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The Effect of Discourse Context on Online Sentence Processing

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Abstract

Information structure describes how the information is packaged within a discourse to optimize information transfer. We addressed the question if and how a discourse context modulates the online processing of German declaratives. Native speakers of German read fictitious stories that depicted a simple action scene of two characters while we recorded event-related brain potentials (ERPs). Two types of discourse contexts (topic vs. neutral) were compared with regard to the processing of declarative canonical subject-before-object (SO) and non-canonical object-before-subject (OS) sentences. The preceding topic context only modulated the processing of OS sentences. This was indicated by a less pronounced positivity around 500 to 900 ms for the topic compared to the neutral context. As supported by previous research we argue that this context-induced effect in the processing of non-canonical sentences reflects reduced processing costs for the integration of the discourse relevant topic information into the current discourse model.

Keywords: information structure; discourse context integration; topic; sentence processing; word order variation; ERP; P600

Introduction

In our everyday-life communicative utterances are typically linked to the discourse environment of the interlocutors. Previous evidence suggests that contextual information (e.g., from prior discourse) plays a crucial role in sentence comprehension. Information structure is concerned with the question how the information is structured and packaged within a discourse to optimize information transfer (e.g., Chafe, 1976). If and to which degree information structure interacts with syntax and other linguistic domains is still under debate (e.g., Büring, 2007; Fanselow & Lenertová, 2011)

Information structure research in the domain of syntax (and in particular word order) addressed the question how word order variation might be affected by information structural concepts such as topic-comment, focus-background, or the given-new distinction (Lambrecht, 1994; Rizzi, 1997). Topic (also aboutness topic) refers to the entity the sentence is about (Gundel, 1988; Reinhart, 1981). Mostly topics are introduced by the previous discourse (e.g., Skopeteas et al., 2006). It has been proposed that topics, independent of their grammatical function, are preferably placed in a specific syntactic position which is sentence-initial (i.e., prefield) for German main clauses (Büring, 1999; Rosengren, 1993).

German is a language with relatively flexible word order because morphological features such as case marking allow the reordering of constituents without changing the grammatical function of the constituents.[1] Therefore, German is ideal to study the effect of information structure on word order. In German, subject-before-object (SO) is the canonical word order which is preferred to object-before-subject (OS) sentences (e.g., Gorrell, 2000). If presented without a felicitous discourse context, OS sentences lead to lower acceptability ratings and longer latencies in reading (e.g., Meng, Bader & Bayer, 1999) compared to SO sentences. It has been pointed out that the processing of OS sentences might require contextual licensing (e.g., Bornkessel & Schlesewsky, 2006; Höhle, 1982; Hörnig, Weskott, Kliegl & Fanselow, 2006). Specific contextual information (e.g., object given in prior discourse or object in contrastive whole-part relation to a referent in the context) has been found to improve acceptability ratings and shorten reading times of OS sentences (Meng et al., 1999; Weskott, Hörnig & Fanselow, 2009).

However, acceptability ratings and reading times do not tell us which underlying mechanisms of information structure help to optimize information transfer. Event-related potentials (ERPs) are a promising tool to shed more light on the effect of context on sentence processing (e.g., Van Berkum, 2008). For instance, a context-induced N400 effect for inferable vs. given referential expressions across different sentence positions was attributed to discourse-linking processes (Schumacher & Hung, 2012). A late positivity was associated with processing costs induced by updating the current discourse model and the integration of a new referent into discourse (e.g., Burkhart, 2007; Schumacher & Hung, 2012).

Although many studies tested the online processing of OS sentences in isolation and indicated higher processing difficulty compared to SO (Matzke, Mai, Nager, Rüsseler &

[1] The subject is marked by nominative case whereas the object is marked by accusative case at the determiner and noun, respectively. For masculine but not for feminine nouns, the subject and object status can be unambiguously differentiated via case marking (e.g., der Uhu/the$_{[NOM]}$ owl$_{[NOM]}$ (subject) vs. den Uhu/the$_{[ACC]}$ owl$_{[ACC]}$ (object)).

Münte, 2002; Rösler, Pechmann, Streb, Röder & Hennighausen, 1998), previous behavioral and neurophysiological research has shown that contextual information (e.g., focus, givenness) is of central relevance for the processing of canonical and non-canonical sentences (e.g., Bornkessel, Schlesewsky & Friederici, 2003; Schumacher & Hung, 2012). However, it remains unclear if a topic introduced by the discourse context reveals an immediate processing advantage at the sentence-initial position of OS sentences.

