Speed and accuracy trade-off and their link to neural processes of meaning composition

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When listeners interpret a message, they activate the meaning of words from memory and integrate them into a discourse representation. Numerous studies have tested the predictive role of context in creating meaning, however they have neglected the contribution of adjectives, which strongly affect the computation of meaning in noun phrases (NPs). While some adjectives like "white" specify the denotation set of the noun and are less context-dependent ("white diamond"), other adjectives like "real" must be enriched since their meaning is context-dependent ("real diamond"). So-called "real"-adjectives might be pragmatically over-informative and therefore readers might need to compute a contrast set to arrive at their interpretation. In contrast, "fake"-adjectives negate the meaning of the noun and lead to a contradiction (a fake diamond is a diamond in some respect and not a diamond in another respect) (Kamp & Partee 1995). Previous ERP studies suggest that "fake"-adjectives initiate processes of reanalysis since listeners need to repair the contradiction, which gives rise to a Late Positive Component (Schumacher et al. 2018). In contrast, "real"-adjectives do not cause extra processing costs (Schumacher et al. 2018). The process of composition is also modulated by the adjective's polarity: negative adjectives like "fake" cause higher processing costs, which is reflected in a higher N400 amplitude relative to positive adjectives (Herbert et al., 2008; Schumacher et al., 2018). How do enrichment and polarity differences in adjectives affect compositional processing? We designed a behavioral study to test how enrichment and polarity modulate the speed and accuracy of composition and what neural mechanisms underlie these processes.

We applied the innovative multi-response Speed-Accuracy-Tradeoff (SAT) task (Foraker & McElree 2011) where the speed and accuracy of a behavioral response are measured as a dynamically developing response function at pre-determined response lags, ranging from incomplete (stimulus onset) to complete processing (5s post stimulus). 22 German participants read sentences on a computer screen presented in segments like "The tradesman | buys | a real diamond". Two factors were varied to build the four experimental conditions: *composition* (neutral: "white", "flawed" vs. enriched adjectives: "real", "fake") and *polarity* (positive: "white", "real" vs. negative adjectives: "flawed", "fake"). Adjective type was determined by pretests on polarity. Upon display of the target NP "a real diamond", a series of 15 tones (1 kHz, 50ms duration, 350ms lag latency) was played. Participants indicated by key press if the sentence was meaningful; they could change their response by switching to a different key. The SAT function (Figure 1) was computed based on three parameters: (i) *asymptote*, the response accuracy (d') at each time lag, (ii) *rate*, the response speed at each lag, and (iii) *intercept*, the time point at which accuracy departs from chance. D' was calculated by scaling the four experimental conditions against an implausible condition "The tourist buys a flying diamond".

