Memory load manipulation in self-paced reading tasks: The case of pronouns interpretation

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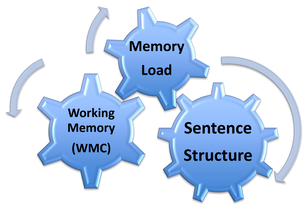
1- The Objective

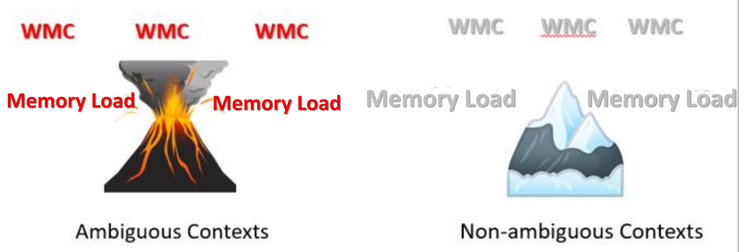


The interpretation of English pronouns

2- Background

Higher Memory Load : Facilitative Role	Higher Memory Load : Deterring Role
(Fiorentino et al. 2018; Qiu et al. 2012; Hammer et al. 2008)	(Streb et al. 2004; Clark & Sengul 1979)

Nieuwland & Van Berkum (2006)



- **Caveats:**
  - ✓ Mixed Results
  - ✓ Only ERP methodology
  - ✓ Only online measures
- **Present Study:**
  - ✓Self-paced reading
  - ✓Both online and offline measures

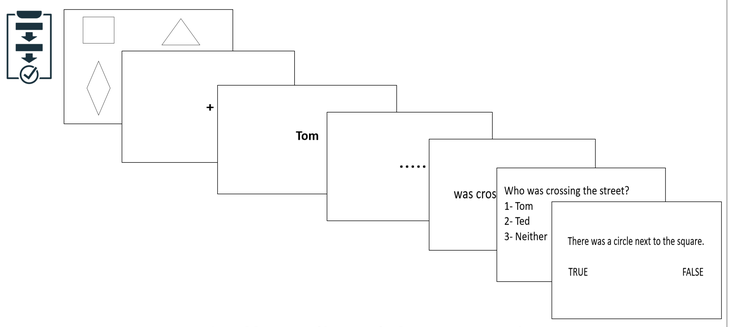
3- Methodology

34 native speakers of English at the University of Calgary

36 main trials divided into 7 regions; half preceded by an image depicting geometric shapes

- **One-referent:**Tom/looked/at/Ana/while/he/was running.
- **Ambiguous:** Tom/ ~ /Ted / ~ /he/ ~
- **No-Referent:** Tom/ ~ /Ted / ~ /she/ ~

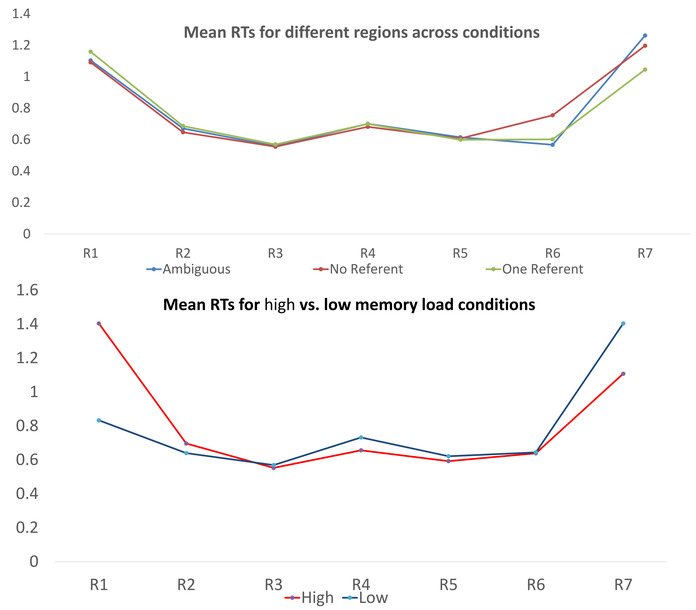
3- Methodology (Cont'd)



