Effects of Referential structure in English pronoun resolution

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Goals

- How do we interpret **multiple pronouns** in the same clause?
- Are there any differences from how we interpret **a single pronoun**?

a) *Henry$_1$ respected Kevin$_2$ because **he$_{1/2}$** visited Tom.*

(One-Pronoun)

b) *Henry$_1$ respected Kevin$_2$ because **he$_{1/2}$** visited **him$_{2/1}$***

(Two-Pronoun)

***Differences lie in referential structure -** whether all or only one of the preceding referents are mentioned by the pronouns*

Overview

I. **Introduction** (referential structure differences)

- **Independence view:** anaphoric dependencies for the two different pronouns are resolved fully independently
- **Dependence view:** resolving one of the pronominal dependencies influences the formation of the other

II. **Experiment 1 – 3:** Multiple pronoun resolution ≠ Single pronoun resolution (*offline picture-writing task*)

III. **Experiment 4:** Real-time processing of multiple pronoun interpretation (*Webcam-based eye-tracking study*)

Introduction

- Pronouns are informationally underspecified on their own
- To fully understand their meanings, we need to identify what they refer to in the previous context
- Not always straight-forward to establish a dependency relation with a previously mentioned entity
- Pronoun interpretation is guided by various factors at different levels of representation (e.g. Givon 1983; Smyth 1994; Grosz et al., 1995; Hobbs 1970)
- Previous findings are largely based on how we interpret **a single pronoun in a single clause** in ambiguous context.

*Jane respected Mary because **she** visited **Lisa**.*

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- These findings are largely based on how we interpret **a single pronoun in a single clause** in ambiguous context.

*Jane respected Mary because **she** visited **her**.*

How do we interpret multiple pronouns?

Background – Referential structure

- **Is reference resolution of multiple pronouns different from that of a single pronoun?**
- **Referential structure:** whether all or only one of the referents in the preceding clause are mentioned with a pronoun in the subsequent clause

  - **1-pronoun structure**

    *Henry$_1$ respected Kevin$_2$ because **he**$_{1/2}$ visited Tom.*

    

  - **2-pronoun structure**

    *Henry$_1$ respected Kevin$_2$ because **he**$_{1/2}$ visited **him**$_{1/2}$.*

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Background – Referential structure

- **Is reference resolution of multiple pronouns different from that of a single pronoun?**
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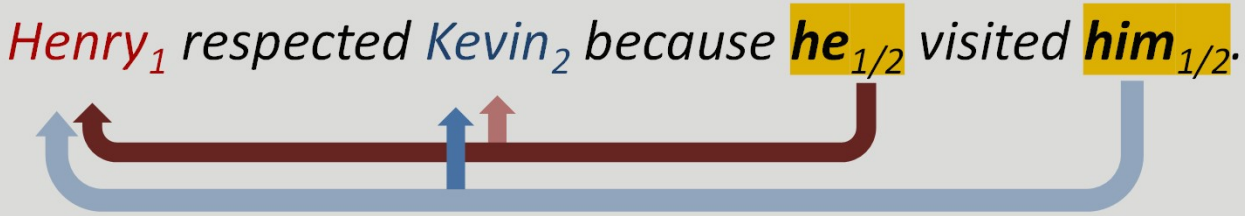
Resolving one pronominal dependency can influence on resolving the other?

– **1-pronoun structure**

– **2-pronoun structure**



Hypotheses – Referential structure effects

I. **Independence view:**
anaphoric dependencies constructed for the two different pronouns are resolved fully independently

II. **Dependence view:**
resolving one of the pronominal dependencies influences the formation of the other dependency in 2-pronoun structure

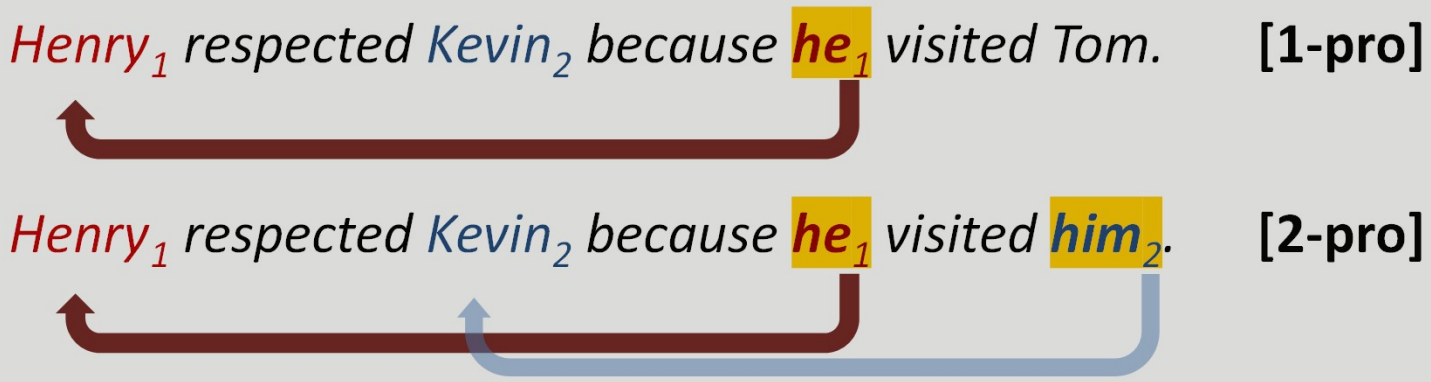
– **1-pronoun structure**

– **2-pronoun structure**

I. Independence view

- **Parallel function strategy (PFS)** (e.g.,Smyth, 1994; Chambers & Smyth 1998)
  A pronoun is coreferential with a preceding noun phrase occupying the same grammatical role as the pronoun.
  - Pronouns search for the best antecedent that has matching morpho-syntactic features – *a gender, number, person and* ***grammatical role***
  - **No referential structure effects:**
    1-pronoun structure = 2-pronoun structure (sbj-pronoun)

Forming one of the pronominal dependencies does NOT influence forming the other



II. Dependence view

- **Centering Theory (CT)** (e.g., Grosz et al., 1995; Walker et al 1998)
  - Discourse-level factors (*discourse coherence*) guide interactions between referential dependencies from two different pronouns
    - The less the salient entity changes, the more coherent the discourse

Most salient *Subject >> Direct object >> Indirect object >> Adjuncts*

    - Pronouns are resolved so that the transition from one sentence to the next is as coherent as possible (e.g., topic maintenance)
    - They are resolved in such a way that maximizes coherence of the discourse transition

Most coherent *CONTINUE >> RETAIN >> SHIFT*

    - **Referential structure effects**:
      1-pronoun structure ≠ 2-pronoun structure

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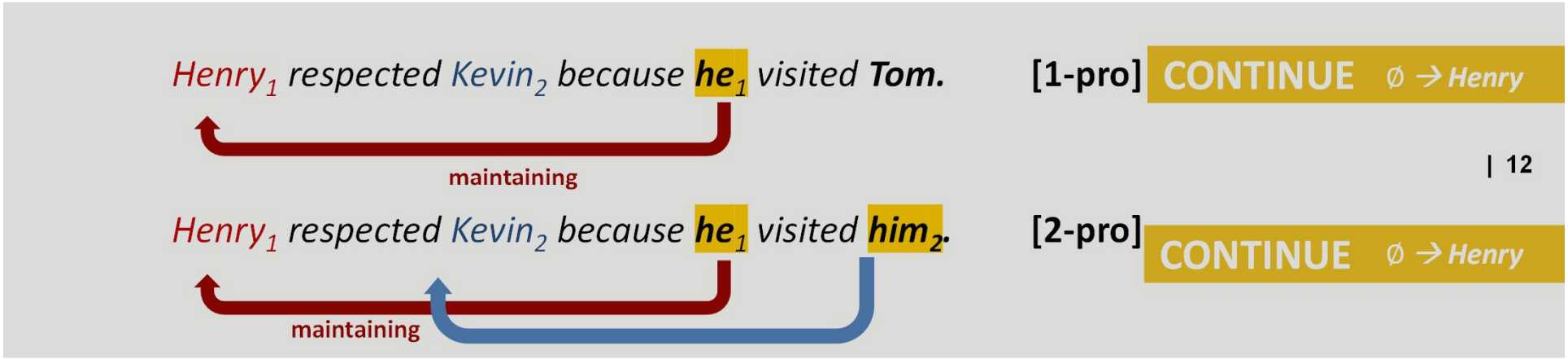
    1-pronoun st. $>_{\text{obj interpretation}}$ 2-pronoun st.



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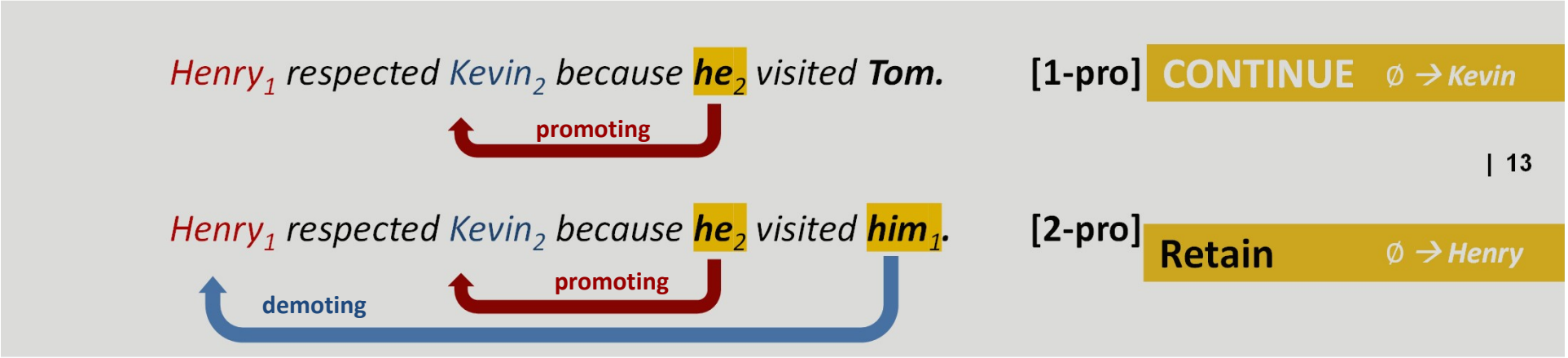

Experiment 1 - 3: The effects of referential structure in pronoun interpretation

Multiple pronoun resolution ≠ Single pronoun resolution?

