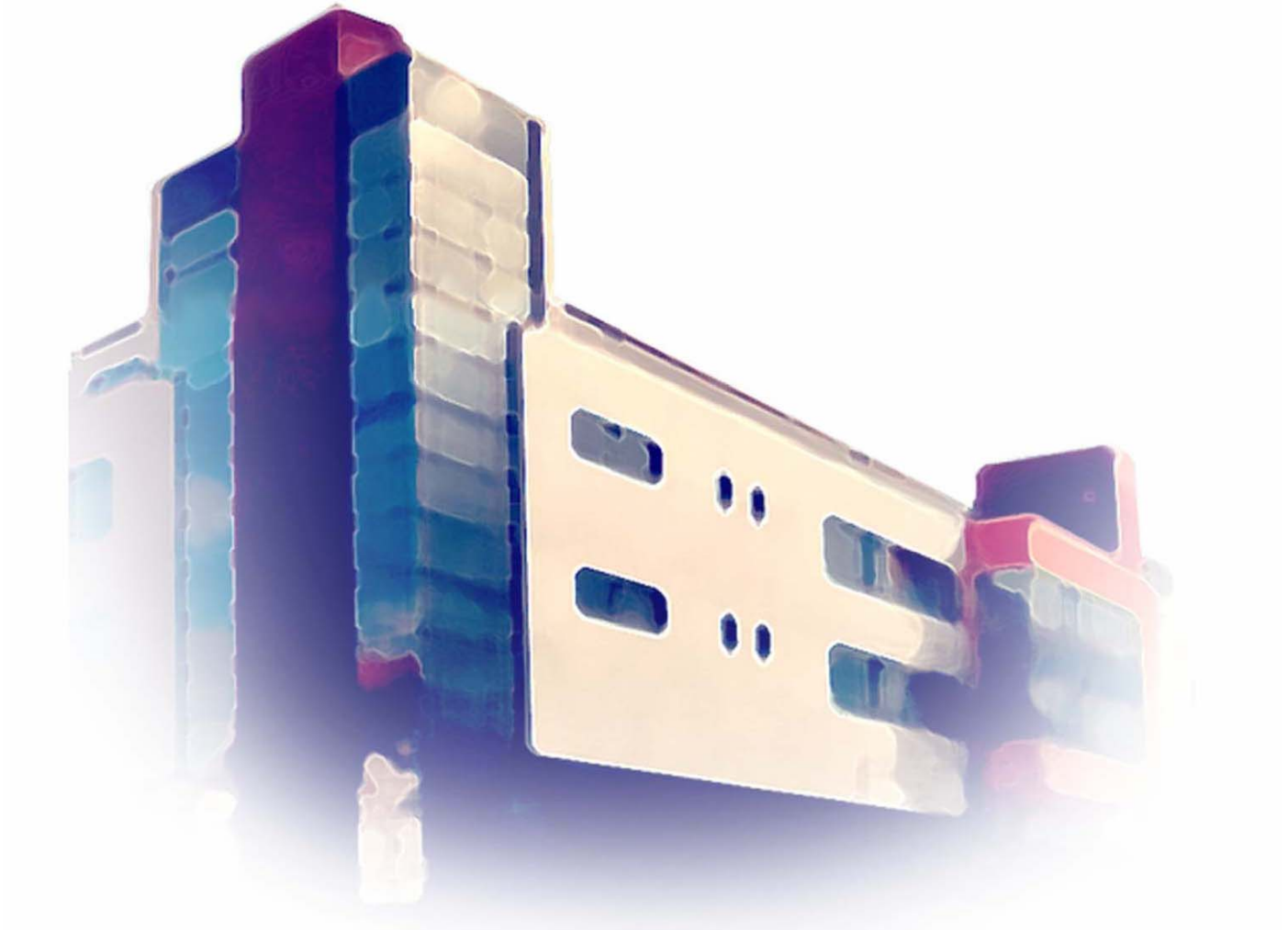
Anke Ninija Karabanov

Eye Tracking as a Tool for Investigating the Comprehension of Referential Expressions



PICS

Publications of the Institute of Cognitive Science

Volume 3-2010

ISSN: 1610-5389

Series title: PICS
Publications of the Institute of Cognitive Science

Volume: 3-2010

Place of publication: Osnabrück, Germany

Date: September 2010

Editors: Kai-Uwe Kühnberger
Peter König
Sven Walter

Cover design: Thorsten Hinrichs

Fachbereich 08: Humanwissenschaften
Cognitive Science Bachelor Program
Januar 2006

Eye Tracking as a tool for investigating the comprehension of referential expressions

Bachelor's Thesis

by

Anke Ninija Karabanov

1st examiner: Prof. Peter Bosch

2nd examiner: Prof: Peter König

TABLE OF CONTENTS

0 Abstract

In the study presented here, we used eye tracking to investigate linguistic comprehension processes. Our main purpose was to focus on differences in the processing of different referential expressions like full noun phrases and pronouns. The temporal process of resolution was of special interest in this context, since it could give an answer to the controversial question of whether pronouns are resolved on the same time scale as full noun phrases.

Eye movements were recorded with a head-mounted eye-tracking system while subjects viewed pictures on a monitor and listened to short pieces of pre-recorded narrative discourse. The discourse made reference to the situation in the picture. We were able to show that each full noun phrase and each anaphoric pronoun is immediately followed by increased fixations on the corresponding referent in the visual scene, and that both noun phrases and pronouns reach their fixation peak at about 1000 ms after the onset of the referential expression.

This suggests that anaphoric pronouns are referentially interpreted very much like definite full NPs, and that no extra processing time is needed to resolve the anaphoric reference. Also, the fact that we could not detect a difference between anaphoric pronouns closely following their antecedents and those following much later, supports the notion that pronouns are interpreted directly with respect to referents, rather than by reference to any antecedents.

1. Introduction

The amount of linguistic information that we encounter every day is enormous. We speak, we listen, we read and almost all the time we effortlessly – and often even automatically – understand what was said. Language understanding, however, is not just based on higher order cognitive processes that are directly concerned with the processing of the information that language conveys. In order to successfully communicate, we also need several lower cognitive functions. Without our auditory sense we would not be able to understand spoken language, and without the involvement of motor activity the production of both spoken and written language would be impossible. Vision can also play an important role in understanding by helping us to disambiguate linguistic information and to relate single utterances to objects in the world surrounding us. Vision also has an important role to play in the investigation of language comprehension: Eye movements can give an interesting insight in the ongoing comprehension process of language. Cooper (1974) first demonstrated in his ground-breaking experiment that people tend to fixate elements in their visual scene that are related to currently heard spoken language. During reading, eye movements can also be used to draw interesting conclusions about the process of language comprehension (see Ranyer, 2002 for an overview). Eye-tracking thus seems to be a promising tool to investigate the processes that underlie the comprehension of referential expressions.

Understanding language requires knowing who is doing what to whom. But how can language comprehenders successfully track who or what is being referred to? All languages have a wide variety of devices for referring back to previously mentioned concepts. These devices are called *anaphors* and the concepts they refer back to are called *antecedents*. Anaphors are characterized by the fact that they cannot stand alone and that they refer back to a concept introduced by the antecedents. All known languages contain a wide variety of these anaphoric forms, which vary in terms of their lexical specificity (Ariel, 1990; Garrod & Sanford, 1994). In most Indo-European languages, anaphors range from various forms of zero anaphors[1] through pronouns and definite descriptions to repeated proper names. Garrod and Sanford give the following examples for different kinds of anaphoric expressions:

(1) Jim bumped into Bill and φ fell over.

(2) Jim bumped into Bill and ***he*** *fell over.*

[1] Here and in the following text we will use the term *anaphor* in the wide, classical sense and not in the more technical sense that is found in Binding Theory.

(3) Jim bumped into Bill and ***the fool*** *fell over.*

(4) Jim bumped into Bill and ***Bill*** *fell over.*

Beside the differences in lexical specificity, anaphoric expressions also vary in the degree to which their interpretation is governed by the surrounding text. In this study, we will mainly focus on the investigation of the interpretation process for anaphoric pronouns.

In order to understand a sentence containing a pronoun, the listener must be able to pick up the interpretation from the correct antecedents in the text. To understand sentence *(*5)

(5)The shop assistant told the craftsman that she was angry

the listener must know that the word *she* refers to the shop assistant. However, while encountering pronouns in a discourse we are not consciously aware of any effort needed to find this reference. On the contrary, we feel that we can immediately relate the pronoun to the correct antecedents. This effortlessness is astonishing, especially since it might be necessary to consider quite some syntactic and semantic constraints in order to determine the correct antecedents for a pronoun.

In their article "*The Psycholinguistics of Anaphora"*, Nicol and Swinney identify five different constraints that seem to play a certain role in the interpretation process of pronouns:

i. *Information about the syntactic position of possible referents.* This includes information about whether an NP is subject or object, whether it is the head of a phrase or part of the modifier. The effect that both the order of mention and the grammatical role information have on the determination of possible antecedents has been shown in various experiments (Gernsbacher & Hargreaves 1988; Carreiras, Gernsbacher & Villas 1995)
ii. *Co-reference constraints* have to be considered in order to connect a pronoun to the correct antecedent. Co-reference constraints (roughly) require that the antecedent of a reflexive (as object of the verb) is the subject of the clause in which the reflexive appears, and that the antecedent of a non-reflexive object pronoun must be some NP other than the subject NP. Also, their influence on pronoun resolution has been shown

in various experiments (Nicol & Swinney 2002; Badecker & Straub 2002; Runner 2003).

iii. *Gender, number and animacy congruency*. It is clear that the gender, number and animacy (or humanness) features of the antecedent should not clash with those of the proform. Arnold (2000) and Nicol and Swinney (2002) have shown that congruency is considered in the resolution of pronouns.

iv. *Prominence in memory.* Nicol and Swinney postulate that the syntactic position of an expression could have effects on its prominence in memory. They claim that, for example, a noun phrase in the subject position could be more salient in memory and therefore more easily accessible as an antecedent (Järvikivi, 2005).

v. *Semantic and pragmatic constraints*. Besides syntactic features, world knowledge is also used to resolve co-reference. In sentence (5), the pronoun *she* is very likely to refer to the shop assistant, not just because gender agreement forbids co-referencing with *craftsman*[2] but also because it seems quite unlikely that the shop assistant is informing the craftsman about his own states of mind (MacDonald & MacWhinney 1995).

According to Garrot, Freudenthal and Boyle (1994), all five of these constraints interact during pronoun resolution in a rather complicated fashion.

Bearing all these interacting constraints in mind, it seems even more astonishing that we can connect pronouns so effortlessly to their antecedents. How can we characterize the mechanism that helps us to determine the antecedent of a pronoun? It would either be possible that pronoun resolution happens in a two step process, in which the antecedents of the pronoun is first identified and then in the second step, the connection to the concept to which the antecedents refers is made up. Another possibility would be that the pronouns themselves are interpreted referentially just like NPs. One important aspect that can help to find an answer to this question is the time course of pronoun resolution. If there is a distinct mechanism that helps in identifying the correct antecedent of a pronoun, it is very probable that the interpretation process should be a little delayed compared to definite NPs. However, if pronouns are interpreted directly and just like full noun phrases, there should be no time delay for their interpretation.

[2] even though *shop assistant* does not require a feminine pronoun *craftsman* can be excluded because it clearly would require a masculine pronoun)

A technique that has extensively been used to investigate the recovery of information is probe verification tasks. This method requires participants to indicate whether a specific word occurred in a previously presented sentence fragment, sentence, or discourse. Sentences are presented visually (word by word or phrase by phrase) and at some point during the presentation of the sentence, a word appears for verification. An example is shown in (6), where the probe point is indicated by an asterisk and the probe word is written in upper case.

MARY

*(6) Sally told Mary that she * is in danger*

Shorter latencies in verification are thought to reflect a higher level of activation of a certain word. Using this method, Gernsbacher (1989) showed that definite full NPs reduced the latency of verification immediately. Pronouns, however, did not cause this facilitation effect immediately – facilitation did not occur until the end of the sentence. Gernsbacher interpreted this as a delay in pronoun resolution. Similar results have been found for sentences presented auditorily (with visually presented probes). MacDonald and MacWhinney (1990) compared response times to a probe in a pronoun clause at three different time points from immediately after the pronoun to 500 ms later. They found that facilitation for verification of the antecedent is just noticeable at the last probe point, 500 ms after the offset of the pronoun.

However, the probe verification method has its pitfalls. Cloitre and Bever (1988) report a number of experiments which suggest that definite full NPs immediately activate surface information such as lexical information about their antecedent, whereas pronouns immediately activate deeper conceptual information such as semantic category information. A second problem with this method is that faster verification times for the antecedent of explicit anaphors can be due simply to priming effects since the subject has seen the exact probe word shortly before verification.

