Differences in the resolution of German personal and demonstrative pronouns and the influence of world knowledge on this process – an eye-tracking study

Bachelor Thesis
September 2007

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Abstract

This thesis investigates the differences in the resolution of German personal and demonstrative pronouns and the influence world knowledge has on this process. In an experiment that combined visual and auditory stimuli the method of eye-tracking was used to observe fixation frequencies on different referents. The results show that the antecedent preference of a personal pronoun differs from that of a demonstrative pronoun. While the personal pronoun has a preference for the referent in subject position, the demonstrative pronoun prefers the referent that is in object position. Furthermore, it could be shown that context information surpasses this linguistic preference if a conflict with world knowledge is present.
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1. Introduction

In linguistic theory a pronoun is an anaphoric expression which refers to an antecedent that has already been introduced as a referent in the discourse before. This antecedent is either a noun or a noun phrase. Pronouns are said to be coreferential with the expression they substitute and their main usage is to avoid repetition of explicit names [Almor et al., 2007]. However, a listener hearing an anaphoric expression like a pronoun is confronted with the task to decide to which antecedent in the discourse it actually refers. This process is known as anaphora resolution. The task itself is most of the time easy to manage and we do not pay special attention to it. Understanding an utterance that uses a pronoun like (1) is straight forward and can be done without any problems. The underlying mechanisms on the other hand do not seem to be that trivial, especially when more than one possible referent is present. Thus, from a psycholinguistic view the interesting questions are how exactly this process works and what influences it. Why and how do we know to what exactly a certain anaphoric expression refers?

(1) Ein Mann geht spazieren. Er fühlt sich wohl dabei.
(A man is having a walk. He is feeling fine.)

In the past this topic has been addressed in different areas and some restrictions on possible antecedents for pronouns have been identified. One of the most important works is Binding Theory [Chomsky, 1981] which is concerned with syntactic restrictions. Chomsky differentiates between three kinds of anaphoric expressions: Anaphors (bound pronouns like "'himself'"), Pronominals (referential pronouns like "'he'") and R-expressions (like "'the car driver'"). The main observation for referential pronouns is that they must not be bound\(^1\) by it’s antecedent. Besides syntactic restrictions semantic processes also seem to be important for choosing the right referent [Caplan and Hildebrandt, 1988]. One essential work that is concerned with semantic factors is Discourse Representation Theory [Kamp, 1981]. The idea here is that the resolution of a pronoun goes beyond sentence boundaries. Every sentence has to be integrated stepwise into a discourse representation structure in which eventually the correct antecedent can be found. Another semantic approach is called Centering Theory [Grosz et al., 1995]. This theory is concerned with differences in the saliency of referents to explain possible restrictions.

\(^{1}\)A binds B if A c-commands B. This means that the ancestor of A is also an ancestor of B.
Furthermore, it seems that also pragmatic factors are somehow involved in the resolution process of pronouns [Bosch et al., 2007].

The interesting question remains, how these different factors play together in the resolution process and what is responsible for a final decision. Can one factor influence or even surpass the others? Is the importance of factors dependent on the information a sentence includes?

In this thesis we address these questions while investigating the resolution process of two special kinds of pronouns: German personal and demonstrative pronouns. We are looking at how those two types differ in processing, how world knowledge influences this process and whether differences in the degree of intelligence are related to the amount of the influence. This was done by conducting an experiment using the method of eye-tracking together with an advanced variant of the visual world paradigm [Tanenhaus, 1996] to check fixation frequencies on pre-defined regions of interest that represented the denominated possible antecedents of the pronouns.

1.1. Personal and Demonstrative Pronouns

In German there are two different types of pronouns that can be used to naturally refer to proper nouns: Personal pronouns like *er, sie, es* and demonstrative pronouns like *der, die, das*. In the past many people believed that demonstrative pronouns in German are only used as a familiar form in a deictic reference. This might have been due to the fact that a personal pronoun is interchangeable with a demonstrative pronoun without a difference in meaning if only one referent is available. A sentence like (2) is understood with either a personal or a demonstrative pronoun.

(2) *Siehst Du den Mann? ER/DER geht gerne spazieren.*

*(Can you see the man? He(PERS/DEM) likes having a walk.)*

However, there is more to it. When more than one possible antecedent is present it seems that there are differences in the preferences of each type of pronoun.

(3) a. *Der Sohn geht nach Hause zu seinem Vater, weil ER zu Abend essen moechte.*

*(The son is going home to his father, because he(PERS) wants to have dinner.)*
Native German speakers intuitively perceive that the antecedent in (3a) has a preference for *Der Sohn* while in (3b) there is a preference for *seinem Vater*. A first observation on what the basis of these preferences could be was formulated in the Complementarity Hypothesis: Demonstrative pronouns in contrast to personal pronouns prefer previously non-salient and non-topical (in respect to the discourse) referents [Bosch et al., 2003]. Bosch et al. found empirical evidence for this hypothesis in a corpus analysis study. These characteristics can also be observed in (3). *Der Sohn* is clearly topical since it is the acting character, while *seinem Vater* is non-topical.

A further interesting criterion is to which phrase category the preferred antecedent of a pronoun belongs. In sentences with an active form it seems that the personal pronoun has a preference for the subject, while the preference for the demonstrative pronoun is the non-subject of the preceding sentence. These observations again are supported empirically by the results of a corpus analysis study as well as different psycholinguistic studies [Bosch et al., 2007]. Additionally this phenomenon can be observed for Italian pronouns [Carminati, 2002] as well as for Finnish pronouns [Kaiser and Trueswell, 2005] and Dutch pronouns [Kaiser and Trueswell, 2007]. And again this is consistent with (3) where *Der Sohn* is the subject and *seinem Vater* the non-subject (the object in this case).

However, there seems to be another factor that can in some cases influence the resolution process.

(4) a. *Der Vater bringt seinen Sohn in den Kindergarten, weil ER spielen will.*
   *(The father is bringing his son to the kindergarten, because he(PERS) wants to play.)*

b. *Der Vater bringt seinen Sohn in den Kindergarten, weil DER zur Arbeit muss.*
   *(The father is bringing his son to the kindergarten, because he(DEM) wants to play.)*
In (4) things are different. Although the preference of ER in (4a) is Der Vater we would not resolve the pronoun in that way. What comes in here is the factor of world knowledge. Since we know on the one hand that children do play a lot more frequently than adults and on the other hand that kindergartens are for playing and for children we can conclude that it is the son who wants to play. Thus, the chosen antecedent will be seinen Sohn. The same holds true for (4b) in which the preference of DER is for seinen Sohn. Since we know that it is adults who go to work, we do resolve the pronoun in a different way. The question that arises here is in which circumstances and to what extent world knowledge does influence the resolution process. Is world knowledge (and thus plausibility) responsible for a final decision? Is there an interference of a decision purely based on linguistic factors before integrating the contextual information with world knowledge for the final decision? How long does it take to integrate contextual information with world knowledge? And what happens, if there is no such information available?

We assume that there are two kinds of effects: A linguistic one and a contextual one. The linguistic effect is triggered by the pronouns itself and is an automatic process. The preference for a certain antecedent for this effect is a lexical property of the pronoun itself (see also [Bosch et al., 2007]). A personal pronoun should have a preference for the referent in subject position, while a demonstrative pronoun should prefer the antecedent which is in object position. This effect should be bigger for the demonstrative pronoun than for the personal pronoun, since a demonstrative pronoun is more uncommon and clearly changes the topic of the story to the character that was the non-topical one before. The contextual effect is triggered by the context information the sentence provides and demands an integration of this information with world knowledge to check for plausibility. If context information is available the final decision will be based on the contextual effect. If no context information is present, the only way to resolve the antecedent is through the lexical property of the pronoun. When a conflict between the linguistic preference and the contextual one is present, the automatic linguistic effect will be triggered first, but afterwards a shift will occur and the contextual factors will be used for the final decision.
1.2. The Relation between World Knowledge and Intelligence

As we all know, intelligence is an important factor in acquiring and using knowledge [Süß, 2007]. In general, intelligence can be divided into two distinct types: Fluid intelligence and crystallized intelligence [Horn and Cattell, 1966]. While fluid intelligence describes the general ability to recognize and apply rules as well as the ability to solve tasks in inductive and deductive ways, crystallized intelligence is the ability to solve a task by using the knowledge one has already acquired. Since we are interested in the integration of world knowledge during the pronoun resolution process, crystallized intelligence is an interesting factor. The question arises whether the degree of (crystallized) intelligence has an influence on the resolution process. If world knowledge determines the final decision for a certain referent, does the degree of intelligence then influence the point in time this decision is made? Do people with lower intelligence need more time to resolve an antecedent of a pronoun?

We assume that in a situation where a conflict between contextual and linguistic preference is present, the point in time of the shift from the linguistic effect to the contextual one should be correlated to the degree of intelligence of the subject.