Independence view *vs.* ***Dependence views***

Exp1 – 3: Design

- **Clause 1**: Implicit causality (IC) verb type *bias to Sbj or Obj for pronoun resolution*

  *Henry {**surprised** (IC1_Sbj) / **respected** (IC2_obj)} Kevin* — EXP 1&2

  *Henry {**cheated** (IC1_Sbj) / **criticized** (IC2_obj)} Kevin* — EXP 3

  - EXP1 (*Stimulus/Experiencer* verb bias): IC1_Sbj M=67.4%, SD=13.6; IC2_Obj M=76.2%, SD=11.7
  - EXP2 (*Agent-Patient* verb bias): IC1_Sbj M=67.7%, SD=9.16; IC2_Obj M=72.1%, SD=5.53

- **Clause 2**: Referential structure type

  *…because **he** daxed.* **[1-pro]** — EXP 1

  *…because **he** daxed **Tom**.* **[1-pro]** — EXP 2&3

  *…because **he** daxed **him**.* **[2-pro]** — EXP 1,2&3

- **Disentangles effects of syntactic parallelism from semantic parallelism**
  - an *explanation* relation (*because*) for the implicit causality effects and to avoid semantic parallelism effects
  - Nonce verbs: no verb semantics

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  *…because **he** daxed **Tom**.* **[1-pro]**

  *…because **he** daxed **him**.* **[2-pro]**

  Obj preference

  EXP 1

  EXP 2&3

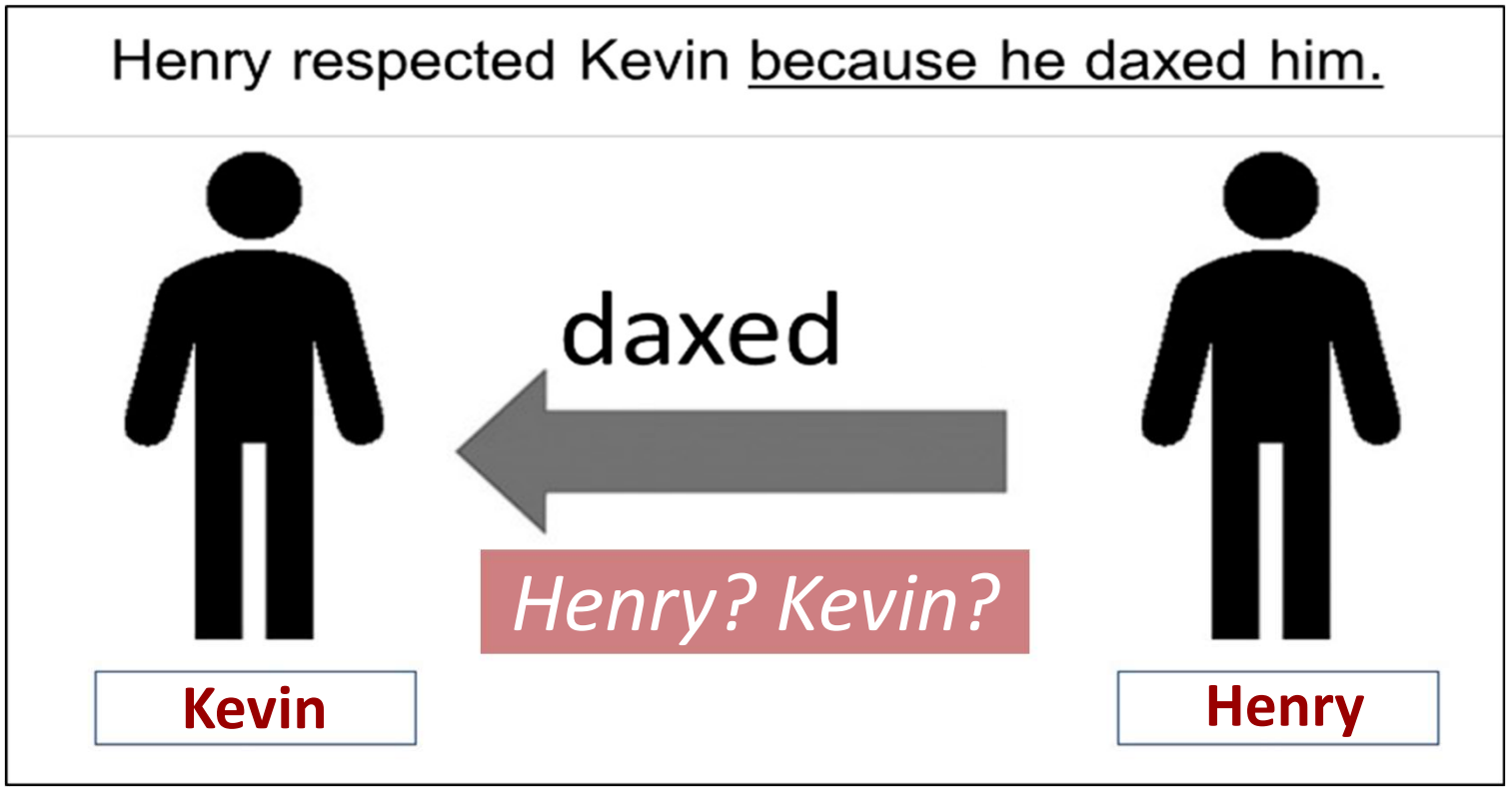
  EXP 1,2&3

Referential structure effects: Would **1-pronoun configurations** pattern differently from **2-pronoun configurations?**

- **Yes:** Dependence view (syntax-level / discourse-level)
- **No:** Independence view (Parallel Function Strategy)

Method – Picture-writing task

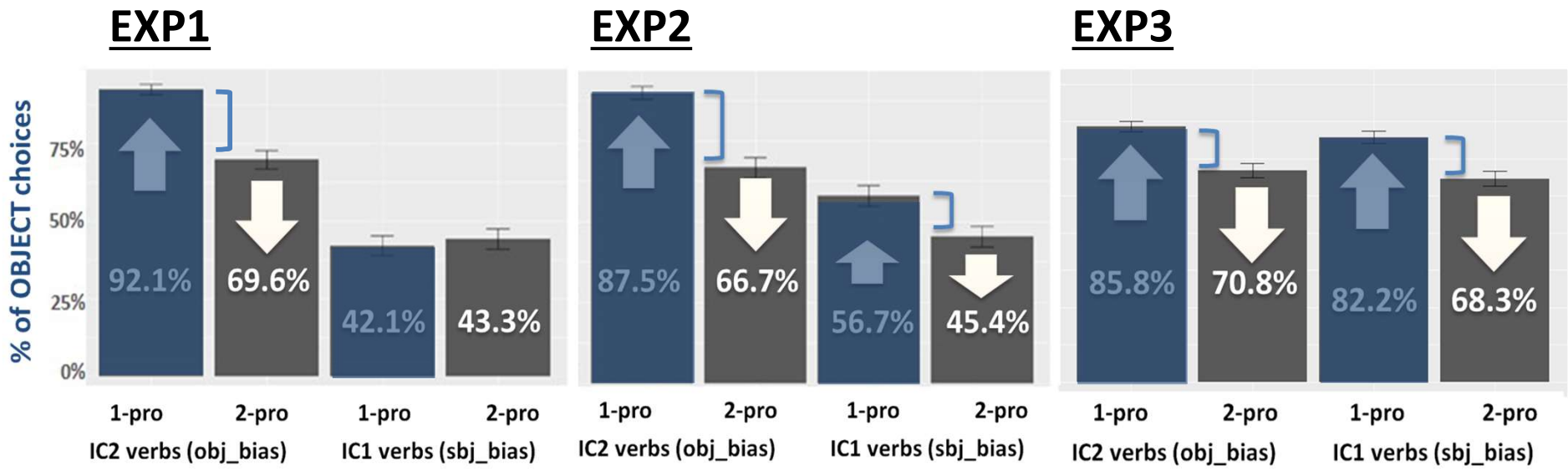
- **Picture-writing task:**



- Participants: Native English speakers (Exp1: n= 45, Exp2: n= 48, Exp3: n= 60)
- Items: 24 Targets + 36 Fillers
- Method: Web survey with Qualtrics + Amazon Mturk

Exp1 - 3 Referential structure effects

Henry {surprised (IC1) / respected (IC2)} Kevin because ***he*** *daxed him/(Tom).*



proportion of trials that the subject-position pronoun is interpreted as referring to the object antecedent

- **Referential structure effects (Dependence views)**

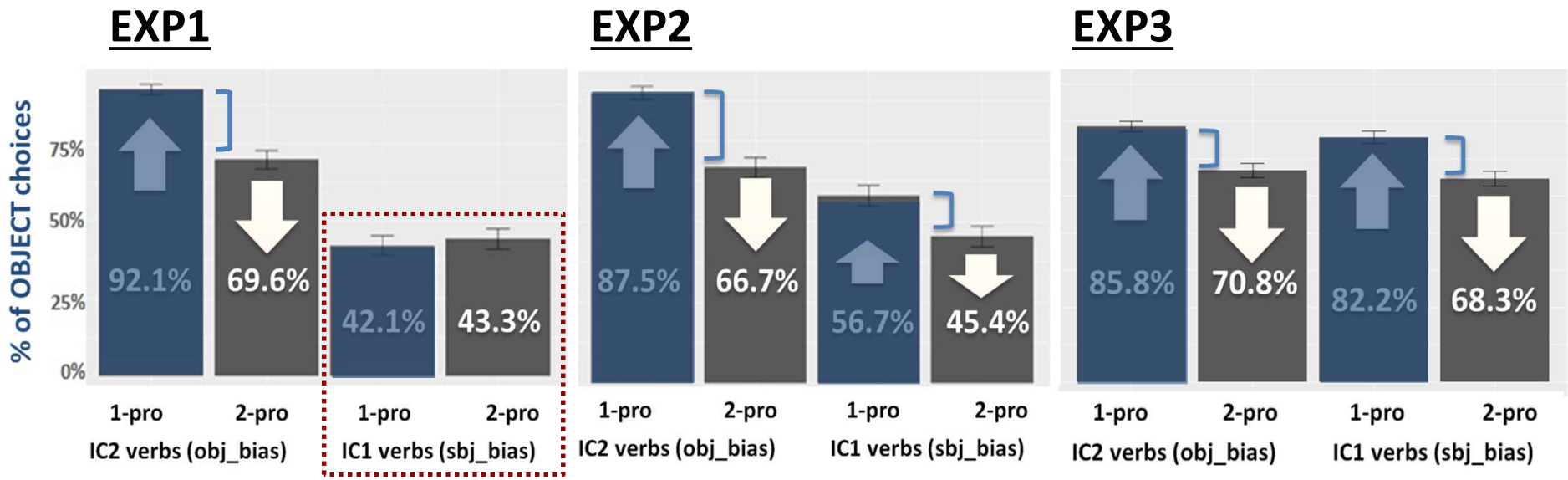
  1-pronoun structure **>obj interpretation** 2-pronoun structure

  He daxed (Tom) *He daxed* ***him***

  *(p <.001***, glmer)*

Exp1 - 3 Referential structure effects

Henry {surprised (IC1) / respected (IC2)} Kevin because ***he*** *daxed him/(Tom).*



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- **Exp1: Referential structure effects only with IC2 verbs**
  - Potential confound stem from verb transitivity
  - *"He daxed"* (Intransitive verb) vs. *"He daxed him"* (Transitive verb)
  - IC1 1-Pro condition: relatively non-prominent subjects in both clauses (Stimulus subjects + Intransitive subjects) → *subject interpretation* ↑

