Investigating the real-time effect of register-situation formality congruence versus verb-argument semantic fit during spoken language comprehension

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Abstract

This visual world eye-tracking pilot study investigates the comprehension of register variants (Stelzen$_{\text{colloquial}}$ vs. Beine$_{\text{standard}}$ transl:.''*legs'*) in a German target sentence when this target sentence (mis)matches the formality of a preceding context sentence, given the object argument either matches or mismatches verb meaning constraints (e.g. *Ich rasiere bald meine Beine/Stelzen/#Autos/#Karren*, transt.: *'I shave my legs$_{standard}$/legs$_{coll}$/#cars$_{standard}$/#cars$_{coll}$'*). The aim of this study is to examine whether register congruence rapidly interacts with verb-argument semantic relations. LME results (n=9) show a main effect of verb-argument congruence but no main effect of formality-register congruence at the region between the verb onset and object-argument onset, indicating that verb-argument relations are computed and used rapidly in online language comprehension. These pilot results suggest that situation formality may indeed modulate verb-argument congruency processing, possibly indicating that standard language processing mechanisms interact closely with register representations.

Keywords: eye-tracking; register; anticipatory processing; visual-world; language comprehension;

Introduction

In sentence processing research, psycholinguists have given considerable attention to understanding the mechanisms of language comprehension and the types of information that comprehenders use during the early stages of parsing (Fodor & Frazier, 1978; Marslen-Wilson, 1973). Early models of auditory word recognition disagree on the role played by the context and how it influences the processing of upcoming words.

While some structural accounts believe that language processing occurs in two stages, with word recognition occurring in a strictly bottom-up fashion and only later context information being integrated (Fodor & Frazier, 1978), interactive accounts (e.g., constraint-based theories) emphasize that syntactic processing has similar properties to lexical processing and operates by activating all available information sources during word processing (MacDonald, Pearlmutter, & Seidenberg, 1994; Marslen-Wilson, 1973). This suggests a rapid feedback from higher-order structures and world knowledge on initial syntactic and semantic processes.

More recent accounts of sentence processing agree that during sentence comprehension, the parser incrementally combines lexical, morphosyntactic, semantic and contextual information to build a representation of the incoming signal (but see de Almeida, Nardo, Antal, & von Grünau, 2019). As studies on native language processing have shown, the parser does not just passively integrate information into the preceding structure as it is encountered (Fodor & Frazier, 1978) but also actively generates expectations on the basis of preceding information (Altmann & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003; DeLong, Urbach, & Kutas, 2005).

Evidence for pre-activation of syntactic information, semantic plausibility and referential context has been found to rapidly constrain the parsers' online interpretation of the incoming input (Altmann & Kamide, 1999; Chambers, Tanenhaus, & Magnuson, 2004; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). However, consider the following situation: You are attending a graduation ceremony and you wish to compliment the cocktail dress of the Headmaster's spouse by saying: "You are wearing some fabulous rags, Mrs. Parker". There would be considerable confusion on Mrs. Parker's side as to how exactly parse this: Is this a crude joke? An insult? Or simply a failed attempt at a compliment? Mrs. Parker might be startled by the word choice, but probably less so if it was uttered in a more casual situation, say, at a bar on a Friday evening after work. This scenario highlights how rich contexts, including situation-formality, can impact lexical selection and support how people build expectations on the basis of their previous experiences (Kuperberg

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& Jaeger, 2016). Yet, the aforementioned accounts do not include explicit representations on the socially-interpreted context and much uncertainty still exists about how linguistic and non-linguistic information interact in real time (Huettig, Rommers, & Meyer, 2011).

The extent to which socially-interpreted information impacts language comprehension is somewhat unclear; however, recent empirical research has found that some factors influencing expectations include the comprehender's literacy levels (Mishra, Pandey, & Huettig, 2012), assumptions and stereotypical knowledge about the speaker (Van Berkum, 2008), hearing conflicting statements that are inconsistent with the comprehender's own moral values (Van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009), world knowledge (Hagoort, Hald, Bastiaansen, & Petersson, 2004) and speaker's emotional facial expressions (Carminati & Knoeferle, 2013). Thus, the comprehender's characteristics and experience, as well as their socially grounded interpretation of the context, have an impact on real-time language comprehension (Münster & Knoeferle, 2018)

While these studies capture speaker and comprehender characteristics in language processing, they generally accommodate language comprehension "on average" (i.e., standard language). On the other hand, variation on comprehender's real-time language comprehension as a function of situational-functional constraints such as *formality* has received less attention.