The present ERP experiment aims to characterize the differential effect of a preceding topic context on the processing of German declaratives. We compare if and how a preceding topic context which assigns topic status to one of two characters of a scene modulates the processing of the following topic-first OS or SO sentence. The effect of the topic context is compared to a neutral context which induces a wide scope on the scene and serves as a baseline. Based on previous research we expect that the processing of the canonical SO sentences is not modulated by the preceding context information. Instead, for the non-canonical OS sentences we predict a processing advantage if they are preceded by a topic context as compared to a neutral context such that the topic status of the sentence-initial object leads to a less effortful linking and integration of information into the current discourse model. This type of processing advantage might be reflected in a reduced P600 component (e.g., Burkhart, 2007).

Methods and Material

Participants

Twenty-one native speakers of German participated in the present ERP experiment. All participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). None of them reported any neurological disorder. All had normal or corrected-to-normal vision. The participants were reimbursed or received course credits for participation. Due to a low behavioral accuracy (< 60 % correct) in the sentence-picture-verification task (see Procedure) the data of two participants were excluded from further analysis. Thus the ERP analysis is based on 19 participants (11 female, mean age 25 years, age range 19-30 years).

Material

Each trial consisted of a description of a fictitious scene with two animals. Each animal was both a plausible agent and a plausible patient of the depicted action. Each trial comprised three parts starting with a lead-in context (1) in which both animals were introduced plus the instrument of the action that is going to be performed (see (1) in Table 1 for an example). Thus both referents were discourse-given in terms of information structure (Prince, 1981). The action was inferable from the instrument mentioned. The lead-in context was followed by one of two context types presented in form of a context question (2) that was either neutral indicating a wide scope on the scene (*`What exactly is going on?`)* or assigned topic status to one of the two animals (*`What about the owl?`).* The context question was followed by the target sentence (3) in SO or OS order revealing the answer to the context question.

Participants were presented with 80 SO and 80 OS target sentences that were either preceded by a neutral context or a topic context (i.e., 40 trials per condition). The different scenes for the 160 trials were created by combining two of the 40 nouns (animals, monomorphemic, masculine, 1-syllabic (n = 18) to 2-syllabic (n = 22)) with one of 10 action verbs (monomorphemic, transitive, 2-syllabic) with its corresponding instrument. The nouns and verbs were controlled for written lemma frequency, type frequency and normalized $\log_{10}$ familiarity values (dlex database: Heister et al., 2011). To avoid lexical-semantic effects of certain nouns in the first and second noun phrase position of the target sentence, each noun occurred once in each of the four conditions at both sentence positions, respectively. Thus each animal served four times as the agent and four times as the patient of the target sentence, respectively, always with a different action. For the lead-in context the first and second mention of the potential agent and patient of the action was counterbalanced across conditions. All animal pairs in the trials always differed in the initial phonemes. The 160 trials were pseudo-randomized such that maximal two consecutive trials were of the same condition or had the same word order in the target sentence to minimize possible effects of structural priming (e.g., Scheepers & Crocker, 2004). To avoid any preferences of thematic role or topic assignment due to the previous trial at least five trials separated the repetition of an animal and at least two trials the repetition of an action.

Procedure

Each participant was seated in a sound-attenuated cabin 90 cm in front of a computer screen and a button box (Cedrus response pad model RB-830). The trials were presented visually in the center of the screen by means of the software Presentation (www.neurobs.com). Each trial began with the presentation of a red asterisk for 1000 ms to indicate the beginning of a new scene. Before and after the lead-in context a blank screen was displayed for 200 ms. Lead-in-context and context question were presented as a whole in a self-paced reading manner with a minimum reading time of 3350 ms and 1400 ms, respectively. The participant had to press a button with the left thumb for further reading. The context question was followed by a fixation cross for 500 ms in the center of the screen. Then the target sentence was presented phrase-wise with 500 ms for each determiner phrase (DP) and prepositional phrase (PP) and 450 ms for the verb with an ISI of 100 ms (as used in previous studies, e.g., Bornkessel et al., 2003).

In 20 % of the trials a sentence-picture-verification task followed the target sentence. The pictures depicted the scene of the preceding target sentence with correct or exchanged thematic roles (the owl painting the hedgehog vs. the hedgehog painting the owl). For each of the four conditions there was the same number of matching/mismatching

Table 1: Example of experimental trial for each condition (vertical bars in target sentence indicate phrase-wise presentation, Abb.: NOM = nominative case, ACC = accusative case, S = subject, V = verb, O = object, PP = prepositional phrase, SO = subject-before-object, OS = object-before-subject).