1.3. Eye-tracking

To investigate the addressed questions, the method of eye-tracking was used together with an advanced variant of the visual world paradigm [Tanenhaus, 1996]. In eye-tracking, the movements of the eyes are recorded and saccades as well as fixations can be identified. Saccades are movements of the eye that are executed approximately every 250 milliseconds. A fixation is when no saccade is done, but a focus is maintained. Since the average fixation frequency is about 4 fixations per second and since fixations and visual focus are in general considered to be closely related to attention, this method allows for a very time accurate measuring of attentional focus. Eye-tracking has become very popular to investigate linguistic issues. Besides its usage in reading tasks, one of the main areas is the methodology of the visual world paradigm. In its original version, a subject does look at a screen which shows different elements while at the same time he or she is presented auditory stimuli that refer to some of the elements on the screen. The eye-movements are recorded during the whole time course and can be associated with certain parts of the auditory stimuli, since experiments using this methodology showed a significant correlation between the auditory mentioning of an element and fixations.
on this element on the screen [Cooper, 1974] [Eberhard et al., 1995]. The advantages of this methodology are obvious: It’s an online measure for attention without the need of a secondary task. Furthermore, it has already been used in experiments that investigated the processing of pronouns and anaphora resolution [Karabanov, 2006] [Jessen, 2006].

1.4. Hypotheses

To summarize, the following hypotheses are made for the experiment:

• The fixation frequency at the point in time of mentioning the personal pronoun Er will be higher for the referent in subject position

• The fixation frequency at the point in time of mentioning the demonstrative pronoun Der will be higher for the referent in object position

• The difference in fixation frequencies between the linguistically preferred and the linguistically non-preferred referent will be higher for the demonstrative pronoun than for the personal pronoun

• In a situation where a conflict between the linguistic preference and the contextual preference is present a shift will occur in the time course after the linguistic effect interfered and the fixation frequency will eventually be higher for the contextually preferred referent.

• The point in time of this shift correlates with the intelligence of the subject. The higher the intelligence, the earlier the shift occurs.

2. Methods

2.1. Visual Material

The visual stimuli were made up of 12 photographs that showed pseudo-natural scenes of Playmobil figures and objects. We avoided drawings as visual stimuli so that the scenes were more realistic and by not using pictures of actual scenes and persons we also accounted for unintentional influences by mimic or other aspects of the pictured humans. All of the images were used with their native resolution but cropped to 2560x1600 pixels. Each scene included three human figures. Two of them were male (referents R1 and R2).
and were mentioned in the auditory stimuli. In Figure 1 the two referents correspond to the policeman and the cardriver. We varied their position in a way that in some pictures R1 is positioned on the right and on other pictures on the left of R2. The third human figure was used as a (female) control which was not mentioned in the auditory stimuli. As it is known that people prefer looking at humans we wanted to make sure that people do not only look to the human figures instead of following the story that is presented auditory. We therefore placed for example the little girl in Figure 1. In the following this female control is referred to as referent R4. Furthermore there was one inanimate referent R3 that was also included in the auditory stimuli. Considering Figure 1 again, this would be the car as it comes up during the story as third referent apparent in the scene. Referents R1, R2 and R3 were arranged in a triangular position in order to exclude accidental fixations on a third referent while performing a saccade from one to the other referent. Additionally, all scenes included various objects and animals as distractors to make the scenes more interesting and natural (see Figure 1). During the experiment the 12 images were shown twice (with a distance of at least 3 images), filled with 36 images of a similar type (only the number, gender and/or visual salience of the referents varied) plus 8 images that showed a load of random Playmobil figures and objects. This was due to the fact that this experiment was conducted as a subproject together with two others (for further information about these experiments see [Bergmann, 2007] as well as [Bärnreuther, 2007] and [Kleemeyer, 2007]).

Figure 1: Example image
2.2. Auditory Material

The auditory stimuli consisted of 6 short stories for each of the 12 images. Each short story included three sentences. The first sentence introduced the scene (starting at 0ms after stimulus onset).

Example:

Eine Verwarnung.

The second sentence introduced the three referents R1, R2 and R3 with full noun phrases (starting at 3000ms after stimulus onset). As the third referent is always neutral in respect to its gender, it cannot function as an antecedent for the pronoun. We introduced this referent in a way that the main referents R1 and R2 of the second sentence do not immediately precede the pronoun denomination of the third sentence.

Example:

Der Polizist (R1) redet gerade mit dem Autofahrer (R2) über das falsch geparkte Auto (R3).

While the first two sentences have been the same in each of the 6 short stories, the third sentence always represented a different Condition (starting at 9000ms after stimulus onset). Condition 1 and Condition 2 had a contextual preference for referent R2. Condition 1 had a linguistic preference for referent R2 not resulting in a conflict with the following context information, while Condition 2 had a linguistic preference for referent R1 and therefore was indisputable. Condition 3 and Condition 4 had a contextual preference for referent R1. Condition 3 had a linguistic preference for referent R2, thus resulting in a conflict, while Condition 4 had a linguistic preference for referent R1 and therefore did not result in any conflict. Condition 5 and Condition 6 were neutral in regard to the contextual preference. Condition 5, however, had a linguistic preference for referent R2 while Condition 6 had a linguistic preference for referent R1.
Examples:

Condition 1:  *Der ist mit der Verwarnung nicht einverstanden und regt sich fürchterlich auf.*

Condition 2:  *Er ist mit der Verwarnung nicht einverstanden und regt sich fürchterlich auf.*

Condition 3:  *Der will 20 Euro für Falschparken kassieren und regt sich fürchterlich auf.*

Condition 4:  *Er will 20 Euro für Falschparken kassieren und regt sich fürchterlich auf.*

Condition 5:  *Der ist ziemlich unhöflich, schreit ganz laut herum und regt sich fürchterlich auf.*

Condition 6:  *Er ist ziemlich unhöflich, schreit ganz laut herum und regt sich fürchterlich auf.*

The fourth sentence was a control question to check if the subjects did understand the meaning of the story and was the same for all conditions.

Example:

*Wer von den beiden regt sich fürchterlich auf?*

An overview of the whole setup of a story including all parts and all conditions can be seen in Figure 2.

Since we measured fixation frequencies on defined regions of interest (the referents) we had to make sure that there was a time distance of at least 500ms between the offset of one referent and the onset of the next one, because fixations usually last about 300ms. If we did not guarantee this minimal time distance the effects on different words could not be distinguished, as the subject needs time to allocate the fixation to the next word.
For the 36 filler images there have also been different conditions (either two or four) and therefore also different short stories (compare [Bergmann, 2007], [Bärnreuther, 2007] and [Kleemeyer, 2007]). None of the auditory filler contained a control question in the end. Only the 8 images showing a load of random Playmobil figures and objects did not have any auditory stimuli.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Introduction of the scene</th>
<th>Pronoun - linguistic preference</th>
<th>Contextual Preference</th>
<th>Neutral end - basis for question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eine Verwarnung</td>
<td>Der ist mit der Verwarnung nicht einverstanden</td>
<td>und regt sich furchterlich auf</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Der Polizist (R1) redet gerade mit dem Autofahrer (R2) über das falsch geparkte Auto (R3)</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td>Ist mit der Verwarnung nicht einverstanden</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Table of one story with all conditions

### 2.3. Combination/Randomization/Balancing

Each subject saw every image twice but each time with a different condition. Therefore, every subject could listen to 24 stories with changing condition which were balanced over three subjects. The minimal distance between the first and the second occurrence of the same image was three to avoid memory effects. We made sure that conditions with a conflict (Condition 2 and Condition 3) only appeared when the corresponding image was shown for the second time. This was to ensure that the subjects did not think we only gave them ”strange” stories. Since some of the filler images were quite similar to the actual stimuli we also put constraints on the minimal distance between similar images. This minimal distance was again three. Eventually, the 12 actual images have been balanced equally in between the filler pictures.

### 2.4. Intelligence Test

In order to investigate the influence of intelligence on the resolution of personal and demonstrative pronouns we used the MWT-B (Mehrfach-Wortschatz-Test) [Lehrl, 1977] which is a test measuring general intelligence with a special remark on crystallized intelligence. As crystallized intelligence is also dependent on cultural background we took into account only participants with similar background namely German native
speakers. This test is only meant as a measure to compare the general cognitive abilities among the subjects. We did not do any comparison with populations outside the subject pool or with what is know as the Intelligence Quotient.

2.5. Participants

60 native speakers of German (32 male; 28 female) participated in the experiment. In order to achieve a very heterogeneous field people of different educational status agreed to participate in our experiment. All of them were between 18 and 50 years old (mean age: 24.8) and had normal or corrected-to-normal vision (with one subject being colourblind). They participated voluntarily and were either paid 7.50 Euro or got 1.5 "Versuchspersonenstunden".

2.6. Apparatus

The images were photographed with a Sony Cyber-shot DSC-V1 5.0 Mega Pixels (Sony Corp., Japan) and were presented on a 30” TFT screen (Apple Cinema HD Display, Apple Inc., USA) with a native resolution of 2560x1600 pixels. The auditory stimuli were recorded with a Shure SM-58 (Shure Incorporated, USA) through a Tascam US-144 Audio Interface (Tascam, USA). They were edited in Audacity (www.audacity.sourceforge.org) and were presented using a Logitech 2.1 system (Z3 Style 2.1, Logitech, Switzerland) with two front loudspeakers being positioned left and right of the screen and the bass loudspeaker standing on the floor under the screen. The eye movements were measured with an Eyelink II eye-tracking system (SR Research, USA) that had a frequency of 250Hz.

