Information Structure Affects the Resolution of the Subject Pronouns *Er* and *Der* in Spoken German Discourse

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Two visual-world eye-tracking experiments were designed to investigate the resolution of ambiguous German pronouns, the personal pronoun (*er*) and the d-pronoun (*der*) in spoken discourse. Specifically, the influence of the order of mention and the information status of the antecedent candidates on the resolution preferences following canonical and non-canonical antecedent structures was explored. The results suggest that the two pronominal forms have different coreference functions when they follow canonical topic-comment antecedent structures, in that personal pronouns prefer first-mentioned topical antecedents and d-pronouns second-mentioned non-topical antecedents. However, after non-canonically marked topic-focus antecedent structures, the pronouns had overlapping functions, namely an overall preference towards the second-mentioned focused entity. The findings suggest that pronoun resolution is affected by the information status of the antecedent candidates and that resolution preferences change across antecedent word orders.

Keywords: pronoun resolution in German, topic-focus, information structure, discourse processing, visual world eye-tracking

1. Introduction

1 Coherent discourse often entails repeated reference to the same discourse entity, and this is frequently achieved by the use of personal pronouns such as *he*, *she*, *it*. Unlike English, German has two pronominal forms which can refer to the same singular, masculine entity: the personal pronoun *er* and the d-pronoun (often referred to as a demonstrative pronoun) *der*[1], as illustrated in example [1].

[1] Peter$_i$ wollte Tennis spielen. Doch **er**$_i$/**der**$_i$ war krank.
'Peter$_i$ wanted to play tennis. But **he** [p$_i$/d$_i$] was sick.'

2 The two forms do not have exactly the same coreference distribution however, as can be seen when more than one potential antecedent is available in the discourse [2].

[2] Peter$_i$ wollte mit Hans$_j$ Tennis spielen. Doch **er**$_i$/**der**$_j$ war krank.
'Peter$_i$ wanted to play tennis with Hans$_j$. But **he** [p$_i$/d$_j$] was sick.'

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1. There are some properties which distinguish d-pronouns from demonstrative forms such as *dieser* (see Ahrenholz, 2007) and some linguists even argue that they are better understood as a second set of personal pronouns in German (Klein & Rieck, 1982; Lambrecht, 1994; Weinrich, 1993). Ahrenholz's (2007) notion of *d-pronouns* is adopted here to distinguish them from other pronominal forms.

3   In this case, *er* is arguably resolved towards the topical entity (*Peter*), while the d-pronoun *der* prefers the non-topical entity (*Hans*) (Comrie, 1994; Lambrecht, 1994; Diessel, 1999; Bosch et al., 2003); or, as some researchers have claimed, the d-pronoun is marked for non-topical reference, whereas the personal pronoun is neutral in this regard (Zifonun et al., 1997; Ahrenholz, 2007; Bosch & Umbach, 2007; Kaiser, 2011b). Interestingly, the assumptions underlying the different coreference functions of personal and d-pronouns have always been formulated with regard to pragmatic differences between topical and non-topical antecedents. According to Reinhart (1982), topicality is understood as the part of the utterance that the utterance is about. A topical entity is thus a foregrounded entity in terms of information structure. Focused entities are assumed to provide new and unexpected information and are selected from a set of alternatives. Thus, they are also foregrounded entities. If personal pronouns have a tendency to be resolved towards foregrounded referents, then one may assume that they are also more prone to be resolved towards focused entities (vs. non-focused entities). Such a claim can be derived from Joshi and Weinstein (1981) who postulated within "Centering Theory" that the focused element (*John*) in cleft-constructions such as [3a] serves as the forward-looking centre (*John*) and is particularly prone to be taken up by a pronoun in the subsequent discourse. The backward-looking centre (*Bill*) is backgrounded and might therefore be appropriately referred to by explicitly reintroducing it. According to this, a discourse continuation as in [3b] where the pronoun refers to *Bill* is awkward. Following this line of thought, one might expect that the coreference functions of personal and d-pronouns are similarly affected by focus information such that the personal pronoun prefers the focused entity while the d-pronoun prefers the non-focused entity.

[3a]   It was John who hit Bill.

[3b]   He was taken to the hospital.

4   The fact that the two pronominal forms may show asymmetric resolution patterns is also predicted by many theories of reference (e.g., Levinson, 1987 and 1991; Ariel, 1990 and 2001; Gundel et al., 1993; Gundel, 2003) which assume that the most reduced referring expression, in terms of lexical or prosodic weight (in this case *er*), resolves towards the most accessible, or cognitively salient referent in the mind of the speaker/hearer. Gundel et al.'s (1993) Givenness Hierarchy further predicts a difference between the resolution of personal pronouns and d-pronouns. This prediction is based on the observation that in English sentences such as [4] (taken from Gundel, 2003), the personal pronoun is resolved towards the first-mentioned topical antecedent (*the package*), while the demonstrative pronoun may be resolved towards both antecedents (*the package*, *the table*).

[4a]   The package$_i$ was on the table$_j$. **That**$_{i/j}$ looked new.

[4b]   The package$_i$ was on the table$_j$. **It**$_i$ looked new.

5   The personal pronoun requires its antecedent to be in the current focus of attention (Gundel et al.'s *in focus* status)[2], while the demonstrative pronoun only requires its antecedent to be in working memory (Gundel et al.'s *activated* status) which is the case for both antecedents. It may also have its antecedent in the current focus of attention; however, unlike personal pronouns this condition does not need to be met for the interpretation of d-pronouns resulting in more flexibility in the direction of their resolution patterns. Thus, in this view d-pronouns may be used for topic continuation as well as for topic-shift. Therefore, it may be possible to obtain the same resolution pattern for personal and d-pronouns in German. Note that this prediction is contrary to the idea that d-pronouns are marked for non-topical coreference, while personal pronouns are neutral in this regard (Zifonun et al., 1997; Ahrenholz, 2007; Bosch & Umbach, 2007; Kaiser, 2011b).