Experiments using methods that are less invasive in the ongoing understanding process do not report a general delay in pronoun resolution. An early eye tracking study by Ehrlich and Ranyer (1983) reports delayed resolution only when a pronoun has a distant, and no longer foregrounded, antecedent. Another study, which measured event-related brain potentials to investigate the difference between pronouns and proper names (Streb 2004), also came to the

conclusion that only pronouns with a distant antecedent have a delayed resolution time. There is other evidence suggesting that there is no general delay in pronoun resolution. Tyler and Marslen-Wilson (1982) report an experiment where participants were required to name a visually presented probe that followed one of the auditorily presented text fragments presented in (7)

(7)As Philip was walking back from the shop he saw an old woman trip and fall flat on her face. She seemed unable to get up again.

(a)Philip ran towards…him/her
(b)He ran towards…him/her
(c)Running towards…him/her

The probes were chosen in a way that one (here *her*) was always pragmatically consistent with the story and the other one was not. They suggested that facilitation in naming latency for the probe could only occur if the listener already established a representation of the subject of the clause at that point. The results showed facilitation for naming the probe in all three conditions. Finally, Garrod, Freudenthal and Boyle (1994) used eye tracking during reading to investigate the mechanisms underlying pronoun resolution, and suggest that pronouns are resolved immediately when they refer unambiguously to the focused main characters. They obtained these results by applying an eye-movement monitoring technique that differed from that used by Gernsbacher (1989), who could not find any evidence. Garrod et al. used sentences like the following:

(8)Right away she ordered/poured a large glass of coke.

Each sentence occurred in a context in which the pronoun either referred to a character ambiguously or unambiguously, the character could either be a focused or a non-focused character. The different verbs denoted actions that were either consistent with the focussed character (passenger *ordered* a drink) or to the non-focussed character (stewardess *poured* a drink). Garrod et al. found evidence for the immediate resolution of the pronoun, at least when it referred unambiguously to the focused referent.

In the study presented here, we want to further investigate the mechanisms underlying pronoun resolution and we want to provide some new ideas regarding this most controversial issue. In order to provide new results to the existing body of research, we used eye tracking to observe the influence that complex narrative discourse has on overt attention. In contrast to the study of Garrod et al., we did not study eye movements during a reading task but instead while participants were viewing detailed photographs of scenarios that were paired with an auditorily presented discourse story. That the eye tracking method is eminently suited for the investigation of linguistic processing was first demonstrated by the pioneering work of Cooper (1975). He showed that people are likely to spontaneously guide their eye-movements to elements in the visual field which are semantically related to the spoken word currently heard. Later, Tanenhaus and his colleagues (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) further elaborated this work and derived this eye-tracking method, also known as the "visual-world" paradigm. In visual world experiments, participants interact with a display of multiple objects and receive spoken instructions to manipulate these objects while their eye-movements are measured.

We used a setup similar to the "visual world paradigm" of Tanenhaus, however, the participants in our experiment were not asked to manipulate the objects in their visual scene. They just had to attend carefully to the scenario and the presented piece of narrative discourse without any further action required. In contrast to many other studies using the eye tracking paradigm (Runner, Sussman & Tanenhaus 2003, Arnold 2000, Tanenhaus 2000, etc.), we did not use cartoons or line drawings but detailed photographs of scenarios built up with Playmobil toy figures.

It was important to us to use photographs instead of line drawings that are normally used in comparable eye-tracking experiments. Line drawings already contain an interpretation of the drawn object. The artist pre-selects certain features, which are depicted in the drawing. This focus on certain pre-selected features might influence the eye movements of the viewers. By using real photographs as visual stimuli we hope to increase the general validity of our findings.

In the study presented here we will focus on two questions, which are essential for the understanding of pronoun resolution. First we want to find out if there are any interesting differences in the fixation probabilities on matching referents for different referential

expressions. Second, we want to investigate the time course of fixations for both full noun phrases and pronouns. Special interest will lie on the question of whether pronouns require additional time for ”resolution”, or whether they are interpreted immediately, just like proper names, as was already argued by Tyler and Marslen-Wilson (1982) and Garrod, Freudenthal and Boyle (1994). By determining if there is any additional time needed for the resolution of pronouns, we hope to be able to provide some indications for or against the existence of a distinct mechanism that binds the pronoun to its antecedent. If we are not able to detect temporal differences in the resolution process of pronouns and definite full NPs, we would have a strong indication for Tyler and Marslen-Wilson’s assumption that pronouns are interpreted directly with respect to the discourse representation and that no prior binding to the antecedents occurs.

As well as the possible differences in fixation probabilities for pronouns and full noun phrases, we will also consider differences between pronouns that might occur in the temporal resolution process due to the “distance” between the pronoun and its antecedent. If the distance to the antecedents plays a role in resolution, this would strongly speak for a pronoun interpretation based on antecedent binding. Finally, we will also consider whether there are differences between the interpretations of pronouns that differ in the syntactic or semantic relationship that they have to their antecedent. In doing so, we hope to see if there are differences in the resolution process of different pronouns.

2. Methods

2.1. Participants

The participants who volunteered for the experiment were 12 native German speakers (5 male). All participants were students of Cognitive Science at the University of Osnabrück. They were aged between 20 and 25 (mean 21.9) and had normal or corrected-to-normal vision, and none reported any speech or hearing deficits which could have influenced their performance. One participant had to be excluded from the experiment because his gaze remained almost static during the whole experiment and we had to abort the experiment with another participant due to very poor calibration (mean error >0.5°). In total, we were able to include ten participants in the analysis. All participants were naïve about the purpose of the experiment and received either course credits or payment for their participation. After the experiment, all participants were informed of the purpose of the experiment.

2.2 Stimuli construction

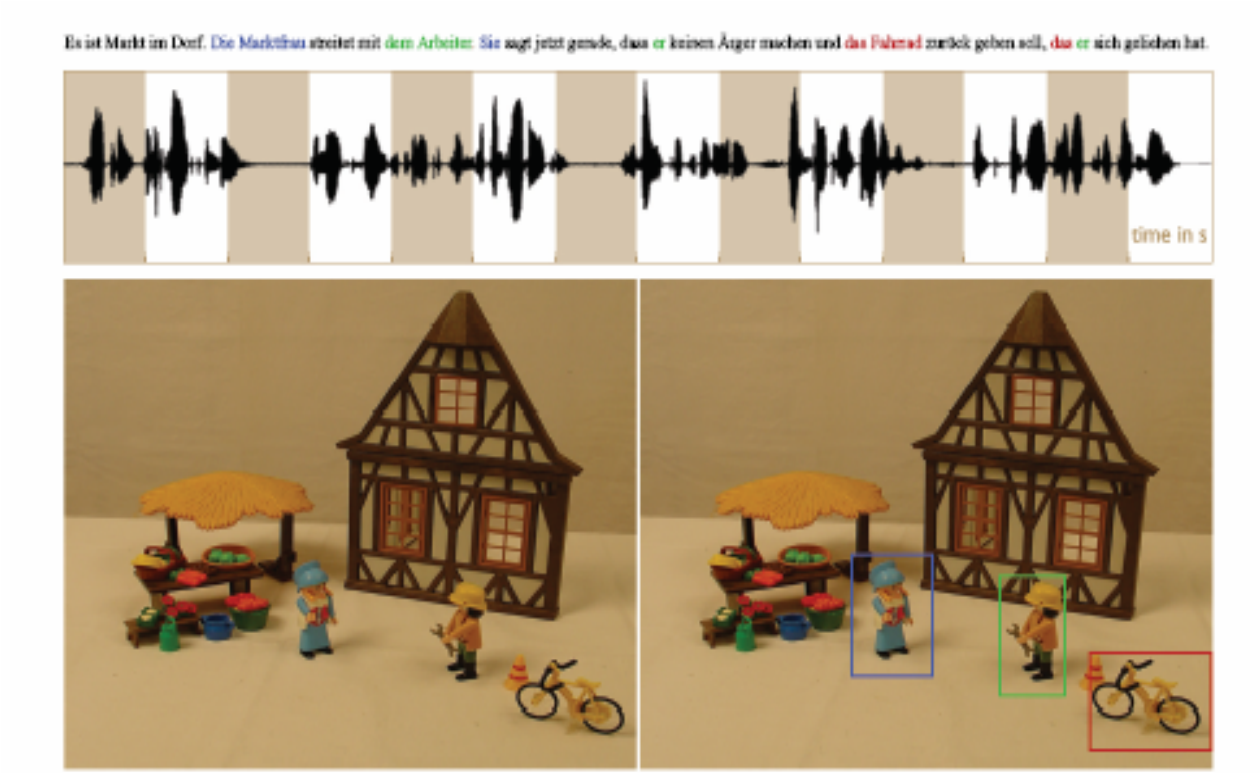


Figure 1: Shows the presented visual and auditory stimuli. An example sentence is presented together with the amplitude of the sound. In the lower part, the corresponding visual stimulus can be seen. Every image comprised two human referents and a third, non-human referent. In the right picture, the three referents are indicated by coloured markings.

10 photographs were paired with pieces of narrative discourse. All pictures were taken by the author using a high quality digital camera (DSC-V1, Cyber Shot, Sony, Japan) and down sampled to a resolution of 1024 x 768 pixels. During the shooting of the photographs, constant light was provided by two studio lamps (InterFit 2300, Tungsten, Paterson). The photographs showed pseudo-natural everyday situations built up with Playmobil toy figures (See Figure 1). Each of the pictures comprised three objects that were named in the narrative discourse. Two of these objects were human figures, whereas the third one was either an inanimate object or an animal. The three referents were named in the corresponding discourse both by a noun phrase and by pronouns. The distractor objects that were present in each photograph were either inanimate objects or animals that fit the general context of the scene.

For each photograph, a corresponding piece of auditorily presented narrative discourse was presented via loudspeakers. These narrative discourse pieces consisted out of three German sentences with the same number of syllables each. The first sentence always described the general scene that was visible in the corresponding photograph, without referring to any specific object in the scene. The second sentence introduced the only two human referents in

the scene with a full noun phrase .The third sentence referred to both of the human referents at least once with a pronoun and introduced the non-human referents with a full noun phrase (see Table 1). The sentences were spoken by a female native German speaker (the author) and recorded using a high quality digital microphone (USB CE FC, Model: A-0205A, Logitech, Switzerland) using the Praat 3.9.12. All pieces of discourse had the same number of syllables and the duration of the discourse pieces ranged between 13.5 and 13.9 seconds.

Each story had four variants. In these variants, or conditions, the pronoun order changed, while the overall theme of the story stayed the same. The first two sentences, introducing the whole scene and the two human referents, did not change in the different conditions. In the third sentence, however, the pronouns were permutated in the following way:

		NP1/NP2	Pro1		Pro2	Pro3		NP3	Pro4	
A	Heute ist Markt im Dorf.	Die Marktfrau streitet sich mit dem Arbeiter	Sie	sagt jetzt gerade, dass	er		keinen Ärger machen und	Das neue Fahrrad zurückgeben soll, das	er	sich geliehen hat.
B					sie					
C					er	ihr				
D					sie	ihm				

Table 1:.This table shows the details of the pronoun permutation in the four different conditions. In the uppermost row, abbreviations for the different pronouns and full NPs are introduced. Pronoun1 has NP1 as antecedent in all four conditions. In Conditions A and C, NP2 is antecedent of Pronoun2, whereas in conditions B and D, NP1 is also the antecedent for Pronoun2. In conditions C and D Pronoun3 exists, referring to NP1 in Condition C and to NP2 in Condition D. In all four conditions, Pronoun4 has NP2 as antecedent.

As we see in Table 1, all conditions start with a Pronoun1 that has NP1 as antecedent. Pronoun2 refers to the NP2 in the conditions A and C and again to NP1 in conditions B and D. Pronoun3 in conditions C and D refers to NP1 in condition C and to NP2 in condition D. All four conditions end with Pronoun4, which has NP2 as antecedent. The idea behind the permutation is to see whether there are differences occurring due to the syntactic relationship between the pronoun and its antecedents. Whereas $Pronoun2_A$ and $Pronoun2_C$[3] both have their antecedents in the preceding sentence, the antecedents for $Pronoun2_B$ and for $pronoun2_D$ are within the same sentence. The antecedent for $Pronoun3_C$ is also located within the same sentence as the antecedents, whereas $Pronoun3_D$ has an antecedent in the sentence before. Linguistic theory differentiates between pronouns that have their antecedents within the same sentence and those that do not. Whereas pronouns with antecedents in another sentence belong to the class of the regular anaphoric pronouns, pronouns with the antecedents within

[3] From here on I will use indices like $Pronoun3_A$ or $Pronoun2_C$ to refer to the pronouns in the different conditions

the sentence belong to the group of c-commanded pronouns that are bound by their antecedents. In our material, all pronouns with the antecedent within the same sentence belong to the class of syntactically bound pronouns that are c-commanded by their antecedents (Bosch, 1983). In contrast, all the pronouns with antecedents in the preceding sentence are ordinary anaphoric pronouns. According to this distinction, we would expect higher fixation probabilities on the matching referents for the regular anaphoric pronouns since they are not syntactically bound to their antecedents but refer independently to the referent. From the arrangement of our four conditions we hope to be able to test whether the differentiation in bound and c-commanded versus anaphoric pronouns is just a theoretical one, or if it can also be observed in human language understanding.