(1) Lead-in context	(2) Context question	(3) Target sentence	Condition
Der Uhu und der Igel haben eine Staffelei im Park aufgebaut. *`The owl and the hedgehog have set up an easel in the park.`*	Was ist denn genau los? *`What exactly is going on?*	Der Uhu | malt | den Igel | im Park. $[\text{the}_{[NOM]}\ \text{owl}_{[NOM]}]_S$ $[\text{paints}]_V$ $[\text{the}_{[ACC]}\ \text{hedgehog}_{[ACC]}]_O$ $[\text{in the park}]_{PP}$. *`The owl paints the hedgehog in the park.`*	NEUTRAL-SO
	Was ist mit dem Uhu? *`What about the owl?`*		TOPIC-SO
	Was ist denn genau los? *`What exactly is going on?`*	Den Uhu | malt | der Igel | im Park. $[\text{the}_{[ACC]}\ \text{owl}_{[ACC]}]_O$ $[\text{paints}]_V$ $[\text{the}_{[NOM]}\ \text{hedgehog}_{[NOM]}]_S$ $[\text{in the park}]_{PP}$. *`In the park the owl is painted by the hedgehog.`*	NEUTRAL-OS
	Was ist mit dem Uhu? *`What about the owl?`*		TOPIC-OS

probes. The picture was presented for two seconds before the participant had to press the corresponding button for match (yes) or mismatch (no) within a time window of two seconds.

Participants were instructed to read each scene attentively and silently and to answer the sentence-picture-verification task after some of the scenes as accurately and fast as possible. The assignment of the response buttons to the right fore and middle finger was counterbalanced across participants. Participants were asked to avoid any movements during the time of sentence reading. To become familiar with the procedure participants performed three practice trials. The whole experiment included pauses after each 40 trials and lasted approximately 30 minutes.

EEG Recording

EEG was recorded by means of a 32 channel active electrode system (Brain Products, Gilching) with a sampling rate of 1000 Hz. The electrode configuration included the following 29 scalp sites according to the international 10-20 system: F7/8, F5/6, F3/4, FC3/4, C5/6, C3/4, CP5/6, P3/4, P7/8, PO3/4, FPz, AFz, Fz, FCz, Cz, CPz, Pz, POz, Oz. To detect blinks and vertical eye movements an electro-oculogram was monitored by one electrode under and one electrode above the right eye. The left mastoid served as the reference electrode but the recording was re-referenced to bilateral mastoids offline. The ground electrode was placed at FP1. Impedance was kept below 5 kOhm.

ERP data analysis

The raw data were filtered by applying the Butterworth zero phase filter with a 0.3 Hz low cutoff and 70 Hz high cutoff (slope: 12 dB/oct) and a Notch Filter of 50 Hz. An automatic artifact rejection was applied to reject blinks and drifts in the time window of -200 to 1700 ms before and after the onset of the target sentence (rejection criteria: max. voltage step of 30 µV/ms, max. 200 µV difference of values in interval). On average 5.43 % of the trials per condition had to be excluded from the analysis. The rejections were equally distributed across the conditions. For the correction of vertical eye movements the algorithm by Gratton, Coles & Donchin (1983) was used. Baseline correction was applied for 200 ms before the onset of the target sentence.

Time locked to the onset of the target sentence, mean amplitude values of the ERPs per condition were analyzed within three time windows (100-300 ms, 300-500 ms and 500-900 ms) based on visual inspection and according to the current literature on language related ERP components (i.e., N400, P600). The following regions of interest (ROIs) were analyzed via mean amplitudes of the three appropriate electrodes: left anterior (F5, F3, FC3), left central (C5, C3, CP5), left posterior (P3, P7, PO3), right anterior (F6, F4, FC4), right central (C6, C4, CP6), right posterior (P4, P8, PO4), anterior midline (FPz, AFz, Fz), central midline (FCz, Cz, CPz), posterior midline (Pz, POz, Oz). For statistical ERP analysis a repeated measures ANOVA was applied for the three within-subject factors WORD ORDER (SO, OS), CONTEXT TYPE (TOPIC, NEUTRAL) and ROI (nine levels) using SPSS Statistics (version 21). The correction according to Greenhouse and Geisser (1959) was applied. We report the corrected F- and p-values but the original degrees of freedom. Only significant main effects and interactions ($p < .05$) including the factors CONTEXT TYPE and/or WORD ORDER are reported and resolved by using paired T-Tests. Note that we only compare context effects on the very same sentence structures, that is, we compare SO with SO sentences and OS with OS sentences, depending on their preceding CONTEXT TYPE (TOPIC vs. NEUTRAL).