6   The above theories of reference make predictions on the basis of the salience of referents. This raises the question of what determines the relative accessibility of one potential antecedent over another, a question that has been the subject of debate in many psycholinguistic studies on pronoun resolution. A particularly important issue has been whether this is determined by the grammatical function or the order of mention of the antecedent referents; more precisely, whether subjecthood (Frederiksen, 1981; Crawley et al., 1990) or first-mention makes a referent more accessible (Gernsbacher, 1989). As this is difficult to disentangle in English because the first-mentioned entity is usually also the syntactic subject, researchers have turned to flexible word-order languages such as Finnish and German. By investigating subject-verb-object (SVO) and object-verb-subject (OVS) antecedent structures, they have attempted to identify the effects of order of mention and grammatical role and/or have tested their influences on different pronominal forms (Crawley et al., 1990; Järvikivi et al., 2005; Bosch & Umbach, 2007; Kaiser & Trueswell, 2008; Wilson, 2009). However, as will be shown below, the results are inconsistent. One reason for this could be that previous studies have overlooked the possible influence of the different word orders on information structure.

2.   The influence of order of mention, grammatical role and topicality information on the resolution of different pronominal forms

7   Regarding previous psycholinguistic results on the resolution of different pronominal forms in German and Finnish, Table 1 shows that while some have found clear influences of grammatical role information on the resolution of personal pronouns (Bouma & Hopp, 2007: for German; Kaiser & Trueswell, 2008: for Finnish) others have found a mixture of grammatical role and order of mention/topicality information (Järvikivi et al., 2005: for Finnish; Wilson, 2009: for German). Similarly, for the

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2.   Note that the *in focus* activation category is used to refer to focus of attention and not to the pragmatic focus function.

resolution of d-pronouns/demonstrative pronouns, either a main influence of order of mention/topicality information has been observed (Bosch & Umbach, 2007: for German; Wilson, 2009: for German) or a mixture of grammatical role and order of mention/topicality information (Kaiser & Trueswell, 2008: for Finnish). Thus, there is a lot of variation in the findings from the above-mentioned studies which may be due to different experimental designs, tasks, materials and languages. However, considering only the resolution preference found after OVS structures (see the last column in Table 1), we observe great similarity between the findings in that there are no first-mentioned preferences *for either pronoun* (Bosch & Umbach, 2007: for German; Kaiser & Trueswell, 2008: for Finnish; Wilson, 2009: for German). These OVS sentences were used to disentangle the effects of grammatical role from positional effects. The grammatical subject which is more prominent than the object is not in the most prominent position. This might have possibly resulted in no clear preference for the personal pronoun. Another way of looking at these structures is that they are non-canonical compared to canonical SVO structures. Therefore the information status of the antecedents might not be directly comparable across sentence structures; i.e., the second-mentioned subject in OVS structures does not only differ from the second-mentioned object in SVO structures in terms of grammatical role, but also in terms of information structure in that it is focused. This might have affected the results.

			Antecedent structures	
	Language	Pronouns	SVO	OVS
Wilson (2009)	German	personal pronoun	no preference[3], 2nd → 1st	no preference
		d-pronoun	2nd	**2nd**
Bosch et al. (2007)	German	personal pronoun	no preference	no preference[4]
		d-pronoun	2nd	**no preference**[5]
Bouma & Hopp (2007)	German	personal pronoun	1st	2nd
Kaiser & Trueswell (2008)	Finnish	personal pronoun	1st	2nd
		demonstrative pronoun	2nd	**2nd**
Järvikivi et al. (2005)	Finnish	personal pronoun	1st	2nd → no preference

Table 1. Overview of results from previous visual-world studies on the resolution of personal and d-pronouns/demonstrative pronouns in German and Finnish (resolution preference for the d-pronoun in bold)

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3. Wilson (2009) reports no preference for the personal pronoun following SVO antecedent structures in an acceptability judgement task, and a switch from a second-mentioned to a first-mentioned preference over time in a visual-world eye-tracking task.

4. Only two items in this condition.

5. Only two items in this condition.

8   Previous studies investigating the influence of (contrastive) focus information on the resolution of personal pronouns have come to mixed results. While some studies found an influence of focus information on English pronoun resolution in that personal pronouns were preferred to refer to the entity in focus (Arnold, 1999, Experiment 1; Cowles et al., 2007), others did not find this effect (Arnold, 1999, Experiment 2; Kaiser, 2011a; Colonna et al., 2012). This might be due to the fact that the studies used different sentence materials. All of the studies used cleft constructions. Cowles et al. (2007) used cleft constructions in [5a] and [5b], and found that the personal pronoun was preferred to co-refer to the focused entity (*Anne*) regardless of whether it was the first- or the second-mentioned entity. As this entity always constituted the grammatical subject of the antecedent sentence this effect cannot be disentangled from effects of grammatical role information.

[5a]   A new movie opened in town. It was **Anne** who called Sarah.

[5b]   A new movie opened in town. The one who called Sarah was **Anne**.

… But later that night, **she** couldn't go to the movie after all.

9   Arnold (1999, Experiment 1) used cleft constructions as in [6a] which realized the focused entity as the syntactic subject and the non-focused entity as an embedded subject. Sentences with pronominal reference to the focused entity received higher ratings than sentences with explicit name reference. This preference changed in Experiment 2, when she topicalized the embedded subject by pronominalizing it as in [6b]. The participants referred more often to the topicalized entity with a pronoun in their sentence completions than to the focused entity.

[6a]   The guests were nervously standing around in the living room, trying to decide which person to talk to. The one Ann decided to say hi to first was **Emily**. Emily/**She** looked like the friendliest person in the group. (rating task)

[6b]   Ron was looking through his address book, trying to make up his mind. He had an extra ticket to the opera, but he didn't know which friend to invite. The one **he** decided on at last was Kysha/Fred. (followed by a sentence completion)

10   This operationalization of topicality by pronominalization was also adopted by Kaiser (2011a) and might explain why she found similar results to Arnold (1999, Experiment 2). Note that all of the above studies were undertaken in English. A recent study on the resolution of German and French personal pronouns (Colonna et al., 2012) found that there was even a dis-preference for focused entities in both languages. They used sentence materials as in [7a] and [7b] investigating intra-sentential pronoun resolution unlike the previous studies which investigated inter-sentential pronoun resolution.

