UNIVERSITY OF POTSDAM

DOCTORAL THESIS

EFFECTS OF EMBEDDED PRONOUNS ON RELATIVE CLAUSE PROCESSING

CROSS-LINGUISTIC EVIDENCE FROM CHILDREN AND ADULTS

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ERKLÄRUNG

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Yair Haendler

Potsdam, den 14. Dezember 2016

ABSTRACT

Difficulties with object relative clauses (ORC), as compared to subject relative clauses (SR), are widely attested across different languages, both in adults and in children. This SR-ORC asymmetry is reduced, or even eliminated, when the embedded constituent in the ORC is a pronoun, rather than a lexical noun phrase. The studies included in this thesis were designed to explore under what circumstances the pronoun facilitation occurs; whether all pronouns have the same effect; whether SRs are also affected by embedded pronouns; whether children perform like adults on such structures; and whether performance is related to cognitive abilities such as memory or grammatical knowledge. Several theoretical approaches that explain the pronoun facilitation in relative clauses are evaluated. The experimental data have been collected in three languages–German, Italian and Hebrew–stemming from both children and adults.

In the German study (**Chapter 2**), ORCs with embedded 1st- or 3rd-person pronouns are compared to ORCs with an embedded lexical noun phrase. Eye-movement data from 5-year-old children show that the 1st-person pronoun facilitates processing, but not the 3rd-person pronoun. Moreover, children's performance is modulated by additive effects of their memory and grammatical skills. In the Italian study (**Chapter 3**), the 1st-person pronoun advantage over the 3rd-person pronoun is tested in ORCs and SRs that display a similar word order. Eye-movement data from 5-year-olds and adult controls and reading times data from adults are pitted against the outcome of a corpus analysis, showing that the 1st-/3rd-person pronoun asymmetry emerges in the two relative clause types to an equal extent. In the Hebrew study (**Chapter 4**), the goal is to test the effect of a special kind of pronoun–a non-referential arbitrary subject pronoun–on ORC comprehension, in the light of potential confounds in previous studies that used this pronoun. Data from a referent-identification task with 4- to 5-year-olds indicate that, when the experimental material is controlled, the non-referential pronoun does not necessarily facilitate ORC comprehension. Importantly, however, children have even more difficulties when the embedded constituent is a

referential pronoun. The non-referentiality / referentiality asymmetry is emphasized by the relation between children's performance on the experimental task and their memory skills.

Together, the data presented in this thesis indicate that sentence processing is not only driven by structural (or syntactic) factors, but also by discourse-related ones, like pronouns' referential properties or their discourse accessibility mechanism, which is defined as the level of ease or difficulty with which referents of pronouns are identified and retrieved from the discourse model. Although independent in essence, these structural and discourse factors can in some cases interact in a way that affects sentence processing. Moreover, both types of factors appear to be strongly related to memory. The data also support the idea that, from early on, children are sensitive to the same factors that affect adults' sentence processing, and that the processing strategies of both populations are qualitatively similar.

In sum, this thesis suggests that a comprehensive theory of human sentence processing needs to account for effects that are due to both structural and discourse-related factors, which operate as a function of memory capacity.

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First of all, I thank **Flavia Adani** and **Reinhold Kliegl** for being supportive and inspiring supervisors, and for teaching me practically everything I currently know about researching language acquisition and processing–a very hard task, considering that I knew absolutely nothing about experimental psycholinguistics when I first came to Potsdam.

From both of them I inherited, I believe, the correct approach to science: the need to constantly question my assumptions and conclusions; the inevitability of accepting that "we don't know", but rather "we assume"; and the importance of listening to what the data tell us, and not to what we would like to hear from them.