Results

Figure 1 displays the grand average ERPs for the factor CONTEXT TYPE (TOPIC vs. NEUTRAL) at the onset of the SO and OS target sentences. The statistical analysis of the ERPs in three different time windows revealed the following results:

Time window 100-300 ms

Statistical analysis in the time window 100 to 300 ms after onset of the target sentence revealed a statistically significant main effect of CONTEXT TYPE

[F(1, 18) = 5.29, p < .05] reflected by less positive going ERP amplitudes following the topic context relative to the neutral context (see Figure 1, panel A and B).

Time window 300-500 ms

The ANOVA in the time window of 300 to 500 ms after the onset of the target sentence neither revealed statistically significant main effects nor interactions.

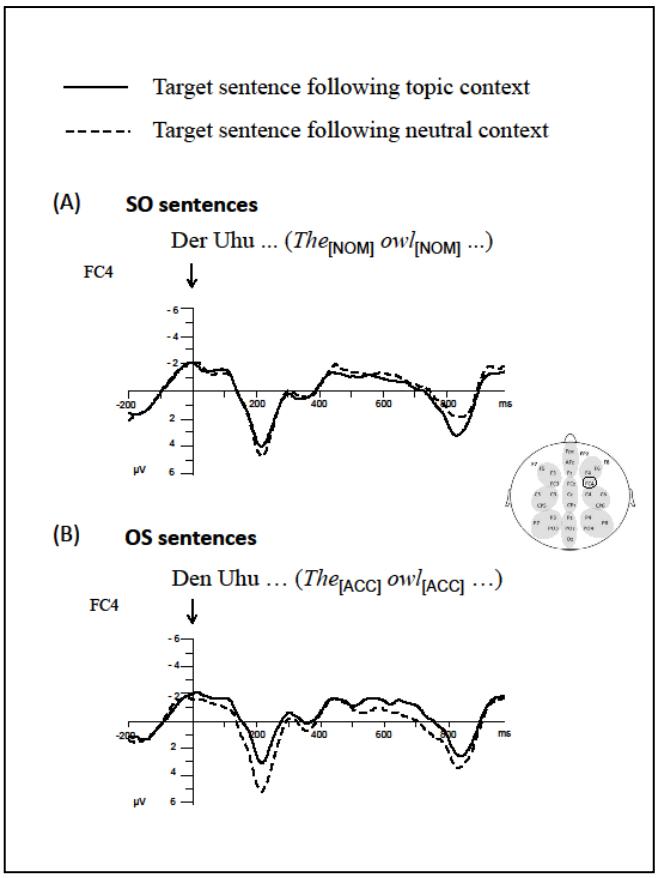

Figure 1: Grand average ERPs of electrode FC4 as an example from the right anterior ROI time-locked to the onset of the target sentences showing the effect of CONTEXT TYPE (TOPIC vs. NEUTRAL) for SO and OS sentences. For presentation purposes the displayed ERP-plots are 7 Hz low-pass filtered. Negativity is plotted upwards.

Time window 500-900 ms

In the late time window of 500 to 900 ms after the onset of the target sentence the ANOVA revealed a statistically significant interaction of WORD ORDER x ROI [F(8, 144) = 4.09, p ≤ .01], WORD ORDER x CONTEXT TYPE [F(1, 18) = 4.84, p < .05] as well as of WORD ORDER x CONTEXT TYPE x ROI [F(8, 144) = 4.29, p ≤ .01]. Follow-up analysis of the three-way interaction reached significance for OS sentences in the right anterior ROI [*t*(18) = -2.20, p = < .05]: OS sentences revealed a less pronounced positivity in case of the preceding TOPIC context compared to the NEUTRAL context. SO sentences did not reveal a statistically significant difference depending on the CONTEXT TYPE in any of the nine ROIs.

Summary of ERP results

The statistical analysis showed that the factor CONTEXT TYPE significantly interacted with WORD ORDER. In the late time window (500 to 900 ms) the preceding context affected the processing of otherwise identical OS sentences: The topic context lead to a less pronounced positivity as compared to the neutral context. For SO sentences no such difference was induced by the preceding context. Besides, the analysis revealed a main effect of the preceding CONTEXT TYPE in the early time window (100 to 300 ms after target sentence onset) such that the topic context induced a reduced positivity compared to the neutral context.