[7a]   Es ist Peter, der Hans geohrfeigt hat, als **er** jung war.
        'It is Peter who slapped Hans when **he** was young.'

[7b]   Es ist Peter, den Hans geohrfeigt hat, als **er** jung war.
         'It is Peter who Hans slapped when **he** was young.'

11   They argue that participants assumed the topic to be constant across the sentence, because topic shift within a sentence makes it less coherent. As a focused entity usually provides new and unexpected information, it therefore does not qualify as a good coreference candidate for intra-sentential pronoun. Still, it may be possible that focusing an entity may very well have an influence on inter-sentential pronoun resolution as topic-shift may occur in these contexts. Furthermore, it is not yet fully clear how contrastive focus information affects the resolution of different pronominal forms when both antecedents are presented as full lexical noun phrases (NPs), and this is what is addressed in the current study.

3.   The current study

12   Given the lack of definitive results on the resolution of personal and d-pronouns on the one hand, and the lack of knowledge about the influence of different pragmatic antecedent properties on the other, a visual world eye-tracking task was designed to further investigate this topic. Two pronominal conditions (*er* vs. *der*) were created. In Experiment 1, a canonical comparative sentence [8a] preceded the pronominal clause in contrast to Experiment 2, where a non-canonical comparative sentence [8b] was used. Both potential antecedents were presented in nominative case, which allowed us to inspect the influence of order of mention without conflating it with grammatical role information. Nevertheless, although the sentences are free of thematic role information (as is typically the case with SVO sentences), they still contain subject verb agreement marking NP1 in [8a] and NP2 in [8b] as the syntactic subject of the sentence. However, as Kaiser (2011a: 1628) has pointed out, the commonly found "subjecthood preference is probably related to a preference for antecedents that are syntactically and semantically prominent". Therefore, we take the current materials to reduce effects of the subjecthood preference to a minimum. In the materials of Experiment 1, NP1 is the foregrounded entity by means of topicality and it is the first-mentioned entity (showing subject verb agreement). This should make it particularly available for the resolution of the personal pronoun while NP2 should be preferred by the d-pronoun.

[8a]   **Der Schrank** ist schwerer als **der Tisch**. *Er/Der* stammt aus einem Möbelgeschäft in Belgien.
         '**The cupboard** is heavier than **the table**. **It [p/d]** comes from a furniture store in Belgium.'

[8b]   Schwerer als **der Tisch** ist **der Schrank**. *Er/Der* stammt aus einem Möbelgeschäft in Belgien.
         'Heavier than **the table** is **the cupboard**. **It [p/d]** comes from a furniture store in Belgium.'

13   To keep the type of construction comparable across experiments, in Experiment 2 we used the same sentence materials, but presented them in a non-canonical structure [8b]. Note however that this is a different focus construction than the cleft-constructions used in previous experiments (Arnold, 1999; Cowles et al., 2007; Kaiser, 2011a; Colonna et al., 2012). In the comparative constructions, NP2 (*the cupboard*) constitutes the entity in focus as it is an answer to the *wh*-question "Which piece of furniture is heavier than the table?". Thus, NP2 (*the cupboard*) is in contrastive focus[6]. It is foregrounded in terms of information structure. The question is whether this foregrounding makes NP2 more available for the personal pronoun and what sort of effect this has on the resolution of the d-pronoun (see predictions next section).

14   The participants viewed a screen which showed pictures of the potential antecedent candidates (e.g., *cupboard* and *table*), and their eye movements were recorded while they listened to the experimental sentences. On hearing the critical pronoun (either *er* or *der*), looks towards one of the pictures was taken as an indication of the participants' preferred referent for the pronoun that they had just heard (see, e.g., Altmann & Kamide [1999] for more details on the assumptions behind the visual-world paradigm). In Experiment 1, it was hypothesized that if order of mention were important, then when hearing personal pronouns, participants would prefer to resolve it towards the first-mentioned topical antecedent and d-pronouns towards the second-mentioned non-topical entity. Furthermore, if the d-pronoun is indeed marked for coreference to non-topical entities while the personal pronoun is neutral in this regard, as has been suggested previously (Zifonun et al., 1997; Ahrenholz, 2007; Bosch & Umbach, 2007; Kaiser, 2011b), we might expect a higher degree of ambiguity for the personal pronoun than for the d-pronoun. On the other hand, if, according to the Givenness Hierarchy (Gundel et al., 1993; Gundel, 2003) we consider d-pronouns to be more neutral in their coreference relations and personal pronouns to be more constrained in this respect (due to the necessary *in focus* criterion), then we would expect to find the reverse pattern, in that more ambiguity would be expected in the resolution of the d-pronoun. Thus, in the case of more ambiguity it was predicted that we would observe a relatively equal number of looks to the two depicted potential antecedent candidates which would last for a relatively longer period of time in the case of unmarked forms compared to marked forms.

15   In the second experiment, it was investigated whether changing the word order of the antecedent clause would affect the resolution patterns. More specifically, it was asked whether the preferences following non-canonical structures would be different from the preferences following canonical structures, i.e., whether the information status (*focus* vs. *non-focus*) or the order of mention of the antecedent

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6. Actually this also fits with the experimental set-up where participants saw the pictures of three potential NPs on the screen (here: *cupboard*, *table*, *sofa*). It is highly likely that the visual input narrowed down the set of possible candidates.

candidates (*first* vs. *second mention*) would be more likely to affect the preferences. On the one hand, theoretical accounts of reference (Levinson, 1987 and 1991; Ariel, 1990 and 2001; Bosch et al., 2003) predict an asymmetric resolution pattern for the two types of pronouns, irrespective of whether higher salience were due to pragmatic topic or focus encodings, such that the more reduced form (*er*) should co-refer with the most highly salient referent, and the fuller form (*der*) with the less salient antecedent. On the other hand, non-canonical word order could make the focused entity a particularly prominent candidate for future reference, and this would therefore predict a similar preference for personal and d-pronouns.