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The Babylonian Talmud (tractate *Bava Metzi'a* page 84a) narrates of Rabbi Yochanan's (180-279 CE, Galilee) deep sadness following the death of Reish Lakish, with whom he used to study and discuss Torah matters. A bright young Torah scholar was sent to him to fill in the intellectual space left by Reish Lakish's departure. Rabbi Yochanan would advance his arguments and his young partner would immediately come up with all the scriptural sources that supported these theses. Rabbi Yochanan then exclaimed with anger and tears: "Send this young man away! I have no need in his sharp memory and knowledge to support my theses. I know very well myself how to defend them. What I truly miss is Reish Lakish's ability to find all the scriptural evidence showing why my arguments do *not* hold! Only this would lead to fuller comprehension and clarification of the matter."

I would like to thank the *Ernst Ludwig Ehrlich Studienwerk*, the foundation that supported me so generously, not only financially but also intellectually, and the staff at the administration office. I am especially grateful to **Jo Frank** and **Eva Lezzi** for their invaluable help and advice.

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After years of being defined as a "student", and right before I will no longer be so, I would like to express my deep gratitude for **my parents, Leah and Yehuda**. It is thanks to their support and encouragement that I was able to pursue my path and do what I like most.

Finally, to my other half, **Cecilia**: like with everything else in my life, everything I do, including the research described in this thesis–all this has no sense at all without you by my side.

וְאָמַרְתָּ בִּלְבָבֶךָ, כֹּחִי וְעֹצֶם יָדִי עָשָׂה לִי אֶת-הַחַיִל הַזֶּה. וְזָכַרְתָּ אֶת-ה' אֱלֹקֶיךָ, כִּי הוּא הַנֹּתֵן לְךָ כֹּחַ לַעֲשׂוֹת חָיִל --
(דברים ח יז-יח, פרשת עקב)

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Why does every Talmud tractate begin on page two?

To remind us that no matter how much we study, we have not reached yet the first page.

Rabbi Levi Yitzhak of Berditchev (1740-1809)

CHAPTER 1

INTRODUCTION

If you torture your data hard enough, eventually they will confess; but then ask yourself whether you really want to rely on the confession of someone who has been tortured.

(R. Kliegl, statistics class in Potsdam, sometime in 2011)

A lot of research has been dedicated in the past decades to questions pertaining how people process and comprehend *restrictive relative clauses*. This term refers to a sentence in which a subordinate (relative) clause is used to describe a nominal phrase–called the *head* of the relative clause–in a way that allows to identify it among a set of tokens of the same type (Heim & Kratzer, 1998). For example, in the sentence *The man who is drinking coffee is writing a thesis*, the (underlined) relative clause enables the hearer or reader to identify the man who is writing a thesis among a set of two or more men that potentially could be referred to. In this sense, the function of a restrictive relative clause is similar to that of an adjectival phrase used to describe a noun: *The coffee sipping man is writing a thesis* (Adani, 2011).

The vast majority of studies on relative clauses has concentrated on subject- and object-extracted relative clauses (henceforth SRs and ORs, respectively). In a SR, example of which is given in (1), the head noun assumes the role of subject of the embedded verb *encounter*. By contrast, in an OR (2) the head noun assumes the role of object of the embedded verb. The underscore in each example marks the position inside the embedded

clause from which the head noun is extracted: subject in (1) and object in (2).

(1) The man that __ encountered the actor has crossed the street.
(2) The man that the actor encountered __ has crossed the street.