Exp1 - 3 Referential structure effects

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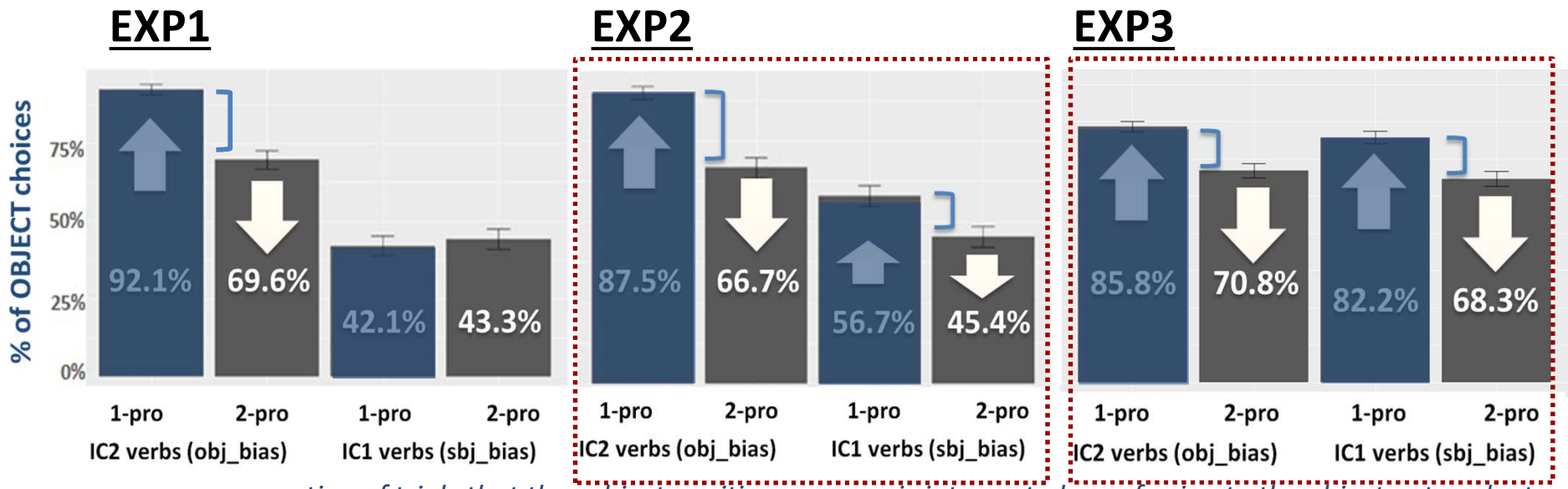

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- **Exp2 & Exp3: Referential structure effects both with IC1 & IC2 verbs**
  - No confound stem from verb transitivity
  - *"He daxed Tom"* (Transitive verb) vs. *"He daxed him"* (Transitive verb)

*Exp2: IC2 verbs (p<.01**), IC1 verbs (p<.001***);Exp3: IC2 & IC1 verbs (p<.001***)*

Exp1 - 3 Referential structure effects

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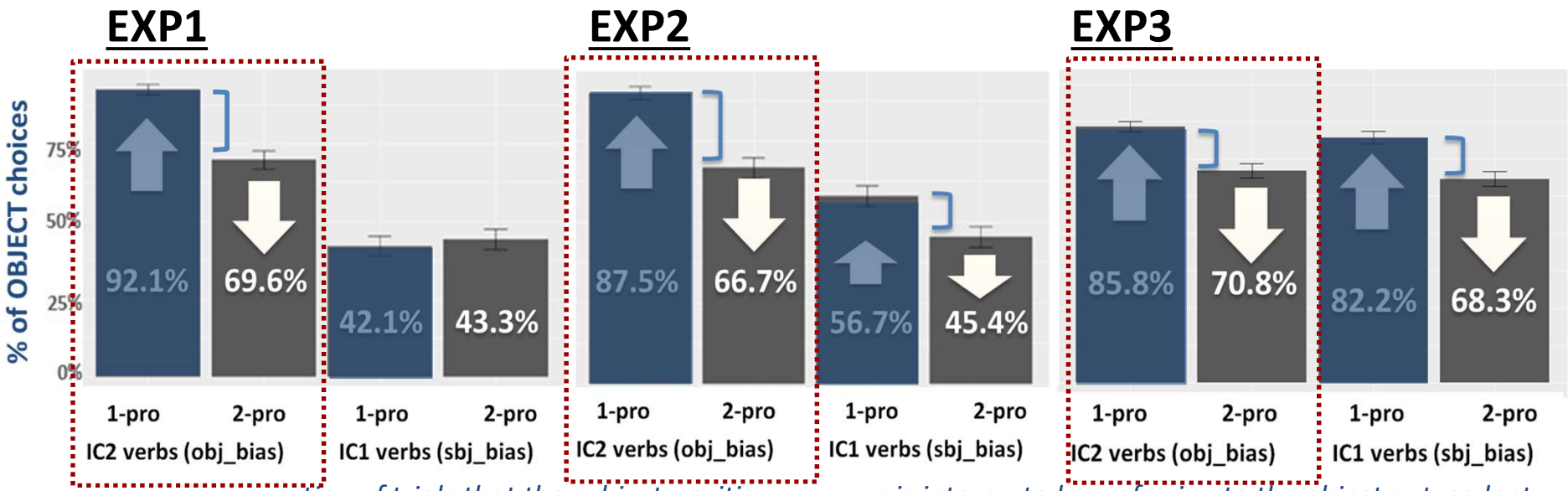

proportion of trials that the subject-position pronoun is interpreted as referring to the object antecedent

- **Replicate IC verb effects**

IC2 verbs (obj-bias) $>_{\text{obj interpretation}}$ IC1 verbs (sbj-bias)

Henry respected Kevin *Henry surprised Kevin*

(p <.05, glmer)*

Discussion of Exp 1 – Exp 3

- **Significant referential structure effects**
  - Multiple-pronoun resolution ≠ single-pronoun resolution
  - Referential structure effects generalize across verb classes with different thematic roles.
- **Support the dependence view** (Centering Theory)
  - There are interactions between the anaphoric dependencies of the two different pronouns.
  - Differences in referential structural properties contribute to discourse coherence (a bias to maximize coherence)
- **Replicated IC verb bias effects**
  - The picture-writing task, even with nonce verbs, yields meaningful data regarding pronoun interpretation.

Experiment 4: Real-time processing of multiple pronoun interpretation

How our mental models of pronoun resolution are dynamically updated in real time

Referential structure effects during real-time processing

- Mental computations in language comprehension occur **incrementally** (e.g., Cooper, 1974; Eberhard et al., 1995; Tanenhaus et al., 1995).
- When faced with an indirect object pronoun → presence/absence of preceding pronoun's dependency information
- **Preceding pronoun's dependency** information is used in forming the subsequent pronominal dependency ('her'), as well as revising the preceding pronominal dependency ('she') in Exp1-3.

Lucy$_1$ tickled Ivy$_2$ on the park bench because John had yolled the lyfander to ***her***

1-Pronoun

Lucy$_1$ tickled Ivy$_2$ on the park bench because she had yolled the lyfander to ***her***

2-Pronoun

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When does this information begin to be used in pronoun resolution?

Lucy$_1$ tickled Ivy$_2$ on the park bench because John had yolled the lyfander to ***her***

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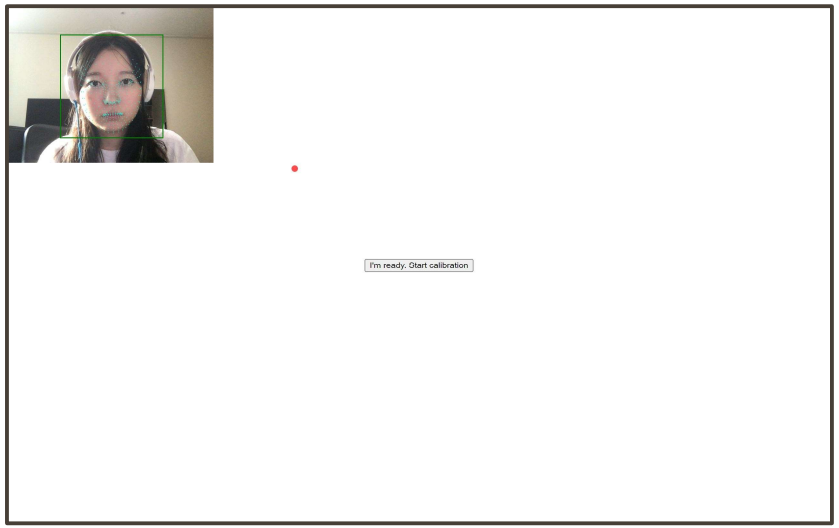
2-Pronoun

preceding dependency info.

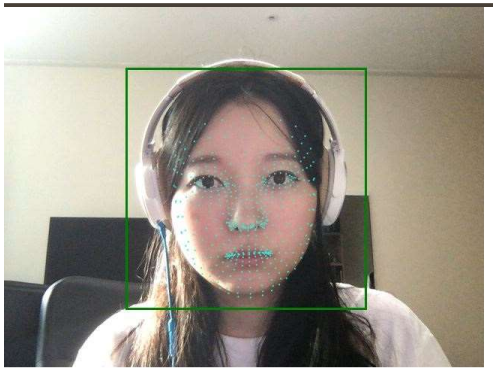
Webcam-based visual-world eye-tracking

- Eye-tracking experiment run remotely over the internet, using *PennController IBEX* (Zehr & Schwarz, 2018) and the eye-tracking JavaScript library *Webgazer.js library* (Papoutsaki et al., 2016)
- Participants' eye gaze information to be gathered/recorded through their webcams
- Spatial and temporal resolution are less fine-grained than with lab eye-trackers
- For visual-world studies, replicated results produced with lab eye-trackers (e.g., Degen et al., 2021; Lee, 2022; Slim & Hartsuiker, 2021; Storbeck, 2022; Vos et al., 2022)
- 70 participants (native English speakers) were included in final analyses out of 98

Image from Papoutsaki et al., (2018)