4.   Experiment 1: pronoun resolution after canonical antecedent structures

4.1.   Method

4.1.1.   Participants

16   28 native speakers of German (22 female) participated in the study. The participants were students at the Radboud University Nijmegen or employees at the Max-Planck Institute (MPI) for Psycholinguistics in Nijmegen. They were aged between 20 and 31 years (mean = 23.25; SD = 2.68). All participants were tested individually and were paid a nominal fee for their participation. All participants had normal or corrected-to-normal vision.

4.1.2.   Apparatus

17   Participants' eye movements were recorded with an SR Research EyeLink II eye tracker. The eye tracker is an infrared video-based system with a head-mounted camera. Only the dominant eye was recorded. A sampling rate of 500 Hz was used which monitored gaze locations every 2 ms. The camera was calibrated using a nine-point grid extending over the whole screen. A drift correction was performed before each trial. The resulting spatial accuracy was at least 0.5° of arc.

4.1.3.   Materials and design

18   24 experimental items were constructed, each beginning with a comparative antecedent sentence of the type *NP1-verb-comparative-NP'* that introduced both referents with a singular masculine definite NP, one in preverbal and one in postverbal position (see [8a]). Both NPs appeared in nominative case. An SVO main clause followed, which constituted the target clause and started with a subject pronoun. The subject pronoun was either a personal pronoun *er* or a d-pronoun *der*, yielding two experimental conditions. Each trial ended with a third sentence, as in [9] below. The sentence segments immediately following the pronoun were constructed to be free of (semantic) bias towards either entity and to make the discourses fully ambiguous throughout the duration of the whole trial.

19   Two lists of each of the 24 experimental items were then created, either containing a personal or a d-pronoun, counterbalanced in a latin square design. Additional 48 filler items were created, half of which started with a comparative structure, and the other half containing only non-comparative clause structures. The comparative fillers presented two NPs of the same gender without being followed by a subsequent subject pronoun as in [9].

[9]   Das Telefon ist lauter als das Radio. Die Zuschauer fühlten sich sehr gestört, als das Telefon im Theater während der Vorstellung klingelte. Das war eine peinliche Situation.
'The phone is louder than the radio. The audience felt very annoyed when the phone rang during the theatre performance. That was an embarrassing situation.'

20   The total of 72 items was split into two experimental blocks, and the order of the blocks was counterbalanced between-participants. The order of the stimuli within the blocks was pseudo-randomized. Additionally, five non-comparative practice trials were constructed.

21   Each item was read aloud by a male native German speaker and digitally recorded to a computer hard disk. The experimental items were recorded separately for each condition to avoid splicing effects. Thus, although the first sentence had the same content across conditions, it was recorded separately[7]. The items were cut into two separate sound files using Praat (Boersma & Weenink, 2009) as in [10a] and [10b], the first sound file playing the antecedent sentence and the second one starting with the critical pronoun.

[10a]   Sound file 1: Der Schrank ist schwerer als der Tisch.
'The cupboard is heavier than the table.'

[10b]   Sound file 2: Er stammt aus einem Möbelgeschäft in Belgien. Das Sofa soll nächste Woche geliefert werden.
'It comes from a furniture store in Belgium. The sofa is supposed to be delivered next week.'

22   Each experimental screen showed three pictures for each trial. The pictures were taken from the MPI picture database. Each picture was presented in a 288 x 288 pixel frame and appeared on three positions on a 1,024 x 768 pixel screen in triangular manner: top left (171, 167) and top right corner (855, 167) and lower central position (512, 599). Each experimental trial contained two target pictures (e.g., *the cupboard*, *the table*) which either appeared in top left or top right position, and a discourse-related non-target picture (e.g., *the sofa*) which appeared in the lower central position. The position of the target pictures was counterbalanced between items. Each target picture appeared once during the experiment.

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7.   The first sound files for both conditions are provided in the Appendix.
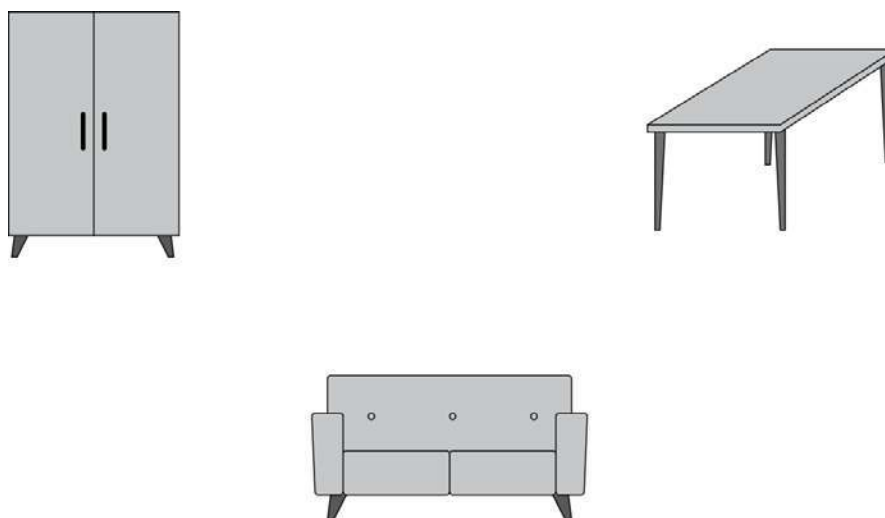
Figure 1. Schematic representation of the pictures appearing on the screen during the visual-world eye-tracking task (adapted by the publisher). The above pictures (cupboard, table) show the two target referents and the picture below (sofa) shows a discourse-related non-target referent

4.1.4. Procedure

23   Each trial began with a drift correction to compensate for minor head movements. After this, the experimental display containing the three pictures was presented. The display was shown for 1,000 ms before the onset of the first sound file. After the first sound file, the pictures on the screen disappeared and a fixation cross was presented for 1,500 ms in the middle of the screen at equal distance from each of the three pictures to avoid fixations on the critical characters at pronoun onset. The experimental display reappeared and the second sound file with the critical pronoun was played simultaneously. Participants were presented with three practice items prior to the experimental blocks. Additionally, one practice item was placed at the beginning of each experimental block. Between the two experimental blocks, the participants paused (ca. 5 min) and the camera was turned off. At the beginning of each block, the camera was recalibrated and validated.