Due to the fact that each story had four different conditions, we have a total amount of 40 experimental sentences (10 pieces of discourse * 4 conditions). Each of the participants saw either conditions a) and c) or conditions b) and d) of each story and 30 additional scenarios that served as fillers. In total, 20 experimental and 30 filler scenarios were presented to each participant. The order in which the experimental and filler scenarios were presented was permutated randomly. The auditory presentation of the discourse pieces varied between 13.5s and 13.9s for the experimental discourses and between 13s and 17s for the filler discourses. Even though the auditory stimulus was often shorter, each picture was presented to the participants for 17 seconds.

2.3. Apparatus

Eye movements were recorded using a binocular eye-tracker (‘Eye Link II’, SR Research, Mississauga, Ontario, Canada, 2003) (see figure 2 for important parts of the eye-tracker). Three infra-red cameras record the position of the participant’s head and the movements of both eyes. The two cameras that record the eye fixations are placed under the participant’s eyes. With the help of an object recognition algorithm, it is possible to identify and record the pupil, which allows for the calculation of gaze positions and fixations. The local position of the head is determined by four infra-red markers at the corners of the monitor that send infra-red rays to the head camera. This makes it possible to compensate for minor head movements. The eye-tracker was controlled by a Pentium 4 PC (Dell Inc., Round Rock, TX, USA) that sampled the eye position signal at a rate of 250 Hz. Besides video-based pupil tracking, the eye-tracker included infrared cornea reflection which reduces susceptibility to headband slips and motion. A second computer (PowerMac G4 800 Mhz) connected by a remote Ethernet

link was used to control the stimulus presentation sequence and to trigger the eye-tracker on each trial. All images were displayed on a 17-inch TFT display (‘SynchMaster 1100DF’, Samsung, Korea). Two loudspeakers were used to generate the auditory stimuli (‘Z3 Style 2.1’, Logitech, [Switzerland).

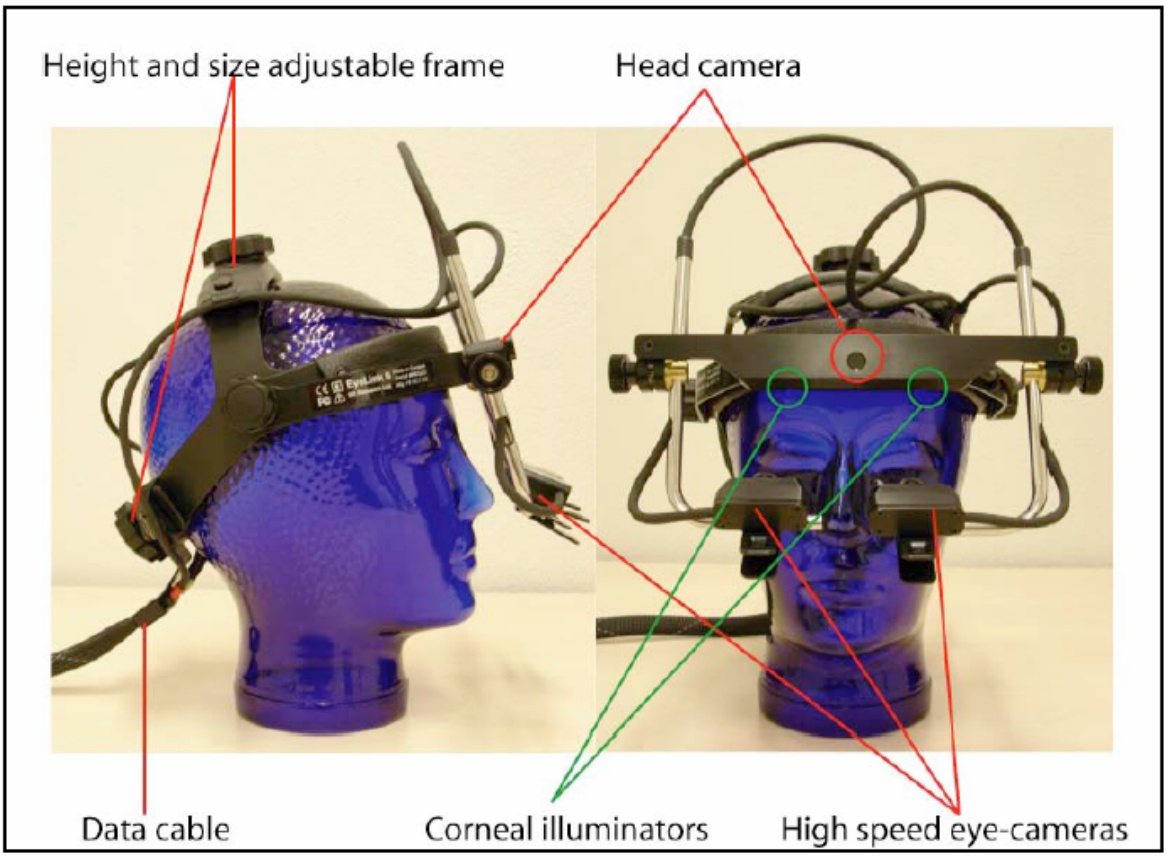


Figure 2: Parts of the eye-tracker headband. The headband was fitted to the subject’s head and adjusted until the eyes were visible to both eye-cameras and corneal illuminators (green circles). The head camera receives a signal from 4 infrared markers attached to the corners of the display monitor. This figure is taken from Klaus Tichanek (2004).

2.4. Procedure

The experiment was carried out in a small room with dim light. Prior to their participation, all participants were introduced to the procedure of the session and were informed that they could cancel the experiment at any time. No information about the purpose of the experiment was given. At the beginning of the experiment, both eyes were calibrated using the nine-point grid procedure. During this procedure, participants were asked to fixate on a small point, which appeared randomly at one of nine locations on the monitor. Only calibration values with a mean error >0.5° were accepted during the validation procedure. Using a standard setting of the Eyelink II, the better eye was selected. Before each stimulus presentation a fixation point was presented. Stimulus presentation was triggered by the experimenter after the participant had stably fixated on the fixation point. This fixation point was used to

perform a correction for drifts and slips of the eye-tracker and allowed participants to take a short break between trials. A total amount of 50 stimuli (20 experimental and 30 filler) was presented to each participant and the order of presentation was randomised. The experiment lasted about 30 minutes. Participants were instructed to “study the images carefully”.

2.5. Data Analysis

In this study we wanted to examine the dynamics of natural language understanding. That overt attention and eye movements are related has been shown by a numerous experiments in the past (e.g. Parkhurst et. al., 2002). Due to this finding, we can treat every eye fixation as an unconscious decision about where to attract attention. To analyze the fixations of the participants, the spatial coordinates of the fixations were stored by the tracking system in a special file format and converted to readable ASCII text.

2.5.1. Fixations

Humans make approximately three to five saccades a second to reorient the high acuity fovea in the centre of the retina onto interesting regions in the field of fixation. The fixations between these saccades are relatively static and last about 200 to 300 ms (Wirtz, 2005; Tanenhaus & Spivey-Knowlton, 1995). For this experiment, fixations were defined as the inverse of a saccade. The subjects’ fixations were directly distinguished from saccades using velocity, acceleration and motion thresholds. A saccade was detected when eye movement velocity exceeded 30 degrees per second and acceleration exceeded 8000° per sec^2. The saccadic motion threshold was set to 0.1 degrees to delay the onset of a saccade until the eyes had moved significantly. To be able to compare the fixation proportions over the whole time course, we established time windows of 500 milliseconds. Fixations to each object that occurred during this time frame were summed.

To define the regions of interest around the referents and the distractors in each scene we used the built-in Matlab function *roiploy*. Each region of interest was defined by hand such that the approximate form of the object was masked with a slight overlap over the actual object (See Figure 3). A fixation was counted as a fixation on an object only if it was located within one of these predefined regions. Otherwise, it was counted as a beyond object fixation.

.

Figure 3: Figure 3 shows the hand-defined regions of interest. The coloured markers around the objects indicate the masks that were used in the analysis to define the different regions of interest. While the three referents were each defined with their own mask (blue, green and red), all the distractor objects were classed under one mask (yellow). The white dots are the fixation points of one participant during a complete presentation of stimuli.

To even out time differences ranging up to 300 milliseconds between word onset and offset of the nouns and pronouns in the different discourse pieces, we adjusted the time course of the narrative discourse to the mean word onset and offset. To do so, we calculated the mean onset and offset of each referential expression (t_{mean}) and added them to a list in which the actual onsets and offsets of the referential expressions were noted (t_{actual}). The mean onsets and offsets were used as a referential frame to transform each time point in the actual discourse piece into the hypothetical mean time point that can be calculated from the mean and actual word onsets and offsets. In doing so, we were able to adjust each time point of a discourse piece such that the onsets and offsets of all referential expressions lay at the same mean time point, for all ten discourse pieces. To do this, we took each real time point (t_{real}) and added to it the factor by which it changed from the mean time point. This factor was computed by the formula shown in Formula 1. Using this method, we were able to account for these small time differences and to modify the time course of the different discourse pieces slightly, so that on

and offset of all referential expressions was equalized and onsets and offsets of all referential expression were identical to the mean onset and offset.

$$\text{Time}_{\text{New}} = t_{\text{actual}} + \frac{t_{\text{actual}} - t_{\text{real}}}{t_{\text{mean}} - t_{\text{actual}}} * (t_{\text{actual}+1} - t_{\text{actual}})$$

Formula 1: With this formula, we computed the temporal adjustment of all the time points in the different stimuli sentences. T_{actual} denotes the actual time point of the next on or offset of a referential phrase, T_{real} the time point at the moment and M_{ean} the average time point of the next on or off set, computed over all stimuli sentences.

2.5.2. Stimuli Validity

As our visual stimuli differed quite a lot from the stimuli used in earlier visual world studies, we first had to check that the salience of the different objects in the scene was balanced and that single objects did not attract an over-average amount of attention per se. To do this, we computed the summed fixations on the single objects during the first discourse sentence that introduced the whole scene without directly referring to any object. A second question concerning the validity of our stimuli concerned the variance between different scenes. To be sure that we can compare the different scenarios with each other, we calculated the variance between the different photographs by computing the average number of fixations on each object over the whole time course for each of the pictures. We also computed the average fixations of each participant to account for the variance between subjects.

2.5.3. Statistical Analysis

To assess the time course of language comprehension as speech unfolded, the fixation probability over time was computed for each referent and the mean was depicted graphically. This was done once summing over all four conditions and once for each condition alone. The first 500 milliseconds were excluded from any further analysis since the fixations were heavily influenced by the central position of the fixation cross that occurred before each stimulus presentation.

In order to test for any interesting differences in the fixation probabilities as the discourses unfolded, t-tests were conducted between the referents. For each participant in each trial the fixations on the different objects were determined. The mean over all trials was computed and served as a basis for the t-tests between all referents. In doing so, we checked whether a difference in fixation probability could be observed over the time course of the narrative discourse. A second series of t-tests was conducted to test for differences between the four

conditions. We did not correct the t-values for multiple testing, but almost all our values are either so strongly significant or so far above the significance threshold that multiple test correction would not have had an influence on their significance. For the sake of better legibility, we did not carry out the multiple test correction. The fixation means of each participant were computed for each condition. Before that, the normal distribution of the data was checked with a Lillifors test.

3. Results

As our visual stimuli differed quite a lot from the stimuli used in earlier visual world studies we first had to check for big variances in fixation probabilities between the different stimulus pictures and for the different objects within single scenes. By doing this, we could make sure that our stimulus material was valid and worthy of further examination.

