Dependency formation during real-time processing: Evidence from webcam-based eye-tracking with subjective and objective adjectives

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We report an eye-gaze-tracking study showing that the idea of certain expressions triggering dependency formation/retrieval of previously-mentioned referents can, at least in certain contexts, be extended to a new domain: adjectives. Our study, testing subjective and objective adjectives, suggests under certain communicative circumstances, even adjectives can trigger looks to previously-mentioned referents. In addition to providing novel evidence that predicates of personal taste can trigger activation of a judge referent, our findings suggest that referential dependencies, broadly construed, may be more widespread than previously thought. Moreover, source-of-information and adjective-type (subjective / objective) effects occur rapidly during comprehension, indicating that these dependency-building are constrained in semantically-principled ways.

1 Introduction

We report a webcam eye-gaze-tracking study showing that the idea of certain linguistic expressions triggering dependency formation/retrieval of previously-mentioned referents can – at least in certain communicative contexts – be extended to a new domain: adjectives.

In a sentence like "*Ben told Jon that the meal was {delicious/vegetarian},*" who thinks that the meal was delicious/vegetarian? You would probably say Ben. In this communicative event, the **source-of-information** (the agent of *told*) is naturally interpreted as being the one who thinks the meal was delicious/vegetarian (see also Kaiser 2020, 2022). This intuition brings up the possibility of **source retrieval effects** during real-time processing; could comprehenders mentally retrieve/reactivate the source-of-information referent (Ben) when they process the embedded clause about the meal being delicious or vegetarian, even though Ben is not explicitly mentioned in it?

Furthermore, it's important to acknowledge that the kind of information communicated by source referents can vary: Saying that a meal is delicious expresses the **source's own subjective taste/opinion,** using a predicate of personal taste (PPT, e.g. Lasersohn 2005). But in saying that a meal is vegetarian, the source is stating a more **objective fact**. (Although one could disagree about what counts as *vegetarian*, this kind of debate involves matters of definition. In contrast, debates about what is *delicious* are matters of subjective taste.)

1.1 Subjective vs. objective

The distinction between subjective adjectives (e.g. *delicious, scary*) and objective adjectives (e.g. *vegetarian, wooden*) is well-established in theoretical semantics and philosophy (e.g. Lasersohn 2005, McNally & Stojanovic 1997, Bylinina 2014 and many, many others). Semanticists have proposed that subjective adjectives have as part of their meaning a special **'judge'** argument/parameter that identifies *the person whose opinion/judgment the adjective expresses* (Ben in (1), e.g. Lasersohn 2005). On this view, subjective adjectives are always linked to a judge, unlike objective adjectives. If this view is on the right track, and if the notion of the judge is at play during real-time processing, it raises the possibility that, when a person encounters a subjective adjective, they mentally retrieve the judge referent linked to that adjective (**judge retrieval effects**).

(1a) Ben: "The meal is delicious"   (1b) Ben: "The meal is delicious_{BEN}" *(delicious to Ben)*

So far, to the best of our knowledge, there have been no systematic experimental investigations regarding the questions of (a) whether source retrieval effects occur during real-time processing and, more specifically relevant for semantic theories of subjective adjectives,

(b) whether judge retrieval effects can be detected during the real-time processing of predicates of personal taste. Our experiment aims to shed light on these issues.

2 Experiment

We **used webcam-based gaze-tracking to** test for evidence of comprehenders retrieving previously-mentioned source referents or judge referents during real-time processing of adjectival expressions that do not explicitly mention the source or the judge.

2.1 Participants, procedure

In a visual-world set-up with auditory stimuli presented alongside images, people (117 native U.S.-English speakers) heard sentences like ex.(2) while seeing displays like Fig.1a, as eye-gaze was tracked (with PCIbex, Zehr & Schwarz 2018, Webgazer.js, Papoutsaki et al. 2016).

2.2 Design

We manipulated adjective type (subjective vs. objective). We also used voice (active vs. passive) to manipulate whether the subject or the object is the source-of-information (2x2, 20 targets), as illustrated in the examples in (2). Participants' eyegaze was tracked during the critical display (Fig.1a), as they heard the critical sentences (ex.2) with a variety of subjective and objective adjectives.

(2) *Example (auditory, presented as eye-gaze was tracked. Items were 50/50 male/female):*
(a) **Ben**$_{SOURCE}$ told **Jon**$_{PERCEIVER}$ that the meal at the event was {delicious/vegetarian}
(b) **Ben**$_{PERCEIVER}$ was told by **Jon**$_{SOURCE}$ that the meal at the event was {delicious/vegetarian}

(3) *Question (written):* Who thought that the meal was {delicious/vegetarian}?