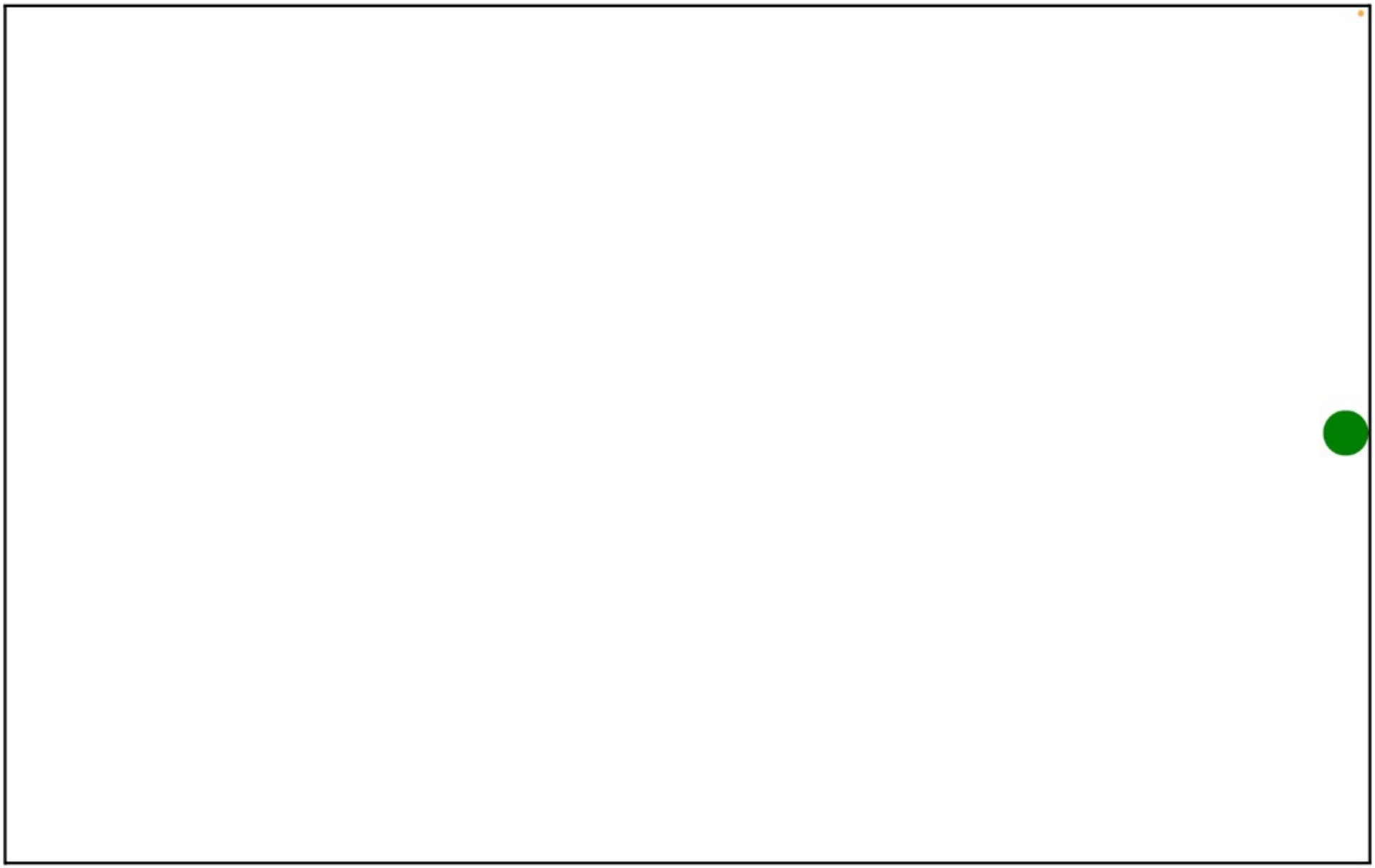


Initial calibration phase



I'm ready. Start calibration

Initial calibration phase



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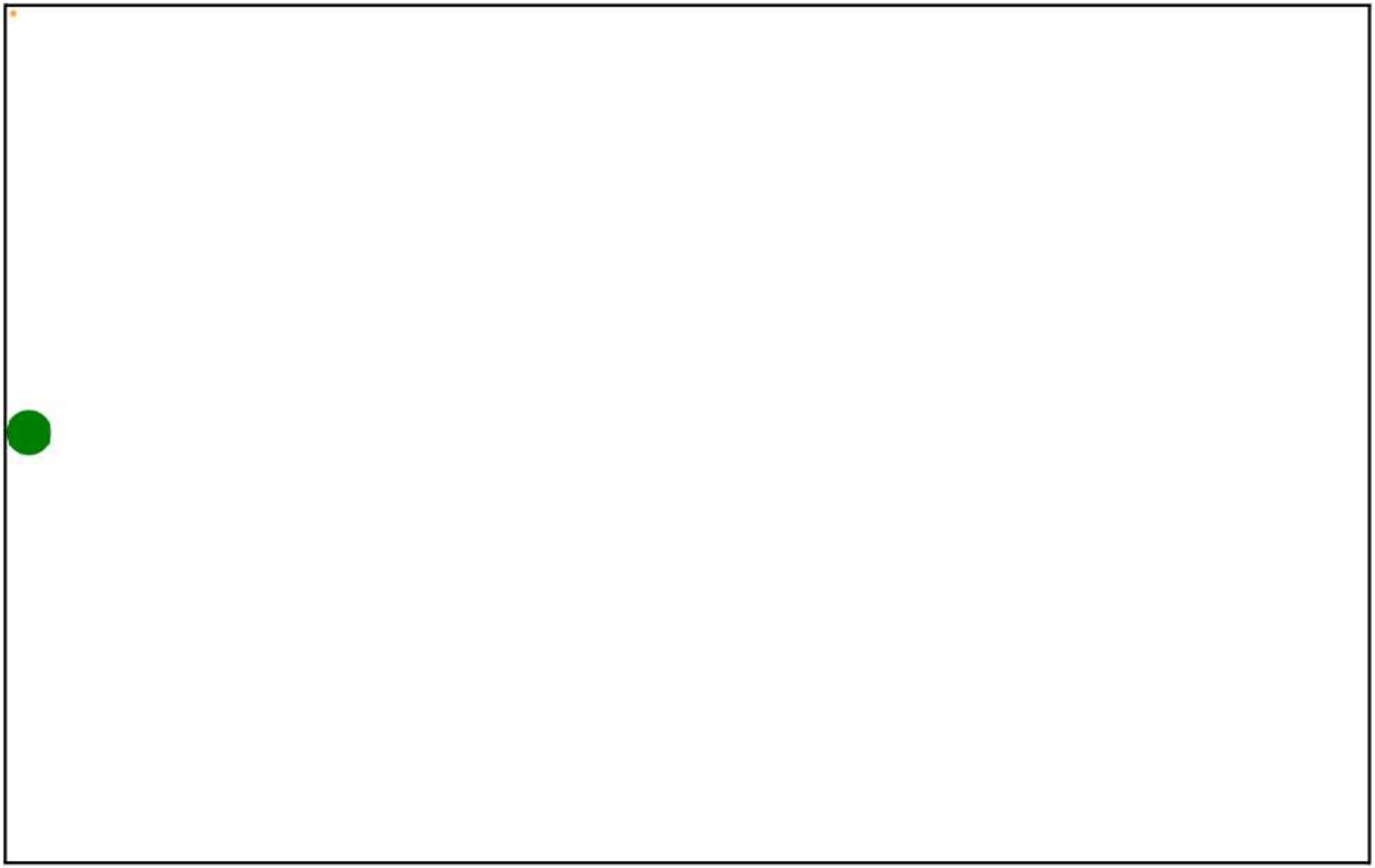

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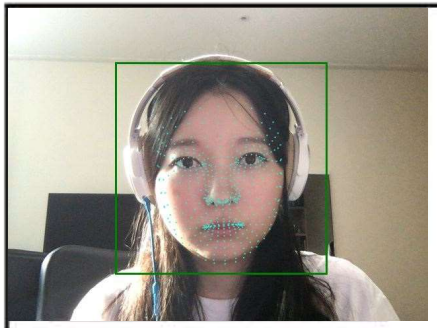

Let's try again! We were not able to precisely calibrate the software.

Your calibration score is 14

Calibration normally takes a few tries. If your computer is unable to calibrate after several tries, don't worry; you can still do the experiment and get paid.

Here are a few tips:

- Adjust your position so that your face fits inside the preview square and the square is green.
- Make sure you are in a well-lit location.
- Make sure you're looking at each green circle the **entire** time it is on the screen.
- Use your eyes to look; try not to move your head.
- If you wear glasses, try to adjust your position so they don't reflect light back into the webcam.
- Adjust the tilt of your screen (or raise your laptop, e.g. with books) so that you look directly at the webcam, not at an upward or downward angle.
- External webcams should be at the top center of the screen.
- If using a laptop, plug it into its power adapter.
- Close other programs that may be using a significant portion of your computer's energy.

Retry

5 attempts above 60%

Auditory stimuli

Ref.st.	Examples
Sbj Pro	*Tommy encouraged Max after the winter vacation because **he** had wengered the neend to **Hanna**.*
Obj Pro	*Tommy encouraged Max after the winter vacation because **Hanna** had wengered the neend to **him**.*
Two Pro	*Tommy encouraged Max after the winter vacation because **he** had wengered the neend to **him**.*

- Two-clause sentence connected by *because*
- **1st clause:** 2 potential antecedents with an equi-biased IC verb

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- Two-clause sentence connected by *because*
- **1st clause:** 2 potential antecedents with an equi-biased IC verb
- **2nd clause:** 1 ditransitive nonce verb and 1 nonce direct object to minimize semantic variability + Pronoun(s) for referential structure manipulation
  - **Referential Structure** (Sbj-Pronoun/Obj-Pronoun/Two-Pronoun)

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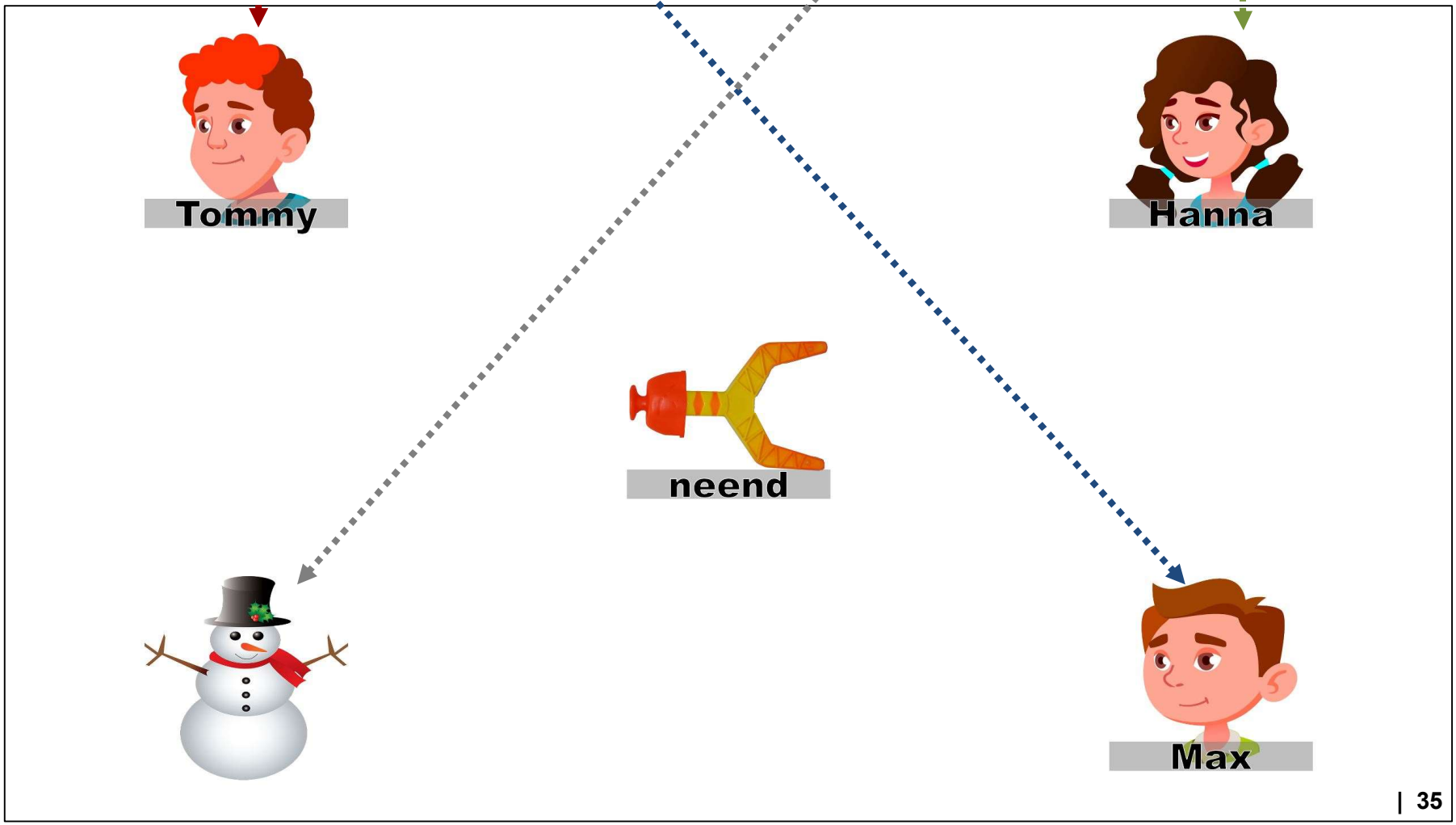
  - **Referential Structure** (Sbj-Pronoun/Obj-Pronoun/Two-Pronoun)
- **2 look-aways** before pronouns: time/location PPs and nonce nouns
  → *attract eye-gaze to a neutral position)*
- **Last-mentioned selection task** (24 Targets & 36 Fillers, 70 people in final analyses):
  - Click on the picture that was mentioned last in the sentence (for Two-pro/Obj-Pronoun condition, pronoun's referent selection)