2.7. Procedure

The conduction of the experiment took place in a darkened room. Before being tracked, the participant was given a consent sheet and a subject questionnaire which he or she had to fill in and to sign. An instruction about the course of the experiment followed, but the subject was left completely naive about the aim of the study. The participant then was placed sitting in front of the screen with a spatial distance of 80cm to the eyes. A chin rest could be used if preferred by the subject but was optional. The eye-tracker was then mounted and calibrated using the 13-dot-grid procedure. Only calibration values
with a mean error of less than 0.3° or less than 0.4° if the maximum was lower than 1.0° in the validation were accepted. The subject was instructed to watch the scenes attentively and to listen carefully to the short stories. The stimulus onset and offset for the images and the short stories was synchronized with the images lasting two seconds longer than the audio. Before every trial the subject was instructed to fixate a fixation point in the middle of the screen which was used for drift correction. Each trial was manually triggered by the experimenter if the drift correction value was valid. Otherwise a recalibration was done. After the presentation of 36 images there was the opportunity to make a break. Before continuing with the experiment a recalibration was forced.

After being tracked the subject was instructed to fill in the MWT-B test. The subjects were not told any results of this test. At the end the participant was informed about the aim of the study and handed out a feedback sheet if wanted.

2.8. Regions of Interest

For the data analysis we used the build-in function ”roipoly” of Matlab in order to define regions of interest (ROI) so that distractors of the scene were excluded from analysis. Firstly, we defined these regions within a picture as narrow as possible along the referents R1, R2, R3 and R4 including only fixations directly on these Playmobil figures. In a second step we considered different factors to enlarge the ROIs in order to make sure that fixations close by which are supposed to be on the referents also belong to the ROI. On the other hand the factor did not have to be too large. Consequently we scaled the regions of interest with a factor of 2.0. We used these scaled ROIs during further analysis of the fixations on the referents. An example of the resulting regions is shown in Figure 3.
3. Results

3.1. Validity of Data

To ensure that all images were perceived as meaningful and to check whether there were drastic differences between the fixations on the regions of interest between images, we computed the fixations for every region of interest summed over all conditions and all subjects for the first 3000ms. During this period the introductory sentence was presented auditory which did not include any naming of referents. All regions of interest have actually been fixated in every image (mean values: \( R_1=21.72, R_2=18.37, R_3=11.72, R_4=6.3, \) Beyond Region of Interest=41.89; standard deviations: \( R_1=6.42, R_2=4.28, R_3=9.04, R_4=2.91, \) Beyond Region of Interest=10.84) (Figure 4). Furthermore, the fixations on the regions of interest around the crucial referents for our hypotheses (referents \( R_1 \) and \( R_2 \)) were equally distributed over all images.
Figure 4: Distribution of fixations on regions of interest during the first 3000ms on a per-image basis (summed over all subjects and all conditions)

We also had to make sure that every participant did understand the task and was comparable to the others. Therefore, we computed the fixations for every region of interest summed over all images and conditions for the first 3000ms. Every subject actually fixated all regions of interest (mean values: R1=21.72, R2=18.37, R3=11.72, R4=6.3, Beyond Region of Interest=41.89; standard deviations: R1=7.52, R2=5.19, R3=4.35, R4=3.11, Beyond Region of Interest=8.71) (Figure 5). Again the distribution was equal, especially for the regions around R1 and R2. Since it was never the case that the fixations of one subject differed more than two standard deviations from the mean for both regions around referents R1 and R2 at the same time, we included all subjects for our analysis.
3.2. General Observations

In order to investigate the differences in fixation frequencies we divided the whole time-course of 14025ms into slots of 33ms to allow for a very accurate measure. We used box-car slots since the difference to Gaussian-filtered slots was minimal. For every condition the number of fixations per referent (number of fixations in the defined region of interest for that referent) was computed for each of the resulting 425 slots. Figure 6 shows the discourse of the fixation frequencies for all referents in the first condition summed over all images and all subjects. The numbers denote observations that will be explained step by step.
Since the first 9000ms were the same in all conditions Observation 1 – Observation 5 are general effects which are independent of the condition. They can therefore be investigated by summing up the fixation frequencies for this period over all images, all subjects and all conditions (Figure 7).

Figure 6: Discourse of fixation frequencies for all referents in the first condition summed over all images and all subjects

Eine Verwarnung.

Der Polizist redet gerade mit dem Autofahrer über das falsch geparkte Auto.

Der ist mit der Verwarnung nicht einverstanden und regt sich fürchterlich auf.
The first observation in this timecourse is that in the first 400ms the fixation frequencies for referents R1 and R2 are constantly increasing (R1: 0% – 34.67%, R2: 0% – 13.96%) while at the same time the fixation frequencies for Beyond Region of Interest are constantly decreasing (68.42% – 38.94%) (Observation 1). Furthermore, the fixation frequency for referent R1 is obviously higher than for referent R2. To investigate whether the distance of a referent to the fixation cross influences the fixation frequency on this referent in the first 400ms, we correlated the difference of the distance between referent R2 and the fixation point and the distance between referent R1 and the fixation point with the difference of the fixation frequency for referent R1 and the fixation frequency for referent R2. The differences are correlated with a value of $r=0.65$ (Figure 8).
After the peaks for R1 and R2 have been reached, the fixation frequencies decrease to a level in which a steady state is accomplished that lasts for about 1000ms (Observation 2). We used the Matlab curve fitting tool cftool to fit a line to the data in a manually defined region. Fitting such a line to the discourse of fixation frequencies for each referent in this state results in extremely small slopes (R1: 0.358602, R2: -0.876487, R3: 0.39395, R4: 0.780027) (Figure 9).
The next observation is the increase of the fixation frequency for referent R1 up to 35.25% during the auditory introduction of this referent with a full noun phrase (Observation 3). The slope of the increase is 23.52 resulting in an intersection with the slope of the steady state at 3465ms (Figure 10).

When referent R2 is named with a full noun phrase in the auditory stimuli (at 4800ms) the fixation frequency for this referent increases in a similar way as the fixation frequencies did for referent R1 with the peak at 31.37% (Observation 4). The slope here is 12.69 which results in an intersection with the slope of the steady state at 4235ms (Figure 11). This is more than 500ms before the onset of the naming of referent R2 in the auditory stimuli.
Figure 10: Slope of increase of fixation frequencies for referent R1 and intersection with slope of steady state

Figure 11: Slope of increase of fixation frequencies for referent R2 and intersection with slope of steady state
Another observation is that the fixation frequency for referent R4 stays very low during the whole timecourse (Observation 5). It has its peak at 8.89% and a mean of 5.35%. These values are remarkably lower than those for the other referents (Figure 12, Figure 13).

Figure 12: Distribution of mean, max and min fixation frequencies for all referents as well as Beyond Region of Interest

<table>
<thead>
<tr>
<th>Referent</th>
<th>Mean (%)</th>
<th>Max (%)</th>
<th>Min (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referent 1</td>
<td>21.62%</td>
<td>40.45%</td>
<td>14.38%</td>
</tr>
<tr>
<td>Referent 2</td>
<td>16.44%</td>
<td>33.38%</td>
<td>7.61%</td>
</tr>
<tr>
<td>Referent 3</td>
<td>15.43%</td>
<td>39.76%</td>
<td>5.31%</td>
</tr>
<tr>
<td>Referent 4</td>
<td>5.35%</td>
<td>8.89%</td>
<td>0.61%</td>
</tr>
<tr>
<td>Beyond Region of Interest</td>
<td>38.96%</td>
<td>68.42%</td>
<td>27.61%</td>
</tr>
</tbody>
</table>

Figure 13: Table showing the distribution of mean, max and min fixation frequencies for all referents as well as Beyond Region of Interest
3.3. Comparison between Referents per Condition

At 9000ms the auditory stimuli started to differ for each condition. Observation 6 – Observation 8 (Figure 6) are therefore condition dependent observations.

Condition 1 was a non-ambiguous one in which there was a linguistic as well as a contextual preference for referent R2. The fixation frequencies for all referents in this condition are depicted in Figure 14.

Figure 14: Fixation frequencies for all referents during the whole timecourse in Condition 1

The first remarkable observation is the increase of fixation frequency for referent R2 shortly after the demonstrative pronoun is named in the auditory stimuli (Observation 6). Fitting a line to this increase in the region between 9400ms and 10000ms results in a slope of 27.57 which is even higher than the increase for the same referent when it is introduced with a full noun phrase. The slope of the line fitted to the region between 8400ms and 9400ms which is the state directly before this increase is 0.83 leading to an intersection of both lines at 9536ms (Figure 15). After the peak at 31.39% is reached
(while the peak for referent R1 in the same period of time is 22.67%), there is a short period in which the distance of the two referents R1 and R2 gets smaller again (from -16.14 to -1.36) (Observation 7, Figure 16) before there is another increase for referent R2 such that it reaches a maximum at 40.19% (while the maximum for referent R1 is 25.23%) (Observation 8).

