

Experimental findings for a cross-modal account of dynamic binding in gesture-speech interaction

We report experimental results of two experiments on pronoun and presupposition binding across modalities. We show that (1) ordinary pronouns (in the spoken/written domain) can be dynamically bound to gesturally introduced discourse referents and (2) that presuppositions induced by presupposition triggers in the spoken/written domain (as e.g. *again* or *too*) can be bound and satisfied by propositions that have been introduced in the gestural domain.

Background. Ebert, Ebert & Hörnig (2020) (based on Ebert & Ebert 2014) suggest a formal framework for gesture semantics where certain iconic and pointing co-speech gestures introduce discourse referents that can serve as antecedents in anaphoric reference. Crucially, this necessitates a unidimensional dynamic system that allows for binding effects across dimensions and, in this case, modalities. Based on the dynamic system of Anderbois et al. (2015) that can handle binding effects across dimensions (with appositives introducing non-at-issue material), Ebert, Ebert & Hörnig (2020) suggest that gestures behave and can be handled on a par with appositives since both contribute propositional non-at-issue information by default. Furthermore and crucially, pointing gestures and iconic gestures introduce discourse referents for rigid designators as their core 'lexical' meaning, i.e. when a pointing gesture is performed this triggers the introduction of a discourse referent that is identified with the rigid concept of the gesture referent. This discourse referent (DR) can then be anaphorically picked up by a pronoun in later discourse. Importantly, in this dynamic semantic framework it is predicted that gesturally introduced DRs allow for anaphoric binding across dimensions, i.e. gesturally introduced DRs can be referents of speech pronouns.

While the introduction of DRs by gesture has been claimed and implemented in the formal system of Ebert, Ebert & Hörnig (2020), this has not been experimentally demonstrated. Here we show that dynamic binding across dimensions can be made with respect to both pronouns and presupposition triggers. It can be shown that gesture can introduce discourse referents which can be picked up by a speech pronoun later-on (as illustrated in (1)). Furthermore, gestures can introduce propositional content that can serve as presupposition binders for presupposition triggers in speech (see ex. (2)).

In the constructed example (1a), the pointing co-speech gesture in the form of extending an index-finger towards a piece of cake as opposed to other baked goods is assumed to introduce a DR for the gesture concept for the referent of said piece of cake and allows it to be bound to the pronoun "it" in the hypothetical follow-up (1b). If (1a) had included a hand-over-stomach gesture to indicate having eaten (1c) and crucially not introducing a DR, then presumably "it" in (1b) cannot be bound. In our experiment, we add as a control (1d) as a possible follow-up. While it seems unlikely that (1a) would be followed by (1d) where a confirmatory response is given that ignores the pointing gesture, (1d) could presumably follow (1c) where no specific referent is indicated. Similarly with presupposition triggers like *again*, the jogging gesture in (2a) - adding the propositional content that Paul was jogging (when the speaker met him) - is assumed to be an additional propositional information given in the visual modality via gesture that can serve to satisfy the presupposition that is triggered by *again* in (2b), namely that Paul went jogging before. In the absence of such a gesture the presupposition triggered by *again* would not be satisfied, at least under the assumption that people don't commonly meet while jogging and hence such a proposition cannot be accommodated. Conversely, a follow up like (2d) is presumably odd following a jogging gesture (2a) under the assumption that people do not jog in cafes, but following (2c) ought to be fine assuming people often meet in cafes.

- (1) a. Have you eaten_[pointing to a piece of cake]? (2) a. Yesterday I met Paul_[jogging gesture]
b. It was too sweet for me. b. He went jogging again today.
c. Have you eaten_[placing hand over stomach]? c. Yesterday I met Paul_[pointing backwards]
d. Yeah, a few too many cookies. d. Was it in the café again?

Experiments. Two experiments were designed in German to test the contrasts demonstrated in (1) and (2). Given the similarity in contrasts, albeit distinct form of gesture and anaphora, the designs were complementary and allowed each to be used as filler for the other. Both experiments had two factors each with two levels, yielding two treatment factor levels (felicitous

or infelicitous). Experiment 1 had the levels GESTURE (pointing (1a) or iconic (1c)) and to-be-bound-PRONOUN (present (1b) or absent (1d)), and Experiment 2 the levels: GESTURE (pointing (2c) or iconic (2a)) and to-be-bound-PRESUPPOSITION (present (2b) or absent (2d)). Each participant participated in each of the within subject conditions in (3)-(4). The minimal pairs resembling (1) and (2) were distributed across four groups of participants. We recruited 60 native German speaking participants via Prolific, following the 2x2 repeated-measures design in Brysbaert (2019). In a variation of the covered-box task (cf. Fanslow et al. 2019), the sentence pairs were presented with the context, e.g. (1a) presented in video form, and the follow-up, e.g. (1b), being presented in written form as one choice in a pair of alternatives, the other being 'covered' (lit. "[geschwärzt]" ('redacted')). Participants were instructed that one of the alternatives was a reasonable follow-up to the context and the other wasn't, and they should select whichever they believe to be more reasonable.