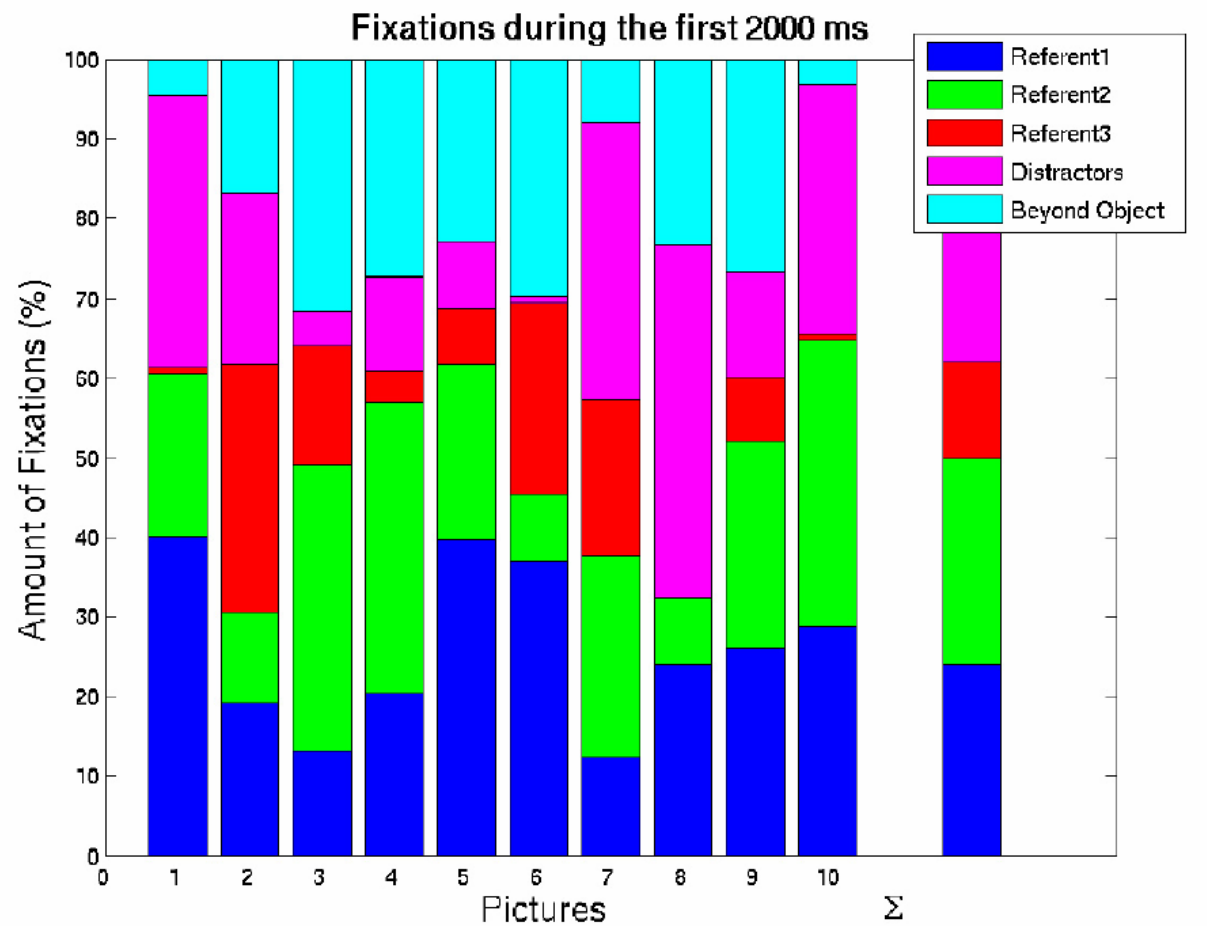


Figure 4: Shows the accumulated number of fixations on different objects in the pictures over the first two seconds before the onset of sentence 2, which introduces the referents. As indicated on the x-axis, the columns stand for the different visual stimuli, with the last column showing the summed fixation probabilities over all pictures. On the y-axis, the fixation probability is depicted. The colour indicates the fixated object.

3.1 Fixation Probability without the Influence of Referential Expressions

By looking at the first 2000 ms of our stimulus presentation – in which the whole scene was introduced without direct reference to any of the objects in the scene – we were able to ensure that our scenes were perceived as meaningful stimuli with the two human referents in the centre of the scene. The analysis showed that the participants already showed a preference for the human figures in the scene before they were mentioned explicitly in the narrative discourse (see Figure 4). Summed over all pictures, the first human referent attracted 26.9 % of the fixations during the first two seconds whereas the second human referent attracted 23.3%. The mean fixation probability reached 11.2% for the third (non-human) referent and 21.5 % for all the distractor objects taken together. The mean probability for fixating a point that was not defined as a region of interest reached 16.2 %.

	Referent 1	**Referent 2**	**Referent 3**	**Distractor**	**Beyond object**
Picture 1	30.60%	25.90%	8.70%	23.30%	11.20%
Picture 2	21.90%	16.80%	23.50%	18.80%	18.90%
Picture 3	15.00%	29.50%	22.00%	9.00%	24.30%
Picture 4	21.90%	31.90%	10.80%	18.50%	16.80%
Picture 5	33.50%	22.30%	11.70%	15.50%	16.90%
Picture 6	34.40%	19.20%	18.50%	2.00%	25.80%
Picture 7	15.40%	18.90%	25.90%	27.10%	12.40%
Picture 8	20.80%	21.90%	4.70%	38.70%	13.80%
Picture 9	17.00%	25.90%	22.20%	13.40%	21.40%
Picture 10	21.90%	34.90%	11.60%	22.90%	8.50%
mean	23.2%	24.70%	16.00%	18.90%	17.00%

Table 2: Shows the fixation probabilities for the different objects in the visual scene summed over all subjects and over the whole time course of stimulus presentation. The last row shows the mean fixation values for each object

The variance in fixation probabilities between the different pictures is quite big. In the different pictures the variance ranges for the non-human referent from 0.7 % up to 31% and for the distractor objects from 0.9 %to 34%. Fixations on the human referents show a slightly smaller variation, ranging from 12.0 %to 36.7 % for Referent 1 and from 8.2 to 31.0 % for Referent 2. Besides the fact that this first analysis showed that the participants perceived the visual stimuli as meaningful scenes with the human referents in the centre of attention, the high fixation probability for distractor objects assured that the distractor objects were also perceived and that the participants' focus did not exclusively lie on the three referents from the beginning. The high fixation probabilities that could not be assigned to any object in the scene (16.1 % Beyond Object fixations) can be explained by the quite narrow definitions of

regions of interest and by the fact that objects often stood so close to each other that it might have been possible to fixate both by looking in the empty space between them.

3.2. Variance between Stimuli and Participants

We also calculated the mean fixation probabilities for each picture over the whole time course of the narrative discourse to check for strong outliers in our stimulus material. The variance between the different pictures can be seen in Table 2. In general, the fixation probabilities over the whole time course do not differ a lot from the results we obtained by just looking at the first two seconds. To make sure that there were also no strong outliers between the participants, we also computed the variance in fixation probability for the different objects over the single subjects. The results we obtained can be seen in Table 3.

3.3. Fixation probabilities over all Conditions

After being sure that our stimulus material did not show severe irregularities, we were able to calculate the grand average of fixation probabilities over all pictures, conditions and participants[4]. The result of this calculation is depicted graphically in Figure 5. In Figure 5 it can be seen that both noun phrases and pronouns are followed by an increase in fixation probability.

	Referent 1	**Referent 2**	**Referent 3**	**Distractor**	**Beyond object**
Subject 1	27.90%	20.10%	13.70%	26.40%	11.50%
Subject 2	26.50%	26.10%	15.30%	13.30%	18.50%
Subject 3	21.50%	23.10%	17.60%	27.40%	10.40%
Subject 4	21.20%	26.40%	12.50%	15.50%	23.80%
Subject 5	22.80%	28.10%	11.50%	18.20%	18.90%
Subject 6	17.70%	23.20%	10.90%	22.60%	25.40%
Subject 7	25.60%	26.30%	15.20%	17.20%	15.70%
Subject 8	21.60%	27.20%	22.30%	21.60%	7.10%
Subject 9	25.50%	30.80%	16.50%	10.00%	16.80%
Subject 10	19.90%	24.10%	17.00%	19.40%	19.30%
mean	23.00%	25.40%	15.50%	19.10%	16.70%

Table 3: Shows the fixation probabilities for each subject in the different objects in the visual scene. Probabilities are summed over all pictures and over the whole time course of stimulus presentation. The last row shows the mean fixation values for each object.

4

For the second of our 10 stimuli scenes, only the first 12 seconds could be used for analysis due to an error in the materials.

The peaks after a referential expression reach from 38.2 % to 50% for full noun phrases and from 27% to 36% for pronouns. By focussing on the first and last of our four pronouns we are able to obtain fixation probabilities summed over all conditions for both full NPs and pronouns. To compare how the fixation probabilities changed as the discourse unfolds over time, we conducted a series of t-tests (t = 0.05) for each 500 millisecond time slot. These series of t-tests were conducted between referent 1 and referent 2, between referent 2 and referent 3 and between referents 1 and 3. Time slots in which the t-tests became significant are indicated in Figure 5.

3.5. Comparison: Referent 1 and Referent 2

The t-tests between Referent 1 and Referent 2 became significant in the time slot from 3000 to 3500 ms (p = 0.000032) and in the slot from 3500-4000 ms (p = 0.019). During that time the fixation probability for Referent1 is significantly higher than the probability for Referent2. This whole significant time interval starts 500 milliseconds after the onset of the full noun phrase and ends 600 milliseconds after the offset of this noun phrase.

The second time that the t-tests became significant was in the time slots ranging from 4500 to 5000 ms (p = 0.026), from 5000 to 5500 ms (p = 0.0003), from 5500 to 6000 ms (p = 0.000016) and from 6000 to 6500 ms (p = 0.0051). In these time frames, fixation probability for Referent2 is significantly significant higher. The whole significant interval starts 500 milliseconds after the onset of the noun phrase referring to Referent2 and ends 1100 milliseconds after the offset of the noun phrase. The t-test also became significant in the time slot from 10000 to 10500 ms (p = 0.006). Finally, the differences between referent 1 and 2 became significant again in the time slots from 12500 to 13000 ms (p = 0.0014) and from 13000 to 13500 (p = 0.00011). These time slots start 100 ms after the onset of the pronoun referring to referent 2 and end 1000 after the offset of the pronoun.

3.6. Comparison: Referent 1 and Referent 3

The t-tests conducted to detect significant differences between Referent 1 and referent three show significant results for each time slot, except for the time frame between 6000 and 6500 ms and the two time slots from 10500 to 11000 ms and from 11000 to 11500 ms. Before these two time frames the fixation probability for Referent 1 is always significantly higher, and from 11500 ms onwards Referent 3 has significantly higher fixation probabilities.

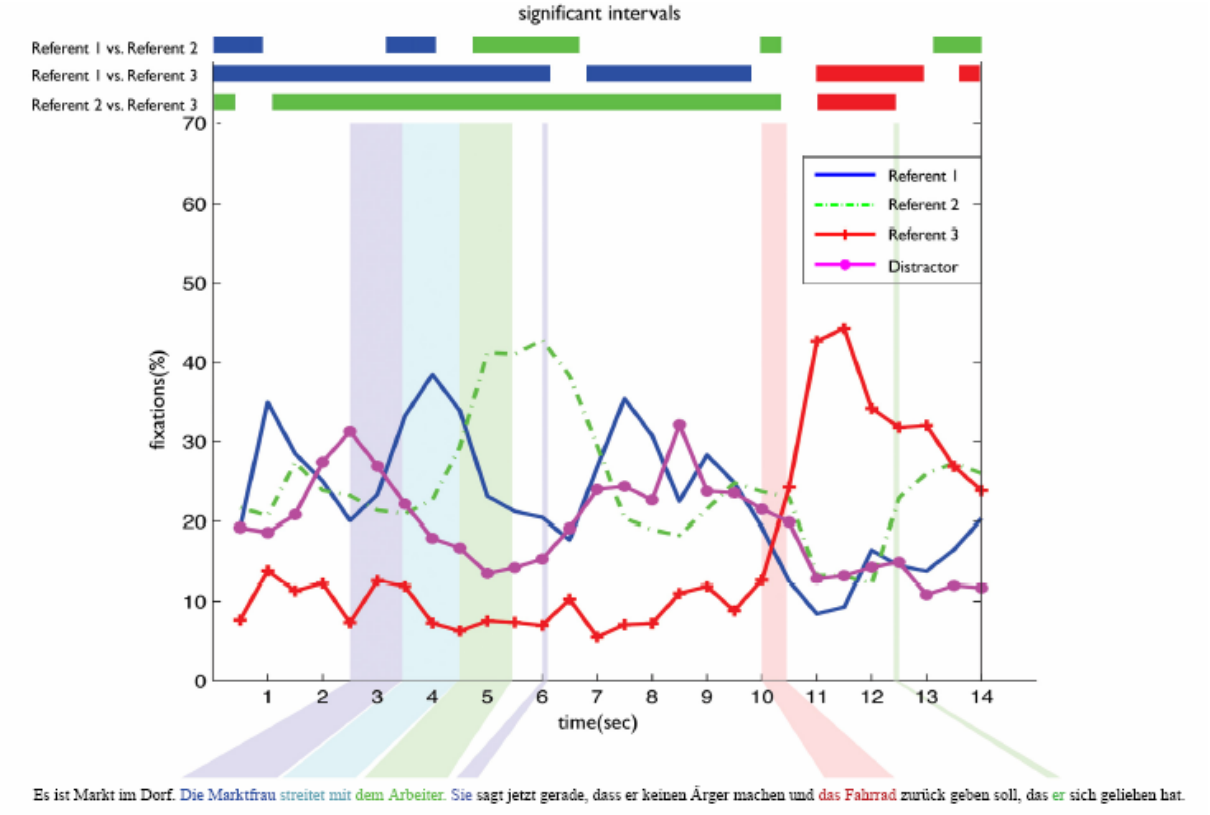


Figure 5: Shows the fixation probabilities for the different referents summed up over all conditions, subjects and stimuli sentences. The x-axis shows the time course of the stimuli presentation and the y-axis the fixation probability. The coloured vertical bars in the background represent the duration of the referential expressions and interaction verbs. The coloured horizontal bars at the top of the figure depict significant differences in fixation probability for different objects. The coloured horizontal bars over the diagram depict the time slots in which the t-tests between the different referents became significant.