In contrast to the above standard-language context effects (revealed via temporally-sensitive measures like eye-tracking), the effects of (socio-)linguistic variability have been examined using mostly offline measures. We know that language users alter their spoken and written production in systematic ways depending on the situation of use (*register*) and speakers normally have no problem recognizing that they need to communicate in accordance with what is happening and with whom they are interacting (recall Mrs. Parker's confusion after hearing an unexpected word uttered at a formal event). Research on this subject has been mostly restricted to understanding the full scope of register analysis (classification vs multidimensional approaches of register variation, see Biber & Conrad, 2009) and the mediating factors affecting register competence, such as social class (Kroch, 1978; Labov, 2009), gender (Labov, 2009) and literacy (Ravid & Tolchinsky, 2002). To our knowledge, however, no previous study has examined the close temporal coordination between language comprehension and the processing of the socially-interpreted context.

The current study

Our research seeks to expand the current literature on social-context effects in language comprehension, as our goal is to examine how language comprehension unfolds in real time when differences in register are conveyed by situation-formality. In particular, we want to test *to what extent* and *how quickly* language users process words that mismatch in register with a context sentence that either sets up a formal or informal situation. Moreover, we test if such effects resemble those of semantic incongruence. This comparison will help us understand whether the processing mechanisms implicated in understanding register variants differ from verb-argument mismatch effects. Our results would help us assess whether or not we can assume a single conceptual store and closely-linked mental representation that encompasses register information, or whether verb-argument relations and register representations are stored in distinct lexical assemblies and processed differently. In particular, we investigate whether (1) formality conveyed by a linguistic context can rapidly affect the visual interrogation of objects and associated comprehension processes; (2) we see rapid effects of the congruence of verb meaning with its argument; and whether (3) register-situation formality congruence interacts with verb-argument semantic relations.

Method

Participants: Nine young adults participated in the pilot experiment (age range: 18-31). Participants were monolingual native speakers of German with normal or corrected vision and hearing. Power analysis on the pilot data will be run to determine the number of participants and items for high-powered studies needed in the main experiment (min. power: d=0.8) (Brysbaert & Stevens, 2018).

Stimuli and design: Using the visual-world eye-tracking paradigm (see Huettig et al., 2011 for an extensive review on the visual-world paradigm), we examine the comprehension of lexical variants (*Stelzen*, colloquial German for '*legs'* vs. *Beine,* transl.: stand. '*legs*') in a (mis)matching context. Table 1 presents each condition blocked by situation-formality.

The stimuli were pseudorandomized and divided into eight lists. Each list contained 34 experimental items interspersed with 64 filler items, with at least one filler between two critical items, for a total of 98 items per list[1]. Lists were blocked by formality; half of the items were introduced by a context sentence conveying a formal situation, and the other half by a context sentence conveying an informal situation (balanced across lists). The level of formality (formal vs. informal) served as a counterbalancing factor as it ensured that the low- and high-register target sentences appeared in both register matching and mismatching conditions, depending on the formality (informal vs. formal) of the context sentence. Prior to the eye-tracking pilot experiment, the appropriateness of the visual and linguistic material was pretested (e.g., status of words and sentences as standard/formal versus colloquial/informal) via eight online pretests (n=324) on the context, target sentences, target words and picture photographs. Items that were persistently problematic (less likely to be

[1]Note: For the main experiment, we removed two additional critical items, bringing the total number to 32. This was done in order to ensure that each condition was distributed evenly throughout the eight lists.