Figure 15: Slope of fixation frequencies for referent R2 in Condition 1 and intersection with the state before

Figure 16: Distance between the fixation frequencies for referents R1 and R2 between 9000ms and 14000ms in Condition 1
Since we were mainly interested in the differences between the fixation frequencies of the two referents R1 and R2 that could function as possible antecedents for the two pronouns, we statistically tested these differences in two directions – on a per-subject basis and on a per-image basis. We used the method of bootstrapping with a sampling time of 1000 to test for significance (with a significance level of $\alpha=5\%$) in each of the 33ms slots over the whole timecourse.

On the per-subject basis the number of significant tests for referent R2 increases after the naming of the demonstrative pronoun in the auditory stimuli with a local maximum of 29 at 10032ms and another one of 30 at 11682ms while at the same time the number of significant tests for referent R1 decreases (Figure 17).

On the per-image basis the significant tests for referent R2 show a similar pattern. They increase after the naming of referent R2 in the auditory stimuli with a local maximum of 4 at 10032ms – 10098ms and have another maximum of 7 at 12144ms (as well as at 12210ms and at 12969ms) while again the number of significant tests for referent R1 is decreased at these slots (Figure 18).

![Figure 17: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 1 on a per-subject basis summed over all images](image)
Figure 18: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 1 on a per-image basis summed over all subjects
In Condition 2 there was a conflict between the linguistic and the contextual preference. There was a linguistic preference for referent R1 and a contextual one for referent R2. Again all fixations on all referents were recorded for the whole timecourse (Figure 19).

Figure 19: Fixation frequencies for all referents during the whole timecourse in Condition 2

In this condition there is an increase of fixation frequency for referent R1 up to 33.64% shortly after the personal pronoun is named in the auditory stimuli (while the peak for referent R2 in the same period is 18.55%) (Observation 6). The slope of the increase (between 9500ms and 10000ms) is 28.31, which results in an intersection with the state immediately before the increase (between 8400ms and 9400 ms, which has a slope of 1.16) at 9486ms (Figure 20). The increase is again higher than when referent R1 is named with a full noun phrase.
After the local maximum is reached, the fixation frequency for referent R1 decreases again (with a slope of -6.83) while at the same time the fixation frequency for referent R2 increases (with a slope of 19.83) up to a maximum of 40.91% (while referent R1 reaches a peak of 35.27%) (Observation 7) resulting in a higher fixation frequency for referent R2 until the end of the timecourse (Observation 8) (Figure 21, Figure 22).
Figure 22: Decrease of fixation frequency for referent R1 and increase for fixation frequency for referent R2 after the local maximum of fixation frequency for R1 in Condition 2.

The number of significant tests for referent R1 on the per-subject basis increases after the personal pronoun is named up to a first local maximum of 23 at 10098ms. The values for referent R2 decrease in this period. Afterwards the values for referent R1 decrease again while the significant tests for referent R2 increase to a maximum of 21 at 11946ms (as well as at 12342ms) (Figure 23).

The number of significant tests on a per-image basis do also increases after the naming of the personal pronoun. The first local maximum is 4 at 10131ms – 10197ms (and another one at 10593ms). Thereafter, the values for referent R1 decrease again while those for R2 increase up to 5 at 11946ms (and also at 12012ms and 12078ms – 12111ms) (Figure 24).
Figure 23: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 2 on a per-subject basis summed over all images.

Figure 24: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 2 on a per-image basis summed over all subjects.

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Condition 3 also contained a conflict between linguistic and contextual preference. The linguistic preference was for referent R2 while the contextual one was for referent R1. The fixation frequencies for all referents during the entire timecourse can be seen in Figure 25.

Figure 25: Fixation frequencies for all referents during the whole timecourse in Condition 3

We fitted a line to the small increase of the fixation frequencies on referent R2 that occurs at the position as the increases in the other conditions (9500ms – 10000ms). This increase has a slope of 3.45. Comparing the local maxima of both referents between 9900ms and 10200ms (as in the other conditions) the values are 27.48% for referent R2 and 30.57% for referent R1 (Observation 6). The slope of the line fitted to the state before this small increase (8500ms – 9500ms) is 9.09 (Figure 26). We did not compute any intersection in this condition since the state before both increases is not steady at all.
After those increases the fixation frequency for referent R2 decreases again (with a slope of -2.88) while that for referent R1 increases (with a slope of 9.27) to a maximum of 44.93% (Observation 7, Figure 27). Subsequently the fixation frequency for referent R1 is higher than the fixation frequency for referent R2 (and also higher than that for Beyond Region of Interest) until the end of the timecourse (Observation 8, Figure 28).

Figure 26: Slopes of increases of fixation frequency for referent R2 in Condition 3

Figure 27: Distance between the fixation frequencies for referents R1 and R2 between 9000ms and 14000ms in Condition 3
Figure 28: Decrease of fixation frequency for referent R2 and increase for fixation frequency for referent R1 after the local maximum of fixation frequency for R2 in Condition 3

On the per-subject basis there is an increase of the number of significant tests for referent R2 in the time interval mentioned above resulting in a local maximum of 23 at 9372ms. The number of significant tests for referent R1 is decreased during that time until it increases shortly after to a maximum of 28 at 11451ms (as well as at 12342ms and at 13728ms – 13761ms). For referent R2 the number of significant tests is decreased in this time interval (Figure 29).

On the per-image basis there is also an increase of the number of significant tests for referent R2 with a local maximum of 4 at 9702ms – 9768ms while that for referent R1 is decreased. Thereafter there is an increase of the numbers of significant tests for referent R1 to a maximum of 7 at 12375ms – 12408ms (as well as at 12606ms and at 13662ms) while the values for referent R2 are decreased (Figure 30).
Figure 29: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 3 on a per-subject basis summed over all images.

Figure 30: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 3 on a per-image basis summed over all subjects.
In Condition 4 there was no ambiguity between the linguistic and the contextual preference since both preferences were for referent R1. The discourse of fixation frequencies for all referents is shown in Figure 31.

Figure 31: Fixation frequencies for all referents during the whole timecourse in Condition 4

There is an increase for referent R1 after the naming of the personal pronoun to a maximum of 26.67% (17.86% for referent R2 in the same period) (Observation 6). The slope of the line fitted to this increase in the region between 9700ms and 10100ms is 20.64 and the intersection with the state before (between 8600ms and 9600ms) is at 9749ms (Figure 32). After this ascent there is another slighter increase (with a slope of 11.46), such that the distance between both referents increases further (Observation 7, Figure 33) and eventually results in higher fixation frequencies for referent R1 until the end of the timecourse (Observation 8). The maximum of this increase of fixation frequency for referent R1 is 33.94% (while the maximum for referent R2 in this period is 19.38%)
Figure 32: Slope of fixation frequencies for referent R1 in Condition 4 and intersection with the state before

Figure 33: Distance between the fixation frequencies for referents R1 and R2 between 9000ms and 14000ms in Condition 4
An ascent in the number of significant tests on the per-subject basis to a first local maximum of 22 at 9042ms – 9075ms for referent R1 can be seen after the onset of the personal pronoun while the number of significant tests for the other referent is decreased in this period. During the further timecourse the values for referent R1 increase up to 32 at 10923ms and at 12045ms (Figure 34).

On the per-image basis the number of significant tests for referent R1 does also rise after the naming of the pronoun. It reaches a first local maximum of 4 at 9009ms and another one of 7 at 12639ms – 12672ms in the timecourse afterwards. The values for the other referent are again decreased during that time (Figure 35).

Figure 34: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 4 on a per-subject basis summed over all images
Figure 35: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 4 on a per-image basis summed over all subjects
Condition 5 was a neutral one which means that there was no contextual preference, but only a linguistic one in favour of referent R2. Fixation frequencies for all referents during the entire timecourse can be seen in Figure 36.

![Fixation frequencies for all referents during the whole timecourse in Condition 5](image)

**Figure 36: Fixation frequencies for all referents during the whole timecourse in Condition 5**

Shortly after the onset of the demonstrative pronoun in the auditory stimuli there is an increase of the fixation frequency for referent R2 up to 29.87% while that for referent R1 decreases (maximum at 19.05% in the same period) (Observation 6). This increase between 9500ms and 10000ms has a slope of 26.93 which leads to an intersection with the slope of the state before (which is 1.76 between 8400ms and 9500ms) at 9525ms (Figure 37). In the unfolding discourse the distance between the fixation frequencies of both referents gets smaller again (Observation 7, Figure 38) until there is another slight increase for referent R2 leading to a state in which the fixation frequencies for referent R2 are higher until nearly the end of the timecourse with a maximum of 38.86% (29.65% for referent R1) (Observation 8).
Figure 37: Slope of fixation frequencies for referent R2 in Condition 5 and intersection with the state before.