Discussion

The present ERP experiment addressed the question if and how a preceding topic context modulates the online processing of German declaratives. In line with previous research the preceding topic context did not affect the processing of SO sentences because SO is the canonical word order in German sentences. Importantly, for the processing of OS sentences we found an impact of the topic context reflected in a reduced late positivity (500 to 900 ms) in comparison to a neutral context.

Besides the late positivity, the early positivity (100 to 300 ms) was modulated by the context type independent of the word order of the target sentence: Sentences following the topic context showed a reduced positivity compared to the neutral context. Note that in the topic context condition the sentence-final noun of the context sentence is repeated in the sentence-initial position of the target sentence, whereas no such repetition occurred in the neutral context condition. As rather early ERP components have commonly been linked to basic visual processes (e.g., Dunn, Dunn, Languis & Andrews, 1998), the reduced P2-like response in our study might be attributable to a pure word repetition effect (e.g., Van Petten, Kutas, Kluender, Mitchiner & McIsaac, 1991). Although recent findings report modulations of an early positivity by contextual information in terms of the integration of semantic information (e.g., Federmeier & Kutas, 2001; Lee, Liu & Tsai, 2012) or the integration of discourse relevant information comparing a focus vs. neutral context (Bornkessel et al., 2003) such an interpretation of the early positivity in our study is not eligible due to the chosen experimental design.

As expected, the late positivity in the time window of 500 to 900 ms (P600) was reduced only for OS sentences following the topic context relative to the neutral context. In line with recent data this reduced P600 might indicate lower processing efforts for updating the current discourse model (e.g., Burkhart, 2007; Schumacher & Hung, 2012) or structural re-analysis (as suggested for instance by the

neurocognitive model of sentence processing by Friederici (2002)). Thus, the chosen topic context elicited a processing advantage for the non-canonical OS sentences such that the integration of the sentence-initial object was facilitated compared to the neutral context in which a wide scope on the scene with the discourse-given referents and action was induced.

Our interpretation of the reduced P600 in OS sentences as reflecting lower processing efforts for the sentence-initial topic compared to a preceding neutral context is in line with the results of a follow-up study using the same experimental material and design as in the ERP experiment combined with a categorical judgment task on the comprehensibility of each story instead of the sentence-picture-verification task. Across 28 participants the mean percentage of stories judged as easily comprehensible was 90.71 % for the condition NEUTRAL-SO, 88.93 % for TOPIC-SO, 34.82 % for NEUTRAL-OS and 51.79 % for TOPIC-OS. Statistical analysis using a linear mixed effects model revealed a significant main effect of CONTEXT TYPE ($z = 3.13$, $p < .01$) and WORD ORDER ($z = -7.41$, $p <. 001$) and a significant CONTEXT TYPE x WORD ORDER interaction ($z = -2.53$, $p < .01$). Post-hoc comparisons showed that stories containing OS target sentences were significantly more likely to be judged as easily comprehensible if presented together with the topic context ($z = 3.22$, $p < .01$), whereas the context type did not affect the comprehensibility of the canonical SO sentences ($z = 0.40$, $p > .05$).

Notably, other than expected we did not see a modulation of the N400 component in our data, neither in SO nor in OS sentences (see e.g., Schumacher & Hung, 2012). Moreover, the effect of canonicity which was reported in form of a negativity at around 400 ms for OS vs. SO sentences in some (e.g., Matzke et al., 2002) but not in other studies (e.g., Frisch, Schlesewsky, Saddy & Alpermann, 2002) was not present in our experiment. This might be due to the rather simple sentences used or due to the fact that 50 % of the presented sentences were OS sentences, so the initial preference for SO might have been "overwritten" by our experimental design.

In summary, our findings suggest that the topic assigning contextual information used in the present experiment seemed to play a crucial role just in the processing of non-canonical OS sentences. The processing of OS sentences was modulated in terms of lower processing costs for the integration of discourse relevant information induced by the preceding topic context relative to a preceding neutral context. For the processing of canonical SO sentences that have been known to be felicitous in the absence of a supportive context no impact of the preceding discourse context was found. Hence our data indicate that the online processing of a sentence-initial object is enhanced by a topic assigning contextual discourse through an easier integration of discourse relevant information into the current discourse model.

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