Table 1: Experimental conditions. Transl.: *Wealthily situated Paula announces/ Massively well-off Paula rambles: I'll shave my legs$_{standard}$ /legs$_{colloquial}$ /#cars$_{standard}$ /#cars$_{colloquial}$ soon.*

	Condition	Context sentence	Target sentence
Block 1		*Formal situation*	
1a	Full match	Vermögend situiert avisiert Paula:	Ich rasiere bald$_{verb+adv}$ meine Beine$_{objectnoun}$
1b	Verb-argument mismatch	Vermögend situiert avisiert Paula:	*Ich rasiere bald$_{verb+adv}$ meine Autos$_{objectnoun}$
2a	Register mismatch	Vermögend situiert avisiert Paula:	Ich rasiere bald$_{verb+adv}$ meine Stelzen$_{objectnoun}$
2b	Double mismatch	Vermögend situiert avisiert Paula:	*Ich rasiere bald$_{verb+adv}$ meine Karren$_{objectnoun}$
Block 2		*Informal situation*	
1a	Full match	Massig betucht schwafelt Paula:	Ich rasiere bald$_{verb+adv}$ meine Stelzen$_{objectnoun}$
1b	Verb-argument mismatch	Massig betucht schwafelt Paula:	*Ich rasiere bald$_{verb+adv}$ meine Karren$_{objectnoun}$
2a	Register mismatch	Massig betucht schwafelt Paula:	Ich rasiere bald$_{verb+adv}$ meine Beine$_{objectnoun}$
2b	Double mismatch	Massig betucht schwafelt Paula:	*Ich rasiere bald$_{verb+adv}$ meine Autos$_{objectnoun}$

linked with a formal or informal register) were eventually removed from the pilot experiment.

Figure 1: Example of a visual display. Each scene depicted 4 objects, two of which were high register pictures, and the other two low register pictures.

Procedure: Participants' eye movements were monitored with an Eyelink-Portable Duo eye-tracker with a sampling at 500Hz which was set up for monocular tracking of the right eye. Stimulus presentation was programmed using the Experiment Builder software with a 9-point sequence calibration procedure which aims for visual acuity below 0.5 degrees. Calibration and validation were performed before the practice session as well as before the main experiment and before each block. The auditory stimuli were presented through two loudspeakers, one on either side of the display screen. The visual scenes were presented on a monitor at a resolution of 1920 x 1080px.

Each trial began with a drift check, which allowed for automatic drift corrections. Participants then saw a visual display (Figure 1) followed by a delayed presentation of the context sentence for approximately 1500 ms from the onset of the visual display. Each trial started with a context sentence (e.g., *Vermögend situiert avisiert Paula:*) followed by a target sentence (e.g., *Ich rasiere bald meine Beine / Stelzen / Autos / Karren*). The objects remained on the screen until 2000ms after the sentence offset.

Each participant completed three practice trials, followed by the main experiment. The experiment was divided into three blocks (a formal block, an informal block and an additional filler block with formality-neutral sentences). To dampen order effects, the presentation order of each block was counterbalanced across lists. If the trial was a filler, a comprehension question with a yes/no response relating to the preceding sentence was shown 75% of the time. This was necessary to check whether or not participants were paying attention to the sentences. Once the answer was computed, a new trial started. The eye-tracking experiment took approximately 30 minutes.

Analysis

To capture early situation-formality effects, we run an exploratory analysis at the context sentence (context-region), before the target sentence was introduced (see Table 1 for reference). This region started from the adverb offset (e.g., formal: *vermögend situiert*, informal: *massig betucht*) until the NP1 offset (e.g., *Paula*).

Our main analysis was time locked to the target sentence and further split into two regions. The first region (verb-region) started from the verb onset until the determiner offset. (e.g., from *binde*$_{verb}$, to *meine*$_{det.}$) The verb region is the first time window for which the entity (or entities) that could fill the thematic role associated with the theme of the verb can be anticipated. The second region (object-noun region) was from the onset/offset of the object noun (e.g., *Beine*$_{stand}$, 'legs' / *Stelzen*$_{coll}$ 'legs' / *Autos*$_{stand}$ 'cars' / *Karren*$_{coll}$ 'cars').