In the critical displays, the L/R positions of the subject and the object, as well as the pairing of names and pictures, were randomized. The central image of the thing being talked about, e.g. *meal*, appeared on the screen when the determiner (*the*) started in the audio and remained on-screen until adjective onset, e.g. during the time when people heard *the meal at the event was*. After this time, the central image disappeared. Thus, image of the thing being talked about, in this example the meal, was not on the screen when participants heard the critical adjective. The appearing-and-disappearing was done in order to attract participants' eyegaze to a central, neutral location, equidistant from the two characters.

Fig.1a. Example of critical display
(The central object was no longer visible when the adjective started, i.e., it was not visible during the time window when people's eyegaze was analyzed)**.**
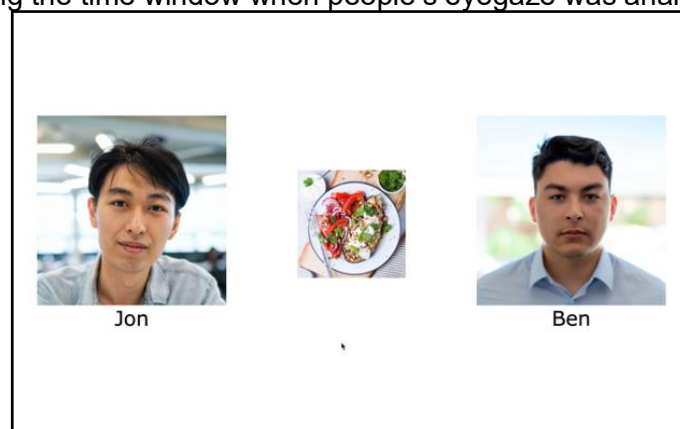
Fig.1b Example 'who thought'- question display. (Participants responded by clicking on the relevant person; the question was shown in writing on the screen)
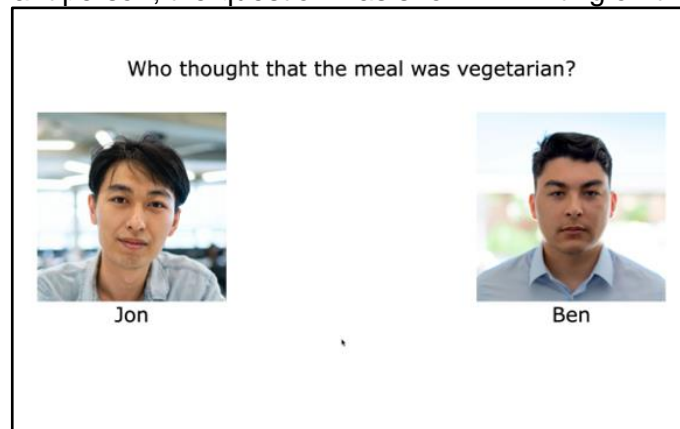
After each trial, people saw a 'who thought' question on the next screen (ex.3, Fig.1b) and clicked the relevant person. These questions ensure participants pay attention to the task, and also render the source-of-information relevant for the task at hand. There were included to ensure that participants do not default to shallow processing. It's important to note that the subjective and objective adjective conditions do not differ in this regard: Both were followed by a 'who thought' question. Thus, any differences between subjective and objective adjectives cannot be attributed to the question, as it is present for both.

As expected based on Kaiser (2020, 2022), participants' click responses to the 'who thought' questions yield the expected source bias, >90% in all conditions. This also serves as a sanity check to confirm participants are paying attention.

2.3 Predictions

First, if **source retrieval effects** occur during online processing of (subjective and objective) adjectives, especially when source retrieval is encouraged by the 'who thought'-questions, both subjective and objective conditions should elicit *more looks to the source than the perceiver* when either a subjective or objective adjective is encountered. Second, if **judge retrieval effects** occur in real-time (if presence of a judge argument triggers retrieval of the judge referent), subjective adjectives should elicit *even more looks to the source* than objective adjectives, since it is only with subjective adjectives that the source is also a judge. (Note that semantically, objective adjectives are analyzed as lacking a judge argument, so semantic theories do not predict objective adjectives to trigger judge retrieval effects.)

3 Results and discussion

Overall, the results provide evidence for both source retrieval and judge retrieval effects, providing novel data for online processing of these kinds of semantic dependencies:

Source-advantage scores (source minus perceiver looks) are plotted in Fig.2. The turquoise lines show source-advantage scores for the subjective adjective conditions, the reddish orange lines show the source-advantage scores for the objective adjective conditions. The y-axis shows *source-advantage scores* (looks to source minus looks to perceiver). The x-axis shows *time*: 0 ms is the onset of the adjective; the source and perceiver images remained on-screen for 3 s after sentence offset (which is when the trial ended).

