




Time Course of Syntactic Dependencies:

Evidence from eye movements

By R. S. Sussman and J. C. Sedivy



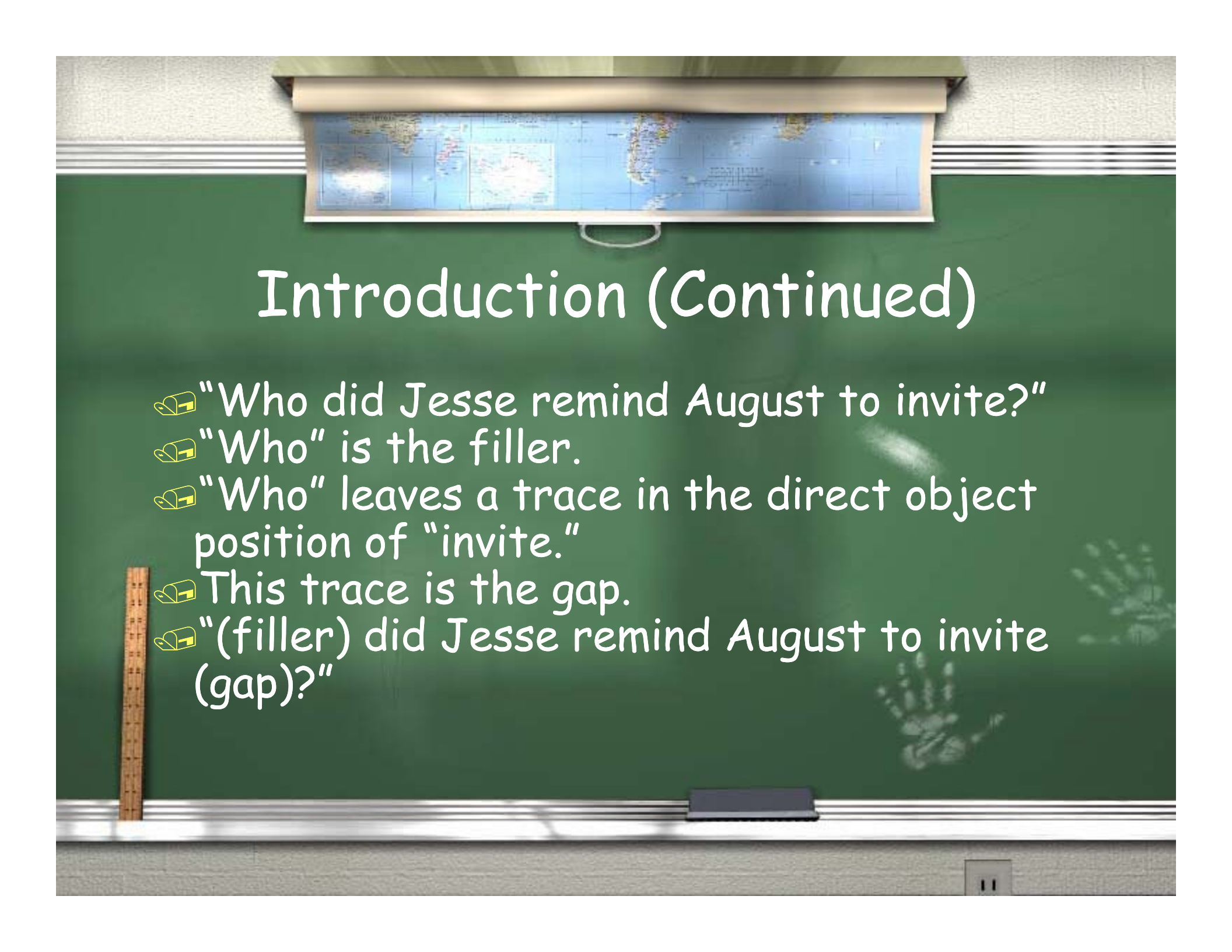
Abstract

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- 📖 In this study, a head-mounted, eye tracking device was used to investigate the nature of processing filler gap relations in WH-questions and the role the verb plays in all of this.
 - 📖 Subjects were asked to listen to a short narrative, while looking at various objects mentioned in the narrative.
 - 📖 At the end of the narrative they were asked WH-question while observing the objects.
 - 📖 The results showed that the participants usually anticipated a gap site at the verb in WH-questions.