Figure 38: Distance between the fixation frequencies for referents R2 and R2 between 9000ms and 14000ms in Condition 5.
On the per-subject basis the number of significant tests for referent R2 increases after the onset of the demonstrative pronoun in the auditory stimuli to a first local maximum of 25 at 10263ms (as well as at 10362ms and at 10428ms) while the number of significant tests is decreased for referent R1. In the later timecourse another local maximum of 24 at 12045ms and at 12903ms is reached. The values for referent R1 are again decreased in that period (Figure 39).

On the per-image basis there is also an increase of the number of significant tests for referent R2 after onset of the pronoun with a maximum of 4 at 10164ms (as well as at 10263ms – 10362ms) while those for referent R1 are decreased. As the timecourse proceeds there is another local maximum of 4 at 11616ms – 11649ms (as well as at 11715ms) while the number of significant test for referent R1 is again reduced (Figure 40).

Figure 39: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 5 on a per-subject basis summed over all images
Figure 40: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 5 on a per-image basis summed over all subjects
Condition 6 was also neutral in respect to the contextual preference, but had a linguistic preference for referent R1. The fixation frequencies during the whole timecourse are shown in Figure 41.

![Figure 41: Fixation frequencies for all referents during the whole timecourse in Condition 6](image)

After the personal pronoun is named in the auditory stimuli there is an increase of fixation frequency for referent R1 up to 25.00% (Observation 6). At the same time the fixation frequency for the other referent is decreased (with a maximum of 15.93%). The slope of the increase for referent R1 between 9500ms and 10000ms is 19.07. Thus, the intersection with the state before (8400ms – 9500ms) is at 9516ms (Figure 42). After the peak of the increase is reached, the distance between the fixation frequencies for both referents gets smaller again (Observation 7, Figure 43) until there is another increase of the fixation frequency for referent R1 up to a maximum of 33.19% (compared to 22.94% for referent R2) (Observation 8). The fixation frequency for referent R1 stays higher than that for referent R2 until the end of the timecourse.
Figure 42: Slope of fixation frequencies for referent R1 in Condition 6 and intersection with the state before.

Figure 43: Distance between the fixation frequencies for referents R1 and R2 between 9000ms and 14000ms in Condition 6.
The number of significant tests on the per-subject basis increases for referent R1 after the onset of the personal pronoun up to a value of 25 at 10296ms – 10329ms. The number of significant tests for the other referent is lowered in that period of time. The values for referent R1 stay increased with another maximum of 26 at 12144ms – 12177ms (Figure 44).

The number of significant tests on the per-image basis does also rise in favor of referent R1 after the naming of the pronoun. This ascent reaches a first peak of 5 at 10032ms while the number of significant tests for referent R2 are decreased at this time. The values for referent R1 stay increased and a second maximum of 4 is reached at 12639ms (as well as at 12705ms and 12804ms) (Figure 45).

![Entire timecourse with significant slots for condition 6 summed over images](image)

Figure 44: Number of subjects with significant results for referent R1 or referent R2 during the whole timecourse for Condition 6 on a per-subject basis summed over all images
Figure 45: Number of images with significant results for referent R1 or referent R2 during the whole timecourse for Condition 6 on a per-image basis summed over all subjects
3.4. Comparison between Conditions per Referent

Since we want to account for antecedent preferences of the different types of pronouns we also tested (besides by contrasting referents) the differences in fixation frequencies for one and the same referent between conditions that differed in the type of the pronoun denominated. Thus, for each of the two referents we tested Condition 1 versus Condition 4, Condition 2 versus Condition 3 and Condition 5 versus Condition 6. We did this again on a per-subject as well as on a per-image basis.

For referent R1 on the per-subject basis the number of significant slots shortly after the naming of the pronoun is very high for Condition 2 (local maximum of 22 at 9867ms), Condition 4 (local maximum of 23 at 9999ms) and Condition 6 (local maximum of 21 at 10296ms), which all included a personal pronoun, while the number of significant tests for the other conditions, which included a demonstrative pronoun (Condition 1, Condition 3 and Condition 5), is decreased (Figure 46, Figure 47, Figure 48).

![Figure 46: Number of subjects with significant results for Condition 1 or Condition 4 during the whole timecourse for Referent R1 on a per-subject basis summed over all images](image)

Figure 46: Number of subjects with significant results for Condition 1 or Condition 4 during the whole timecourse for Referent R1 on a per-subject basis summed over all images
Figure 47: Number of subjects with significant results for Condition 2 or Condition 3 during the whole timecourse for Referent R1 on a per-subject basis summed over all images.

Figure 48: Number of subjects with significant results for Condition 5 or Condition 6 during the whole timecourse for Referent R1 on a per-subject basis summed over all images.
On the per-image basis a similar situation can be seen. The number of significant tests is also high for Condition 2 (local maximum of 5 at 9867ms), Condition 4 (local maximum of 4 at 10032ms and 10098ms) as well as Condition 6 (local maximum of 4 at 10329ms – 10362ms) while that for the other conditions again is decreased (Figure 49, Figure 50, Figure 51).

Figure 49: Number of images with significant results for Condition 1 or Condition 4 during the whole timecourse for Referent R1 on a per-image basis summed over all subjects
Figure 50: Number of images with significant results for Condition 2 or Condition 3 during the whole timecourse for Referent R1 on a per-image basis summed over all subjects.

Figure 51: Number of images with significant results for Condition 5 or Condition 6 during the whole timecourse for Referent R1 on a per-image basis summed over all subjects.
Regarding referent R2, the number of significant tests on the per-subject basis is very high for the conditions that included a demonstrative pronoun, namely Condition 1 (local maximum of 23 at 10032ms), Condition 3 (local maximum of 22 at 9438ms) and Condition 5 (local maximum of 28 at 10329ms – 10395ms). At the same time the number of significant tests is decreased in Condition 2, Condition 4 as well as Condition 6, which all included a personal pronoun (Figure 52, Figure 53, Figure 54).

Figure 52: Number of subjects with significant results for Condition 1 or Condition 4 during the whole timecourse for Referent R2 on a per-subject basis summed over all images
Figure 53: Number of subjects with significant results for Condition 2 or Condition 3 during the whole timecourse for Referent R2 on a per-subject basis summed over all images.

Figure 54: Number of subjects with significant results for Condition 5 or Condition 6 during the whole timecourse for Referent R2 on a per-subject basis summed over all images.
Finally, the situation is again similar on the per-image basis. The values are high for Condition 1 (local maximum of 5 at 10164ms), Condition 3 (local maximum of 4 at 9636 and 5 at 10527ms – 10560ms) as well as Condition 5 (local maximum of 7 at 10131ms) while they are decreased in Condition 2, Condition 4 and Condition 6 (Figure 55, Figure 56, Figure 57).

Figure 55: Number of images with significant results for Condition 1 or Condition 4 during the whole timecourse for Referent R2 on a per-image basis summed over all subjects
Figure 56: Number of images with significant results for Condition 2 or Condition 3 during the whole timecourse for Referent R2 on a per-image basis summed over all subjects.

Figure 57: Number of images with significant results for Condition 5 or Condition 6 during the whole timecourse for Referent R2 on a per-image basis summed over all subjects.
3.5. Difference between Pronouns

We also wanted to investigate whether there is a difference in the intensity of the linguistic effects both pronouns elicit. Therefore, we summed up the differences in fixation frequencies between the preferred and the non-preferred referent for all conditions that included a demonstrative pronoun as well as for those that contained a personal pronoun. This difference for the demonstrative pronoun is 39.95 while the difference for the personal pronoun is 42.12 (Figure 58).

![Figure 58: Differences in fixation frequencies for preferred and non-preferred referent for conditions with a demonstrative pronoun as well as conditions with a personal pronoun](image)

3.6. Responses to Control Questions

After each story there was a control question in which the subject had to choose which referent was the acting character by pressing the corresponding button. We summed up the number of choices for each referent in every condition.

In Condition 1 and Condition 2 the number of choices for referent R2 is much higher than those for referent R1 (87.03 vs. 13.97 in Condition 1 and 68.07 vs. 31.93 in...
Condition 2). In Condition 3 and Condition 4 the number of choices for referent R1 is considerably higher than the choices for referent R2 (75.83 vs. 24.17 in Condition 3 and 85.89 vs. 14.11 in Condition 4). In Condition 5 the number of choices for referent R2 is above those for referent R1 (59.67 vs. 40.33) and in Condition 6 the number of choices for referent R1 is higher than those for referent R2 (75.73 vs. 24.27). This distribution is shown in Figure 59.

![Answers by keypress for each condition](image)

Figure 59: Answers to the control question for every condition

### 3.7. Performance in MWT-B

The numbers of correct answers for each subject in the MWT-B are normally distributed over all subjects as confirmed by a Lilliefors-Test ($p<0.05$). They vary from 17 to 36 and the majority of subjects has 25 correct answers (Figure 60).
Since we were concerned with whether intelligence has an influence on the resolution process we were interested in the point in time at which the shift from one referent to the other in the conflict conditions (Condition 2 and Condition 3) occurred. This point was determined by finding the first slot after 9000ms in which the distribution of the numbers of significant tests for both referents on the per-subject basis switched. This was done for each subject for both conflict conditions. The resulting values were then tested for correlation with the performance in the MWT-B which resulted in $r=-0.02$ for Condition 2 (Figure 61) and $r=0.07$ for Condition 3 (Figure 62).
Figure 61: Correlation between performance in the MWT-B and point in time of shift from referent R1 to R2 in Condition 2

Figure 62: Correlation between performance in the MWT-B and point in time of shift from referent R2 to R1 in Condition 3
We also computed the correlation between the choice for the contextual preference (given as an answer pressing a key) by each subject in the conflict conditions and the performance in the MWT-B. The correlation is $r=0.43$ (Figure 63).