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| (3) | a. | GESTURE—pointing + PRONOUN—present | (felicitous, (1a)+(1b)) |
| | b. | GESTURE—pointing + PRONOUN—absent | (infelicitous (1a)+(1d)) |
| | c. | GESTURE—iconic + PRONOUN—present | (infelicitous (1c)+(1b)) |
| | d. | GESTURE—iconic + PRONOUN—absent | (felicitous (1c)+(1d)) |
| (4) | a. | GESTURE—iconic + PRESUPPOSITION—present | (felicitous, (1a)+(1b)) |
| | b. | GESTURE—iconic + PRESUPPOSITION—absent | (infelicitous (1a)+(1d)) |
| | c. | GESTURE—pointing + PRESUPPOSITION—present | (infelicitous (1c)+(1b)) |
| | d. | GESTURE—pointing + PRESUPPOSITION—absent | (felicitous (1c)+(1d)) |

Results. Starting with the pronoun experiment, for items with pointing gestures, follow-ups with pronouns meant to be bound to the gesture DR were largely accepted (3a, n=115), and, surprisingly, those without such a pronoun were accepted nearly as much (3b, n=105). As expected, with iconic gestures, pronouns that could not be bound to a DR were not accepted (3c, n=63) unlike those with other continuations (3d, n=133). In the presupposition experiment, items with iconic gestures plus follow-ups with presuppositions meant to be bound to iconic gestures were largely accepted (4a, n=129), and those with such presuppositions absent less so (4b, n=86). As expected, the same items albeit with pointing gestures plus follow-ups with to-be-bound-presuppositions were generally not accepted (4c, n=72) and those without were accepted (4d, n=138). Responses for each experiment were analyzed with a 2x2 ANOVA with the within-subject factors. A significant interaction of GESTURE+PRONOUN was found ($F(1,716) = 39.54, p < 0.001, \eta^2 = 0.055$) as well as GESTURE+PRESUPPOSITION ($F(1,716) = 75.32, p < 0.001, \eta^2 = 0.105$)—i.e. the null hypothesis of no interaction between gesture and anaphora is unlikely.

Discussion. There are two key contrasts targeted in this study: (i) when pronouns have gesture DR vs. when they have no obvious referent (cf. (1a+1b) vs. (1c+1b) and (ii) when presupposition triggers can be bound to a gesture-introduced proposition vs. when they have no obvious referent (cf. (2a+2b) vs. (2c+2b)). In both contrasts the former has been assumed to be felicitous, and the latter not, and the interaction between gesture and binding found in the experiments support these assumptions. In other words, we have provided experimental findings that substantiate the introspectively supported claims of the need for a cross-modal account of dynamic binding in gesture-speech interaction.

References. Brysbaert, M. 2019 How Many Participants Do We Have to Include in Properly Powered Experiments? A Tutorial of Power Analysis with Reference Tables. *Journal of Cognition*, 2(1): 16, pp. 1–38. DOI: <https://doi.org/10.5334/joc.72> • Anderbois, Scott & Brasoveanu, Adrian & Henderson, Robert. 2013. At-issue proposals and appositive impositions in discourse. *Journal of Semantics* 32(1). 93–138. • Ebert, Cornelia & Ebert, Christian. 2014. Gestures, demonstratives, and the attributive/referential distinction. *Talk at Semantics and Philosophy in Europe 7, Berlin: ZAS*. • Ebert, Christian & Ebert, Cornelia & Hörnig, Robin. 2020. Demonstratives as dimension shifters. In Franke, Michael & Kompa, Nikola & Liu, Mingya & Mueller, Jutta L. & Schwab, Juliane (eds.), *Proceedings of Sinn und Bedeutung 24*. 161–178. • Fanslow, G. & Zimmermann, M. & Philipp, M., (2022) “Accessing the availability of inverse scope in German in the covered box paradigm”, *Glossa: a journal of general linguistics* 7(1).