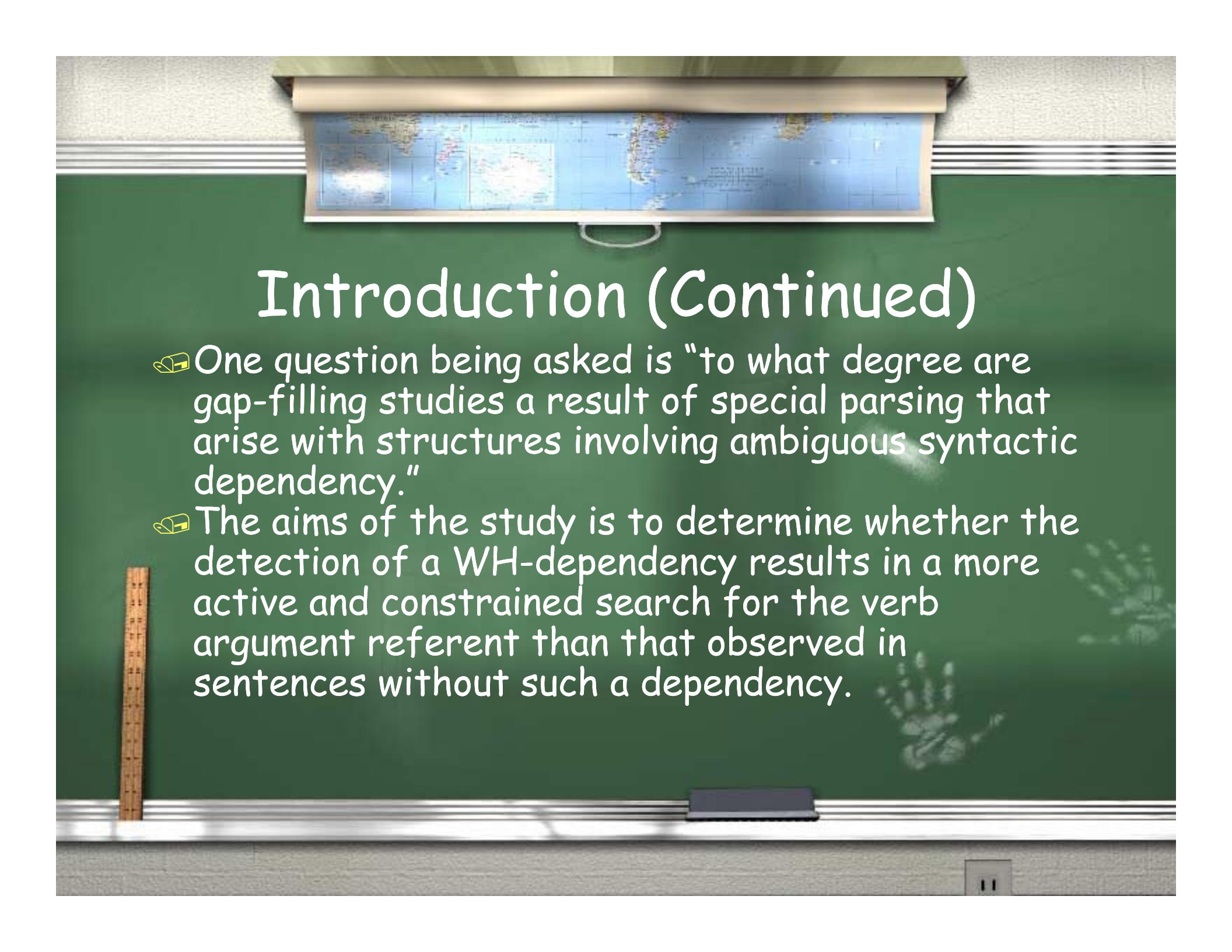
Introduction

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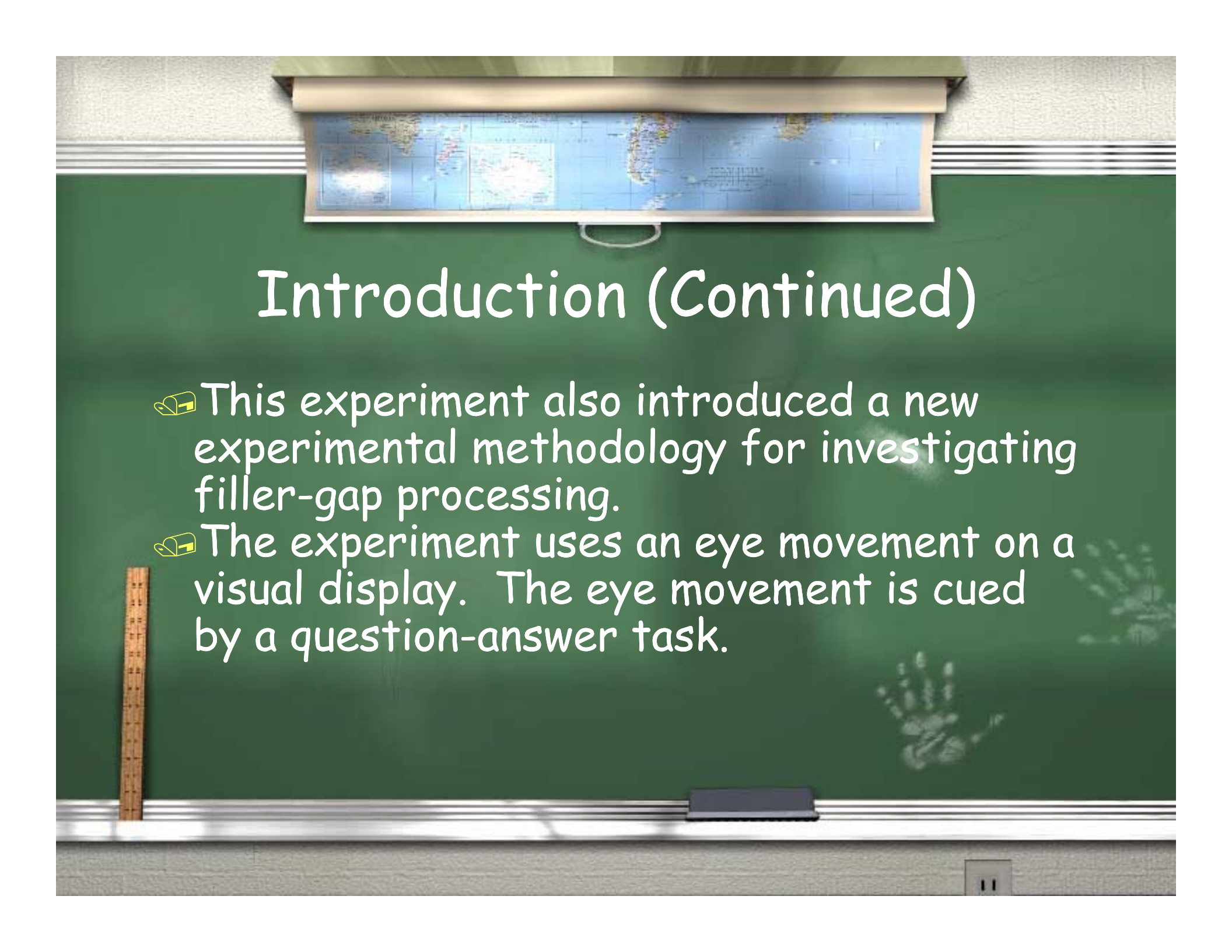
Introduction (Continued)

- 📖 "Who did Jesse remind August to invite?"
- 📖 "Who" is the filler.
- 📖 "Who" leaves a trace in the direct object position of "invite."
- 📖 This trace is the gap.
- 📖 "(filler) did Jesse remind August to invite (gap)?"