Linear mixed-effects models were fitted to each predefined region. For the context region, we computed the mean log-ratio indicating a fixation bias towards high over low register objects using the formula `log((high.register+.5)/(low.register+.5))`. A positive log-ratio value indexes the bias of fixating the high register over the low register pictures, and a negative value indicates that there were more fixations to the low register rather than the high register pictures. A value of zero indicates that there was no fixation bias for either. At the verb region, we computed the empirical-logit transformed fixation proportions to the verb-argument (mis)matching and formality-register (mis)matching objects based on the expec-

tations given by the context sentence and the verb constraints. In addition, mean log-ratios to the verb-argument matching objects over the mismatching objects were computed in this region. At the object-noun region, we calculated the empirical-logic transformed fixation proportions to the object noun referent for each condition. To test register competition effects, we additionally computed a log-ratio of fixation proportions to the target vs. competitor register on each condition (full match: $Beine_{stand.}$ *vs* $Stelzen_{coll.}$; Register mismatch: $Stelzen_{coll.}$ *vs* $Beine_{stand.}$; Verb-argument mismatch: $Autos_{stand.}$ *vs* $Karren_{coll.}$; Double mismatch: $Karren_{coll.}$ *vs* $Autos_{stand.}$).

For each model at the verb and object noun region, we initially created a model that tested formality-register congruence (matching/mismatching) and verb-argument congruence (matching/mismatching) as fixed factors, as well as an interaction of formality-register and verb-argument congruence, including by-participant and by-item random intercepts and by-participant and by-item random slopes for formality-register and verb-argument congruence. When this model did not converge, we simplified the model by removing the variable(s) that accounted for the least variance.

Significance values were obtained using the R package *lmerTest* following Luke (2017) and were reported by convention of $|t| > 2$ ($p < 0.05$). The fixations on critical objects were coded for each 50 ms bin relative to the adverb offset (context-region), verb onset (verb-region) and object noun onset (object-region). Deviation coding (-0.5 vs. 0.5) was used to enable direct comparison between the two levels of each fixed effect. For the analysis, each time window was shifted forward by 200 ms, to account for initial saccadic planning and execution (Saslow, 1967).

Hypotheses

If participants are sensitive to register information at the context region, we would expect them to look at the formality-register matching objects in the standard variation, namely, (*Beine*) and (*Autos*), rather than the formality-register mismatching objects (*Stelzen*) and (*Karren*). On the contrary, we would not expect any preferential looks toward any object if formality or register do not affect linguistic processing.

At the verb region, we examined participant's visual anticipation to each object when it (mis)matched the verb meaning constraints (e.g., *Ich rasiere bald meine Beine*, lit.trans. *I soon shave my legs* versus *Ich verschrotte bald meine Beine*, lit.trans. *I soon scrap my legs*). If participants are sensitive to formality-register and verb-argument congruence we expect more looks to the formality-register and verb-argument matching object (*Beine*) when it matches the formality and verb-meaning constraints than when it mismatches either or both. If they are sensitive to verb-argument congruence irrespective of formality-register congruence, we predict greater fixations to the referent of *Beine* (*'legs'*) in the verb-argument congruent condition irrespective of whether it matches or mismatches the formality of the context sentence.

At the object noun, if formality-register congruence rapidly modulates visual attention to the objects and associated comprehension, we expect more looks to the object referent in the formality-register matching (*Full match; Verb-Argument (VA) mismatch*) than mismatching conditions (see Table 1). If fixations to the object referent are modulated by verb-argument congruence (main effect of verb-argument congruence) independent of formality-register congruence, we should likewise see more looks to the object referent in the verb-argument matching than mismatching conditions (*Full match; Register mismatch*). Moreover, if formality-register and verb-argument congruence interact during the object noun region, how verb-argument congruence is processed may depend on formality-register congruence. The latter might indicate that standard language processing mechanisms are in close interaction with register representations, supporting the interpretation of a single conceptual store and set of mechanisms.

Results

Context sentence region: Figure 2 shows fixation proportions to the high (formal) vs low (informal) register objects split by context-formality. Analysis of the log-ratios did not show a significant effect of formality (β=.36, *SE*=.28, *t*=1.28), suggesting that the fixation bias towards the high and low register objects was similar in the formal and informal context sentence (see Figure 2).