24   The participants were informed that they would hear mini stories and see related pictures on the screen. They were told that once in a while a content question would appear on the screen and were instructed to answer the question by clicking the left mouse button for "yes" and the right mouse button for "no". In order to ensure that they paid attention to the mini stories, they were given immediate visual feedback on the correctness of their answer. The accuracy of the responses was very high with 95% correct answers (24 questions; mean correct answers = 22.79, SD = 1.01). Each session lasted approximately 45 minutes.

4.2.   Results

25   For each 4 ms time point starting 200 ms prior to the pronoun onset until 2,000 ms after the pronoun onset (551 time points in total), it was coded whether participants fixated the first- or the second-mentioned character. For the statistical analyses, these time points were aggregated into larger time windows of 200 ms. During the time window starting 200 ms before the pronoun onset the participants saw a fixation cross, i.e., no pictures were shown. However, if they had already looked at a target region even though it was blank, then these looks were excluded from the analysis (Altmann & Kamide, 1999; Järvikivi et al., 2005) [8]. This cleaning procedure was chosen to ensure that these looks were not caused by the post-processing of the first sound file or by memory specific effects and that all target looks entering the analysis would therefore inform us about the pronoun resolution preferences. Thus, 42 looks (< 1%) were excluded resulting in a total of 4,577 fixations that entered the analysis. Figure 2 presents the time course of the effects for the 200 ms analysis regions.
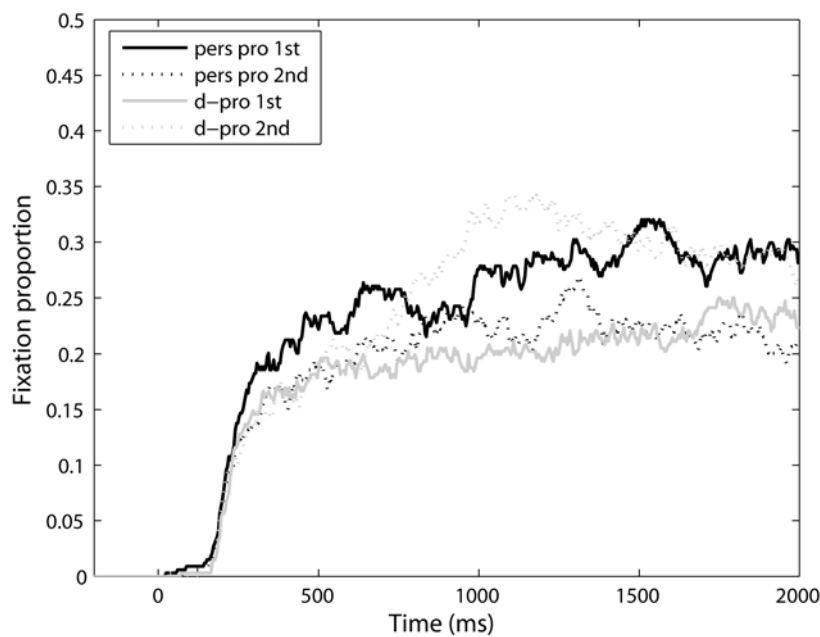

Figure 2. Probability of fixating the first-and second-mentioned referent as a function of time in each of the two conditions (personal pronoun, d-pronoun) in Experiment 1

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8.   Due to technical problems with the hardware set-up (namely the presentation of the stimuli was realized with a DirectX soundcard instead of an ASIO soundcard), there were random processing delays between the reappearance of the experimental screen and the start of the second sound file, so that an accidental second preview time was given to some of the participants for some of the trials. However, this problem was negligible, since the delays occurred randomly and our data cleaning procedure prevented any looks to the target picture prior to the onset of the second sound file from entering the analysis.

26   The eye-tracking data were analyzed using linear mixed-effect models (Baayen, 2008; Baayen et al., 2008) with participants and items as a crossed-random factor and condition (*er* vs. *der*) and order of mention (1st vs. 2nd) as fixed predictors. The interaction between condition and order of mention was only considered when the saturated model predicted the outcome significantly better than the one without the interaction. The proportions of fixations (relative to all looks) to the first-mentioned and second-mentioned target pictures were transformed into empirical logits (Barr, 2008), and entered the analysis as the dependent measure. Loglikelihood analyses (ANOVA function in R) were used to compare the fit of the models to the data, showing that the saturated model better predicted the outcome in the time windows between 600-2,000 ms, showing a consistent significant interaction between pronoun condition and order of mention across these analysis windows (600-2,000 ms).

