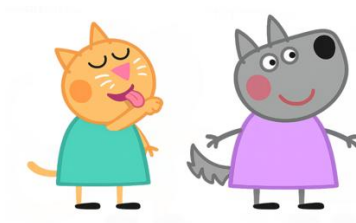
Target scenario 4:



Filler scenario 4:



Target scenario 5:



Filler scenario 5:



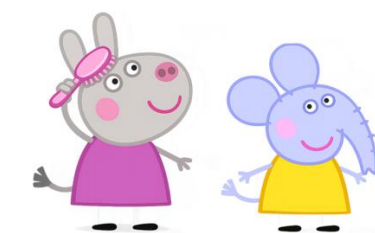
Target scenario 6:



Filler scenario 6:



Target scenario 7:



Filler scenario 7:



Target scenario 8:



Filler scenario 8:



Appendix D: Memory Task design.

| Trial          | Picture in memory task  |
|----------------|-------------------------|
| Target Trial 1 | Picture stayed the same |
| Filler Trial 1 | Picture changed         |
| Target Trial 2 | Picture changed         |
| Filler Trial 2 | Picture stayed the same |
| Target Trial 3 | Picture stayed the same |
| Filler Trial 3 | Picture changed         |
| Target Trial 4 | Picture changed         |
| Filler Trial 4 | Picture changed         |
| Target Trial 5 | Picture changed         |
| Filler Trial 5 | Picture changed         |
| Target Trial 6 | Picture stayed the same |
| Filler Trial 6 | Picture changed         |
| Target Trial 7 | Picture changed         |
| Filler Trial 7 | Picture stayed the same |
| Target Trial 8 | Picture stayed the same |
| Filler Trial 8 | Picture stayed the same |

## Appendix E: Information sheet for all participants.

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NE1 7RU, United Kingdom



### Participant Information Sheet

|                                   |                                                                                                                                     |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| <b>Project</b>                    | Exploring the effect of cognitive load on children's sensitivity to the rules governing interpretation of pronouns and proper names |
| <b>Principal Investigator</b>     | Niamh O'Gara, supervised by Dr Rebecca Woods                                                                                        |
| <b>Researcher collecting data</b> | Niamh O'Gara                                                                                                                        |

**What is this document?** This document explains what kind of study your child is being asked to take part in, what your rights are, and what will be done with your child's data. If there are any special benefits or risks to participation, they will be explained here. Please read the information carefully and retain it for your records.

**The Project:** Your child is about to participate in a study which involves watching short videos with a puppet. The puppet will say something about the video and your child will be asked whether the puppet's sentence about each story is true or false. In some sessions, your child will also be asked to do a short, simple memory task, similar to Kim's Game, at the same time. I will audio record participants' answers, but no names or identifying information will be collected. Your child will take part in two sessions, two weeks apart. Each session should last for about 15 minutes. Your child will be given full instructions and a short training session before they begin.

**Risks and benefits:** There are no anticipated risks to participating in this study. The only benefits to you personally are those you draw from your child making a contribution to our knowledge about children's acquisition of pronouns and proper names and the effect of increased processing load.

**Right to Withdraw:** Your child's participation is voluntary and they may stop at any time for any reason without penalty. You and they have the right to refuse to answer any questions you are asked. To withdraw during participation, you can contact me by email: [c3026900@newcastle.ac.uk](mailto:c3026900@newcastle.ac.uk). If you withdraw your child, any data that you have already provided or produced will be deleted. To withdraw after your child's participation is complete, you can contact me via my email: [c3026900@newcastle.ac.uk](mailto:c3026900@newcastle.ac.uk). If you choose to withdraw, all your child's data will be deleted. You may withdraw your data up to the date at which data collection will be complete, which is planned to be on 28/02/2026.

**Confidentiality:**

- We will not be collecting any identifying information, and none of your responses can be associated with your name or with any other personal details.
- We will collect audio transcripts of your session, but these will be transcribed immediately after the session and the audio recording deleted as soon as transcription is complete.