A widely attested phenomenon in psycholinguistic research, which has emerged in numerous studies on different languages, is that SRs are easier to process and comprehend than ORs. This SR-OR asymmetry is found both in adults (Gennari & MacDonald, 2008; 2009; Gibson, 1998; 2000; Gordon et al., 2001; 2004; Grodner & Gibson, 2005; Just & Carpenter, 1992; King & Just, 1991; Mak et al., 2002; Reali & Christiansen, 2007; Staub, 2010; Traxler et al., 2002; Wells et al., 2009; Yang et al., 2013) and in children (Adani, 2011; Adani et al., 2010; 2014; Adani & Fritzsche, 2015; Arnon, 2010; Arosio et al., 2012; Belletti et al., 2012; Brandt et al., 2009; Contemori & Marinis, 2014; Diessel & Tomasello, 2000; Friedmann et al., 2009; Goodluck & Tavakolian, 1982; Guasti et al., 2012; Kidd et al., 2007; Varlokosta et al., 2015). It is worth noting, though, that in Basque the exact opposite pattern is found (Carreiras et al., 2010; Gutierrez-Mangado, 2011) and in Chinese there is an on-going debate as to which relative clause type is easier (Gibson & Wu, 2013; Hsiao & Gibson, 2003; Hsiao & MacDonald, 2016; Hu et al., 2016; Jäger et al., 2015; Vasishth et al., 2013). The languages with which this thesis deals are German, Italian and Hebrew, and in all three the SR advantage typically emerges.

The results from a number of studies on relative clause processing show that, when the embedded constituent in an OR is a pronoun rather than a lexical noun phrase, the OR becomes significantly easier to process. Thus, compared to the sentence in (2), its counterpart with an embedded pronoun (3) should be processed more easily.

(3) The man that you encountered __ has crossed the street.

This pronoun facilitation has been demonstrated both with adults (Gordon et al., 2001; Heider et al., 2014; Kaan, 2001; Mak et al., 2008; Reali & Christiansen, 2007; Warren &

Gibson, 2002) and with children (Arnon, 2010; Brandt et al., 2009; Brandt et al., 2016; Friedmann et al., 2009; Kidd et al., 2007; Lassotta et al., 2015). There are several theoretical approaches that can explain this facilitation of ORs with embedded pronouns. Among them, four accounts are at the focus of this dissertation: *Intervention Locality Approach* (Belletti et al., 2012; Bentea et al., 2016; Friedmann et al., 2009; Grillo, 2009); *Similarity-Based Approach* (Gordon et al., 2001; Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & McElree, 2006; 2011); *Experience-Based Approach* (Brandt et al., 2009; Hsiao & MacDonald, 2016; Kidd et al., 2007; MacDonald, 2013; Reali & Christiansen, 2007; Roland et al., 2012); and *Storage and Integration Cost Metric Approach* (Gibson, 1998; 2000; Warren & Gibson, 2002).

The ***Intervention Locality Approach*** (ILA) has its roots in Rizzi's (1990) *Relativized Minimality* principle, developed to explain degraded acceptability of a particular type of syntactic structure called *weak islands* (see Rizzi's original monograph for details). This principle is based on the configuration in (4), where X is a constituent that undergoes syntactic movement from its original gap site Y, crossing over an intervening constituent Z, such that X c-commands Z and Z c-commands Y (for the concept of c-command, see Reinhart, 1976). In such a configuration, if X and Z are of the same structural type, the local relation between X and Y is disrupted and the sentence is harder to process, or results as ill-formed (cf. Rizzi, 2013).

(4) X Z Y

Grillo (2009) and Friedmann et al. (2009) extend the *Relativized Minimality* principle to explain the SR-OR asymmetry. In both relative clause types, X is the head noun, Y is its gap position and Z is a constituent inside the embedded clause. As can be seen in (5), in a SR Z does not intervene between X and Y. Hence, SRs are easy to process. By contrast, in an OR (6) Z intervenes between X and Y. If X and Z are of the same structural type, the OR is hard to process.

(5) The man X that __ encountered Y the actor Z has crossed the street.

(6) The man X that the actor Z encountered __ Y has crossed the street.

Friedmann et al. (2009) define the structural similarity between X and Z as a case in which both constituents are marked with an NP-feature. Using their own term, that is when both are *lexically restricted* DPs, as is the case in (6). Crucially, personal pronouns lack an NP-feature, which is why an OR with an embedded pronoun like (3) is predicted to be easier to process. In such an OR, although Z (the pronoun) intervenes between X and Y, the intervention does not hinder processing because the lexically restricted head noun (*The man*) and the pronoun (*you*) are not of the same structural type: the former is marked with an NP-feature while the latter is not.