Introduction (Continued)

- 📖 One question being asked is "to what degree are gap-filling studies a result of special parsing that arise with structures involving ambiguous syntactic dependency."
- 📖 The aims of the study is to determine whether the detection of a WH-dependency results in a more active and constrained search for the verb argument referent than that observed in sentences without such a dependency.



Introduction (Continued)

- 📖 This experiment also introduced a new experimental methodology for investigating filler-gap processing.
- 📖 The experiment uses an eye movement on a visual display. The eye movement is cued by a question-answer task.



Why use this experimental protocol?

- 📖 It provides an opportunity to observe what is expected rather than unexpected; it is a glimpse at everyday sentence processing rather than a measurement of breakdown due to a surprising occurrence.
- 📖 It provides a continuous record of the listeners' eye movements/expectations as the utterance unfolds, yielding a more detailed picture of processing time, as well as an indication of the time course of initial expectations versus readjustment of expectations and recovery from misanalyses.




Why this experimental protocol?

- 📖 It provides data that is grounded; hence, while filled gap effects in reading time studies, for example, can tell us whether a gap was expected, eye movements in principle can indicate the referential content of the expected gap.
- 📖 Because the task is made so simple, it can be performed by subjects who are illiterate.



Why are they doing this to us?

 The purpose of the experiment was to determine whether the presence of a WH-filler, and hence, the detection of a syntactic dependency, results in an active search for the gap site and the corresponding assignment of a referent to the filler over and above any mechanism involved in general anaphoric mapping of a verb's arguments to an available discourse context.



Hypothesis

📖 If eye movements reflect underlying syntactic processing, then sentences containing WH-dependency should trigger an active search for the gap (i.e., trace) where the dependency can be resolved

📖 That is, eyes should look at possible referents that "fill" the gap once the gap is recognized

📖 Authors predict that **verb** is crucial for identifying gap



Possible Outcomes

- 📁 If WH-dependency DOES trigger active search for the gap/trace site, we should expect anticipatory eye movements to referents that are candidates for the "filler" position
- 📁 If not, occurrence of anticipatory eye movements will be random and unpatterned



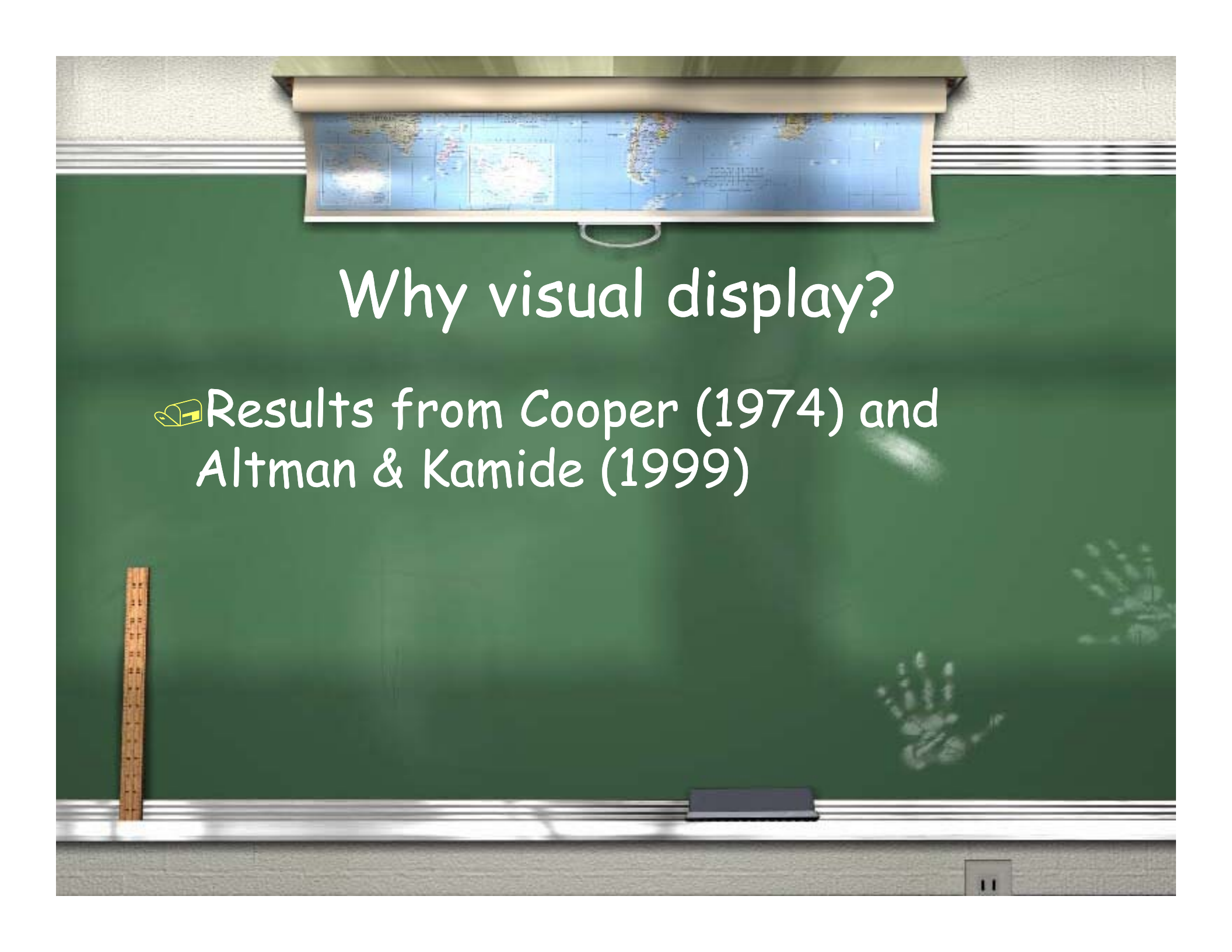
A bit about the methods...