Visual Stimuli: Screen layout for the targets

*Tommy encouraged Max after the winter vacation because {**he**/Hanna} had wengered the neend to {Hanna/**him**}.*



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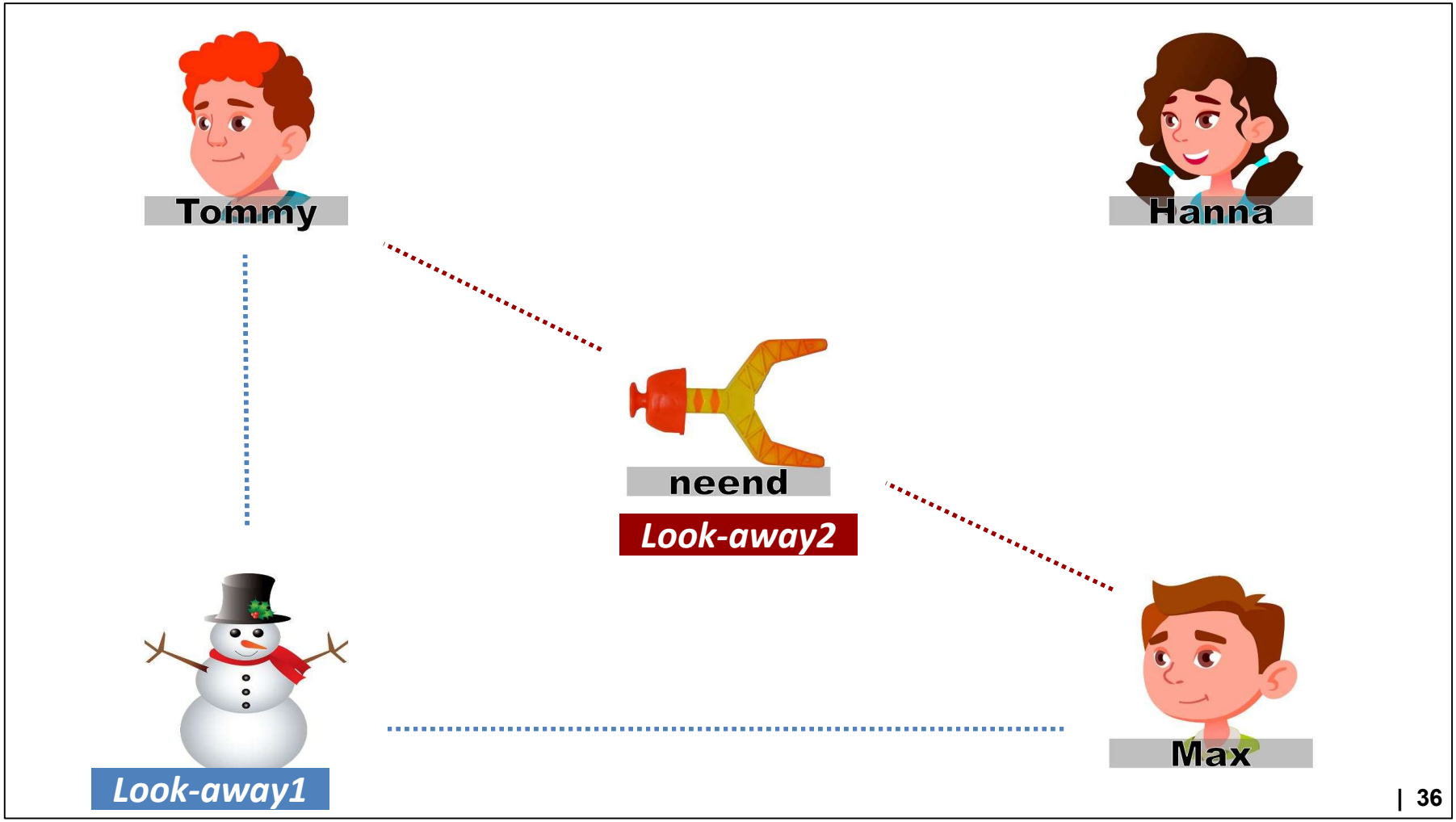

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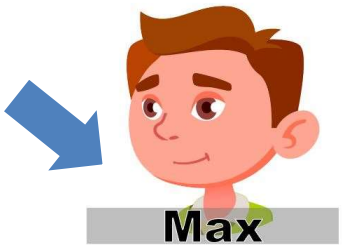
Click on the 'last-mentioned entity'



Predictions: last-mentioned selections

- **Centering Theory (CT)** (e.g., Grosz et al., 1995; Walker et al 1998)
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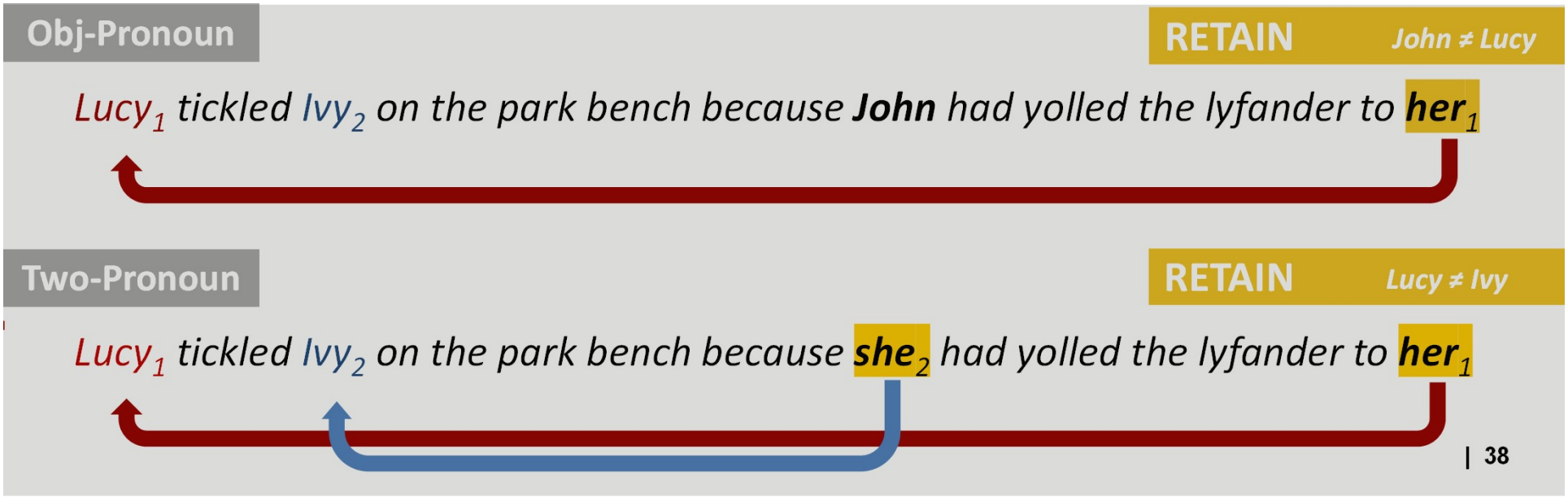
  - They are resolved in such a way that maximizes coherence of the discourse transition (CONTINUE > RETAIN > SHIFT)
- **Referential structure effects**:

  Obj-pronoun st. $>_{\text{sbj selections}}$ 2-pronoun st.



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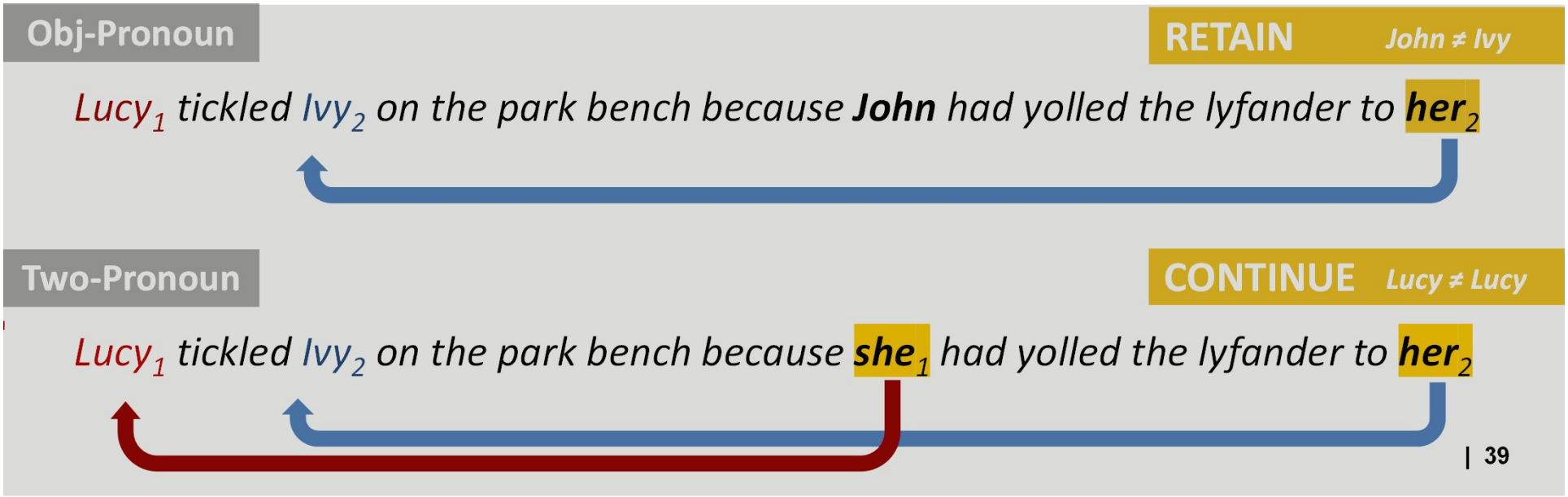