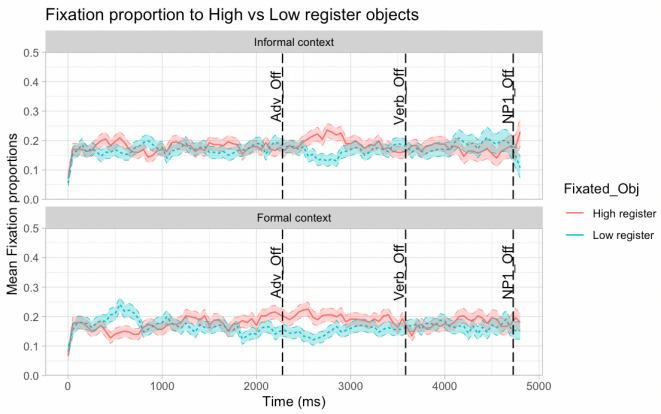

Figure 2: Context region. Fixation proportions to the objects that are stereotypically associated with a formal register (red line) vs informal register (blue line) across two-levels of formality. *Note.* Adv Off = Adverb offset; Verb Off = Verb offset; NP1 Off = NP1 offset; shaded areas = 95% CI.

Verb region: Figure 3 shows the mean fixation proportion to the verb-argument and register matching object (target) across different formality-register and verb-argument (mis)matching conditions. Log ratio analysis revealed a significant fixation bias towards the verb-argument matching over mismatching objects (β=.74, *SE*=.18, *t*=4.07). The full model with verb-argument and formality-register congruence as fixed and random effects did not yield a main effect of

verb-argument congruence. To explore why the two analyses showed inconsistent effects, we removed formality-register congruence from the by-subject random slope, resulting in a main effect of verb-argument congruence that mirrored the log-ratio analysis result. Thus, formality-register congruence in the verb region appears to capture much of the variance, which presumably covers the main effect of verb-argument congruence when included in the model as a by-participant random slope. Moreover, verb-argument congruence interacted with formality-register congruence, with larger fixation proportions to the target object (β=-.28, *SE*=.04, *t*=-6.70) when it matched the semantic constraints of the verb and mismatched the formality of the context sentence.

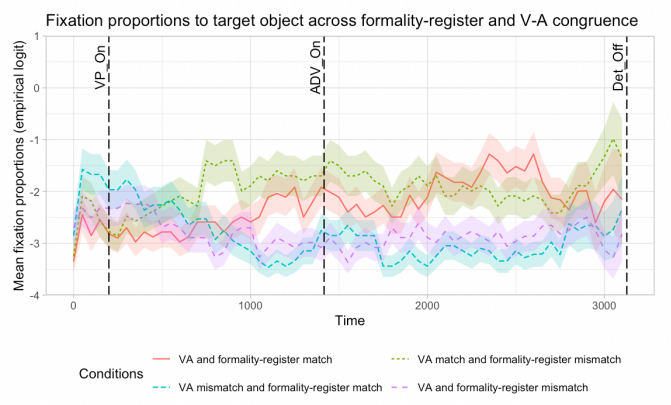

Figure 3: Verb region. Fixation proportions to the formality-register and verb-argument matching object (target) across each formality-register and verb (mis)matching condition. Participants looked more at the target object when it matched the verb-meaning constrains (green and red lines) than when it did not (purple and blue lines). *Note.* VP On = Verb onset; Adv On= Adverb onset; Det Off = Determiner offset; shaded areas = 95% CI.

Object noun region: Figure 4 plots the mean fixation probabilities for the object referent in each experimental condition. In the object noun region, the model testing the effect of formality-register congruence and verb-argument congruence did not show a significant main effect for either (formality-register congruence: β=-.34, *SE*=.24, *t*=.16; verb-argument congruence: β=.26, *SE*=.24, *t*=.29).

As observed in Figure 4, analysis on this region revealed an interaction between verb-argument and formality-register congruence (β=-.08, *SE*=.03, *t*=-2.71). This effect was observed when the object referent appeared in a verb-argument matching and formality-register mismatching condition compared to when the object referent appeared in a verb-argument and formality-register mismatching condition, indicating that participants fixated more on the object referent when it matched the verb meaning constrains but mismatched in the formality of the context sentence (e.g., *Stelzen*$_{\text{coll.}}$ lit.trans: *legs*$_{\text{coll.}}$), than when it mismatched both (e.g., *Karren*$_{\text{coll.}}$ lit.trans: *cars*$_{\text{coll.}}$). Regarding register competition effects, the mean log-ratio analysis did not show a significant effect of register (β=.03, *SE*=.12, *t*=0.08), suggesting that participants were not more likely to look at the picture referent for the mentioned object over the register competitor.