3.7. Comparison: Referent 2 and Referent 3

The fixation differences between Referent 2 and Referent 3 are also significant most of the time. The first time slot ranging from 0 to 500 ms is insignificant; however after that the differences between Referent 2 and 3 stay significant until 10500 ms. Until that time point, fixation probabilities for Referent 2 are significantly higher. At 10500 ms the fixation probability gets significantly higher for Referent 3. It is worth mentioning that this time frame starts 100 ms after the offset of the noun phrase that is referring to the 3 Referent. The significantly higher fixation probability for Referent 3 is kept over the next 3 time frames, until the frame from 11500 to 12000 ms. From this frame on the differences between Referent 2 and 3 are no longer significant. This is due to the increase in fixations on Referent 2 that follows the pronoun onset referring on Referent 2 at 12400 ms.

3.8. Time Delay for Full Noun Phrases and Pronouns

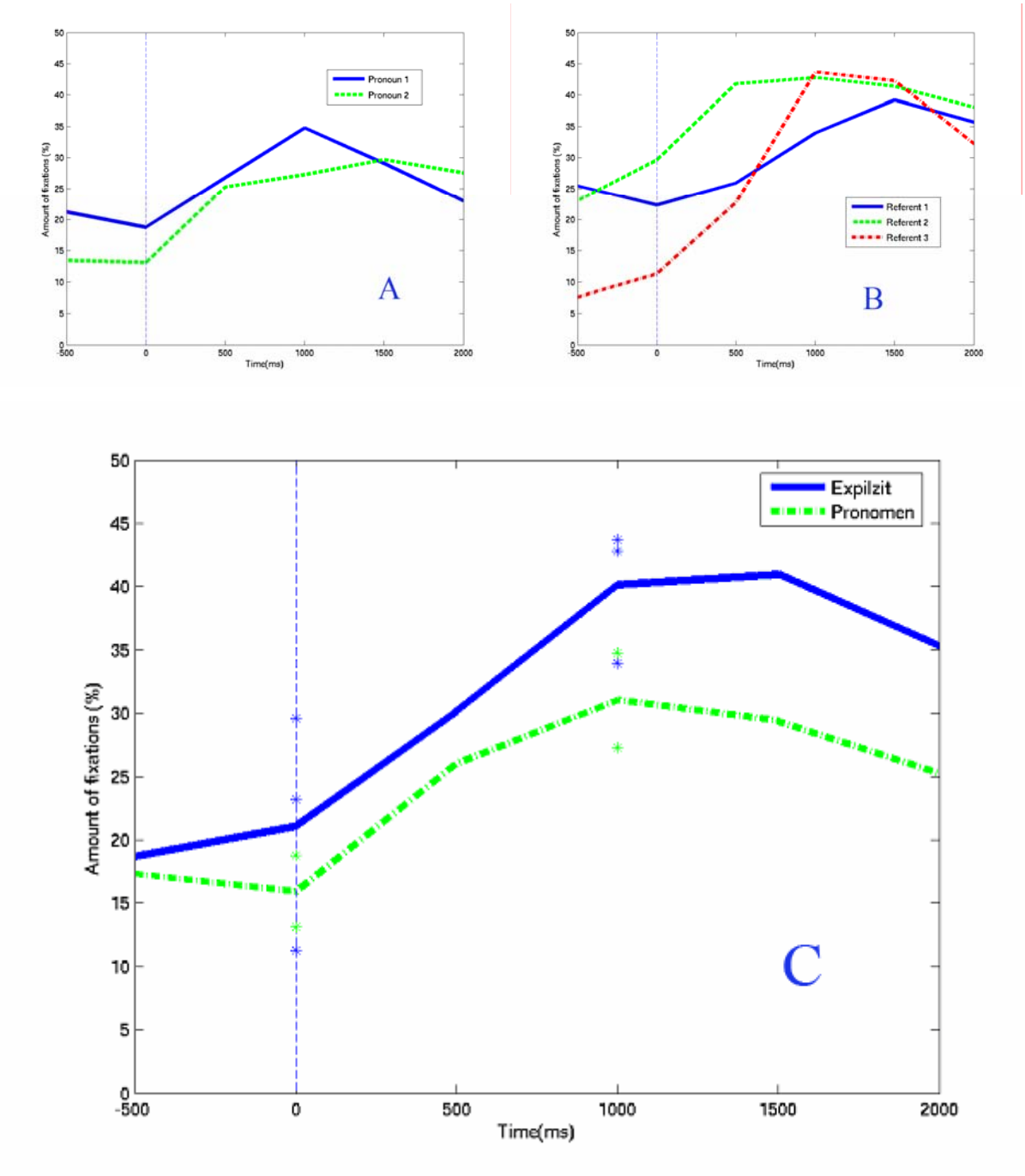


Figure 6: Figure 6b shows the fixation probabilities for the three different referents when they were named explicitly. The blue line indicates referent 1, the dotted green line referent 2 and the dotted red line referent 3. The vertical dashed line indicates the onset of the referential expression. The time that is depicted on the x-axis ranges from 500 ms before the onset of the referential expression to 2000 ms after its onset. The y-axis shows the fixation probability in percent. Figure 6a shows the fixation probabilities for pronoun naming. In Figure 6c we see the mean fixation probabilities for explicit and pronoun naming. The blue line shows the mean fixation probability for explicit naming and the dashed green line the probability for pronoun naming. The stars located around the word onset and around the fixation peak show the variance.

In order to compare the peaks in fixation probabilities that were caused by full NP reference with those caused by pronoun reference, we looked at the fixation curve of each referent during both explicit and pronoun naming in a time window beginning 500ms before the onset of the referential expression and lasting until 2000 ms after the onset of the expression (Figure 6a for pronoun naming and Figure 6b for explicit naming). In Figure 6a we can see the fixation probabilities caused by the two pronouns. Pronoun 1 is the first pronoun in our discourse story, standing very close to its antecedents, whereas pronoun 2 is the last pronoun of our discourse story, and has the highest distance to its antecedents. It can be seen in Figure 6a that pronoun 1 reached its probability peak at 1000 ms after the onset of the referential expressions and decreased directly after that. Pronoun 2, however, reached its peak only at about 1500 ms. However, the difference in the two fixation curves did not become significant. In figure 6b the different fixation curves are shown for the three referents that are referred to by a full noun phrase. It is interesting to note that referent 2 has already reached its peak 500 ms after the onset of the referential expression and stays at this plateau until 1500 ms after the onset of the expression, whereas referent 1 only reaches its fixation peak at 1500 ms after the onset of the referential expression. Referent 3 had a fixation plateau from 1000 ms to 1500 ms. The fixation pattern of Referent 2, with its early peak, was significantly different from both other fixation curves ($t = 0.0148$ for the comparison between Referent 1 and Referent2 and $t = 0.128$ for the comparison of Referent 3 vs. Referent 2). The difference between Referent 1 and Referent 3 did not become significant. We merged the explicit fixation curves and the pronoun fixation curves for all referents. In doing so, we obtained one fixation curve for pronoun and one for full NP reference (Figure 6c). Both pronoun and full noun reference resulted in an increase of fixations on the visual referent. The fixation probability for pronouns reached its fixation peak at 1000 ms after the onset of the pronoun. Until 1500 ms after the pronoun onset the fixation probability decreased only slightly, forming a plateau of highest fixation probability between 1000 and 1500 ms. In the case of full noun phrases, the peak of fixation probabilities was also almost reached 1000 ms after the onset of the referential expression. However, fixations following full NP reference kept on increasing until 1500 ms after the onset of the expression forming a slightly increasing plateau from 1000 to 1500 ms. The peak in fixation probabilities caused by the full noun phrases reaches up to 43% and is significantly higher ($p=0.00005$) than the fixation peak caused by pronouns, which reaches up to 32%.

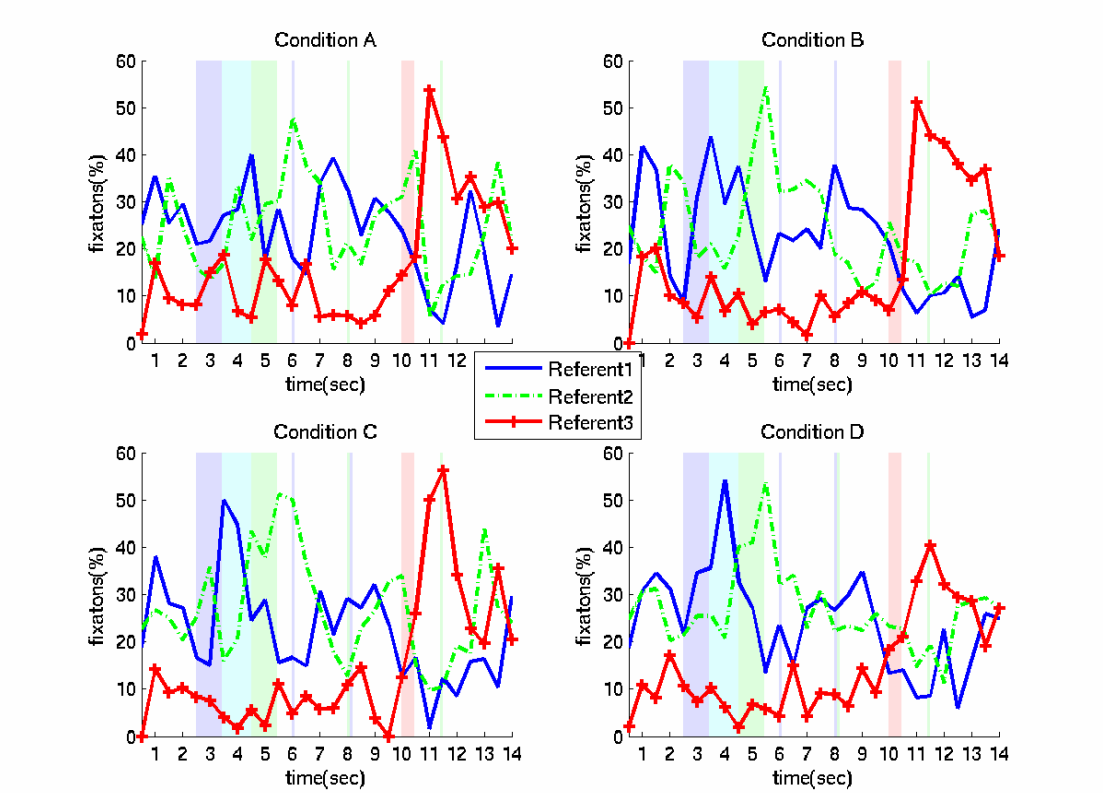


Figure 7: Figure 7 shows the mean fixation probabilities for each condition over the whole time course. As in Figure 5 the coloured bars in the background indicate the time point and duration of all referential expressions.

3.9. Comparison between the Different Conditions

As already mentioned, each story had four different conditions. To account for differences between the four conditions we calculated the average of fixation probabilities over pictures and participants for each condition (see Figure 7). The time frame between 7000 and 10000 ms was of special interest for the comparison between the four conditions, since it was in this time segment that the differences between the four conditions occurred (see Figure 8). To find significant differences between the four conditions, we conducted a series of t-tests (t = 0.05), again for each 500 millisecond time slot. We tested each referent in condition A against its counterpart in condition B, and each referent in condition C against its counterpart in condition D. The only comparison that became significant was the comparison of Referent2 in conditions A and B in the time slot between 10000 and 10500 ms. This time slot is approximately two seconds after the onset of the crucial pronouns in this condition. During this time interval, the probability to fixate Referent2 in Condition A was significantly higher than in condition B. No other time frame and no other referent showed significant differences. The comparison between condition C and D did not yield any significant results at all.