Predictions: last-mentioned selections

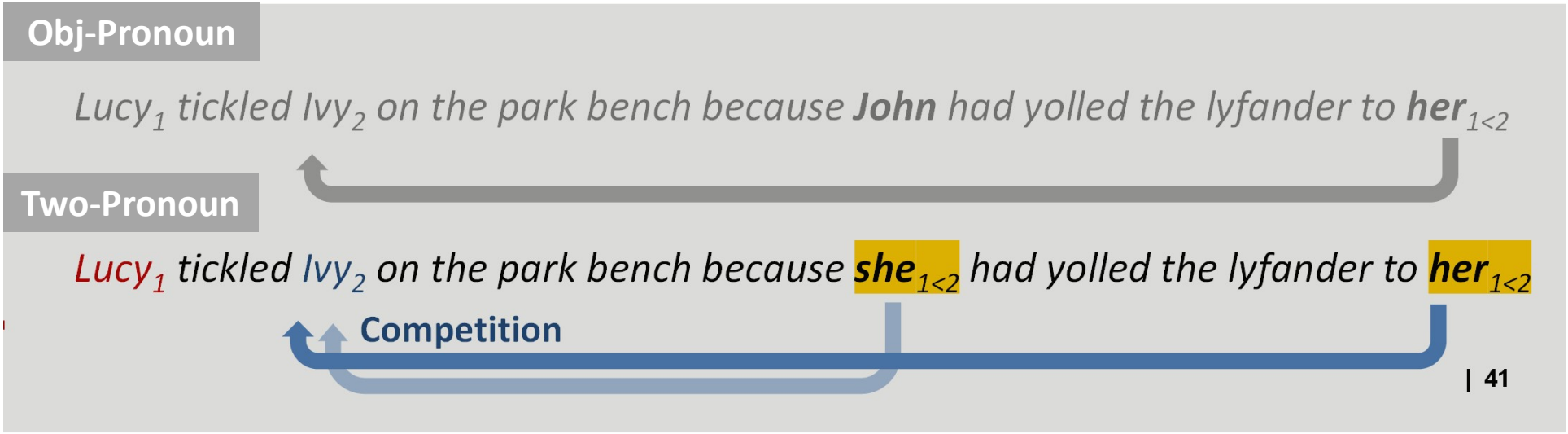
- **Antecedent recency** guides pronoun resolution (Arnold, 1998; Cunnings et al., 2014; Streb et al., 2004)
  - Most recently mentioned element is favored as the antecedent for a pronoun
  - Found in ambiguous/complex contexts (e.g., antecedents are far from the pronoun or multiple antecedents present); degrading of representations in memory over time
- **Referential structure effects**: **Obj-pronoun st. $<_{\text{sbj selections}}$ 2-pronoun st.**
  - Stronger subject preference ('him') in 2-Pronoun than Obj-Pronoun structure
  - **Competition** for the object antecedent between the subject and indirect object pronoun in the 2-Pronoun condition

Obj-Pronoun

*Lucy$_1$ tickled Ivy$_2$ on the park bench because **John** had yolled the lyfander to **her**$_{1<2}$*

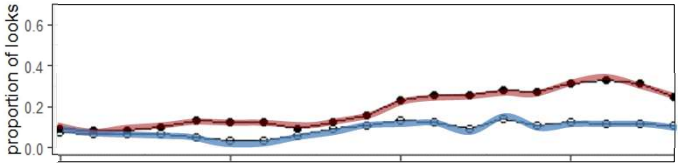
Predictions: last-mentioned selections

- **Antecedent recency** guides pronoun resolution (Arnold, 1998; Cunnings et al., 2014; Streb et al., 2004)
  - Most recently mentioned element is favored as the antecedent for a pronoun
  - Found in ambiguous/complex contexts (e.g., antecedents are far from the pronoun or multiple antecedents present); degrading of representations in memory over time
- **Referential structure effects**: **Obj-pronoun st. $<_{\text{sbj selections}}$ 2-pronoun st.**
  - Stronger subject preference ('him') in 2-Pronoun than Obj-Pronoun structure
  - **Competition** for the object antecedent between the subject and indirect object pronoun in the 2-Pronoun condition



Predictions: Gaze patterns during pronoun resolution

- **Subject advantage scores** (proportion of looks to the object – looks to the subject) (e.g., Arnold et al., 2000, 2007; Kaiser, 2011) to compare pronoun resolution by ref. structure type
- **During *subject* pronoun interpretation (NOT a critical region)**
  - No referential structure effects: Subject-Pronoun = Two-Pronoun condition
  - Two conditions will not show different gaze patterns (same until indirect obj)
  - No peak in looks to either antecedent, because of the equi-biased IC verbs (maybe with recency/ discourse coherence)

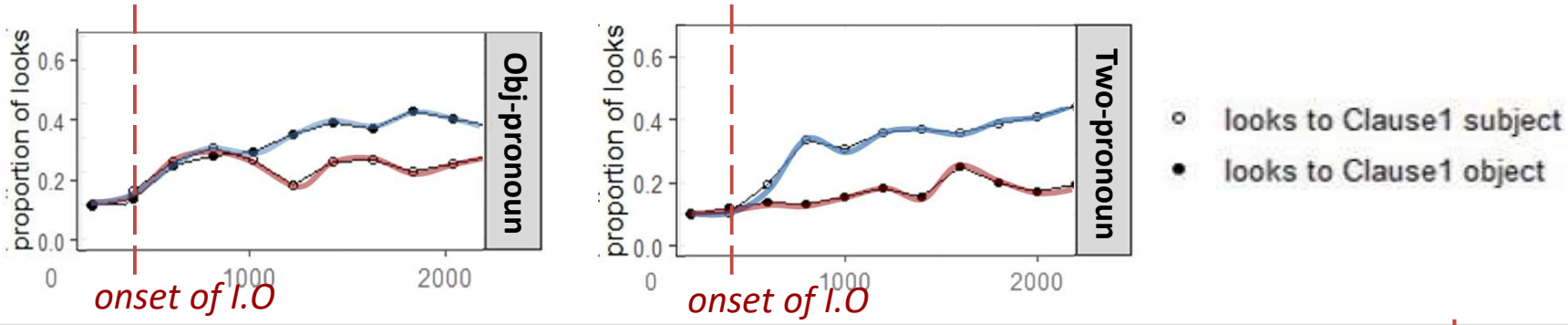


Lucy$_1$ tickled Ivy$_2$ on the park bench because ***she*** *had yolled the lyfander to* ***John***

Lucy$_1$ tickled Ivy$_2$ on the park bench because ***she*** *had yolled the lyfander to* ***her***

Predictions: Gaze patterns during pronoun resolution

- **During *indirect object* pronoun interpretation (Critical region)**
  - Referential effects (different gaze patterns): Obj-Pro ≠ Two-Pro *(sbj advantage score)*
  - **Immediate activation hypothesis**: Early emergence of referential effects
    - Subject pronoun's referential dependencies and related information are IMMEDIATELY utilized into building referential dependencies with indirect object pronoun.

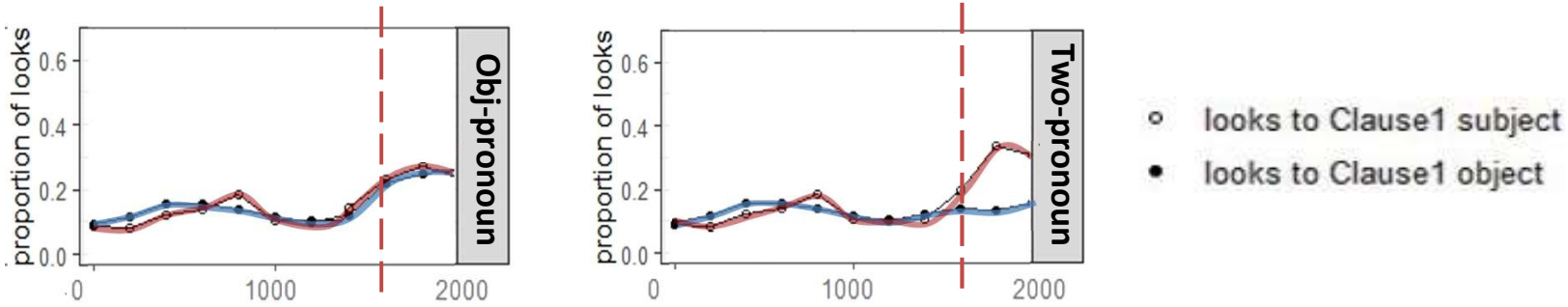


*Lucy$_1$ tickled Ivy$_2$ on the park bench because **she** had yolled the lyfander to **her***

Immediate activation

Predictions: Gaze patterns during pronoun resolution

- **During *indirect object* pronoun interpretation(Critical region)**
  - **Delayed activation hypothesis:** Late emergence of referential effects
    - Retrieval of the subject pronoun's dependencies are delayed
    - Initially, interpret object pronoun in an 'encapsulated' way regardless of referential dependencies from the sbj pronoun. And then the pre-existing dependencies come into play (processing of the object pronoun)



*Lucy$_1$ tickled Ivy$_2$ on the park bench because **she** had yolled the lyfander to **her***

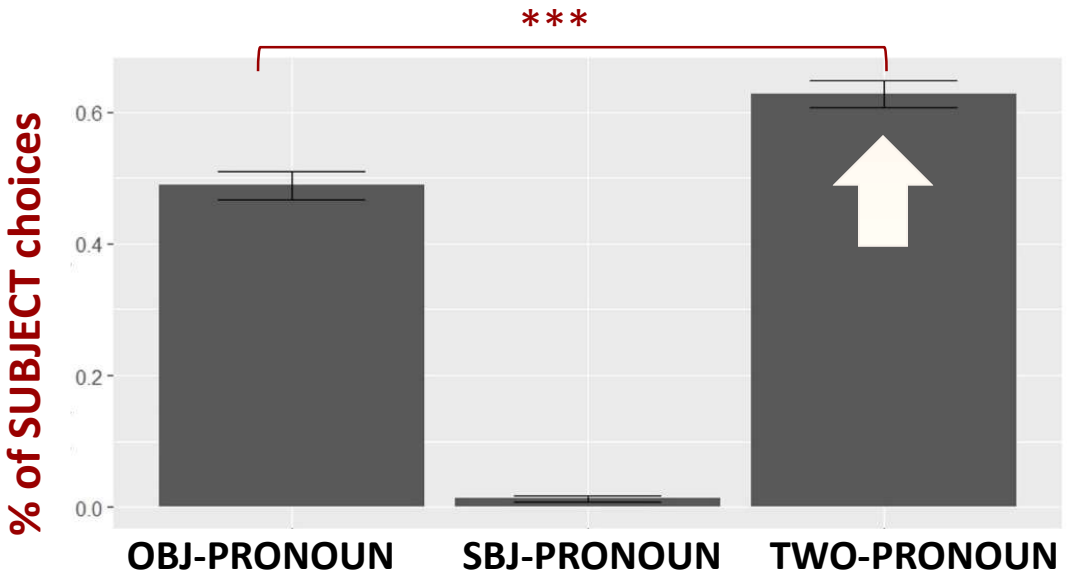
Immediate activation

*Lucy$_1$ tickled Ivy$_2$ on the park bench because **she** had yolled the lyfander to **her***

Delayed activation

Results: Last-mentioned referent choices

Tommy *encouraged Max after the winter vacation because {he/Hanna} had wengered the neend to {Hanna/him}.*