$\sum_x$ Linear mixed-effects (lmer) for RT analysis in R
Multinomial logistic regression for Referent Choice analysis in R

4- Results

- **Online (Reaction Times)**



- While reading the sentence, English monolinguals:

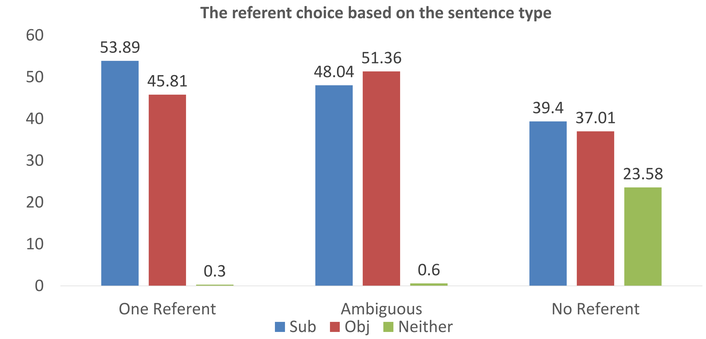
Critical region:
No-referent
One-referent~**Amb**

Spillover region:
No-referent~**Amb**
One-referent

Memory Load:Reading Time

4- Results (Cont'd)

- **Offline (Referent Choice)**



- After reading the sentence:

Ambiguous/One-referent:	**No-referent:**
✗ Memory Load	✗ Memory Load
✗ WMC	↑ WMC : Neither Selection ↑

5-Take-home message

- None of the models discussed in Section 2 is confirmed:
  - ✓The ambiguity of the context is **NOT** a predictive factor in the processing of the pronouns.
  - ✓Memory load has a main effect on processing of first and final regions of the sentence, but not on the processing of pronouns.
  - ✓WMC shows its effect only in selecting the antecedent for no-referent pronouns, but not ambiguous ones.
- Results of studies using one type of methodology (e.g. ERP) should be cautiously generalized to other types of methodologies
- Online results should be cautiously extended to offline results.

Selected References

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•Fiorentino, Robert, Lauren Covey & Alison Gabriele. 2018. Individual differences in the processing of referential dependencies: Evidence from event-related potentials. *Neuroscience Letters* 673. 79-84.
•Hammer, Anke, Bernadet M. Jansma, Monique Lamers & Thomas F. Münte. 2008. Interplay of meaning, syntax and working memory during pronoun resolution investigated by ERPs. *Brain Research* 1230. 177-191.
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Qiu, Lijing, Tamara Y. Swaab, Hsuan-Chih Chen & Suiping Wang . 2012. The role of gender information in pronoun resolution: Evidence from Chinese. *PLoS One* 7(5).
•Streb, Judith, Erwin Hennighausen & Frank Rösler. 2004. Different anaphoric expressions are investigated by event-related brain potentials. *Journal of Psycholinguistic Research* 33(3). 175-201.

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➢ Objectives:

This study investigates how ***the memory load*** on speakers, ***sentence structure*** and their ***working memory capacity*** (WMC) influence ***the referent choice*** for English pronouns.

➢ Background:

✓ **Memory load has a negative effect** (Clark & Sengul 1979; Streb et al. 2004)**:**

- It makes pronouns being read more slowly. Participants had less difficulty reading pronouns which refer to an antecedent in previous sentence compared to pronouns referring to an antecedent in some sentences before

✓ **Memory load has a positive effect** (Fiorentino et al. 2018; Hammer et al. 2008; Qiu et al. 2012)**:**

It makes participants read the sentences with linguistic anomalies or ambiguities with less difficulty and faster. Participants did not show N400 or Nref effects in ambiguous sentences or semantically anomalous sentences under high memory load conditions.