Time window	In millisecond	Fixed predictors		
		Pronoun condition: *der*	Order of mention: 1st	Interaction
1	0-200	0.06 (0.901)	-0.01 (-0.167)	
2	200-400	0.2 (1.223)	-0.17 (-1.019)	
3	400-600	0.18 (0.92)	-0.23 (-1.191)	
4	600-800	0.5 (1.79) †	0.4 (1.422)	-0.81 (-2.033) *
5	800-1,000	0.53 (1.823) †	0.93 (3.168) **	-1.16 (-2.81) **
6	1,000-1,200	0.91 (3.026) **	1.35 (4.527) ***	-1.84 (-4.354) ***
7	1,200-1,400	0.65 (2.139) *	1.05 (3.487) ***	-1.47 (-3.428) **
8	1,400-1,600	0.86 (2.829) **	0.96 (3.15) **	-1.76 (-4.096) ***
9	1,600-1,800	0.53 (1.769) †	0.7 (2.314) *	-1.3 (-3.063) **
10	1,800-2,000	0.56 (1.868) †	0.55 (1.826) †	-1.29 (-3.015) **

Table 2. Experiment 1 results of the time course analyses for the time segments following the onset of the pronoun for the fixed factors pronoun condition (*er* vs. *der*) and order of mention (1st vs. 2nd). Note: first numbers are coefficients. Numbers in parentheses are *t*-values. † p < .1; * p < .05; ** p < .01; *** p < .001; outcome variable: proportion of fixations transformed into empirical logits

27   The main effects of pronominal condition and order of mention were either marginally significant or significant across the same time windows (600-2,000 ms), except for time window 4 where there was only a marginally significant main effect of the pronominal condition (600-800 ms). The positive sign of the coefficient (*beta*) indicated that overall there were more looks for the personal than for the

d-pronoun to both target pictures, while at the same time there were overall more looks to the second-mentioned target picture than to the first-mentioned target picture. To break down the interaction, separate analyses for each type of pronoun were calculated entering order of mention as a predictor. These analyses showed that for the personal pronoun there were more looks to the first-mentioned entity than to the second-mentioned entity. This effect was significant in time windows 8 to 10 (1,400-2,000 ms). For the d-pronoun significantly more looks were triggered to the second-mentioned than to the first-mentioned entity across time windows 5 to 10 (800-2,000 ms). Thus, the interaction was due to there being significantly more looks to the second-mentioned antecedent for the d-pronoun than for the personal pronoun, and later more looks to the first-mentioned entity for the personal pronoun than for the d-pronoun, indicating an effect of order of mention.

Time window	In millisecond	Fixed predictor – order of mention: 1st	
		Personal pronoun	d-pronoun
4	600-800	-0.41 (-1.402)	0.4 (1.463)
5	800-1,000	-0.24 (-0.807)	0.93 (3.143) **
6	1,000-1,200	-0.49 (-1.647)	1.35 (4.495) ***
7	1,200-1,400	-0.41 (-1.342)	1.05 (3.547) ***
8	1,400-1,600	-0.81 (-2.656) **	0.96 (3.142) **
9	1,600-1,800	-0.61 (-2.018) *	0.7 (2.314) *
10	1,800-2,000	-0.74 (-2.457) *	0.55 (1.805) †

Table 3. Experiment 1 results of the separate time course analyses for each type of pronoun (*er* and *der*) for the time segments which showed a significant interaction. Order of mention (1st vs. 2nd) was entered as a fixed predictor. Note: first numbers are coefficients. Numbers in parentheses are *t*-values. † p < .1; * p < .05; ** p < .01; *** p < .001; outcome variable: proportion of fixations transformed into empirical logits

4.3. Discussion

28 The eye-movement measures showed a clear effect of order of mention on both pronouns. After hearing the personal pronoun *er*, participants fixated more often the pictures of the first-mentioned than the second-mentioned character of the antecedent sentence, while in the d-pronoun condition the participants fixated the picture of the second-mentioned character more than the first-mentioned character.

29 Our findings are in line with the assumption that personal and d-pronouns have different coreference functions, such that personal pronouns prefer first-mentioned

topical antecedents, while d-pronouns prefer second-mentioned non-topical antecedents (Levinson, 1987 and 1991; Ariel, 1990 and 2001; Lambrecht, 1994; Bosch et al., 2003; Kaiser & Trueswell, 2004 and 2008; Bosch et al., 2007; Wilson, 2009). However, this preference emerged quite late (1,400 ms) compared to the second-mentioned non-topical preference for the d-pronoun that appeared much earlier (800 ms after the onset), suggesting a higher degree of ambiguity for the personal pronoun. This is in line with the assumption that the d-pronoun is marked for non-topical coreference relations while the personal pronoun is thus unmarked and therefore more ambiguous (Zifonun et al., 1997; Ahrenholz, 2007; Bosch & Umbach, 2007; Kaiser, 2011b). At the same time the results are in contrast with the prediction of the Givenness Hierarchy (Gundel et al., 1993; Gundel, 2003) which, according to observations from English personal and demonstrative pronouns, suggests that personal pronouns are marked for topicality (due to the *in focus* requirement of its antecedent), while it is the d-pronouns that are more flexible in their coreference relations.

30   The observed pattern of results could be predicted from Kaiser and Trueswell's (2008) Form-Specific Multiple-Constraints Approach according to which different pronouns, e.g., personal and demonstrative, are differentially sensitive to salience factors such as grammatical role and topicality information. However, in the Kaiser and Trueswell's (2008) study of Finnish, it was the demonstrative pronoun that induced less robust resolution preferences. For German, Wilson (2009) has claimed that personal pronouns are sensitive to grammatical role information and discourse factors, while d-pronouns are mainly sensitive to discourse factors. With regard to our results this could mean that the missing grammatical role information affected the resolution of the personal pronoun, since it is usually disambiguated by grammatical role information. In other words, more ambiguity was observed for the personal pronoun, whereas the d-pronoun was not affected to the same extent, perhaps because d-pronouns in general are more sensitive to order of mention/ discourse information to begin with[9].

31   In sum, the order of mention of the antecedent candidates influenced the resolution of personal and d-pronouns. However, the relative influence of the order of mention information cannot be assessed, since it coincided with the topicality information in the materials of Experiment 1. The first-mentioned entity was always topical and the second-mentioned entity non-topical. Therefore, in the second experiment, it was investigated whether the resolution preferences of personal and d-pronouns would vary following non-canonical antecedent structures; that is, whether the information status of the antecedent candidates would influence the order of mention preferences for *er* and *der*.

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9. This is highly interesting as it would then mean that subject verb agreement information in absence of any thematic role information is not sufficient to trigger a clear/early subjecthood preference (in line with Kaiser, 2011a: 1628).