1. Eye movement tracking
2. Visual display
3. Spoken stimuli



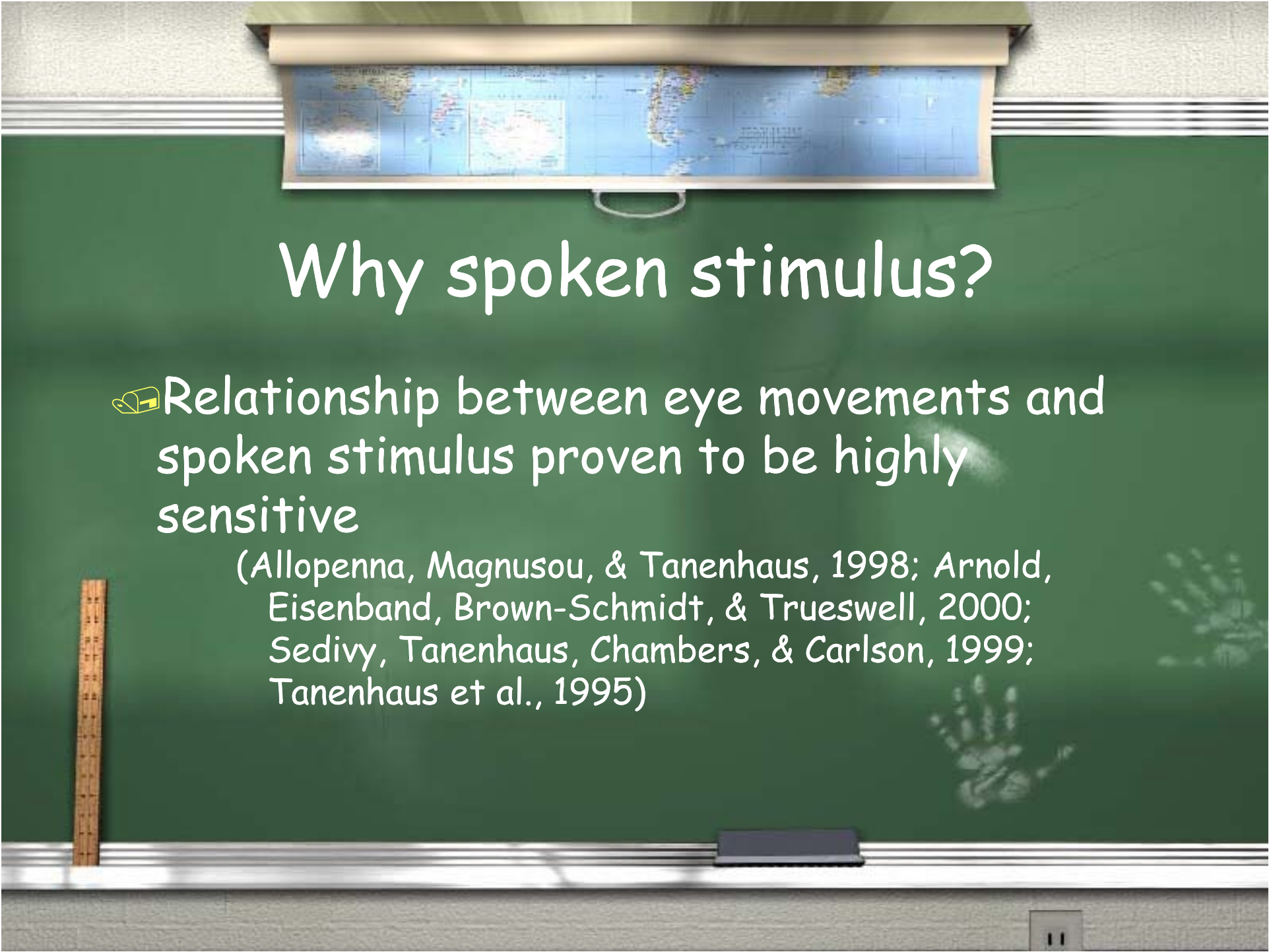
Why eye movement tracking?

- 📖 Cooper (1974) found that subjects had anticipatory eye movements to images depicting referents shortly after referential expression was uttered
- 📖 Altman & Kamide (1999) found subjects to do this even BEFORE utterance of referential expression, given semantic content of verb
- 📖 Tanenhaus, Spivey-Knowlton, Barnyard, & Sedivy (1995) argued that different eye movement patterns reflect different interpretations of syntactic ambiguity



Why visual display?

📁 Results from Cooper (1974) and Altman & Kamide (1999)



Why spoken stimulus?