The ***Similarity-Based Approach*** (SBA) highlights the limits imposed by memory capacity during sentence processing (for details see Lewis et al., 2006; see also Lewis & Vasishth, 2005; Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006; 2011). The underlying idea is that there are three phases. First, in the ENCODING phase, a filler constituent (*the man* in example 7) is encountered and encoded in memory. While reading the sentence further and looking for the gap site to resolve the filler-gap dependency, other linguistic material is processed in what is termed STORAGE INTERVAL (*that* and *the actor* in example 7). At the RETRIEVAL site (*encountered* in example 7), the parser recognizes that the filler must be retrieved from memory. The identification of the correct constituent is based on the so-called *retrieval cues* that characterize the filler constituent. For instance, upon processing the verb *encountered*, the parser will look for a filler that is marked as [+grammatical subject] and [+animate] (typically, only animate entities encounter something or someone). Depending on the language, other cues might be relevant as well,

for instance, Number (singular/plural/dual), Gender (masculine/feminine/neuter), Person (1st-/2nd-/3rd-person) and so on.

(7) The man that the actor encountered __ has crossed the street.
ENCODING | STORAGE INTERVAL | RETRIEVAL

When a constituent within the STORAGE INTERVAL is marked by the same retrieval cues as the filler, retrieving the correct constituent from memory will take longer, or be generally harder. In this situation, a *similarity-based interference* occurs, which makes processing more costly for memory resources. In the case of (7), there is interference from the embedded subject *the actor*, since it has the same cues as *the man*. But if the embedded subject is a pronoun (as in *The man that you encountered has crossed the street*), the similarity between the head noun and the embedded subject pronoun is eliminated and the reduced interference effect makes processing easier (Gordon et al., 2001).

The ***Experience-Based Approach*** (EBA) generally explains effects in sentence processing as due to distributional properties that occur in language production (MacDonald, 2013; Hsiao & MacDonald, 2016). Any language exhibits structures with certain characteristics through its community of users. Assuming that the frequency of occurrence of a given linguistic structure plays an important role during sentence processing, structures that occur frequently will be more easily processed than less frequent ones.

Specifically with regard to relative clauses, corpus analyses have shown that ORs with an embedded pronoun are more frequent in natural speech than ORs with an embedded lexical noun phrase (Heider et al., 2014; Reali & Christiansen, 2007; Roland et al., 2012). The EBA predicts the pronoun facilitation in ORs based on this pattern of frequency of occurrence. When language users encounter and produce ORs, they do so mostly with an embedded pronoun. Hence, their performance during controlled experimental settings will be affected by this experience and we will find that they process ORs with pronouns with relative ease.

The ***Storage and Integration Cost Metric Approach*** (SICMA) explains human sentence parsing in the following manner. Processing structural dependencies in a sentence is composed of two cognitive operations: *storage* and *integration*. Storage is defined as the instances in which we keep in memory incomplete structural dependencies and information thereof. Integration is defined as the moment in which a previously stored word or constituent are connected to the structure that is currently under analysis. These two operations are constrained by memory load. The human capacity to store elements in memory and retrieve them later on in order to integrate them into the structure is limited.

In relative clauses, the head noun needs to be kept active in memory until the embedded verb is encountered. At this point, the structural dependency between the head noun and the verb is resolved. According to the SICMA, memory load will increase with each referent that is introduced between the point in which the head noun is stored and the point in which the embedded verb is reached (Gibson, 1998; 2000). Crucially, intervening referents that are discourse-new will demand more memory resources than referents that are discourse-old (Warren & Gibson, 2002; 2005). Thus, when an embedded pronoun–which typically refers to a given, discourse-old referent–appears in the relative clause, memory cost is smaller and processing easier. In sum, according to the SICMA sentence processing is determined by memory load, which is affected by *structural factors*, such as the distance between a displaced constituent and its gap and the number of referents that intervene between them, as well as *discourse factors*, such as the status of the intervening referents as being discourse-old or -new.