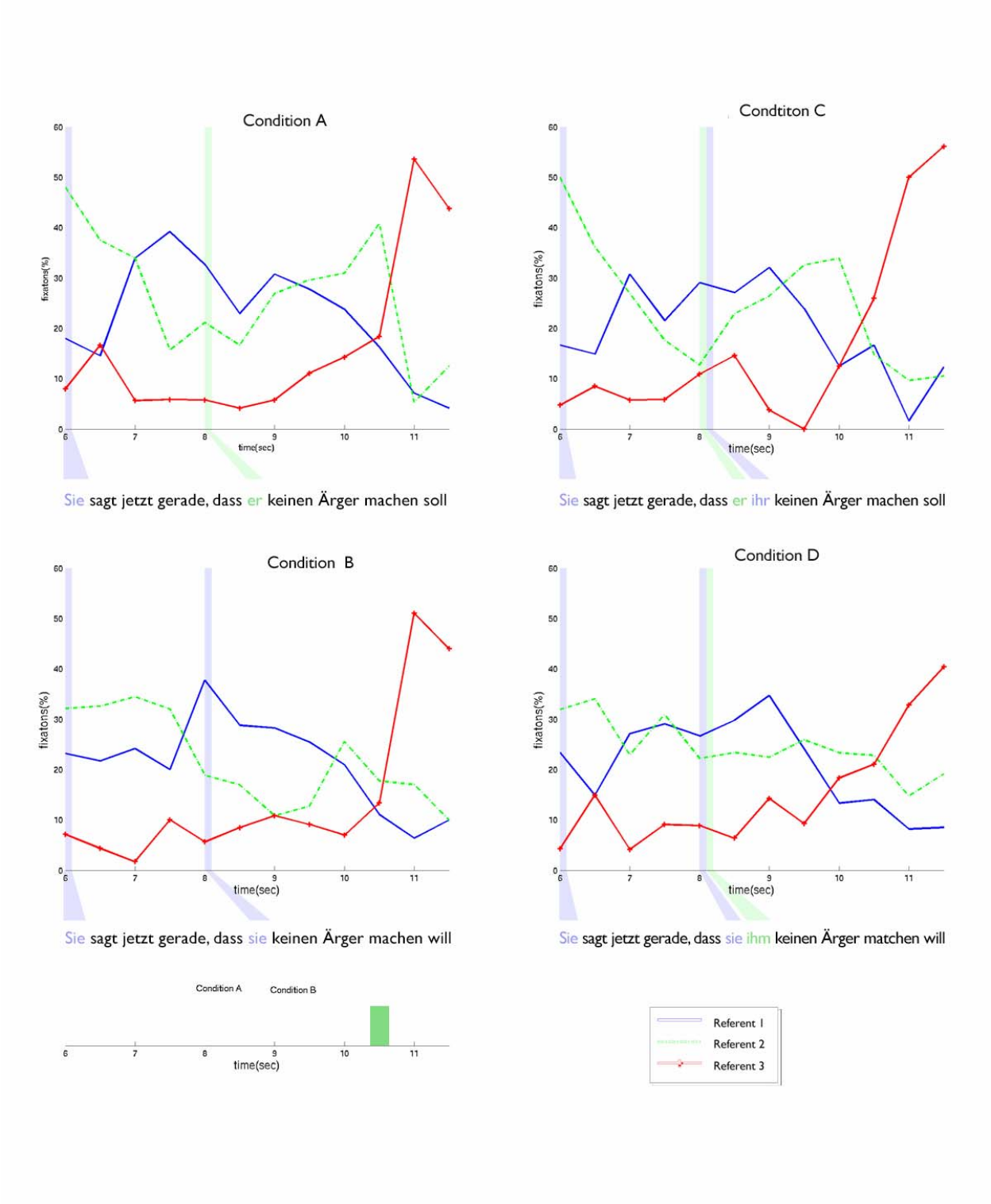


Figure 8: Figure 8 shows the time frame (6 - 11 seconds) in which the differences between the four conditions occur. The only time slot in which there is a significantly different fixation probability between the four conditions lies at 10.5 sec in conditions A and B. This time frame is indicated by the green square in the time axis in the lower left corner. At that time the probability to fixate Referent 2 is significantly higher in condition A.

4. Discussion

In this study our main focus was on the question of whether full noun phrases and pronouns are interpreted in the same way, or if there are differences in interpretation of different referential expressions. Our results can be summarised by three main findings:

1. Both full noun phrases and pronouns cause increased fixations on the matching referent.
2. The temporal resolution of pronouns in unambiguous texts happens just as fast as the resolution of full NPs
3. There seem to be few pronouns that do not elicit higher fixation probabilities on the matching referent. These differences in the referentality between different pronouns might be due to the syntactic relation between the pronoun and its antecedent.

In the following discussion, we will first try to interpret each of these three findings, followed by an outlook on how the study presented could be improved in future work. Finally, we will try to place our findings into the existing framework of previous research.

4.1 Interpretation of our results

Our results show that both full NPs and pronouns caused increased fixations on the matching visual referents. However, fixation probabilities for full NPs were significantly greater than the fixation probabilities for pronouns. This means that even though both kind of referential expressions do elicit higher fixation probabilities on their matching referents, we are still able to detect differences between full NPs and pronouns in the amount of fixations they cause. Since we only used unambiguous pronouns[5] in our stimulus material, the differences in fixation probability between NPs and pronouns can not be attributed to the fact that participants had problems in finding the right antecedents to the pronouns.

However, even though we were able to detect this general difference in fixation probability, this does not have to mean that full noun phrases generally create a stronger connection to the matching referent in the visual scene than pronouns do. We assume that the difference in the fixation probability might be due to the fact that full NPs newly introduce referents, whereas pronouns just pick up a referent that has previously been introduced by a full NP. In other

[5] Gender Agreement allowed only one possible antecedent for each of the two pronouns.

words: While the participant's attentional focus gets directed to a totally new object by a full NP, the pronouns can just re-direct the focus back to an object that has been recognised earlier. It seems reasonable that a newly introduced object causes a higher amount of fixations than a previously introduced one that has already been examined once.

We were also able to find that each full NP produces a fixation probability on the matching referent that is significantly higher than the fixation probabilities for all other referents and objects at this time point. The fixation probabilities caused by pronouns were also tested for significance. It is interesting to note that from two tested pronouns[6], only the one with the larger distance to its antecedents caused a significant difference in fixation probability compared to the other human referent. The pronoun with the shorter distance to its antecedents did not produce a significant difference compared to the fixation curve for the competing human referent, even though the magnitude of the fixation peak in percentage was higher than for the second significant pronoun. This could be explained by the fact that the attentional focus was directed to both of the human referents at the time point the first pronoun occurred, since this pronoun directly followed the explicit introduction of both human referents by a full NP.

Another interesting aspect is the temporal duration of the significant intervals for each referential expression. While the significant interval following the full NP referring to Referent 1 starts with *off*set of the word and the NP referring to Referent 3 starts 500 ms after the offset of the word, the significant interval following the NP referring to Referent 2 already starts 200 ms after the *on*set of the referential expression. The fact that the significant interval for Referent 2 already starts very shortly after the onset of the expression could be due to the fact that Referent 2 is always preceded by an interaction verb like *talk, fight, speak* that requires a second human character as an object. This might enable the listener to anticipate the outcome of the story, since – apart from Referent 1 who is already the head of the phrase – Referent 2 is the only human object present in the visual scene and therefore the only one that allows a sound unfolding of the story.

[6] In this analysis, only two of the four pronouns in each stimuli text were included since just these two were the same in all four conditions. A detailed analysis of the pronoun differences in the different conditions will be discussed later.

The significant interval following the second pronoun becomes significant 500 ms after the offset of the referential expression and is therefore temporally similar to the pattern of explicit naming for Referents 1 and 3.

Besides the significant fixation probabilities caused by referential expressions, we were also interested in the temporal resolution of different referential expressions in general. As a first step, we compared the temporal pattern of the fixation curves caused by the three NPs. This comparison gives results very similar to those obtained by the comparison of the temporal duration of the significant intervals caused by full NPs. It shows that the NP referring to Referent 2 reaches its fixation peak already 500 ms after the *onset* of the referential expression. This is of special interest since it means that the peak is reached even before the end of the relevant phrase. As already mentioned, we assume that the interaction verb between Referent 1 and Referent 2 triggered an anticipation effect that might have caused this early fixation peak. Participants were able to anticipate the continuation of the story because interaction verbs like *talk to, fight with* most often require a human object to follow. Since there was just one other human figure in the visual scene besides Referent 1, the participants were able to foresee the continuation after the verb by integrating the available visual and the linguistic information.

The non-human Referent 3 reached its fixation peak 1000 ms after the onset of the referential phrase, whereas Referent 1 took 1500 ms until the highest fixation peak was reached. That Referent 3 reached its fixation peak 500 ms before Referent 1 may partly be caused by the fact that the referential expressions referring to Referent 3 were on average 600 ms shorter than those referring to Referent 1.

As a next step we compared the temporal fixation pattern of the fixation curves caused by the pronouns. As already mentioned, this part of the analysis included only those pronouns that were the same in all four conditions. Whereas the first pronoun we were looking at stood in the sentence directly following the one containing its antecedents, the second pronoun had a whole sentence distance to its matching antecedents. Comparing these two, we found that Pronoun 1, having a short antecedents distance, reaches its fixation peak already after 1000 ms, whereas Pronoun 2 needs 1500 ms until it reaches its fixation peak. However, the difference in percentage between the fixation probabilities caused by the two pronouns is not statistically significant. That’s why we do not assume that the temporal difference until the

absolute fixation peak is reached can be interpreted as some kind of indication for the fact that pronouns with a longer distance to their antecedents need a longer time for resolution.

Comparing the mean temporal fixation pattern of full NPs with the mean fixation pattern for pronouns, we were able to see that the temporal pattern of both fixation curves looks very similar. Both full NPs and pronouns reach the highest fixation probability between 1000 and 1500 ms after the onset of the referential expression. The fact that both have their highest fixation probability in the temporal interval between 1000 and 1500 ms after the onset of the expression indicates that there is no temporal delay for the resolution of pronouns in unambiguous texts.

One possible objection to this interpretation of our findings is that we compared the fixation curves from the onset of the referential expressions and not from the offset. Due to the longer duration of full NPs, their offset is much later than that of the pronouns. This means that even though the temporal resolution for both kinds of expressions is equal with respect to their onsets, the temporal delay measured from the offset is much bigger for the pronouns. However, we decided to take the onset of the expression as a fixed point since we assume that even as the referential expression unfolds, participants already anticipate the matching referent. This assumption is supported by the eye-tracking experiment of Hartmann (2004) that examined gender effects in sentence processing in German. Her results indicate that the gender information carried by the determiner of a full NP has an early effect on fixation probability for a matching referent, and supports the interactive view on language understanding, which claims that the comprehension process already starts during the perception of the word and not just after the offset of an expression.

Accounting for the interactive view, it is not totally valid to compare the offset of German full nouns consisting of a determiner and a noun with pronoun offsets, since the full NPs unfold over a much longer time period and thus give rise to a comprehension process that begins much earlier. Due to this fact we decided to compare the onsets of different referential expressions with each other even though, as far as we know, all other experiments investigating the temporal resolution of referential expressions used the offset of the expressions in their measurements (Gernsbacher, 1989, MacDonald & MacWhinney, 1990, Tyler & Marslen –Willson, 1982).

The third main finding of this study was that there seem to be few pronouns that do not elicit higher fixation probabilities on the matching referent. We obtained this finding by comparing the permutations in pronoun order in the four different conditions. The four conditions differed with respect to the syntactic relation that the pronoun had to its antecedents (see Table 1 in the Methods Section). Comparing all four conditions, just one single time spot is shown to be significant: The probability to fixate Referent 2 is significantly bigger in Condition A than in condition B in the time slot between 1500 -2000 ms after $pronoun_A$[7] and $pronoun_B$ were spoken.

According to our first claim that both full NPs and pronouns elicit higher fixation probabilities on the matching referent, it was expected that fixation probability in condition A becomes higher for Referent 2 than in condition B, since $pronoun_A$ refers to Referent 2 whereas $pronoun_B$ refers to Referent 1 instead. So, the higher fixation probability in Condition A is not surprising. However, since $pronoun_B$ refers to Referent 1 we would expect an increase in fixations on Referent 1 in condition B compared to Condition A. In our data, however, we can not find any indication for an increase in fixation probability for Referent 1. On the contrary, after $pronoun_B$ is spoken, the fixation curve for Referent 1 keeps on decreasing .

What could be the reason for this strange asymmetry in referential strength between the pronouns in Condition A and B? There are several possible answers to this question. The first one takes the attentional focus of the participants as a possible explanation for the missing fixation increase in condition B. As already mentioned, the variation of the pronouns starts after the first pronoun, which is the same in all four conditions. This first pronoun is refers to Referent1 in all of the conditions. This means that that Referent1 is in the centre of attention when the variations in the different condition start. Since $pronoun_A$ refers to Referent2, the participants have to change their centre of attention to Referent2 when the pronoun occurs. In condition B however, the attention focus stays on Referent1 since $pronoun_B$ just re-refers to Referent1. In this condition no “new” information is added and the attention focus stays the same over a longer time period. The fact that condition B does not require a shift in attention to another referent can account for the missing fixation increase, since participants already made reference to Referent 1 and integrated him in their mental model.

[7] Please remember that indices behind the pronouns denote the conditions in which the pronouns occur.
E.g. $pronoun_A$ = The pronoun in Condition A

Another possible explanation for the asymmetry between the pronouns in condition A and B comes from linguistic theory (Bosch, 1983). It could be that the differences in fixation probability are caused by general differences in the referentiality of pronouns. It has been proposed that pronouns can be divided in two main groups: The regular anaphoric pronouns and the c-commanded pronouns, which are bound by their antecedents. The difference as far as German personal and possessive pronouns are concerned is not a difference in form: the same forms occur in either use. Whereas the anaphoric pronouns occur referentially and the relation to their antecedents is just mediated by reference, the c-commanded pronouns just link up to their antecedents by syntactic agreement. Their relation to their antecedents is free of reference and purely syntactic in nature.