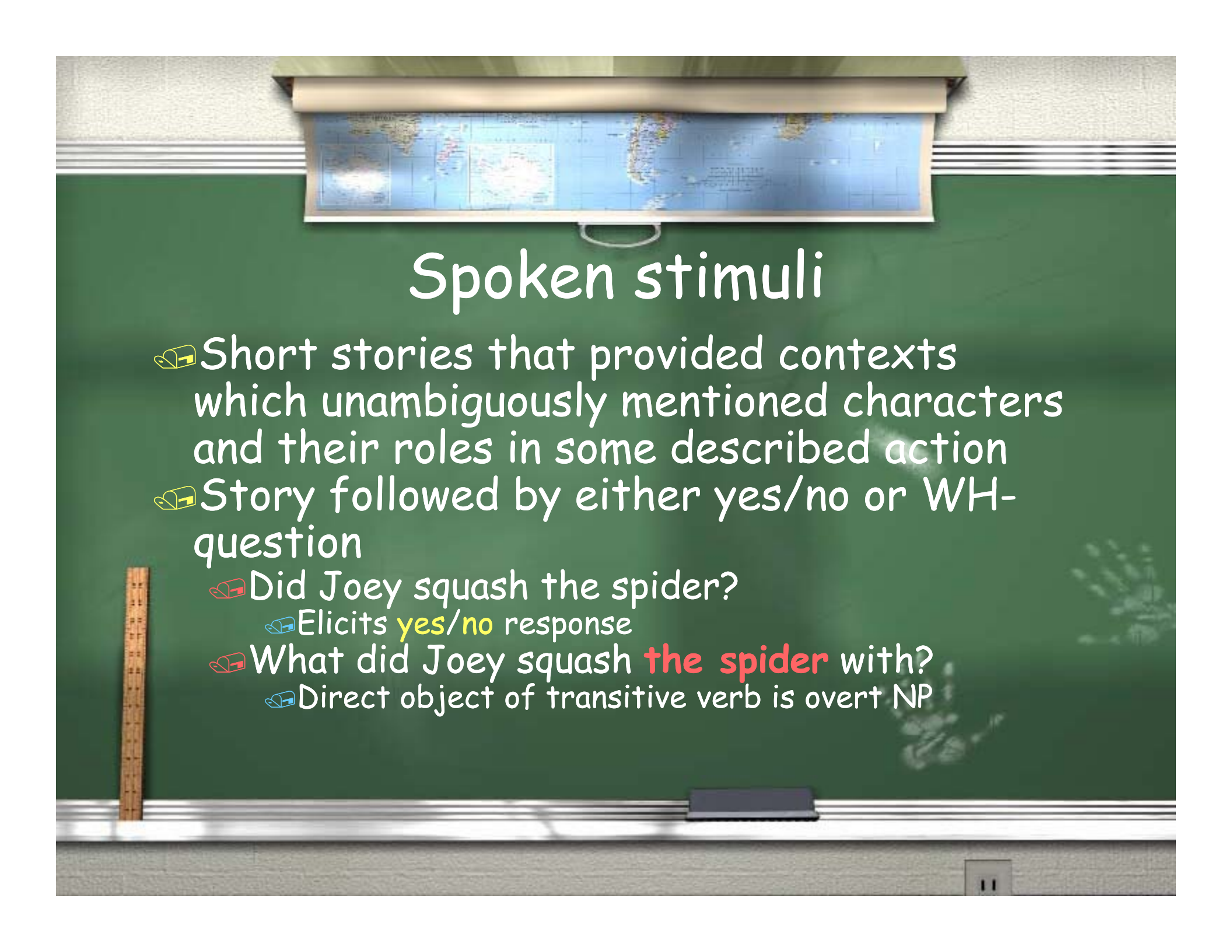
📖 Relationship between eye movements and spoken stimulus proven to be highly sensitive

(Allopenna, Magnusou, & Tanenhaus, 1998; Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000; Sedivy, Tanenhaus, Chambers, & Carlson, 1999; Tanenhaus et al., 1995)



Participants

- 📁 26 non-bilingual native speakers of American English
- 📁 Normal (un)corrected vision



Spoken stimuli

- 📖 Short stories that provided contexts which unambiguously mentioned characters and their roles in some described action
- 📖 Story followed by either yes/no or WH-question
 - 📖 Did Joey squash the spider?
 - 📖 Elicits **yes/no** response
 - 📖 What did Joey squash **the spider** with?
 - 📖 Direct object of transitive verb is overt NP



A bit about the stimuli...

- 📖 Verbs already "normed" for transitivity by 16 non-participants
- 📖 Stories, then partial questions presented
- 📖 Told to complete question however most appropriate
- 📖 Experimenters only used verbs that reliably elicited a question with direct object gap/trace and corresponding referent as answer
 - 📖 Q: What_↑ did Mary eat_↑?
 - 📖 A: The cake



In total...

 10 critical questions

 5 WH-dependency questions

 What did Sammy catch the ball with?

 5 yes/no questions with "YES" answer

 Did Sammy catch the ball? **YES**

 10 "filler" questions

 5 WH-dependencies with gap/trace in direct object position

 What did Sammy catch?

 5 yes/no questions with "NO" answer

 Did Sammy throw the ball? **NO**



Show time!

📖 1/2 of subjects heard critical WH-question, 1/2 heard related critical yes/no question