As we have seen, at least for two of the theoretical approaches that are central in this thesis (SBA and SICMA), memory plays a crucial role in sentence processing in general, and in determining the pronoun facilitation in relative clauses in particular. Therefore, in some of the studies included in this thesis I have looked also at the relation between participants' performance in the experimental task and their memory skills. In doing so, there is an additional advantage in that the individual differences among participants are accounted for when analyzing the data (Just & Carpenter, 1992; King & Just, 1991; Nicenboim et al.,

2015). The use of advanced statistical methods, such as *linear mixed-effects modeling* (Baayen et al., 2008; Barr, 2008; Gelman & Hill, 2007; Jaeger, 2008), allows this procedure to be an integral part of the analysis of the experimental effects (Kliegl et al., 2010). In one of the studies of this thesis, I assessed not only children's memory, but also their grammatical skills. The motivation to do this, as well as the relation between these two types of cognitive abilities, is described and discussed in detail in the relevant chapter (**Chapter 2**).

Despite the fact, stated above, that numerous studies in various languages have found the same SR-OR asymmetry, it is nevertheless important to recall that different results across studies do emerge sometimes. These might be due to the employment of various testing methods, or perhaps due to the inclusion of different participant samples. But they might also be rooted in the fact that languages are characterized differently with respect to a certain structure, for instance, relative clauses. Since the aim of psycholinguistic research is to formulate theoretical accounts that are valid for all languages, it is highly important to test similar phenomena across different languages. For this reason, this thesis is based on cross-linguistic evidence concerning the same linguistic phenomenon of pronoun facilitation in relative clause processing. However, the sentences tested in each language are not exactly the same. Rather, I have tested properties that are peculiar to each language.

Relative clauses in **German**, differently from English ones, have the same word order. Hence, whereas identifying a relative clause as a SR or an OR in English requires an analysis of word order, in German it requires an analysis of the case-marking on the relative pronoun and on the determiners or the number-marking on the embedded verb. The advantage in using German relative clauses lies in the ability to construct minimally differing sentences in which word order expectation plays a very small role (cf. Levy & Keller, 2013; Konieczny, 2000; Vasishth & Drenhaus, 2011).

Like English, **Italian** SRs and ORs in which the embedded constituent is a lexical noun phrase differ with respect to their word order. However, when the embedded constituent is a personal pronoun SRs and ORs may display the same word order. Therefore, Italian

relative clauses with pronouns are an interesting case to test, since it is possible to construct sentences with an identical word order, although the default word order differs between SRs and ORs. Italian differs in this respect from German, whose speakers typically do not rely on word order, whether the relative clause contains a pronoun or not.

In **Hebrew**, the pronoun manipulation includes an impersonal arbitrary subject pronoun, a special kind of pronoun that is often used in ORs by speakers of this language. Testing Hebrew is therefore justifiable, first of all, because this pronoun does not exist in the other two languages. In addition, the Hebrew study was designed to test predictions made based on previous findings concerning this impersonal subject pronoun in Hebrew ORs (Friedmann et al., 2009).

This thesis is based not only on cross-linguistic, but also on cross-population evidence, presenting data from both children (4- to 6-year-olds) and adults. The importance of comparing young acquirers of a certain language to adult speakers is important in the light of research on the so-called *Continuity Hypothesis*, which assumes the existence of a continuity between children's and adults' language processing system. Studies that support this hypothesis have found that young children process sentences in a manner which is qualitatively similar to adults (e.g., Adani & Fritzsche, 2015; Contemori & Marinis, 2014; Felser et al., 2003; Love, 2007; Roberts et al., 2007; Trueswell & Gleitman, 2007). These findings suggest that children already master the grammatical knowledge of their language, and that their processing pattern differs from the adult one only in terms of cognitive abilities such as limited memory capacity, or general slower task-performance. The data from both children and adults will enable the assessment of whether the processing strategies employed by these two populations differ qualitatively or not, and to what extent.