5. Experiment 2: pronoun resolution after non-canonical antecedent structures

5.1. Method

5.1.1. Participants

32 German native speakers (18 female, 14 male) who had not taken part in Experiment 1, participated in Experiment 2. They were aged between 17 and 25 years (mean = 19.47; SD = 2.22). All participants were tested individually and were paid a nominal fee for their participation. All had normal or corrected-to-normal vision. Seven participants were students at the Karlsruhe University of Education, and twenty-five participants were pupils at the high school Goethe Gymnasium Karlsruhe (grades 12 and 13) [10].

5.1.2. Apparatus

The apparatus was the same as in Experiment 1.

5.1.3. Materials and design

The stimuli were the same as those used in the first experiment only the comparative sentences were changed from *NP1-verb-comparative-NP'* to *Comparative-NP'-verb-NP1* as in [11a] and [11b] below. This included all 24 experimental items, as well as 24 comparative fillers.

[11a]   Sound file 1: Schwerer als der Tisch ist der Schrank.
         'Heavier than the table is the cupboard.'

[11b]   Sound file 2: Er stammt aus einem Möbelgeschäft in Belgien. Das Sofa soll nächste Woche geliefert werden.
         'It comes from a furniture store in Belgium. The sofa is supposed to be delivered next week.'

5.1.4. Procedure

The procedure was the same as in the first experiment. The pictures were the same as in the first experiment except that the position of all pictures was rotated and counterbalanced among all three available positions. The accuracy of the responses to the content questions was very high with 94% correct answers (24 questions; mean correct answers = 22.61, SD = 0.97).

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10.   Note that German pupils who graduate from high school with a diploma enabling them to study at a University, need to attend school for 13 years, usually starting at age 6 or 7 and ending at age 19 or 20. Therefore, German high school students of grades 12 and 13 are as old as undergraduate students in the Netherlands.

5.2.   Results

36   The data analysis was conducted as in Experiment 1. 70 target looks (1.41%) which had started before pronoun onset (-200-0 ms) were excluded, resulting in 4,914 analyzable samples in total. Figure 3 presents the time course of the effects for the analysis regions.

37   As for the first experiment, the fixation proportions to the first- and second-mentioned target picture (out of all looks) were transformed into empirical logits, and the data were analyzed using linear mixed effect models. Participant and item information was entered as a crossed-random factor, and pronoun condition and order of mention as fixed predictors. Because the loglikelihood test showed that the full model did not increase the fit to the data in any of the analysis regions, the statistics for the interactions will not be reported.
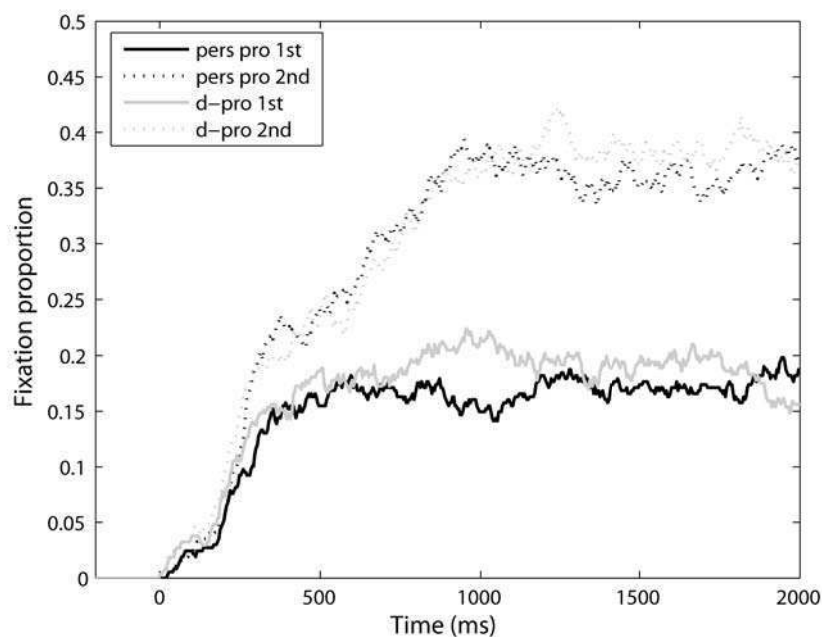

Figure 3. Probability of fixating the first- and second-mentioned referent as a function of time in each of the two conditions (personal pronoun, d-pronoun) in Experiment 2

38   The analysis of the fixed effects showed a consistent highly significant main effect of order of mention across the time windows 2 to 10, depicting an overall preference for the focused second-mentioned antecedent over the non-focused first-mentioned antecedent. This indicates an effect of the focus information on the resolution of the two pronominal forms.

Time window	In millisecond	Fixed predictors	
		Pronoun condition: *der*	Order of mention: 1st
1	0-200	-0.05 (-0.552)	0.02 (0.259)
2	200-400	0 (0.009)	0.52 (3.255) **
3	400-600	0.02 (0.112)	0.7 (3.727) ***
4	600-800	-0.06 (-0.317)	1.22 (6.198) ***
5	800-1,000	-0.23 (-1.137)	1.75 (8.587) ***
6	1,000-1,200	-0.24 (-1.206)	1.98 (9.824) ***
7	1,200-1,400	-0.27 (-1.324)	1.93 (9.484) ***
8	1,400-1,600	-0.17 (-0.859)	1.91 (9.431) ***
9	1,600-1,800	-0.25 (-1.241)	1.92 (9.413) ***
10	1,800-2,000	0 (-0.014)	2 (9.879) ***

Table 4. Experiment 2 results of the time course analyses for the time segments following the onset of the pronoun for the fixed factors pronoun condition (*er* vs. *der*) and order of mention (1st vs. 2nd). Note: first numbers are coefficients. Numbers in parentheses are *t*-values. † $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$; outcome variable: proportion of fixations transformed into empirical logits