**Your Data:** Any data your child provides will be handled in accordance with the [UK Data Protection Act of 2018](#). Your child's anonymous data will be securely stored and may be used only by the above-named researcher(s) as well as by other qualified researchers for teaching or

research purposes, and in professional presentations. Any identifying information you have provided during recruitment or on consent forms will only be accessible by the named researchers, stored separately from your response data, and not used as part of the research. Any recordings will be transcribed only for the purpose of checking answers before recording any results with any identifying information anonymised and the original recordings will be destroyed.

**Contact Information:** This research is being conducted by Niamh O’Gara at Newcastle University and overseen by Dr Rebecca Woods. Dr Woods can be contacted via email: [rebecca.woods@ncl.ac.uk](mailto:rebecca.woods@ncl.ac.uk) for questions or to report a research-related problem. If you have any concerns regarding your rights as a participant in this research, you can contact the chair of the Faculty of Humanities and Social Sciences Ethics Committee, (currently Dr Sara Ganassin, [sara.ganassin@ncl.ac.uk](mailto:sara.ganassin@ncl.ac.uk)).

## Appendix F: Child consent form.

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Newcastle upon Tyne  
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### Participant Consent Form

|                                   |                                                                                       |
|-----------------------------------|---------------------------------------------------------------------------------------|
| <b>Project</b>                    | Exploring the effect of cognitive load on children's sensitivity to Principle B and C |
| <b>Principal Investigator</b>     | Niamh O'Gara, supervised by Dr Rebecca Woods                                          |
| <b>Researcher collecting data</b> | Niamh O'Gara                                                                          |

In addition to this form, you have been given a **Participant Information Sheet** outlining the purpose of the project and describing what your participation will involve. **Read that sheet carefully first, please.** If you have any questions arising from the Participant Information Sheet or this Consent Form, please ask the researcher before you decide whether to take part.

Please enter 'Y' or tick (✓) in the boxes on the left to acknowledge before signing below.

- ☐ I am 18 years of age or older and have legal responsibility for the child named below.
- ☐ I have read and understood the detailed **Participant Information Sheet** about the study and been given a copy to keep for my records.
- ☐ I understand that my child's participation is voluntary and they can withdraw without penalty at any time before the data collection is completed (which is planned to be on 28/02/2026) (see section on **Right to Withdraw** in Participant Information sheet)
- ☐ I understand you will not be collecting any identifying information as part of the study, and that this consent form will be stored apart from my child's data. (see section on **Confidentiality** in Information sheet)  
I understand that my child's data will be completely anonymised when this research is reported as part of a presentation or scholarly publication. (see section on **Confidentiality** in Information sheet)
- ☐ I agree that my child's anonymous data may be kept permanently in secure Newcastle University archives and may be used by qualified researchers for teaching and research purposes. (see section on **Your Data** in Participant Information Sheet)

|                          |      |               |
|--------------------------|------|---------------|
| <b>Child participant</b> | Name | Date of Birth |
| <b>Caregiver</b>         | Name | Signature     |
| <b>Researcher</b>        | Name | Signature     |
| <b>Date and Time</b>     |      |               |

## Appendix G: Adult consent form.

School of English Literature, Language and Linguistics  
Percy Building  
Newcastle University  
Newcastle upon Tyne  
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### Participant Consent Form

|                                   |                                                                                       |
|-----------------------------------|---------------------------------------------------------------------------------------|
| <b>Project</b>                    | Exploring the effect of cognitive load on children's sensitivity to Principle B and C |
| <b>Principal Investigator</b>     | Niamh O'Gara, supervised by Dr Rebecca Woods                                          |
| <b>Researcher collecting data</b> | Niamh O'Gara                                                                          |

In addition to this form, you have been given a **Participant Information Sheet** outlining the purpose of the project and describing what your participation will involve. **Read that sheet carefully first, please.** If you have any questions arising from the Participant Information Sheet or this Consent Form, please ask the researcher before you decide whether to take part.

Please enter 'Y' or tick (✓) in the boxes on the left to acknowledge before signing below.