📖 While listening to story and questions, visual display presented

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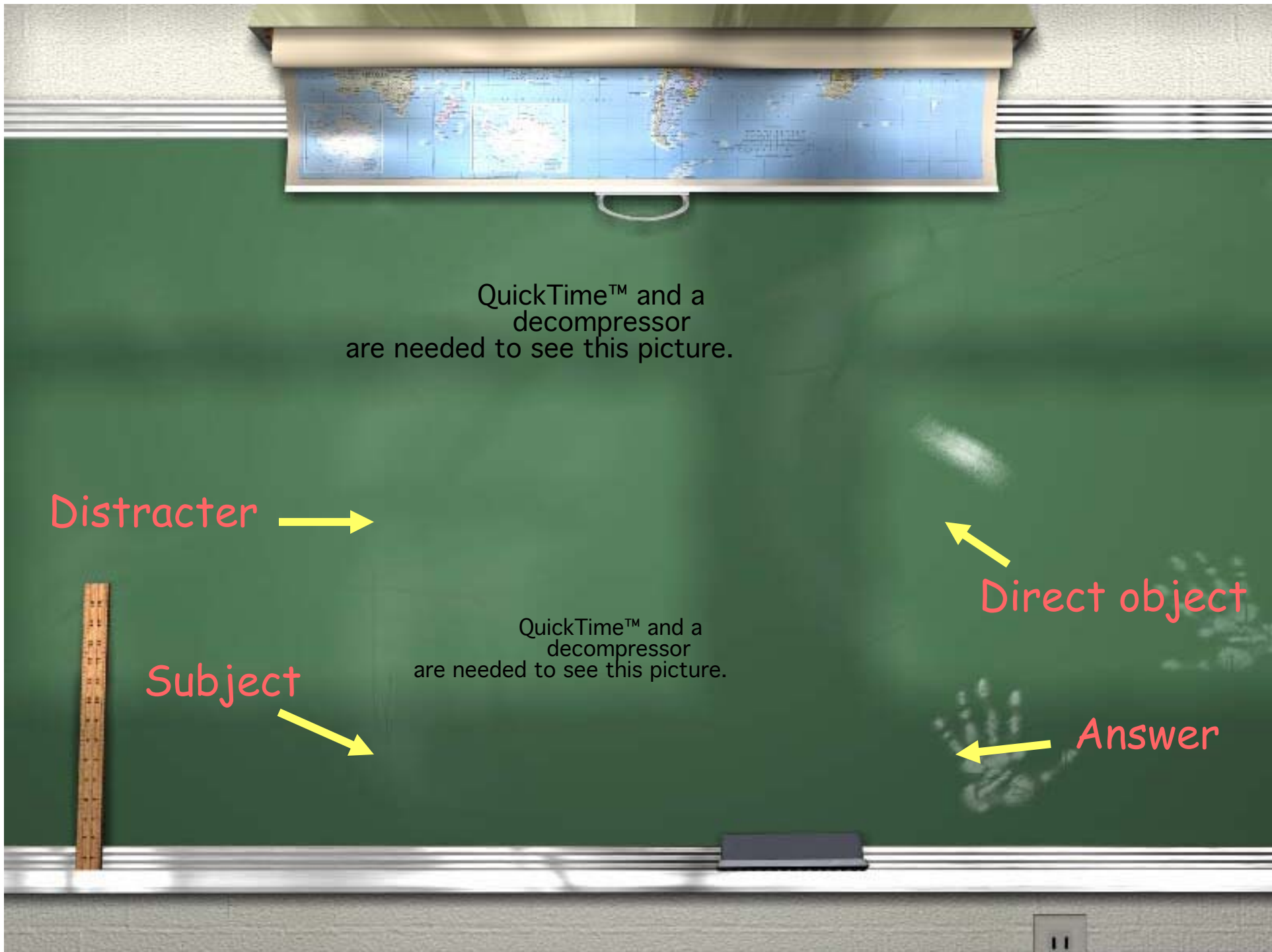
Distracter →

← Direct object

Subject →

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← Answer







Results

- 📖 Eye movements were tracked from the onset of "did."
- 📖 In doing so, the eye movements were tracked during identical phrases for both sentence types.



Results (Continued)