5.3. Discussion

39 The eye-movement measures showed a very strong effect of the information status of the antecedents in ambiguous pronoun resolution. Shortly after pronoun onset (200 ms), participants fixated more often the pictures of the focused second-mentioned than the non-focused first-mentioned character of the antecedent sentence regardless of the pronoun, as was indicated by the overall persisting main effect of order of mention. This is in line with previous research on pronoun resolution in English which found that the personal pronoun preferred focused entities compared to non-focused entities (Arnold, 1999, Experiment 1; Cowles et al., 2007). For example, Cowles et al. who used a cross-modal priming task, found that the focus/non-focus antecedent distinction had a comparable influence on pronoun resolution as the topic/non-topic distinction (in that topicality and focus information increased the degree of salience of the antecedents). In contrast, the use of the visual-world eye-tracking task in the current study allowed us to detect a qualitative resolution difference. Specifically, the focus/non-focus distinction was found to be a stronger cue than the topic/non-topic distinction in the first experiment as indicated by the clear and early effects after non-canonical antecedent structures.

40   Our results are different from previous studies which used cleft constructions and topicalized the non-clefted antecedent by pronominalizing it (Arnold, 1999, Experiment 2; Kaiser, 2011a). These studies found that when a pronominalized entity was presented, it was preferred over the non-pronominalized focused entity for subsequent pronominal reference. We take our results to further suggest that when both antecedents are non-pronominalized and thus provide the same level of referential content (so when this strong topic cue is missing), focus information has an effect on pronoun resolution.

41   Our results also differ from Colonna et al.'s (2012) results which found an effect of topicalization on the resolution of German and French personal pronouns, but not of focusing. As they measured intra-sentential resolution preferences, topic shift interpretations were avoided within the sentence and led to a preference for the sentence topic. Our results showed that focus information affected inter-sentential pronoun resolution preferences; topic shift may occur between sentences but is avoided within sentences.

42   In fact, the effects after marked antecedent structures emerged very rapidly, immediately after 200 ms from pronoun onset, and remained very strong throughout the whole analysis window (until 2,000 ms), indicating no ambiguity after the present type of antecedent structures. If we acknowledge that it takes about 200 ms to program and launch a saccade (Matin et al., 1993) and that the duration of the pronouns was about 100-150 ms, this suggests that participants did not wait until they heard the incoming information about the pronominal form used (bottom-up processes), but instead that they had some predictions about the subsequent discourse when listening to the first sound file (top-down processes) which were not disconfirmed when encountering the pronominal form. It is very probable that the participants had a topic-shift-interpretation in mind when listening to the first sentence. The focused entity, which is assumed to represent new or unexpected information, was conceived to represent the topical entity of the subsequent sentence [11].

43   Interestingly, this indicates that personal and d-pronouns may not only have overlapping functions when only one potential antecedent is available as in [1], but also when more than one potential antecedent is available. That is, the discrimination of the functions of the two pronouns as observed in Experiment 1, may only take place when other discourse cues for disambiguation are less strong or unavailable.

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11.   Note that there is another alternative: since the second-mentioned entity showed subject verb agreement and thus constituted the syntactic subject of the clause, personal pronouns might have favoured it due to its syntactic role, and d-pronouns might have favoured it due to its position. Although such an explanation cannot be ruled out on the basis of these materials, we think that it is less likely given the fact that a) both pronouns were resolved as early as was possible and that there were no timing differences in resolution patterns between them, and b) in Experiment 1 the personal pronoun was resolved very late (1,400 ms) although its antecedent had been the syntactic subject and was the topic of the sentence.

44   This finding is particularly important with regard to previous research on personal and d-pronouns/demonstratives which has mainly focused on investigating pronoun resolution after SVO and OVS antecedent structures in order to disentangle effects of subjecthood and position (Bosch et al., 2007; Kaiser & Trueswell, 2008; Wilson, 2009). Since SVO structures represent canonical structures and OVS non-canonical structures, the different information statuses of the antecedent candidates across structures might have interacted with grammatical role and positional cues, making it difficult to fully disentangle the above mentioned factors. Future studies should thus pay attention to the interaction of these factors when constructing materials.

6.   Conclusion

45   The current study has shown that information structure affects the resolution of personal and d-pronouns in ambiguous discourses in German. Notably, it was found that the coreference functions of personal and d-pronouns only differed after canonical topic-comment antecedent structures, in that the personal pronoun was resolved towards the topical and the d-pronoun towards the non-topical entity. However, the resolution preferences for the two pronominal forms did not differ after non-canonical focus structures, where both forms were resolved towards the focused entity. This is taken as evidence that discourse pragmatic information plays an important role in pronoun resolution. Furthermore, the effect of focus emerged so early that it was argued that the ambiguity had been resolved by the structure (top-down processes) and this interpretation was supported by the presence of a pronoun (bottom-up processes). This finding is particularly interesting with regard to previous pronoun resolution findings after non-canonical antecedent structures, in that it suggests that the information structural cues of such structures might account (at least partly) for the findings, and it further shows the need to differentiate between resolution preferences found after canonical and non-canonical antecedent structures. With regard to the co-reference functions of personal and d-pronouns, the findings suggest that even in contexts where two potential antecedents appear, the pronouns may show overlapping functions.

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Appendix

Experiment 1: first sound files

- https://archive.org/download/Exp1Der1401/exp1_der14_01.wav
- https://archive.org/download/Exp1Der1401/exp1_der14_02.wav
- https://archive.org/download/Exp1Der1401/exp1_er14_01.wav
- https://archive.org/download/Exp1Der1401/exp1_er14_02.wav

Experiment 2: first sound files

- https://archive.org/download/Exp1Der1401/exp2_der14_01.wav
- https://archive.org/download/Exp1Der1401/exp2_der14_02.wav
- https://archive.org/download/Exp1Der1401/exp2_er14_01.wav
- https://archive.org/download/Exp1Der1401/exp2_er14_02.wav

These 8 sound files are available online: https://archive.org/details/Exp1Der1401.