As can be seen in Fig.2, soon after adjective onset (0ms, dotted line), the source advantage scores increase steeply with both subjective and objective adjectives, in both active and passive conditions (more looks to source than perceiver; positive numbers on the y-axis). This suggests that adjectives can trigger **retrieval of the source**. Given the presence of the 'who thought' questions, we view these source-retrieval effects as expected: They provide a sanity check that participants are attending to the task at hand and show that source activation can occur rapidly after participants hear the relevant adjective.
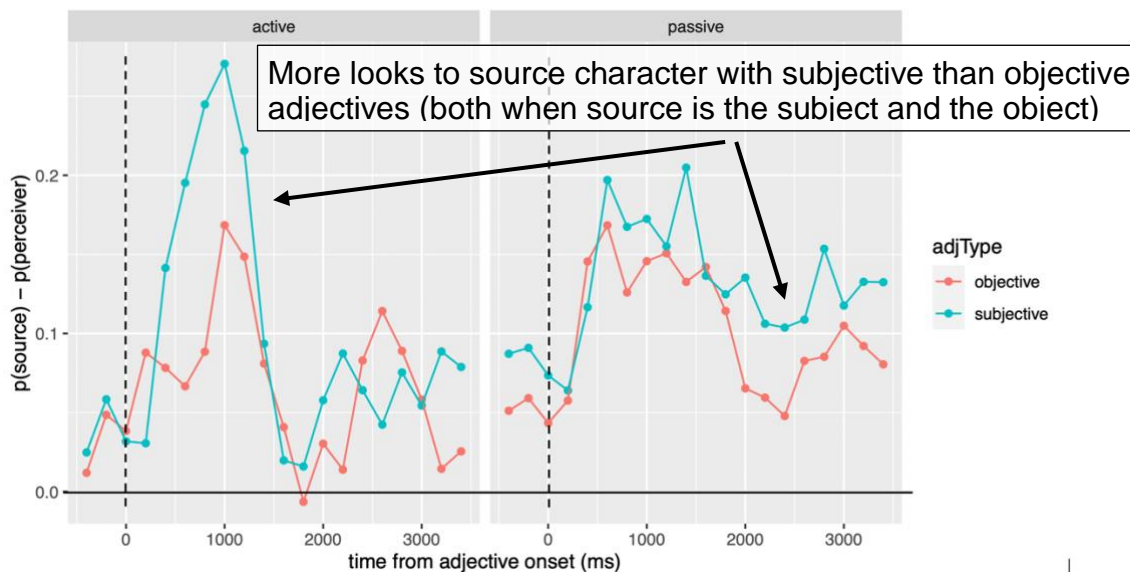
Crucially, we also find an effect of *adjective type*: From adjective onset until the end of the

trial, subjective adjectives trigger more looks to the source character than objective adjectives (t=2.15, p=0.033). This is exactly what is predicted under the view that only subjective adjectives trigger **retrieval of the judge**, due to their special semantic status (judge argument/parameter) that is not shared by objective adjectives.

We also observe a marginal effect of voice (t=1.86, p=0.068), suggesting subjects may be more easily retrieved than objects, a finding that fits with prior work indicating that subjects are more prominent/salient – but no interaction between voice and adjective type (p>.9).

Time permitting, we will also discuss results from another study that did not include 'who thought' questions and thus explores how automatic the source and judge retrieval effects are.

Fig.2: Eye-gaze patterns during the critical sentence
(left panel: active voice; right panel: passive voice)

More looks to source character with subjective than objective adjectives (both when source is the subject and the object)

4 Conclusions

As a whole, our results suggest that in the right context, even adjectives (not typically viewed as 'anaphoric') can trigger looks to previously-mentioned referents. This suggests referential dependencies, very broadly construed, may be more widespread than often thought. Moreover, gaze patterns reveal that effects of source-of-information and adjective type occur rapidly during comprehension, and show that the dependency-building/retrieval processes triggered by adjectives are incrementally constrained in semantically principled ways.

References

Bylinina, L. (2014) *The grammar of standards: Judge-dependence, purpose-relativity, and comparison classes in degree constructions.* LOT Dissertation Series 347. Utrecht: LOT.

Kaiser, E. (2020). Shifty behavior: Investigating predicates of personal taste and perspectival anaphors. In *Semantics and Linguistic Theory 30 (SALT 30),* 821–842. Ithaca, NY: CLC. DOI: https://doi.org/10.3765/salt.v30i0.4850

Kaiser, E., (2022) Do perspective-sensitive anaphors and subjective adjectives exhibit perspectival uniformity? An experimental investigation. *Glossa: a journal of general linguistics* 7(1). doi: https://doi.org/10.16995/glossa.5768

Lasersohn, P. (2005) Context dependence, disagreement, and predicates of personal taste. *Linguistics & Philosophy*, 28, 643-686.

McNally, L. & Stojanovic, I. (2017). Aesthetic adjectives. In James O. Young (ed.), *The Semantics of Aesthetic Judgment,* 17-37. Oxford University Press.

Papoutsaki, A. et al. (2016). *Webgazer: Scalable webcam eye tracking using user interactions.* In Proceedings of the 25th IJCAI, 3839-3845. ACM.

Zehr, J., & Schwarz, F. (2018). *PennController for Internet Based Experiments (IBEX).* https://doi.org/10.17605/OSF.IO/MD832