According to this theory, the use of the pronoun in Condition A would be anaphoric since $pronoun_A$ is mediated by reference. It stands independently from its antecedents in a new sentence and thus can not be c-commanded by the antecedents of $pronoun_A$. The pronoun in Condition B, however, is c-commanded by the subject of the sentence. $Pronoun_B$ would therefore be interpreted syntactically rather than referentially. If this linguistic interpretation of our results would yield true, it would mean that the distinction between referential and c-commanded pronouns is not just a theoretical one but a difference that is implemented in human language understanding as well. However, at the moment, we are not able to decide whether one of our two theories really can account for the differences in fixation probability between condition A and B. Further investigation will be required to be able to come to more valid conclusions.

The comparison between the conditions C and D did not yield any significant results. This might have been mainly due to a mistake in stimuli construction. As can be seen in Table 1 in the Methods section we tried to per mutate two pronouns in condition C and D. However the temporal distance between these two pronouns was so small that a comparison was just not possible with the temporal resolution of the eye tracker[8].

[8] Whereas the two pronouns in condition C referent first to Referent2 and then to Referent 1, the arrangement of pronouns was exactly the opposite in condition D. However in both conditions the two pronouns fell in the same time slot of 500 ms, which made it impossible to analyse the differences caused by the arrangement of the pronouns.

4.2. Improvements for Further Investigations

To investigate the differences in referentiality between the different pronouns more closely and to find out if attention shift or differences in the syntactic relation between antecedents and pronoun are the reason for the asymmetry in referentiality, further experimental work is needed. These follow-up studies should contain two major improvements to the study presented here: First, an improvement in the four conditions we used in our stimuli is clearly needed. It would be advisable to make sure that all relevant pronouns occur with a certain temporal distance to each other so that the temporal resolution of the eye tracker is able to catch differences in fixation probability caused by these pronouns. As well as this, the stimulus material should be constructed in a way that allows for a differentiation between effects caused by the repetition of referents that are already in the centre of attention and effects caused by the difference between anaphoric and c-commanded pronouns.

The second improvement concerns the amount of participants used in our experiment. A study more closely investigating the differences between conditions would need to increase the amount of participants in order to improve the significance of the results in the single conditions. Additionally, future studies might check if the intonation of the speaker affects the participants' interpretation of the pronouns. However, we do assume that an effect will be detectable.

4.3 Relation to Previous Studies

What are the conclusions that we can draw from the result we obtained in this study, and how can we relate them to the existing body of knowledge about the resolution of referential expressions?

We were able to confirm that both full NPs and pronouns elicit eye movement but that generally the in-peak fixation probability is smaller for pronouns than for nouns. As far as we know, the literature does not contain an explicit comparison between the fixation probabilities of full noun phrases and pronouns. While Cooper (1975) even includes pronouns in the same class as full NPs in his experiment, the experiments of Runner (2003) and Arnold (2000) focus on the fixation probabilities for pronouns and do not comment on the fixation probabilities for the full NPs in their stimuli. Concerning the fixation probabilities for full NPs that we obtained in our experiment, we were also able to detect strong anticipation

effects caused either by the word preceding the actual NP (such as the interaction verb indicating that another human referent has to follow) or caused by the unfolding NP itself. These results confirm the findings of Hartmann (2004) and Dahan, Swingley, Tanenhaus, & Magnuson (2000), stating that anticipation plays a big role in understanding and that fixation probabilities are already influenced by anticipation effects as the word unfolds.

Concerning the temporal resolution of different referential expressions, we were able to contribute to a long ongoing discussion. Two main conflicting hypotheses about the resolution of referential expressions have existed since the middle of the 1980s. As far as we know, eye-tracking has not been used to investigate this controversial issue until now, even though the fact that eye-tracking allows an online measure of the resolution process makes this method extremely suitable for the closer investigation of the temporal resolution of pronouns.

Since our results clearly show that there is no difference in the temporal resolution of nouns and pronouns in unambiguous sentences, we are able to support the hypothesis of Tyler and Marslen-Willson (1982). They claim that pronouns are directly interpreted referentially in the same way as full NPs and that the resolution of pronouns happens as immediately as the resolution. The theory of Tyler and Marslen-Wilson seems to be much more coherent with our findings than the hypothesis of Gernsbacher (1989) claiming that the resolution of pronouns happens in two stages, first the search of the antecedents and then recognition of the fitting referent. According to this theory, the temporal resolution of pronouns has to take longer time than the resolution of full NPs since the process of resolving pronouns requires two separate stages, whereas the resolution process of full NPs just requires a single process.

Finally, we were able to find first indications that the distinction in referential and non-referential pronouns as proposed by Bosch (1983) might be not just theoretical but also mirrored by human language understanding. However, as mentioned, to be able to make clear statements about differences in referentiality between pronouns, much more work is required.

5. Conclusion

This study was the first to compare the understanding process of different referential expressions using the visual world paradigm. Our experiment shows that both full NPs and pronouns cause increased fixations on the matching referent and that there is no difference in the temporal resolution of pronouns and full NPs. Our study also indicated that the referentiality of pronouns might depend on the syntactic relation that the pronoun has to its antecedent.

6. Acknowlegements

First and foremost I would like to thank both my supervisors, Prof. Peter Bosch and Prof. Peter König for their help and guidance during this project. Without their expertise, good advice and patient assistance this work would not exist. Secondly I would also like to thank Selim Ornat and Hans-Peter Frey for their help with MatLab programming and for a good introduction to the eye-tracking methodology. For significant help with the layout of my graphs and figures I would like to thank my personal design consultant Boris Bernhardt. For a great and very entertaining working atmosphere I thank all the members of the Neurobiopsychology Department - It was a pleasure to work with all of you. Finally I would like to thank my family and all my friends for morale support during this period. Special thanks go to Niki Vavatzanidis and Andrea Albrecht for their generous hospitality and much more. Last but not least I would like to thank Ablahad Lahdo for all the patience and love and understanding he showed during the last year.

7. References

Ariel, Mira. (1990) *Accessing Noun Phrase antecedents*. London: Routledge.

Arnold, J., Eisenband, J., Brown-Schmidt, S., Trueswell, J (2000): The Rapid Use of Gender Information: Evidence of the Time Course of Pronoun Resolution from Eye Tracking. *Cognition* 76, B13-B26 (2000)

Baedecker, W. & Staub, K. (2002): The Processing Role of Structural Constraints on the Interpretation of Pronouns and Anaphors. *Journal of Experimental Psychology: Learning Memory and Cognition* .Vol. 28, No.4, 748-769 (2002)

Bosch, P. (1983): Agreement and Anaphora - A Study of the Roles of Pronouns in Discourse and Syntax. Academic Press. London & New York. 1983

Carreiras, M., Gernsbacher M. A., & Villas, V., (1995) The advantage of first mention in Spanish. *Psychonomic Bulletin and Review*, 2, 124-129 (1995)

Cloitre, M. & Bever, T. G. (1988). Linguistic anaphors, levels discourse. *Language and Cognitive Processes*, 3, 293-322.

Cooper, R. (1974): The Control of Eye Fixation by the Meaning of Spoken Language. *Cognitive Psychology* 6, 84-107

Ehrlich, K. & Rayner, K. (1983). Pronoun assignment and semantic integration during reading: Eye movements and immediacy of processing. *Journal of Verbal Learning and Verbal Behavior*, 22, 75-87.

Garrod, S., Freudenthal, D., Boyle, E. (1994). The role of different types of anaphor in the on-line resolution of sentences in a discourse. *Journal of Memory and Language* 33. 39-68.

Gernsbacher, M. A. (1989). Mechanisms that improve referential access. *Cognition,* 32, 99-156.

Gernsbacher, M. A. & Hargreaves, D. J. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory & Language*, 27, 699-717.

Hartmann, N. (2005): Processing Grammatical Gender in German. Bachelor Thesis, unpubl.. Univ. of Osnabrück, Cognitive Science.

Järviki, J., van Gompel, R., Hyönä, J.,Bertram,R.(2005): Ambiguous Pronoun Resolution: Contrasting the First-Mention and Subject-Preference Accounts. *Psychological Science*, Vol.4, No.16, 260-264, (2005)

Mc Donald, J.L., & Mac Whinney, B. J., (1995): The Time Course of Anaphor Resolution: Effects of Implicit Verb Causality and Gender. *Journal of Memory and Language,*34, 543-566

MacDonald, M. C. & MacWhinney, B. (1990). Measuring inhibition and facilitation from pronouns. *Journal of Memory & Language*, 29, 469-492.

Marslen-Wilson, W. Tyler. L.K. (1987): Against Modularity. In: Garfield, J.L. (ed): Modularity in Knowledge Representation and Natural L anguage Understanding. MIT Press. 1987. pp. 37-62

Nicol, J. & Swinney, D. (2002) The psycholinguistics of anaphora. In A. Barss (ed.) *Anaphora*. Oxford. Blackwell. pp. 72-104

Parkhurst, D. J., Law, K., Niebur, E. (2002):Modeling the role of salience in the allocation of overt visual attention. *Vision Research* 42: 107-123.

Rayner, K., & Clifton, C., Jr. (2002). Language processing. In D. Medin (Volume Editor) Stevens Handbook of Experimental Psychology, Third Edition: Volume 2, Memory and Cognitive Processes (pp 261-316). New York: John Wiley and Sons,

Runner, J., Sussman R. S. & Tanenhaus, M. K.(2003): Assignment of Reference to Reflexives and Pronouns in Picture Noun Phrases: Evidence from Eye Movements. *Cognition* 81.1, B1-B13 (2003).

Streb, J., Rösler, F., Hennighausen, E. (2004). Different anaphoric expressions are investigated by event-related brain potentials. *Journal of Psycholinguistic Research*, 33, 175-201

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. Science, 268:1632-1634.

Tanenhaus, M. K., Magnusson, J. S., Dahan, D., Chambers, C., (2000): Eye Movements and Lexical Access in Spoken Language Comprehension: Evaluating a Linking Hypotheses between Fixations and Linguistic Processing. *Journal of Psycholinguistic Research*, Vol.29 No.6 (2000)

Tichaneck, K. (2004):Cross-Modal Integration of Natural Visual and Auditory Stimuli. Bachelor Thesis, unpubl.. Univ. of Osnabrück, Cognitive Science.

Tyler. L.K. & Marslen-Wilson, W. (1982): Processing utterances in discourse context: Online resolution of anaphors. Journal of Semantics 1: 297-314.

Wirtz, K.(2005): The influence of chromatic information on guiding human overt attention. Bachelor Thesis, unpubl.. Univ. of Osnabrück, Cognitive Science.

8. Appendix

8.1 Consent Sheet

Anke Karabanov
Arbeitsgruppe Neurobiopsychologie
Universität Osnabrück
Albrechtsraße 28
49069 Osnabrück
Tel.: 0541/9692251
email: akaraban@uos.de

Aufklärung / Einwilligung

Sehr geehrte Teilnehmerin, sehr geehrter Teilnehmer,

Sie haben sich freiwillig zur Teilnahme an dieser Studie gemeldet. Hier erhalten Sie nun einige Informationen zu Ihren Rechten und zum Ablauf des folgenden Experiments. Bitte lesen Sie sich die folgenden Abschnitte sorgfältig durch.

1) Zweck der Studie
Ziel dieser Studie ist es, neue Erkenntnisse über die Sprachverarbeitung zu erhalten.

2) Ablauf der Studie
In dieser Studie werden Ihnen 52 Bilder auf einem Computermonitor gezeigt. Über die Lautsprecher hören gleichzeitig kurze Geschichten die zu den Bildern passen. Bitte verfolgen Sie die Szenen genau.
Um Ihre Blickposition zu errechnen, wird Ihnen ein “Eye-Tracker” auf den Kopf geschnallt. Dieses Gerät erfasst die Position Ihres Auges mit Hilfe von kleinen Kameras und Infrarotsensoren. Dieses Verfahren ist ein psychometrisches Standardverfahren, das in dieser Art bereits vielfach angewandt und getestet wurde. Bei unseren bisherigen Erfahrungen und Experimenten mit dem Gerät ist keine Versuchsperson zu Schaden gekommen.
Zu Beginn der Untersuchung muss der “Eye-Tracker” eingestellt werden, dieser Vorgang dauert etwa 5-15 Minuten. Das eigentliche Experiment dauert dann etwa 20 Minuten. Der Versuchsleiter wird während des ganzen Experiments mit Ihnen im Versuchsraum sein und steht Ihnen für Fragen jederzeit zur Verfügung. Nach der Studie erhalten Sie weitere Informationen zum Sinn und Zweck dieser Untersuchung. Bitte geben Sie diese Informationen an niemanden weiter um die Objektiviät eventueller Versuchspersonen zu wahren.