Figure 63: Correlation between performance in the MWT-B and the choice for the contextual preference in Condition 2 and Condition 3
4. Discussion

Prior to testing our hypotheses we had to make sure that the stimuli we presented were valid such that they could be included in further investigations. As we can see in the results the distribution of the fixation frequencies for the different referents as well as that for Beyond Region of Interest does not vary much among the different images. This tells us that all scenes were perceived as meaningful. The fact that the referents that are named in the auditory stimuli have higher mean fixation frequencies than the unnamed one (R4) and the fact that referents R1 and R2 (the acting characters of the story) do both have a higher mean fixation frequency than the inanimate referent (R3) also contribute to the interpretation that the stories were well understood. The same holds for the distribution of fixation frequencies among subjects. Again the variance is not very high which indicates that all subjects have found the stimuli to be meaningful. A further aspect was that every image was presented twice to each participant. We thus had to make sure that there were no priming effects for the second presentation. This topic is discussed in detail in [Meyer, 2007].

Before discussing the results in regard to our hypotheses I first want to have a closer look at the general observations presented above (Observation 1 – Observation 5), since they also point at very interesting effects.

In Observation 1 we can see that in the first 400ms the fixation frequencies for referent R1 and R2 are constantly increasing. This is particularly interesting in regard to our knowledge about saccades which tells us that in this period maximally two saccades can be made. That means that even without mentioning the referents in the auditory stimuli the very first fixations fall upon one of them. The effect seems to be purely bottom-up since the referents were the most interesting Playmobil figures next to the fixation point (together with referent R3). The fact that the fixation frequency is higher for referent R1 than for referent R2 can be explained by the correlation of the differences in distance to the fixation point and the differences in fixation frequencies. Referent R1 was in most cases just closer to the fixation point and a saccade towards this referent was more likely.

After the bottom-up effect of subjects looking around at the most salient objects in the scenes, a state is reached in which the fixation frequencies are very close to the means in the whole timecourse and have very flat slopes. During that period no auditory stimuli have been presented. This goes along with the steadiness of the state which reflects the relation between the denomination of a referent and the increased fixation frequencies.
for this referent which was the main assumption we based our experimental setup on.

Observation 3 and Observation 4 are concerned with the increases of fixation frequencies for referent R1 and referent R2 after they have been introduced with a full noun phrase. This again shows that our main assumption holds true and that subjects do look at what they hear. This goes along very well with the findings of Cooper [Cooper, 1974] and Eberhard et al. [Eberhard et al., 1995] as well as with recent studies that used the same methodology as we did [Karabanov, 2006] [Jessen, 2006].

We computed the intersection of the fitted line to the increase of the fixation frequencies for one referent with the fitted line to the state before to investigate the point in time of the beginning of the increase in respect to the onset of the denomination of the referent. For referent R1 this point is at 3465ms which means that the effect is triggered 465ms after onset. This is a similar timing than that in the findings of Hagoort et al. who showed that it takes about 400ms to recognize the meaning of a word in a written sentence [Hagoort et al., 2004]. For referent R2, however, the intersection is at 4325ms which is more than 500ms before the onset of the denomination of that referent in the auditory stimuli. While this anticipatory effect seems strange at first, it becomes clearer when we look at the auditory stimuli. After referent R1 is named there was always a transitive verb. Since it was most probable that referent R2 was the second argument for this verb, it could explain why the fixation frequency for referent R2 increases even before the onset of the denomination of this referent.

Finally, in the last general observation (Observation 5) we can see that referent R4 has a very low fixation frequency during the whole timecourse. This referent was a female control that was never mentioned in the auditory stimuli and could also never be falsely detected as an antecedent for a pronoun. Thus, the low fixation frequency is what we expected and is important in regard to the other animate referents since it shows that the higher fixation frequencies for referent R1 and R2 are not only due to the fact that animate referents are in general more interesting than inanimate ones.

We hypothesized five findings for the experiment. At first, we will find an increased fixation frequency for the referent in subject position at the point in time of the mentioning of the personal pronoun. At the point in time of the denomination of the demonstrative pronoun the fixation frequency for the referent in object position will be increased. Furthermore, the differences in fixation frequency will be higher for the demonstrative pronoun than for the personal pronoun. We also hypothesized that there will be a shift in fixation frequencies from the linguistically preferred referent to the contextually pre-
ferred one after the linguistic effect interfered, when a conflict between both preferences is present. Additionally, we think that the point in time of the shift is correlated to the intelligence of the subject.

Our first hypothesis predicted higher fixation frequencies for the referent in subject position after the personal pronoun is named. The conditions which included a personal pronoun were Condition 2, Condition 4 and Condition 6. The referent in subject position was referent R1. In all of these conditions an increase of fixation frequency for referent R1 can be seen directly after the personal pronoun is named while the fixation frequency for the other referent is decreased in that time. We also computed the intersection of the slope of the increase and the slope of the steady state before to know where the increase (and thus the linguistic effect elicited by the pronoun) starts. In Condition 2 this intersection is at 9486ms, in Condition 4 at 9749ms and in Condition 6 at 9516ms. Thus, the effect seems to be triggered between 486ms and 749ms after onset of the personal pronoun. If we compare this with the time it took to elicit fixations on this referent when it was introduced with a full noun phrase, we can see that it takes up to 300ms longer for the pronoun to elicit fixations on the referent. This could be explained by how the information is accessed in both cases. It could be the case that when the referent is named with a full noun phrase, only one lookup in the mental lexicon takes place. If it is referred to by a pronoun, we first might have to look up the pronoun itself which then tells us by a lexical property, which antecedent is meant. The latter has one step more and therefore needs more time.

The statistical results maintained by the means of bootstrapping support our first hypothesis. The significance in fixation frequencies for referent R1 over referent R2 after the onset of the personal pronoun can be shown in all of the three conditions that included a denomination of a personal pronoun. Furthermore, this significance can be shown on both, a per-subject basis and a per-image basis. Additionally, the fixation frequency for referent R1 is significantly higher after the onset of the pronoun in those conditions that included a pronoun than it is in the other conditions. This again holds on a per-subject as well as on a per-image basis.

The second hypothesis was the counterpart to the first one, namely that the fixation frequencies for the referent in object position after the denomination of the demonstrative pronoun will be higher than those for the other referent. In this case the referent in object position was referent R2 and the conditions that included a demonstrative pronoun were Condition 1, Condition 3 and Condition 5. Again there is an increase in
fixation frequency for referent R2 directly after the demonstrative pronoun was named. The intersection of the line fitted to this increase with the line fitted to the state before is at 9536ms in Condition 1 and at 9525ms in Condition 5. For Condition 3 we did not compute the intersection, since the state before the increase was not steady at all. What is also interesting in this condition is that there is an increase in fixation frequency for referent R2 even before the pronoun is named. Next, the fixation frequency for the other referent (referent R1) increases in a similar fast way and at the same position at which we would have expected an increase for referent R2, namely shortly after the personal pronoun is named. One possible explanation for this pattern is that one of the constraints in the randomization of the auditory stimuli was that the conflict conditions (Condition 2 and Condition 3) were only presented when the corresponding image was shown for the second time. The corresponding condition to the first presentation of the image was either Condition 1, Condition 5 or Condition 6. Thus, it could well be that the subjects have been primed for referent R2 regarding a particular scene, since it was the preferred antecedent in Condition 1 (linguistically and contextually) as well as in Condition 5 (linguistically). Therefore, subjects could have looked at referent R2 even before it was named, since they remembered that it was the antecedent the last time they saw the image and heard the story (which was the same until the denomination of the pronoun). When the pronoun then actually was named it could not trigger a saccade to referent R2 since that one was fixated already, but elicited a saccade to referent R1 instead since this one was the only one that also could act as an antecedent. This means that subjects may have become unsure about referent R2 when the pronoun was named. What remains is the question why we do not see a similar (but reversed) behaviour in Condition 2, since the randomization pattern was equal, so that a priming for referent R1 should have occurred, too. A possible explanation could lie in the difference of the type of pronoun. It could well be that the priming was more effective in stories where the antecedent was referred to with a demonstrative pronoun, because this is more uncommon or unexpected. A demonstrative pronoun changes the topic of the story, because it refers to the referent in object position and makes this one the acting character which it was not before. Thus, those situations are more salient than others and this could be the reason why they are better memorized.