✓ **Memory load and WMC only in ambiguous sentences** (Nieuwland & Van Berkum 2006) **:**

A hypothesis which states that the memory load and working memory capacity are only activated in ambiguous contexts in that participants show smaller Nref effect under high memory load condition only in ambiguous contexts; however, the amplitude of N400 in semantically anomalous sentences did not change in high memory load condition.

➢ Research Questions:

✓ Do memory load and WMC have a facilitative or deterring role in the processing of English pronouns?

✓ Are WMC and memory load factors have a role in the processing of English pronouns only in ambiguous contexts?

✓ Is there a difference between online and post-online results?

➢ **Design:**

Three independent variables yielding six conditions and two dependent variables as shown in Table (1):

Table 1. Summary of conditions

Independent Variables			**Dependent Variables**	
Memory Load	*Structure*	*WMC*	*Reading Times*	*Referent Choice*
High	One referent	Continuous		
Low	No referent			
	Ambiguous			

➢ **Method:**

✓ **Participants**

- 34 monolingual speakers of English studying at the University of Calgary recruited from the linguistic 201 pool

✓ **Trials**

- 30 experimental sets and 42 fillers
- Each set consists of six items representing a condition
- Six lists are prepared. Each list consists of five items from each condition pseudo-randomized with 42 filler items such that each participant reads only one item from each set yielding (5 items) * (6 conditions) + (42 fillers) = 72 items.
- Each item is divided by 7 regions an in (1):

(1) a. *One Referent*: **Tom** / said hello / to / **Mary** / while / **he** / was crossing the street.
b. *No Referent*: **Tom** / said hello / to / **Mark** / while / **she** / was crossing the street.
c. *Ambiguous*: **Tom** / said hello / to / **Mark** / while / **he** / was crossing the street.

Question: Who was crossing the street?
1- Tom
2- Mark/Mary
3- Neither

- To manipulate the memory load, the items are preceded by an image depicting a set of geometric shapes (Figure 1). A statement about the initial picture will be displayed after reading the sentence and participants should determine whether it is true of false.

Figure 1. The memory load image

✓ **Working memory test**

- Simple arithmetic (addition or subtraction) equation appears on the screen and remains for 6 seconds. The solution presented with the equation could be either right or wrong. Participants should first decide whether the solution is right or wrong. They should also retain in the memory the solution they see and recall them after a set of equations when they are asked to do so.

- There are five sets in total. The sets include between three and seven equations.

- If participants recall the solutions correctly and in the perfect order, they will be credited the score of 5 for each equation.

➢ **Results:**

- After filtering the data for outliers through eliminating those items whose total reading times were more than 2.5 standard deviation away from the mean, the following results were obtained:

✓ **Online Stage (Self-paced reading):**

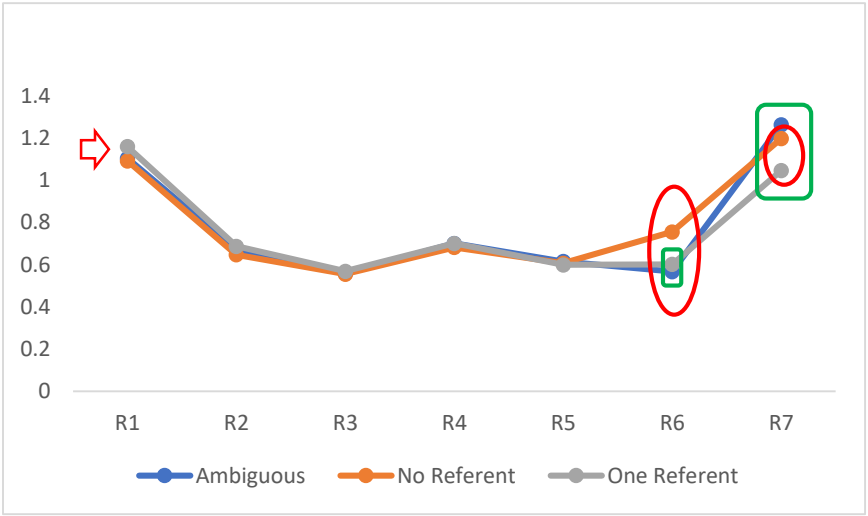

Figure 2. Mean RTs for different regions across conditions

- **In the critical region (Region 6 including the pronoun):**

  Running linear mixed-effects and going through a set of model comparisons with memory load, sentence structure and WMC as independent variables and reading times as the dependent variable:

  - No significant effect of the memory load or WMC
  - No-referent condition is read significantly faster than other conditions (Figure 2)
  - No significant difference between ambiguous and one referent conditions (Figure 2)

- **In the spillover region (Region 7 – the final region of the sentence):**

  - No significant effect of WMC
  - Main effect of the memory load (low memory load sentences are read more slowly) (Figure 3)
  - No-referent and ambiguous conditions are read significantly faster than one-referent condition (Figure 2)
  - No significant difference between no-referent and ambiguous conditions (Figure 2)

  Note!!! The RT in region 1 is unexpectedly higher. While comparing high memory and no memory load conditions, it was found out that the RT for high memory load condition is significantly higher than low memory load condition (Figure 3). This can be explained by the fact that participants were still dealing with remembering the memory image displayed immediately before the first region leading to increasing the RT in region 1.

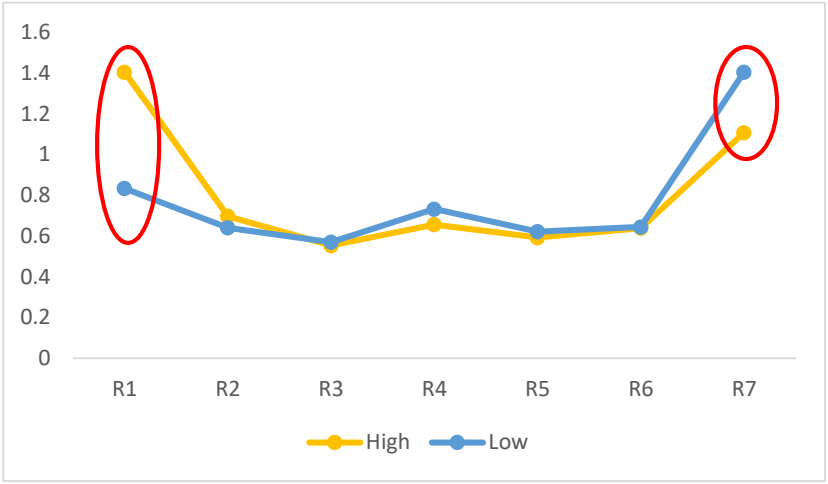

Figure 3. Mean RTs for different regions in low and high memory load conditions

✓ **Post-online Stage (Referent Choice):**

Running multinomial logistic regression and going through model comparisons to find the best-fitting model, the following results were obtained:

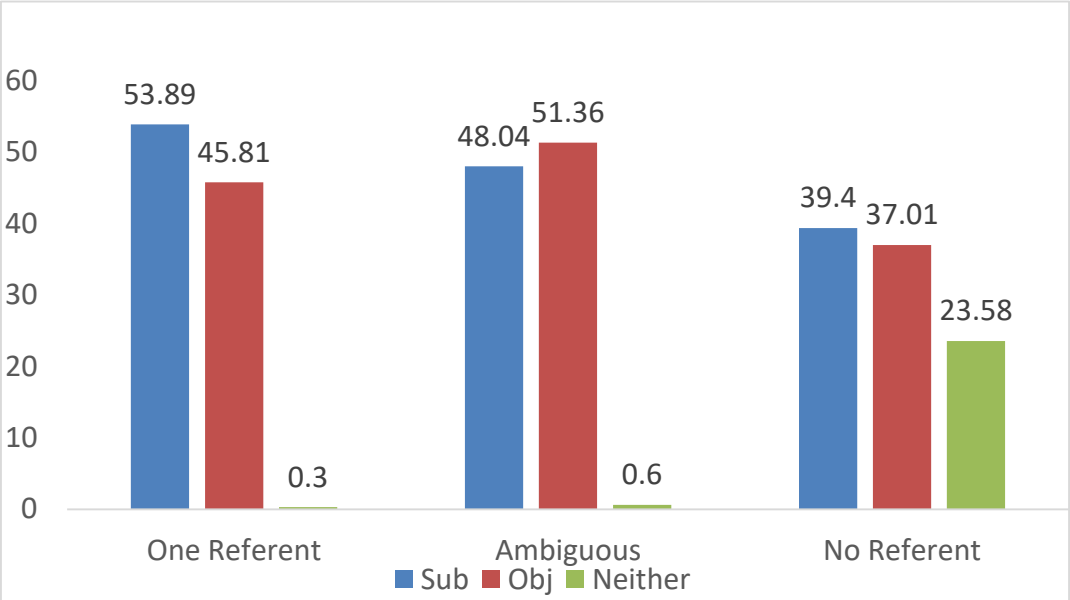

Figure 4. The referent choice based on the sentence type

- **In one-referent and ambiguous conditions:**

  - No significant effect of WMC or memory load

- **In no-referent condition:**
  - No significant effect of the memory load
  - Significant effect of WMC such that those with higher WMC are more likely to select "neither" option compared to "object" option.

  Note!!! As shown in Figure 4, participants tend to choose one of the subject or object antecedents more compared to "neither" option in no-referent condition. In other words, it seems that they prefer to attribute the pronoun to an intra-sentential antecedent although it is grammatically unavailable which is pretty odd! With regard to this, following points are noteworthy:

  - 16 out of 34 participants had responded unexpectedly. So, the possibility of the data being skewed by one or two participants is out.

  - There was no difference between reading times of those who had responded unexpectedly and those who had responded expectedly (Figure 5). Those who had responded incorrectly had even pondered more in the final region of the sentence which confirms that they had realized there was something odd about no-referent sentence.

Figure 5. The comparison of RTs for both expected and unexpected responses

- There was no significant difference in reaction time for choosing the response between those who had responded expectedly and those who had responded unexpectedly.

- One possibility is that participants feel forced to choose one of the antecedent options compared to "neither" options. More investigations need to be done why this has occurred!

➢ **Conclusion:**

✓ Do memory load and WMC have a facilitative or deterring role in the processing of English pronouns?

While processing the sentence, WMC shows no effect. But, in post-online stage those with better WMC is helpful only in no-referent sentences. Memory load, however, shows no effect in post-online stage whereas while processing the sentence it has a detrimental role in the first and final regions of the sentence.

✓ Do WMC and memory load factors play a role in the processing of English pronouns only in ambiguous contexts?

No. English speakers tolerate ambiguous pronouns with the hope of disambiguating them until the end of the sentence. However, when they remain globally ambiguous, it leads to increasing the reading time of the final region.

✓ Is there a difference between online and post-online results?

Yes. As discussed earlier, some factors such as the memory load or ambiguity are only predictive in online stage whereas others like WMC are effective in post-online stage.

- **Take-home message:**

  - ✓ There might be a difference between online and post-online results, especially in the realm of pronoun resolution.
  - ✓ The results obtained from a specific methodology (e.g. ERPs) might not be generalizable to other ways of collecting data (e.g. Self-paced reading method).

- **Selected References:**

- Clark, Herbert. H., C. J. Sengul. 1979. In search of referents for noun phrases and pronouns. *Memory & Cognition* 7. 35-41.
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