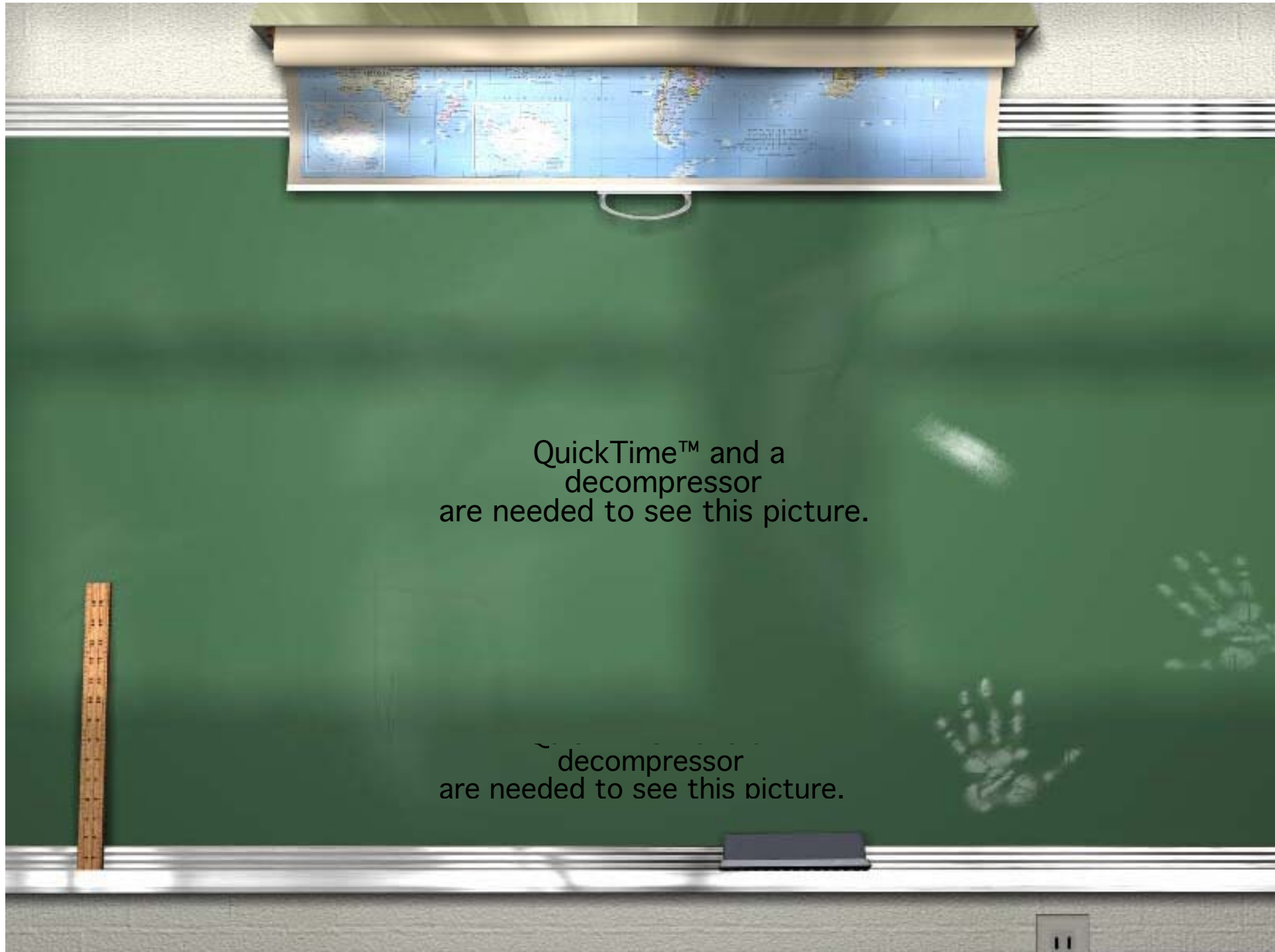
Other		Target
	+	
Subject		Competitor





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Results (Continued)

📖 In the yes/no condition, it was observed that eye movement towards the object occurred around the same time the object was uttered.



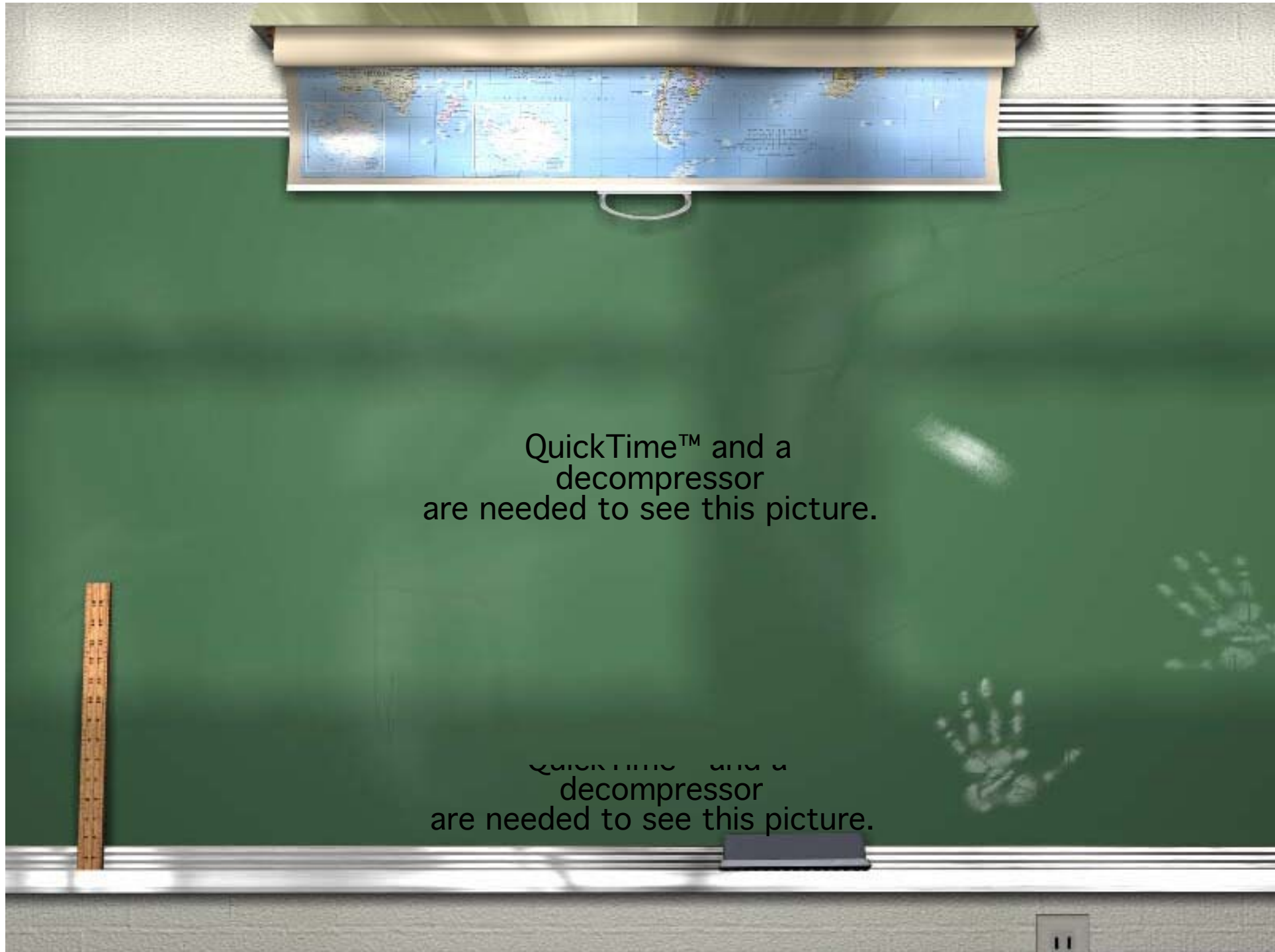
Results (Continued)

- 📖 In the WH- condition the results depict that the processing system is actively engaged in search for the argument associated with the WH-filler.
- 📖 The occurrence of looks to the subject entity does not rise noticeably above the baseline observed at the outset.
- 📖 Looks to the competitor (direct object referent) begin to rise approximately 50 ms after the onset of the verb, and peak at about 150 ms after the offset of the verb.