Nevertheless, our hypothesis regarding the increase in fixation frequency for referent R2 after the denomination of the demonstrative pronoun is supported by the results of the statistical tests. The significance of referent R2 over referent R1 in the timeslots
after the naming of the pronoun can be seen in all of the conditions that included a demonstrative pronoun (Condition 1, Condition 3 and Condition 5) on a per-subject basis as well as on a per-image basis. Furthermore, the fixation frequency for referent R2 is also significantly higher in these conditions than it is in the other conditions. This is again on a per-subject and on a per-image basis. Our findings are therefore consistent with the Complementary Hypothesis [Bosch et al., 2003] as well as with the idea of a non-subject bias of demonstrative pronouns [Bosch et al., 2007].

The prediction of our third hypothesis was that the effect of the demonstrative pronoun is bigger than that for the personal pronoun. We therefore computed the differences between the fixation frequencies on the preferred referent and the non-preferred one in the period around the peak of fixation frequencies after the naming of the pronoun. As we can see this difference is slightly bigger for the personal pronoun than for the demonstrative pronoun. Although the difference is minimal, the results do obviously not support the hypothesis. It seems that there is no difference in the strength of the effect elicited. It should, however, be mentioned that the shift of the peak for the linguistic effect in Condition 3 (as discussed above) could have contributed to this result.

Our fourth hypothesis was about the shift in the increase of fixation frequencies in the conflict conditions from the referent that is linguistically preferred to the one that is contextually preferred. The final decision should in these cases eventually be based on the contextual information. The conditions that inhaled a conflict were Condition 2 and Condition 3. In both conditions we can easily see this shift by looking at the fixation frequencies during the whole timecourse. In Condition 2 the high fixation frequency shifts from referent R1 to referent R2 and in Condition 3 from referent R2 to referent R1. The statistical tests do also support this hypothesis. As we have already seen above, the linguistic effect is significant for both conditions. Further on, the switched pattern of significantly more fixations for the other referent after the switch occurred can be shown on a per-subject basis as well as on a per-image basis. As it can be seen by looking at the key press responses, the final decision is most of the time for the contextually preferred referent. This is particularly interesting since it shows that if a conflict between both preferences (the linguistic and the contextual) is present, people tend to rely more on the context information available than on the lexical property of the antecedent preference of the pronoun. The contextual effect surpasses the linguistic one. This does of course make sense, since the goal in anaphora resolution is to understand what the correct referent is. By integrating the available context information with world
knowledge people check the plausibility of a referent being the antecedent. If, however, no context information is available, as it was the case in Condition 5 and Condition 6, people have to rely on the linguistic preference of the pronoun alone which reflects their final decision.

The last hypothesis finally predicted a correlation of the shift mentioned above with the intelligence of the subjects. We therefore tested the correlation between the results in the MWT-B and the point in time of the shift for each condition. The results show that there is no significant correlation between those two factors. Thus, our hypothesis is not supported. One possible reason for these results might be our choice for the MWT-B. This test is a short intelligence test and only consists of 37 questions. It therefore might not really reflect the intelligence in any meaningful way. Some of the words that have to be recognized are very old and not really common anymore these days. Furthermore, it could be that the range of intelligence in our subjects was still not big enough for the effect to be visible. We also tested the correlation between the performance in the MWT-B and the key press response for each subject. Although this correlation is also not significant, an interesting observation is that the subjects with the worst performance decided more often for the linguistically preferred referent, while those subjects with the best performance decided nearly exclusively on basis of the context provided. This tendency is consistent with what has been described above. Subjects with a bad performance might not have understood the context and thus may not have been aware of a conflict and had to decide on the linguistic preference alone, while subjects with better test results were able to integrate context information with their world knowledge to additionally base their choice on plausibility.

This said, we still believe that intelligence has a strong effect on the resolution process. Since our results are not significant and only show a small tendency, further research has to be done in this direction. It might be a good idea to not rely on a short intelligence test, but instead on a sophisticated one. Those tests, however, have to be made under the observation of a specially trained person and have a very long duration time (about 3 – 4 hours). It should eventually also be mentioned that the measuring of intelligence is a very controversially discussed topic in general, which is of course problematic for any research in this direction [Gould, 1996].
5. Conclusion

In this study we investigated the differences in the resolution of German personal and demonstrative pronouns as well as the influence of world knowledge and intelligence on this process.

The results show that personal pronouns have a preference for the antecedent in subject position while demonstrative pronouns have a preference for the antecedent in object position. This linguistic preference is a lexical property of the pronoun itself. If this is the only information available, it determines our understanding of which antecedent is the one referred to with the pronoun. When additional meaningful context information is available it is integrated with world knowledge and also serves to resolve the pronoun. As it can be seen in situations that include a conflict between the linguistic and the contextual preference, people eventually tend to rely more on context information when available.

The influence intelligence has on the resolution process has to be investigated in further research since our results can only show small tendencies.

6. Acknowledgements

I first off all want to thank Prof. Dr. Peter Bosch and Prof. Dr. Peter König for supervising this thesis. I highly benefited from their knowledge, guidance and support while planning the experiment, analyzing the data as well as preparing and writing the thesis. Furthermore, I would like to thank all the people in the Neurobiopsychologie at the University of Osnabrück who helped us a lot throughout the whole experiment (particularly Sonja Schall and Johannes Steger). Last but not least I especially thank the Playmo-Crew for the brilliant teamwork and the remarkably nice time we spent together working on this project.

References


7. Appendix

A. Visual Stimuli

Figure 64: Image 1  
Figure 65: Image 2  
Figure 66: Image 3  
Figure 67: Image 4  
Figure 68: Image 5  
Figure 69: Image 6
B. Auditory Stimuli

1. Eine Verwarnung.

*Der Polizist redet gerade mit dem Autofahrer über das falsch geparkte Auto.*

Condition 1: *Der ist mit der Verwarnung nicht einverstanden und regt sich fürchterlich auf.*
Condition 2: *Er ist mit der Verwarnung nicht einverstanden und regt sich fürchterlich auf.*
Condition 3: *Der will 20 Euro für Falschparken kassieren und regt sich fürchterlich auf.*
Condition 4: *Er will 20 Euro für Falschparken kassieren und regt sich fürchterlich auf.*
Condition 5: *Der ist ziemlich unhöflich, schreit ganz laut herum und regt sich fürchterlich auf.*
Condition 6: *Er ist ziemlich unhöflich, schreit ganz laut herum und regt sich fürchterlich auf.*

2. Im Tiergarten.

*Der Wärter spricht eindringlich mit dem Besucher neben dem Löwengehege.*

Condition 1: *Der findet den Eintrittspreis unverschämt hoch und verzieht grimmig den Mund.*
Condition 2: *Der findet den Eintrittspreis unverschämt hoch und verzieht grimmig den Mund.*
Condition 3: *Der sagt man dürfe hier keine Tiere füttern und verzieht grimmig den Mund.*
Condition 4: *Er sagt man dürfe hier keine Tiere füttern und verzieht grimmig den Mund.*
Condition 5: *Der sagt früher wär’s im Zoo viel schöner gewesen und verzieht grimmig den Mund.*
Condition 6: *Er sagt früher wär’s im Zoo viel schöner gewesen und verzieht grimmig den Mund.*
3. Auf dem Spielplatz.

Der Vater diskutiert lange mit dem kleinen Sohn vor der großen gelben Rutsche.

Condition 1: Der ist wohl geärgert und gehauen worden und will nach hause gehen.

Condition 2: Er ist wohl geärgert und gehauen worden und will nach hause gehen.

Condition 3: Der hat gleich noch einen Termin im Büro und will nach hause gehen.

Condition 4: Er hat gleich noch einen Termin im Büro und will nach hause gehen.

Condition 5: Der hat keine Lust noch länger hierzubleiben und will nach hause gehen.

Condition 6: Er hat keine Lust noch länger hierzubleiben und will nach hause gehen.

4. Es hat gebrannt.

Der Feuerwehrmann steht erschöpft neben dem Passanten an dem Feuerwehrauto.

Condition 1: Der kam zufällig auf dem Spaziergang hier vorbei und wüsste gern die Brandursache.

Condition 2: Er kam zufällig auf dem Spaziergang hier vorbei und wüsste gern die Brandursache.

Condition 3: Der hat schon alles Material wieder eingepackt und wüsste gern die Brandursache.

Condition 4: Er hat schon alles Material wieder eingepackt und wüsste gern die Brandursache.

Condition 5: Der meint letzthin sei viel los in dieser Gegend und wüsste gern die Brandursache.

Condition 6: Er meint letzthin sei viel los in dieser Gegend und wüsste gern die Brandursache.
5. In der Schule.

Der Lehrer steht zusammen mit dem Schüler an der alten Kreidetafel.

Condition 1: Der hat mal wieder im Unterricht nicht aufgepasst
un und hat den Termin fr die Arbeit vergessen.

Condition 2: Er hat mal wieder im Unterricht nicht aufgepasst
und hat den Termin fr die Arbeit vergessen.

Condition 3: Der ist schon ziemlich alt, denkt nicht mehr an alles
und hat den Termin fr die Arbeit vergessen.

Condition 4: Er ist schon ziemlich alt, denkt nicht mehr an alles
und hat den Termin fr die Arbeit vergessen.