- ☐ I am 18 years of age or older
- ☐ I have read and understood the detailed **Participant Information Sheet** about the study and been given a copy to keep for my records.
- ☐ I understand that my participation is voluntary and I can withdraw without penalty at any time before the research is completed (which is planned to be on 06/01/2026) (see section on **Right to Withdraw** in Participant Information sheet)
- ☐ I understand you will not be collecting any identifying information as part of the study, and that this consent form will be stored apart from my data. (see section on **Confidentiality** in Information sheet)  
I understand that my data will be completely anonymised when this research is reported as part of a presentation or scholarly publication. (see section on **Confidentiality** in Information sheet)
- ☐ I agree that my anonymous data may be kept permanently in secure Newcastle University archives and may be used by qualified researchers for teaching and research purposes. (see section on **Your Data** in Participant Information Sheet)

|                      |      |           |
|----------------------|------|-----------|
| <b>Participant</b>   | Name | Signature |
| <b>Researcher</b>    | Name | Signature |
| <b>Date and Time</b> |      |           |

## Appendix H: Digit span task.

Children completed the forward version of this task only.

### THE DIGIT MEMORY TEST

An assessment procedure for specialist teachers to investigate verbal memory difficulties in children's learning. Both parts are administered.

#### Digits forwards

- Start** Item A
- Finish** Failure on both trials of a pair.
- Directions** "Listen carefully as I say some numbers. When I finish, you say them."
- Delivery** Digits should be given at the rate of one per second. Administer both trials of each item. Recite digits in an even monotone without any variation in pitch of voice.
- Scoring** The individual's score is the total number of items correctly repeated forwards.

#### WORKED EXAMPLE

| Item | First Trial | ✓ or X | Second Trial | ✓ or X |
|------|-------------|--------|--------------|--------|
| A    | 43          | ✓      | 16           | ✓      |
| B    | 792         | ✓      | 847          | ✓      |
| C    | 5941        | X      | 7253         | ✓      |
| D    | 93872       | X      | 75396        | X      |

In this example, the total correct is 5.

#### Digits Backwards

- Directions** Administer as above but say, "Repeat these numbers after me but this time I want you to say them backwards." Give two practice trials of two digits first – any two numbers. If the child gets them wrong - correct her or him. If the child repeats the digits *forwards*, give a reminder that they should be reversed.
- Score** As for digits forwards.
- Final score** Total number managed (ticks) backwards and forwards *added together*. Consult Table 1 for standard score. This can also be expressed as a percentile equivalent: consult Table 2.
- Comparison** Most people can remember two more digits forwards than they can backwards. If the gap is larger than three, or smaller than one, this may be worthy of note.

### DIGITS FORWARDS

| Item | First trial | √ or X | Second trial | √ or X          | Total |
|------|-------------|--------|--------------|-----------------|-------|
| A    | 43          |        | 16           |                 |       |
| B    | 792         |        | 847          |                 |       |
| C    | 5941        |        | 7253         |                 |       |
| D    | 93872       |        | 75396        |                 |       |
| E    | 152649      |        | 216748       |                 |       |
| F    | 3745261     |        | 4925316      |                 |       |
| G    | 82973546    |        | 69174253     |                 |       |
| H    | 246937185   |        | 371625948    |                 |       |
|      |             |        |              | Forwards score: |       |

### DIGITS BACKWARDS

| Item | Trial one | √ or X | Trial two | √ or X           | Total |
|------|-----------|--------|-----------|------------------|-------|
| A    | 83        |        | 29        |                  |       |
| B    | 475       |        | 615       |                  |       |
| C    | 2619      |        | 3852      |                  |       |
| D    | 28736     |        | 59413     |                  |       |
| E    | 624719    |        | 276391    |                  |       |
| F    | 4183627   |        | 1586937   |                  |       |
| G    | 52624197  |        | 94617385  |                  |       |
|      |           |        |           | Backwards score: |       |

### FINAL SCORE:

|                               |  |
|-------------------------------|--|
| Total forwards and backwards: |  |
| Standard score:               |  |
| Percentile equivalent:        |  |

Martin Turner  
 Jacky Ridsdale  
 revised 6th October 2004