3) Risiken und Nebenwirkungen
Diese Studie ist nach derzeitigem Wissenstand des Versuchsleiters ungefährlich und für die Teilnehmer schmerzfrei. Durch Ihre Teilnahme an dieser Studie setzen Sie sich keinen besonderen Risiken aus und es sind keine Nebenwirkungen bekannt. Da diese Studie in ihrer Gesamtheit neu ist, kann das Auftreten von noch unbekannten Nebenwirkungen allerdings nicht ausgeschlossen werden.

Wichtig: Bitte informieren Sie den Versuchsleiter umgehend, wenn Sie unter Krankheiten leiden oder sich derzeit in medizinischer Behandlung befinden. Teilen Sie dem Versuchsleiter bitte umgehend mit, falls Sie schon einmal einen epileptischen Anfall hatten. Bei Fragen hierzu wenden Sie sich bitte an den Versuchsleiter.

4) Abbruch des Experiments
Sie haben das Recht, diese Studie zu jedem Zeitpunkt und ohne Angabe einer Begründung abzubrechen. Ihre Teilnahme ist vollkommen freiwillig und ohne Verpflichtungen. Es entstehen Ihnen keine Nachteile durch einen Abbruch der Untersuchung.
Falls Sie eine Pause wünschen oder auf die Toilette müssen, ist dies jederzeit möglich.
Sollten Sie zu irgendeinem Zeitpunkt während des Experiments Kopfschmerzen oder Unwohlsein anderer Art verspüren, dann informieren Sie bitte umgehend den Versuchsleiter.

5) Vertraulichkeit
Die Bestimmungen des Datenschutzes werden eingehalten. Personenbezogene Daten werden von uns nicht an Dritte weitergegeben. Die von Ihnen erfassten Daten werden von uns anonymisiert und nur in dieser Form weiterverarbeitet oder veröffentlicht.

6) Einverständniserklärung
Bitte bestätigen Sie durch Ihre Unterschrift die folgende Aussage:

"Hiermit bestätige ich, dass ich durch den Versuchsleiter dieser Studie über die oben genannten Punkte aufgeklärt und informiert worden bin. Ich habe diese Erklärung gelesen und verstanden. Ich stimme jedem der Punkte zu. Ich ermächtige hiermit die von mir in dieser Untersuchung erworbenen Daten zu wissenschaftlichen Zwecken zu analysieren und in wissenschaftlichen Arbeiten anonymisiert zu veröffentlichen.
Ich wurde über meine Rechte als Versuchsperson informiert und erkläre mich zu der freiwilligen Teilnahme an dieser Studie bereit."

…….
Ort, Datum Unterschrift

…….
Bei Minderjährigen, Unterschrift des Erziehungsberechtigten

8.2 Instruction sheet (used in the study)

Instruktionen

Einstellen des Eyetrackers:

- Es werden auf dem Bildschirm eine Reihe Fixations-punkten an unterschiedlichen Stellen auftauchen. Bitte konzentriere Deinen Blick darauf.
- Es geht erst weiter, wenn das Programm deine Fixation bestätigt hat.

Untersuchung

- Es werden Dir nacheinander 52 Farbbilder für jeweils 17 Sekunden gezeigt.
- Bitte sieh sie Dir aufmerksam an.
- Nach etwa der Hälfte der Bilder machen wir eine kleine Pause, damit Du deine Augen entspannen kannst.

!WICHTIG!

- Vor jedem gezeigten Bild wird ein Fixationspunkt gezeigt. Bitte konzentriere deinen Blick darauf.
- Solange dieser Fixationspunkt gezeigt wird, hast Du die Möglichkeit, noch mal zu blinzeln, oder um eine kurze Pause zu bitten.
- Es geht erst weiter, wenn dein Blick wirklich auf dem Fixationspunkt ruht.

8.3 Stimuli

8.3. Auditory Stimuli

Sentence 1

a) Heute ist Markt im Dorf. Die Marktfrau streitet sich mit dem Arbeiter. Sie sagt jetzt gerade, dass er kein' Ärger machen und das neue Fahrrad zurückgeben soll, das er sich geliehen hat
b) Heute ist Markt im Dorf. Die Marktfrau streitet sich mit dem Arbeiter. Sie sagt jetzt gerade, dass sie kein' Ärger machen und nur das neue Fahrrad zurückhaben will, das er sich geliehen hat.
c) Heute ist Markt im Dorf. Die Marktfrau streitet sich mit dem Arbeiter. Sie sagt jetzt gerade, dass er ihr jetzt das neue Fahrrad zurückgeben soll, das er sich geliehen hat
d) Heute ist Markt im Dorf. Die Marktfrau streitet sich mit dem Arbeiter. Sie sagt gerade, dass sie ihm jetzt das neue Fahrrad zurückgeben will das er sich geliehen hat.

Sentence2

a) Es herrscht angespannte Stille im Operationssaal. Die Schwester spricht leise mit dem Chirurgen Sie fragt gerade, ob er nicht vielleicht doch schon mal die große Lampe heran schieben kann die sie gerade eingeschaltet hat.
b) Es herrscht angespannte Stille im Operationssaal. Die Schwester spricht leise mit dem Chirurgen Sie fragt gerade, ob sie nicht vielleicht doch schon mal die große Lampe heran schieben soll die sie gerade eingeschaltet hat.
c) Es herrscht angespannte Stille im Operationssaal. Die Schwester spricht leise mit dem Chirurgen Sie fragt gerade, ob er ihr jetzt die große Lampeheran schieben kann die sie gerade eingeschaltet hat.
d) Es herrscht angespannte Stille im Operationssaal. Die Schwester spricht leise mit dem Chirurgen Sie fragt gerade, ob sie ihm jetzt die große Lampe heran schieben soll die sie gerade eingeschaltet hat.

Sentence 3

a) Der Bauernhof wird regelmäßig kontrolliert. Der Bauer steht besorgt bei der Tierärztin Er will 'gern wissen ob sie jetzt vielleicht doch schon mal die braune Kuh untersuchen will die sie erwähnt hatte.
b) Der Bauernhof wird regelmäßig kontrolliert. Der Bauer steht besorgt bei der Tierärztin Er will 'gern wissen ob er jetzt vielleicht doch schon mal die braune Kuh rüberholen soll die sie erwähnt hatte.
c) Der Bauernhof wird regelmäßig kontrolliert. Der Bauer steht besorgt bei der Tierärztin Er will 'gern wissen ob sie ihm jetzt die braune Kuh noch mal zeigen kann die sie erwähnt hatte
d) Der Bauernhof wird regelmäßig kontrolliert. Der Bauer steht besorgt bei der Tierärztin Er will 'gern wissen ob er ihr jetzt die braune Kuh noch mal zeigen soll die sie erwähnt hatte

Sentence 4

a) Es wird Frühling auf der Burg. Der Ritter streitet sich mit dem Burgfräulein. Er sagt mit Ärger dass sie ganau so aussieht wie das dicke Pferd dort auf der Weide das sie reiten wird.
b) Es wird Frühling auf der Burg. Der Ritter streitet sich mit dem Burgfräulein. Er sagt mit Ärger dass er genauso wild wird wie das dicke Pferd dort auf der Weide das sie reiten wird.
c) Es wird Frühling auf der Burg. Der Ritter streitet sich mit dem Burgfräulein. Er sagt mit Ärger dass sie ihm jetzt das dicke Pferd zurückgeben soll das sie reiten wird.
d) Es wird Frühling auf der Burg. Der Ritter streitet sich mit dem Burgfräulein. Er sagt mit Ärger dass er ihr jetzt das dicke Pferd präsentieren wird das sie reiten soll .

8.3.2 Visual Stimuli

Image 1

Image 2

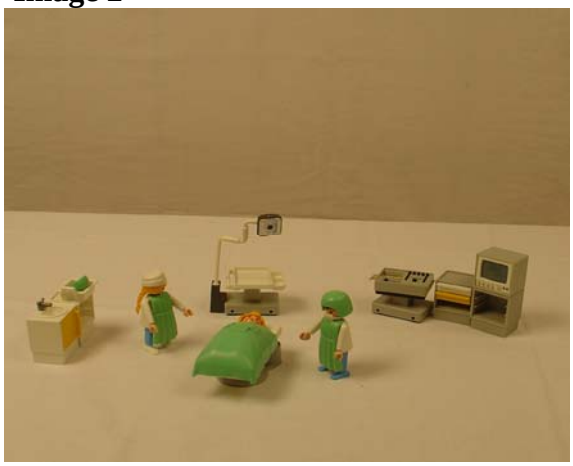


Image 3

Image 4

8.4 Filler Stimuli

8.4.1 Auditory Filler Stimuli

Auditory Filler 1

a) Das Wetter ist heute richtig herrlich. Die Oma geht mit ihrem Enkel spazieren. Sie erzählt ihm von ihrer Jugend während sie den Kinderwagen schiebt in dem das Baby liegt.
b) Das Wetter ist heute richtig herrlich. Die Oma geht mit ihrem Enkel spazieren. Erwill unbedingt den Kinderwagen schieben in dem seine kleine Schwester liegt.
c) Das Wetter ist heute richtig herrlich. Die Oma geht mit ihrem Enkel spazieren. Sie beschwert sich weil es ihr so schwer fällt den Kinderwagen mit dem Baby zu schieben
d) Das Wetter ist heute richtig herrlich. Die Oma geht mit ihrem Enkel spazieren. Er meckert die ganze Zeit weil er den Kinderwagen schieben muss in dem seine kleine Schwester liegt.

Auditory Filler 2

a) Das war mehr als knapp. Der Motorradfahrer hat das Auto grade noch gesehen. Er beschimpft den Autofahrer und behauptet dass dieser die Ampel völlig übersehen hat.
b) Das war mehr als knapp. Der Motorradfahrer hat das Auto gerade noch gesehen. Der Autofahrer ist sauer und fragt ihn ob er die Ampel vielleicht übersehen hat.
c) Das war mehr als knapp. Der Autofahrer hat das Mottorad fast gerammt. Er hat vor lauter Müdigkeit die Ampel nicht gesehen die an der Kreuzung steht.
d) Das war mehr als knapp. Der Autofahrer hat das Mottorad fast gerammt. Der Motorradfahrer steht unter Schock und hört das Rufen der Autofahrers an der Ampel nicht.

Auditory Filler 3

a) Dunkele Wolken hängen über der Burg. Der Ritter kämpft mit dem Drachen. Er hält ihm sein Schwert entgegen und befiehlt ihm die Prinzessin freizulassen die er gefangen hält.
b) Dunkele Wolken hängen über der Burg. Der Ritter kämpft mit dem Drachen. Der ist rasend vor Wut und weigert sich die Prinzessin freizulassen die er gefangen hält.
c) Dunkele Wolken hängen über der Burg. Der Drache kämpft mit dem Ritter. Er droht dem Ritter erst ihn und dann die Prinzessin zu töten, die er gefangen hält.
d) Dunkele Wolken hängen über der Burg. Der Ritter kämpft mit dem Drachen. Er fordert von dem Drachen dass er die Prinzessin freilässt die er gefangen hält.

Auditory Filler 4

a) Die Mittagspause hat gerade begonnen. Die Krankenschwester unterhält sich mit dem Mechaniker. Sie schlägt ihm vor sich mit ihr auf die Bank zusetzen die dort in der Sonne steht.
b) Die Mittagspause hat gerade begonnen. Die Krankenschwester unterhält sich mit dem Mechaniker. Er finde sie arbeitet zu viel und schlägt ihr vor sich mit ihm auf eine Bank zu setzen
c) Die Mittagspause hat gerade begonnen. Die Krankenschwester unterhält sich mit dem Mechaniker. Sie ist in ihn verleibt und setzt sich mit ihm auf eine Bank.

d) Die Mittagspause hat gerade begonnen. Die Krankenschwester unterhält sich mit dem Mechaniker. Der freut sich über das schöne Wetter und schlägt vor sich auf eine Bank zu setzen.

8.4.2 Visual Filler Stimuli

Filler Image 1

Filler Image 2

Filler Image 3

Filler Image 4

9. Affirmation

9.1 Eidesstattliche Erklärung

Hiermit erkläre ich, Anke Karabanov, die vorliegende Arbeit "Eye-Tracking as a Tool for Investigating the Comprehension of Referential Expressions" selbstständig verfasst zu haben und keine anderen Quellen oder Hilfsmittel als die angegebenen verwendet zu haben.
Uppsala, den 18.02.2006

_____
Anke Karabanov

Matrikelnummer: 909560

9.1 Affirmation

I, Anke Karabanov, hereby confirm that I composed the work at hand, entitled "Eye-Tracking as a Tool for Investigating the Comprehension of Referential Expressions " independently and that I did not use any other resources or auxiliary means than the ones stated.

Uppsala, 18.02.2006

_____
Anke Karabanov
Student-ID: 909560