Condition 5: Der war im Krankenhaus, ist jetzt erst wieder gesund
und hat den Termin fr die Arbeit vergessen.

Condition 6: Er war im Krankenhaus, ist jetzt erst wieder gesund
und hat den Termin fr die Arbeit vergessen.

6. Regionalliga.

Der Strmer diskutiert energisch mit dem Schiedsrichter vor dem gegnerischen Tor.

Condition 1: Der droht natrlich gleich mit Platzverweis
und fhlt sich voll im Recht.

Condition 2: Er droht natrlich gleich mit Platzverweis
und fhlt sich voll im Recht.

Condition 3: Der hat einen sauberen Torschuß gemacht
und fhlt sich voll im Recht.

Condition 4: Er hat einen sauberen Torschuß gemacht
und fhlt sich voll im Recht.

Condition 5: Der verlangt eine sachliche und verständliche Erklärung
und fhlt sich voll im Recht.

Condition 6: Er verlangt eine sachliche und verständliche Erklärung
und fhlt sich voll im Recht.

Der Bootsverleiher geht gerade mit dem Touristen zu dem kleinen Ruderboot.

Condition 1: Der will gleich ablegen und seinen Spaß haben und achtet nicht auf den aufziehenden Sturm.
Condition 2: Er will gleich ablegen und seinen Spaß haben und achtet nicht auf den aufziehenden Sturm.
Condition 3: Der denkt nur an Tagesgeschäft und Geld verdienen und achtet nicht auf den aufziehenden Sturm.
Condition 4: Er denkt nur an Tagesgeschäft und Geld verdienen und achtet nicht auf den aufziehenden Sturm.
Condition 5: Der schwärmt nur von dem herrlichen Natursee und achtet nicht auf den aufziehenden Sturm.
Condition 6: Er schwärmt nur von dem herrlichen Natursee und achtet nicht auf den aufziehenden Sturm.

8. Gewehre für die Indianer.

Der Häuptling verhandelt ausdauernd mit dem Händler vor dem großen Zelt.

Condition 1: Der will diesmal wirklich einen guten Gewinn machen und feilscht lange um den Preis.
Condition 2: Er will diesmal wirklich einen guten Gewinn machen und feilscht lange um den Preis.
Condition 3: Der braucht bessere Gewehre für seinen Stamm und feilscht lange um den Preis.
Condition 4: Er braucht bessere Gewehre für seinen Stamm und feilscht lange um den Preis.
Condition 5: Der sagt, dass es ein faires Geschäft sein muss und feilscht lange um den Preis.
Condition 6: Er sagt, dass es ein faires Geschäft sein muss und feilscht lange um den Preis.
9. **Auf der Straße.**

Der Müllmann plaudert gerade mit dem Mieter neben der übervollen Mülltonne.

Condition 1: *Der will wissen wann wieder Müll abgeholt wird und beschwert sich über die Unordnung.*

Condition 2: *Er will wissen wann wieder Müll abgeholt wird und beschwert sich über die Unordnung.*

Condition 3: *Der hat den ganzen Tag schon Müll abgeholt und beschwert sich über die Unordnung.*

Condition 4: *Er hat den ganzen Tag schon Müll abgeholt und beschwert sich über die Unordnung.*

Condition 5: *Der findet Sauberkeit wär wirklich das Allerwichtigste und beschwert sich über die Unordnung.*

Condition 6: *Er findet Sauberkeit wär wirklich das Allerwichtigste und beschwert sich über die Unordnung.*

10. **In der Manege.**

Der Zauberer trifft gerade zufällig den Clown vor der leeren Tribüne.

Condition 1: *Der sieht echt zum Lachen aus und freut sich auf die Abendvorstellung.*

Condition 2: *Er sieht echt zum Lachen aus und freut sich auf die Abendvorstellung.*

Condition 3: *Der murmelt einige Zaubersprüche und freut sich auf die Abendvorstellung.*

Condition 4: *Er murmelt einige Zaubersprüche und freut sich auf die Abendvorstellung.*

Condition 5: *Der ist auf dem Weg zum Eingang und freut sich auf die Abendvorstellung.*

Condition 6: *Er ist auf dem Weg zum Eingang und freut sich auf die Abendvorstellung.*
11. In der Klinik.

*Der Arzt steht wieder vor dem Patienten am sauberen Krankenbett.*

**Condition 1:** *Der beklagt sich ber die Schmerzen und befürchtet leichte Nebenwirkungen.*

**Condition 2:** *Er beklagt sich ber die Schmerzen und befürchtet leichte Nebenwirkungen.*

**Condition 3:** *Der rät die Medizin einzunehmen und befürchtet leichte Nebenwirkungen.*

**Condition 4:** *Er rät die Medizin einzunehmen und befürchtet leichte Nebenwirkungen.*

**Condition 5:** *Der ist mit der Operation nicht zufrieden und befürchtet leichte Nebenwirkungen.*

**Condition 6:** *Er ist mit der Operation nicht zufrieden und befürchtet leichte Nebenwirkungen.*


*Der Klempner berät altklug den Bauern wegen der kaputten Wasserpumpe.*

**Condition 1:** *Der bemerkte den Schaden vor dem Melken und muss eine Lösung für das Problem finden.*

**Condition 2:** *Er bemerkte den Schaden vor dem Melken und muss eine Lösung für das Problem finden.*

**Condition 3:** *Der ist extra auf den Bauernhof gekommen und muss eine Lösung für das Problem finden.*

**Condition 4:** *Er ist extra auf den Bauernhof gekommen und muss eine Lösung für das Problem finden.*

**Condition 5:** *Der ist ziemlich gestresst, hat kaum Zeit und muss eine Lösung für das Problem finden.*

**Condition 6:** *Er ist ziemlich gestresst, hat kaum Zeit und muss eine Lösung für das Problem finden.*
C. Consent Sheet
D. Subject Questionnaire
E. Feedback Sheet
F. Affirmation

Hiermit erkläre ich, Florian Krause, die vorliegende Arbeit ”‘Investigating the influences of world knowledge and intelligence on the resolution of German personal and demonstrative pronouns’‘ selbstständig verfasst zu haben und keine anderen Quellen oder Hilfsmittel als die angegebenen verwendet zu haben (siehe auch ”‘Assignment of Tasks’‘”).

Osnabrück, den 28.09.2007

Affirmation

I, Florian Krause, hereby confirm that I composed the work at hand, entitled ”‘Investigating the influences of world knowledge and intelligence on the resolution of German personal and demonstrative pronouns’‘ independently and that I did not use any other resources or auxiliary means than the ones stated (see also ”‘Assignment of Tasks’‘”).

Osnabrück, 28.09.2007
G. Assignment of Tasks

• **Within the whole group:**

  – Before experiment:

    1. Preparation:
       * Python introduction by Johannes Steger: Birgit Bärnreuther, Dominique Goltz, Maike Kleemeyer, Marlene Meyer
       * AVMZ for microphone: Birgit Bärnreuther, Marlene Meyer

    2. Stimuli construction:
       * Writing stories: each group on their own
       * Taking photographs of Playmobil scenes: Birgit Bärnreuther, Christina Bergmann, Dominique Goltz, Maike Kleemeyer, Marlene Meyer
       * Audio recordings:
         · Speaker: Dominique Goltz
         · Recording: Florian Krause
       * Cutting audio files: Birgit Bärnreuther, Dominique Goltz, Maike Kleemeyer, Florian Krause
       * Cutting images: Birgit Bärnreuther

    3. Python programming: mainly Florian Krause, Maike Kleemeyer, Marlene Meyer

    4. Randomisation: Christina Bergmann, Florian Krause, Marlene Meyer

    5. Recruiting participants:
       * Flyer: Marlene Meyer
       * E-mails etc.: everybody

    6. Organizing MWT-B: Christina Bergmann, Florian Krause

    7. Documents:
       * Feedback-Sheet: everybody
       * Consent-Sheet: Birgit Bärnreuther, Maike Kleemeyer
       * Experimental plan of procedure: Dominique Goltz

    8. Eye-tracking introduction by Sonja Schall and practice: everybody

  – During Experiment:
1. Eye-tracking: everybody
2. ROI definition: each group their own
3. Fixmat & Roimat construction: Florian Krause, Marlene Meyer

- After experiment:
  1. Scaling ROIs: Birgit Bärnreuther, Dominique Goltz
  2. Functions: each group on their own, exchange of those that each group needed

- Within IQ group:
  1. Analyzing Data: Florian Krause, Marlene Meyer
  2. Writing Bachelor Thesis:
      * Outline: everyone on his/her own
      * Introduction: everyone on his/her own
      * Methods: Are equal in both theses, that of Marlene Meyer and that Florian Krause
        - Visual Material: Florian Krause
        - Auditory Material: Florian Krause
        - Combination/Randomization/Balancing: Florian Krause
        - Intelligence Test: Marlene Meyer
        - Participants: Marlene Meyer
        - Apparatus: Florian Krause
        - Procedure: Marlene Meyer
        - Regions of Interest: Marlene Meyer
      * Results: everyone his/her own
      * Discussion: everyone his/her own
      * Conclusion: everyone on his/her own

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