Results (Continued)

- 📖 During the overt noun phrase region, where it becomes apparent that the competitor cannot be associated with the WH-filler, looks to the competitor drop sharply, and there is a steep rise in looks to the target object.
- 📖 Thus, where the yes/no condition elicits peaks of uniform height for each entity mentioned in the sentence, roughly time locked to the occurrence of each referential expression, the fixation pattern for the WH-condition shows that the occurrence of eye movements for each object is related to the possibility of that object being associated with the WH-filler, rather than simply reflecting the fact that the object was referred to.



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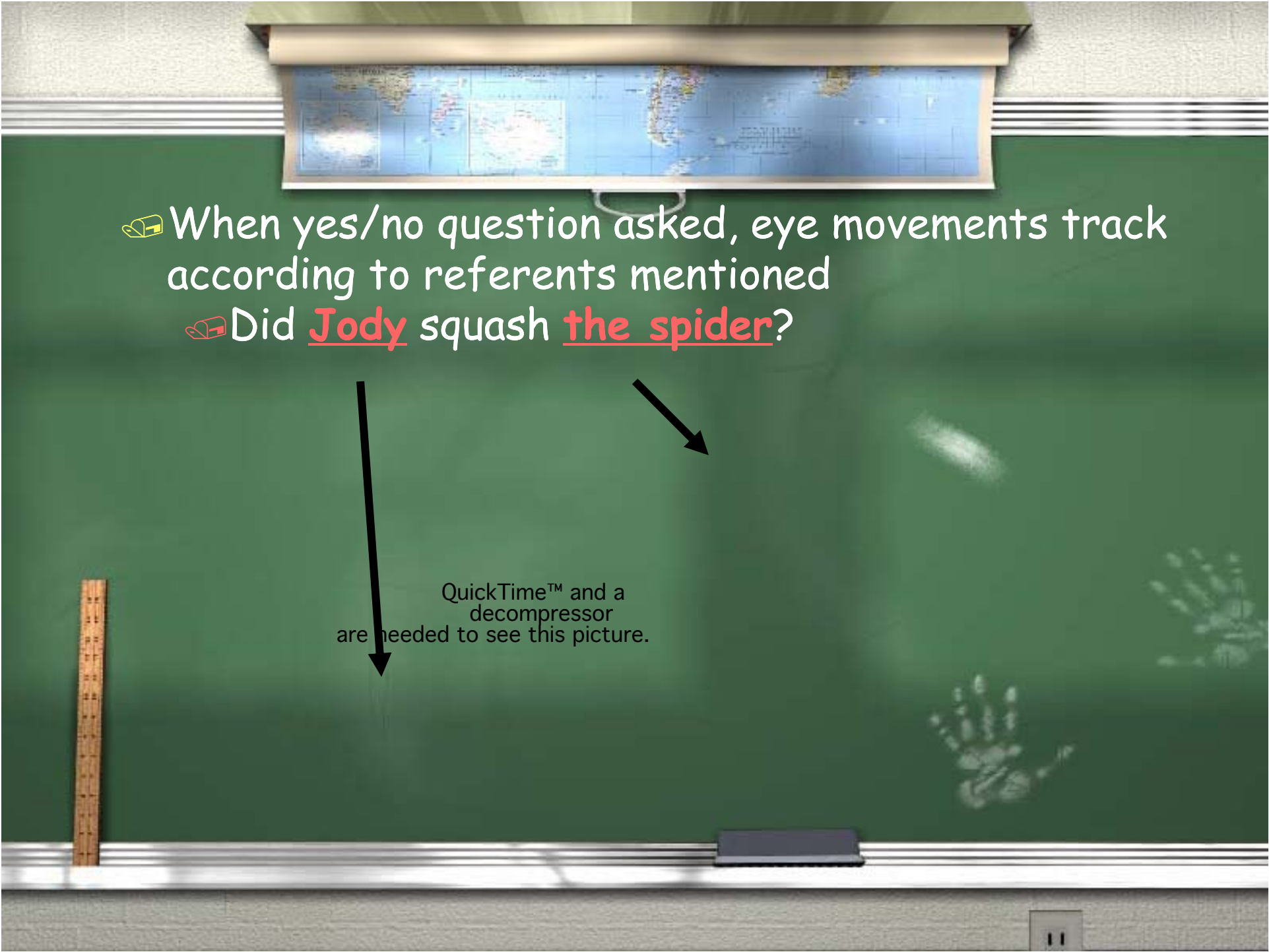


Discussion

- 📖 When WH-questions are asked, anticipatory eye movements go to image corresponding with answer
- 📖 What did Jody squash the spider with?

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📖 When yes/no question asked, eye movements track according to referents mentioned

📖 Did Jody squash the spider?

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Implications

- 📖 Eye movement tracking can be used to study syntactic constraints
- 📖 Discourse is entirely relevant for resolving wh-dependency
- 📖 Verb is especially important
 - 📖 What did John **eat** the bacon with?
📖 TRANSITIVE VERB
 - 📖 Where did John **sleep**?
📖 INTRANSITIVE VERB

Hypothesis: Confirmed!

 Identification of WH-filler in WH-question spurs active search for possible referent to fill the gap!

 What did Jody squash the spider with?

FILLER

QuickTime™ and a decompressor are needed to see this picture.

REFERENT



But what about...

📁 Why don't the eyes start searching for possible gap-fillers upon hearing the **SUBJECT**, the first possible gap/trace location?

📁 **What**₊ did **Jody**₊ squash the spider **with**₊?