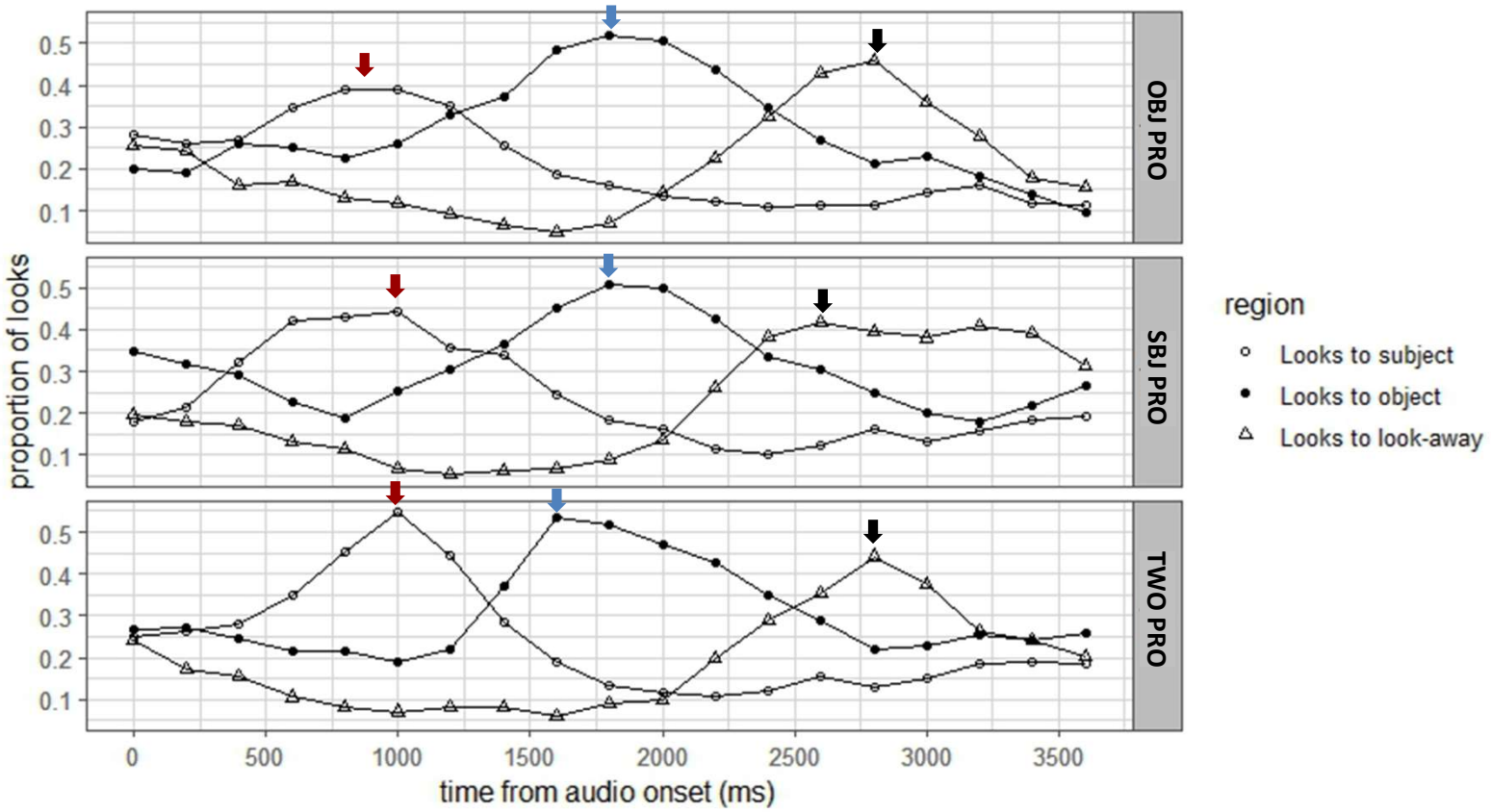
The proportion of selections of the preceding SUBJECT as the last-mentioned referent (error bars ±1 SE)

- **Effects of referential structure**
- Subject-antecedent preference:
  OBJ-Pronoun **<** Two-Pronoun
  (p < .001, glmer)
- **Recency** guides pronoun resolution

➔ Competition for the object antecedent (most recently mentioned) with two pronouns

Results: Gaze patterns during the matrix-clause

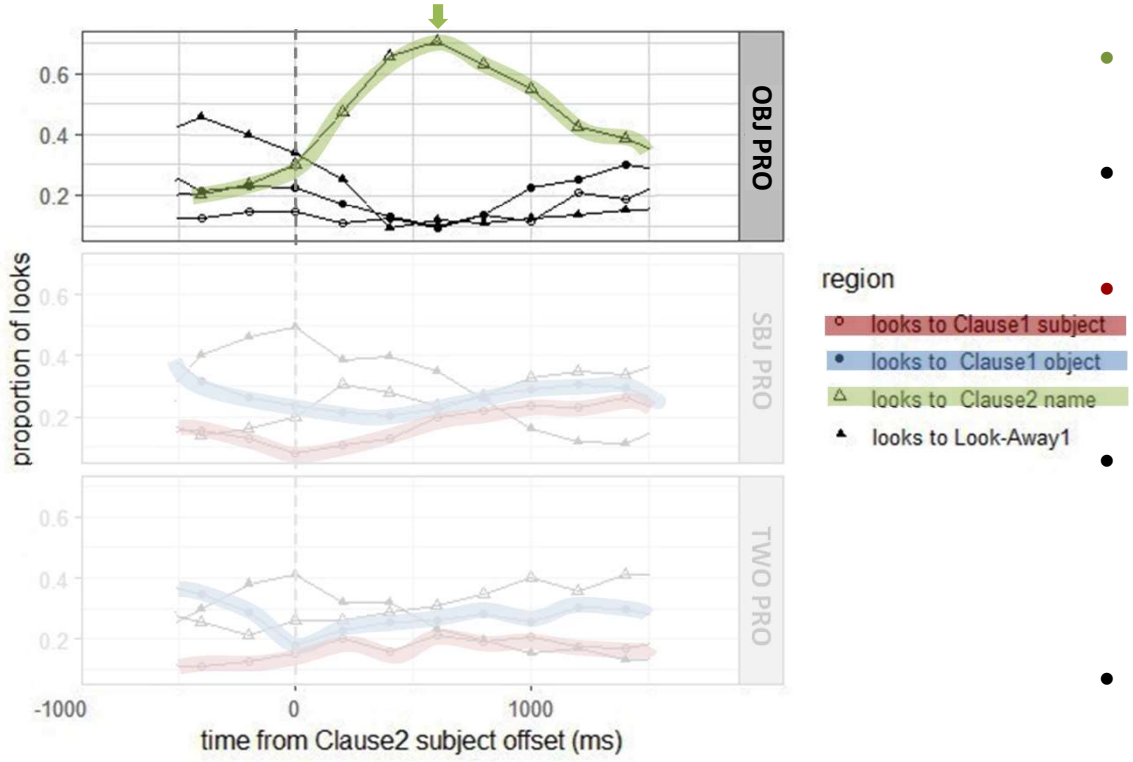
Tommy *encouraged* ***Max*** ***after the winter vacation*** *because {he/Hanna} had wengered the neend to {Hanna/him}*



Eye movements relative to the onset of the matrix-clause subject
(each facet shows looks to the three regions of interest within a condition)

Results: Gaze patterns in subject pronoun

Tommy *encouraged* ***Max*** *after the winter vacation because* ***Hanna*** *had wengered the neend to him.*



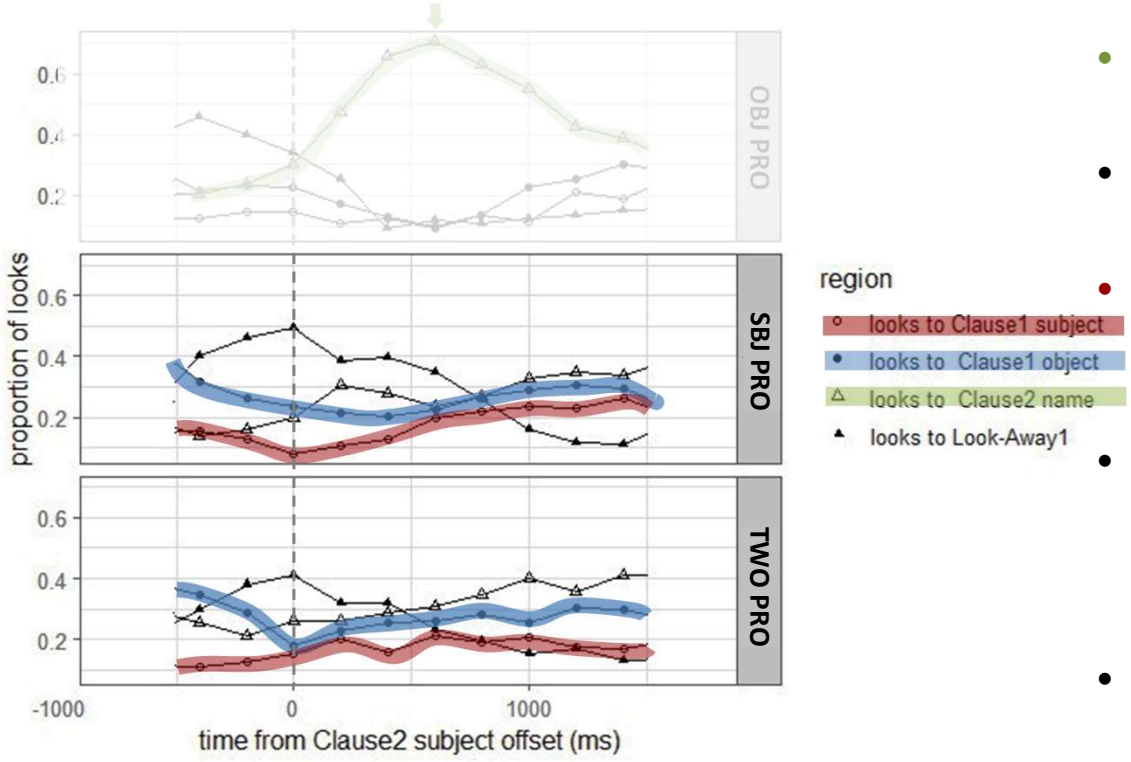
Eye movements relative to ***the offset*** *of the because-clause subject*

Why offset? *because /z/+ she /ʃ/* → sibilants assimilation

- **Sbj-Name ≠ Sbj pronoun**
- **No referential structure effects**
- No subject-antecedent preference in all time windows
- Subject advantage scores:
  SBJ-Pronoun = Two-Pronoun
  (p >.01, lmer)
- Visually**, equi-biased IC verbs** and **recency** factor affect pronoun resolution

Results: Gaze patterns in subject pronoun

Tommy *encouraged* ***Max*** *after the winter vacation because* ***he*** *had wengered the neend to Hanna.*



Eye movements relative to ***the offset*** *of the because-clause subject*

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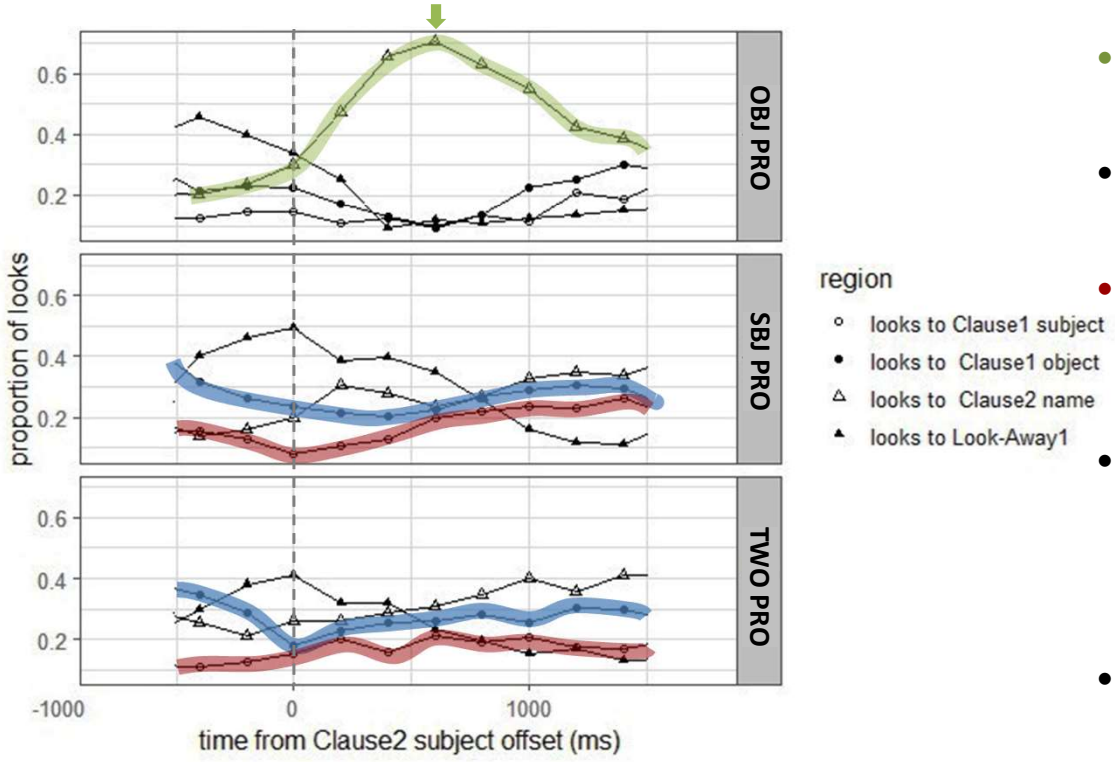
- Subject advantage scores:
  SBJ-Pronoun = Two-Pronoun
  (p >.01, lmer)
- Visually**, equi-biased IC verbs** and **recency** factor affect pronoun resolution

Results: Gaze patterns in subject pronoun

Tommy encouraged Max after the winter vacation because {he/Hanna} had wengered the neend to {Hanna/him}.