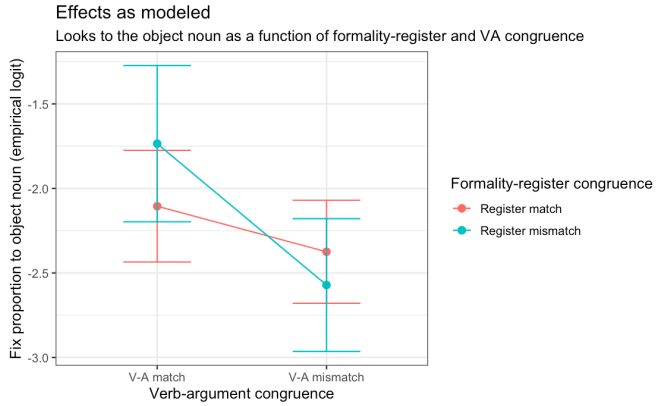

Figure 4: Object region. Mean fixation proportions (empirical logit) to the object referent as a function of verb-argument (V-A) and formality-register congruence. Participants looked more at the object noun referent in the V-A matching and formality-register mismatching condition than in the verb-argument and formality-register mismatching condition.

Discussion

In this pilot study, we investigated whether (1) formality conveyed by a linguistic context can rapidly affect the visual inspection of objects and associated comprehension processes; (2) we see rapid effects of semantic congruence between the verb and object argument and if (3) register-situation formality congruence interacts with verb-argument semantic relations.

Although we have only tested a small sample (so far), our results on the effects of register-situation formality during the processing of the context sentence may provide a first indication that richer contexts such as situation-formality are difficult to access in real-time for prediction. However, our findings are compatible findings on the visual world eye-tracking paradigm, which show higher fixation proportions to the referent that satisfies the semantic constraints of the verbs (Altmann & Kamide, 1999). Upon hearing the verb, more fixations seem to be directed to the referents that were semantically congruous with verb meaning independent of formality-register congruence, possibly indicating that semantic associations are a stronger predictive cue than register-congruence information. This effect, however, was only observed in the log-ratio analysis and in the full model after removing formality-register congruence as a random slope. More participants are needed to examine whether the lack of significant effects with formality-register congruence as a random slope could be due to the pilot being underpow-

ered. Moreover, at the object-noun region, there were more fixation proportions to the object referents appearing in the verb-argument matching than mismatching conditions.

Lastly, our analysis also revealed an interaction of register situation-formality and verb-argument congruency in the verb-region and object region. Given that our findings hold up in the full study with 32 participants, these findings taken together imply that situation-formality might indeed modulate the processing of verb-argument congruence, possibly indicating that standard language processing mechanisms are in close interaction with register representations. When comparing fixation proportions to the object referent at the object-noun region, our results show that fixation proportions to the object referent are higher for verb-argument matching conditions and greater when the object mismatched in formality-register. This numeric trend goes against our predicted direction (i.e., higher fixation proportion to objects when they matched the formality of the context sentence). While the social context did not reliably affect looks in the predicted direction, these findings are taken to suggest that semantically-related representations affected the probability of fixating on the target object. Presumably, our results shed light on how comprehenders build expectations based on their knowledge of the wider discourse, their own lexical biases as well as their knowledge about the world to predict upcoming words in an unfolding utterance.

Investigating the real-time effect of register-situation formality could help us refine current accounts of language processing to better understand how we integrate social-context effects into the unfolding interpretation of a sentence. That said, the main experiment with a larger sample size is underway and follow-up studies using EEG will explore whether there may be costs associated to encountering unexpected information (N400 effect, see Van Berkum, 2008 for a related study) at the object noun region, when this information mismatches the verb-argument and register-situation formality related expectations.

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