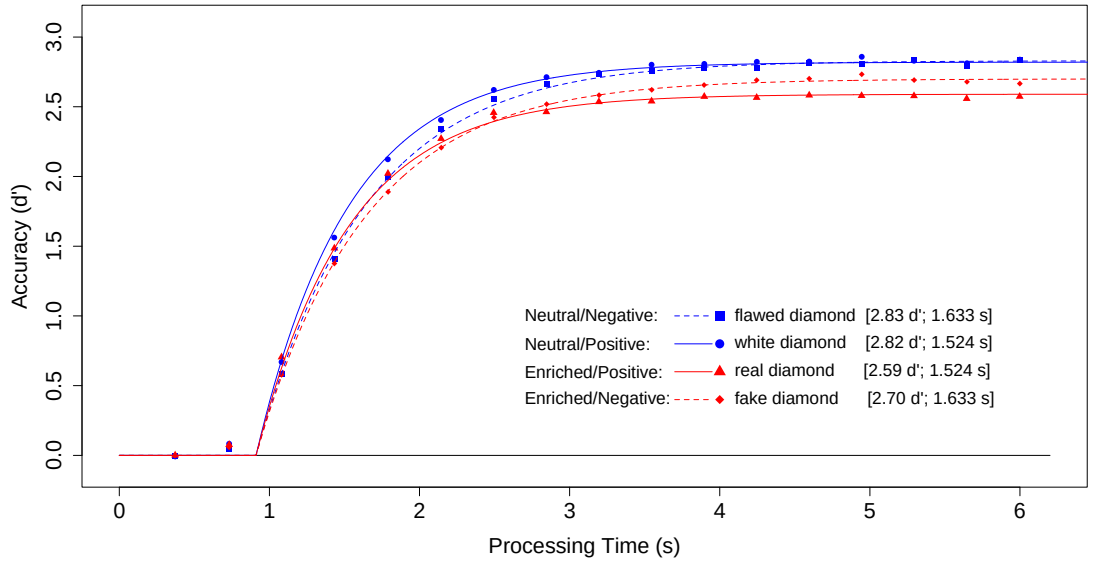
The results show first that accuracy judgments are significantly lower for enriched NPs ("real/fake diamond") vs. neutral NPs ("white/flawed diamond"), with "real"-type adjectives having the lowest asymptote. This suggests that listeners may not always arrive at an enriched representation of "real diamond"-NPs, since their interpretation strongly depends on subjective judgment and sentience, which vary across individuals. In contrast, "fake diamond"-NPs seem to be more easily interpretable, since the contradiction (a fake diamond is a diamond in some respect and not a diamond in another respect) must be resolved during composition. The finding that "fake"-type combinations are more accurate than "real"-type combinations also narrows down the possible explanations of the Late Positivity observed in previous ERP research: it precludes well-formedness as a potential explanation and substantiates the claim that processing costs are associated with reconceptualization. Second, concerning polarity, the SAT data show that it

modulates processing rate: negative adjective-noun combinations (“flawed/fake diamond”) had a lower rate and thus required more processing time than positive adjective-noun combinations (“white/real diamond”). This result is in line with prior ERP studies that found enhanced processing demands for negative information (Herbert et al. 2008; Schumacher et al. 2018). The longer processing time for negative adjectives further supports the claim for a negative bias in information processing (e.g., Alves et al. 2017). These demands are observable independent of the type of composition (neutral vs. enriched). We conclude that processes of enrichment are modulated by the polarity of adjectives and the type of composition. Contradictions arising during compositionality must be resolved and engender processing costs (reflected by Late Positive ERP effects) while combinations with more vague, over-informative adjectives may not be fully interpreted (indicated by lower accuracy).

Example stimuli

(1a) Enriched/Positive: The tradesman buys a real diamond.
(1b) Neutral/Positive: The tradesman buys a white diamond.
(2a) Enriched/Negative: The tradesman buys a fake diamond.
(2b) Neutral/Negative: The tradesman buys a flawed diamond.

Figure 1: SAT function to the four experimental conditions.



References

Alves, H., Koch, A. S., & Unkelbach, C. (2017). Why good is more alike than bad: Processing implications. *Trends in Cognitive Sciences*, *21*, 72–82.

Foraker, S., & McElree, B. (2011). Comprehension of Linguistic Dependencies: Speed-Accuracy Tradeoff Evidence for Direct Access Retrieval From Memory. *Language and Linguistics compass*, *5*(11), 764-783.

Kamp, H., & Partee, B. (1995). Prototype theory and compositionality. *Cognition*, *57*(2), 129-191.

Schumacher, P. B. (2013). When combinatorial processing results in reconceptualization: toward a new approach of compositionality. *Frontiers in Psychology*, *4*, 677.

Schumacher, P. B., Brandt, P., & Weiland-Breckle, H. (2018). Online processing of “real” and “fake”: The cost of being strong. In: Castroviejo, E., McNally, L., & Weidman Sassoon, G. (Eds.) *The Semantics of Gradability, Vagueness, and Scale Structure: Experimental Perspectives*. Heidelberg: Springer.