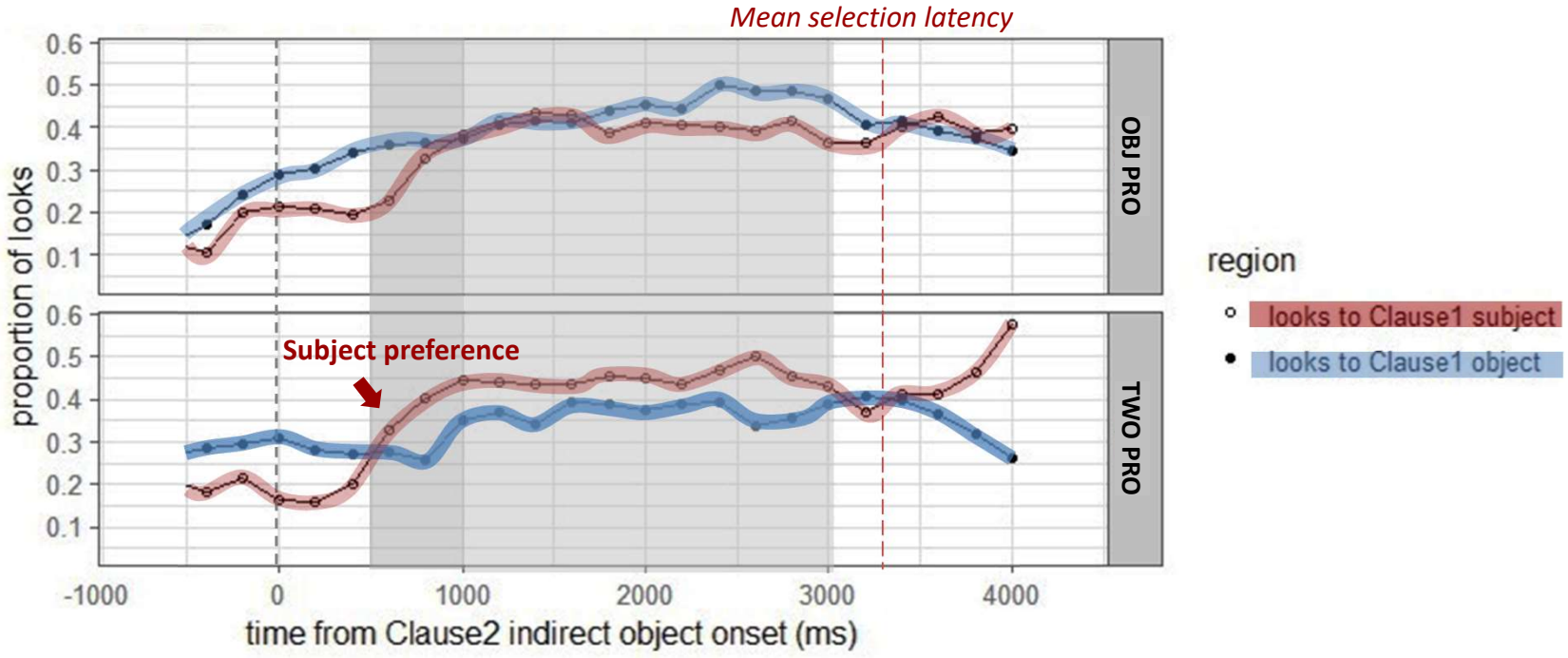
*Eye movements relative to **the offset** of the because-clause subject*

Why offset? *because /z/+ she /ʃ/* → sibilants assimilation

- **Sbj-Name ≠ Sbj pronoun**
- **No referential structure effects**
- No subject-antecedent preference in all time windows
- Subject advantage scores:
  SBJ-Pronoun = Two-Pronoun
  (p >.01, lmer)
- Visually**, equi-biased IC verbs** and **recency** factor affect pronoun resolution

Results: Gaze patterns in indirect object pronoun

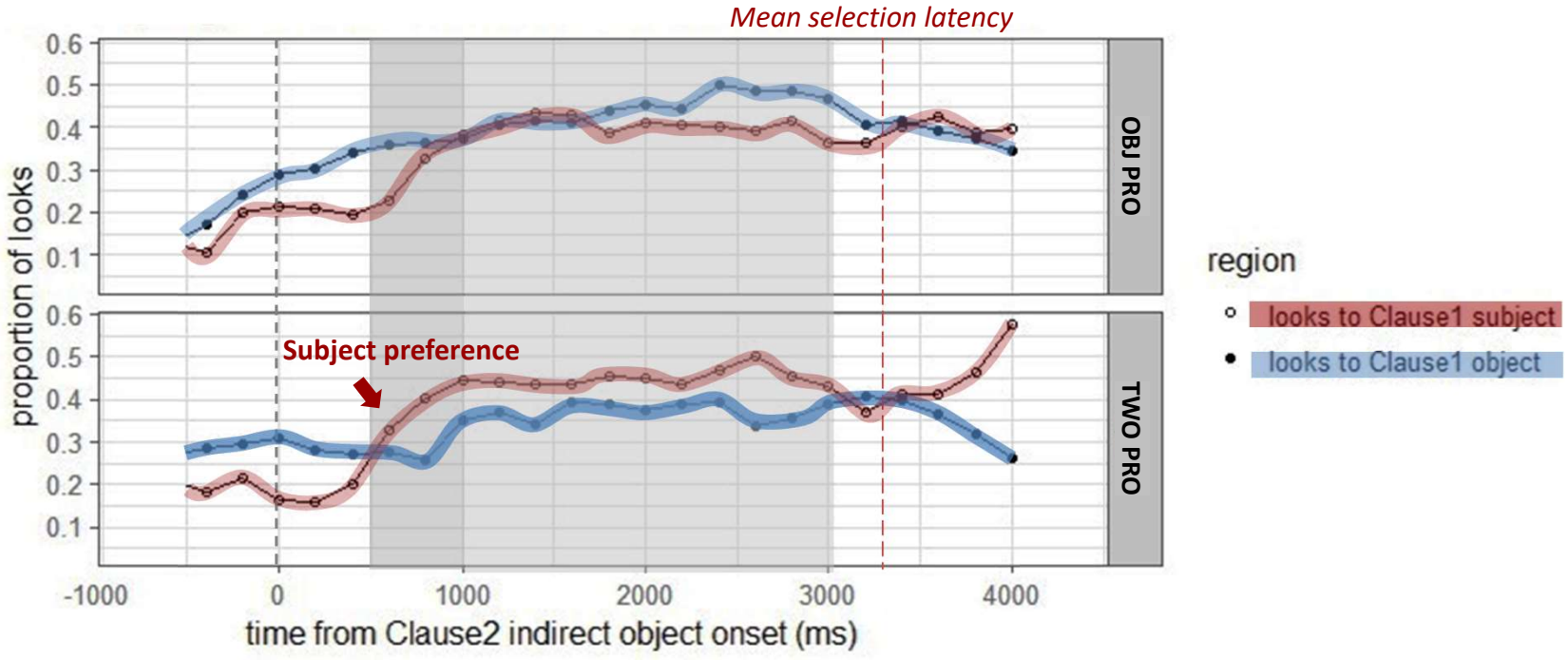
Tommy *encouraged* ***Max*** *after the winter vacation because {he/Hanna} had wengered the neend to* ***him.***



- **Referential structure effects** *(500-1000ms (p = .0402***) & 1000-3000ms (p=.037***))*
  - Subject preference (subject advantage scores) = OBJ-Pronoun < Two-Pronoun
  - Recency effects as in last-mentioned selection results

Results: Gaze patterns in indirect object pronoun

Tommy *encouraged* ***Max*** *after the winter vacation because {he/Hanna} had wengered the neend to* ***him.***



- **Immediate activation hypothesis**: referential structure effects emerge early on upon hearing the subsequent pronoun→ the antecedents are almost immediately retrieved with the dependencies linked to the preceding subject pronoun during indirect pronoun resolution

Discussion

- **Support immediate activation hypothesis:** referential structure effects emerge early on during indirect object pronoun resolution

- **Why early activation** of the preceding pronominal dependencies?
  - Due to eagerness to complete open dependencies (the storage costs associated with keeping dependencies open during processing)
  - Cataphora resolution: preference for the closest referent has been found

*When **he** was at the party, **the girl/boy** cruelly teased the boy/girl .*

(Eye-tracking study by Van Gompel and Liversedge (2003)

Discussion

- **Recency effects on pronoun resolution**
  - Subject-antecedent preference was stronger in the Two-Pronoun than One-Pronoun condition (last-mentioned selection/ gaze patterns)

- **Discourse coherence factor might play a role**
  - In the Object-Pronoun condition (1-pronoun), no strong object-antecedent preference (last-mentioned selection/ gaze patterns)

- Different factors exert their effects differently from one context to another during pronoun resolution

- **Referential structure effects can be generalized beyond particular contexts**
  - Convergent evidence on the effects of referential structure in different context with multiple methodology provides strong evidence on it

Conclusion

- **Importance of 'forward-looking approach' in pronoun resolution**
  - Most existing models of pronoun resolution take a 'backward-looking' approach (e.g., salience of potential antecedents in the prior context)
  - A comprehensive model of pronoun resolution should include forward-looking approach (i.e., referential structure effects)

When interpreting a pronoun, what comes next matters!

In particular, who is or isn't mentioned later.

Thank you.


Prof. Elsi Kaiser


Dr. Jesse Storbeck


Ian Rigby


Haley Hsu

- **Exp1-3:** Song, Jina. & Elsi Kaiser. (2023). Effects of referential structure on pronoun interpretation *Language, Cognition and Neuroscience*,(printed online)
- **Exp4:** Song, Jina., & Elsi Kaiser. (2023, 03). Interpretation of multiple pronouns in English: A webcam eye-gaze study, *Poster presentation at HSP Conference*. University of Pittsburgh, USA.