The thesis consists of three journal articles, of which one is already published, one is under review and the third has been recently submitted. The German study (**Chapter 2**) was designed to test the ILA, and specifically the prediction that any type of pronoun in the embedded subject position of an OR should facilitate its processing to a similar extent.

Three types of sentences were compared: ORs with an embedded lexical noun phrase, ORs with an embedded 1st-person pronoun and ORs with an embedded 3rd-person pronoun. Explicit comprehension was measured by means of response accuracy and implicit processing was measured by means of eye movements, in a visual-world paradigm (Henderson & Ferreira, 2004; Tanenhaus et al., 1995; Trueswell et al., 1999). In this study, the relation between children's performance on ORs and their memory and grammatical skills was assessed as well.

The Italian study (**Chapter 3**) pits several theoretical approaches against each other, putting to test their predictions concerning the facilitation effect of embedded pronouns not only in ORs, but also in SRs. The conditions that are tested are SRs and ORs whose embedded constituent is either a 1st- or a 3rd-person pronoun. This study is composed of a corpus analysis of Italian relative clauses, based on which the predictions of the EBA are formulated for this language, a visual-world experiment with children and adult controls, and a reading experiment with adults in the self-paced reading methodology (Just et al., 1982).

Finally, the Hebrew study (**Chapter 4**) tests, foremost, the ILA. The goal is to try to replicate Friedmann et al.'s (2009) finding that ORs with an embedded impersonal subject pronoun are easy for children, while controlling for a potential confound in their material. However, the results of this study put into question other theoretical frameworks as well, for instance the SBA. The sentences that were tested here are ORs with an embedded lexical noun phrase, ORs with an embedded impersonal subject pronoun and ORs with an embedded referential 3rd-person pronoun. The presented data are based on participants' response accuracy in a referent-identification task. In this study, the role of memory skills was assessed as well.

Although the presented data stems from testing different types of sentences in different languages with different populations, my goal in this thesis is to draw overarching conclusions that are based on the three studies, and to explain all the patterns in the results

under the same theoretical account. Based on the findings, I draw three main conclusions:

1) Any model of sentence processing needs to take into account not only structural, or syntactic, factors, but also discourse-related factors–for instance, discourse accessibility or pronouns' referential properties.

2) Just like effects that are due to the structural factors, the ones driven by discourse factors are related to, and modulated by, memory skills.

3) The comparison of children and adults supports the *Continuity Hypothesis*.

CHAPTER 2

DISCOURSE ACCESSIBILITY CONSTRAINTS IN CHILDREN'S PROCESSING OF OBJECT RELATIVE CLAUSES

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ABSTRACT

Children's poor performance on object relative clauses has been explained in terms of intervention locality. This approach predicts that object relatives with a full DP head and an embedded pronominal subject are easier than object relatives in which both the head noun and the embedded subject are full DPs. This prediction is shared by other accounts formulated to explain processing mechanisms. We conducted a visual-world study designed to test the off-line comprehension and on-line processing of object relatives in German-speaking 5-year-olds. Children were tested on three types of object relatives, all having a full DP head noun and differing with respect to the type of nominal phrase that appeared in the embedded subject position: another full DP, a 1st- or a 3rd-person pronoun. Grammatical skills and memory capacity were also assessed in order to see whether and how they affect children's performance. Most accurately processed were object relatives with 1st-person pronoun, independently of children's language and memory skills.

Performance on object relatives with two full DPs was overall more accurate than on object relatives with 3rd-person pronoun. In the former condition, children with stronger grammatical skills accurately processed the structure and their memory abilities determined how fast they were; in the latter condition, children only processed accurately the structure if they were strong both in their grammatical skills and in their memory capacity. The results are discussed in the light of accounts that predict different pronoun effects like the ones we find, which depend on the referential properties of the pronouns. We then discuss which role language and memory abilities might have in processing object relatives with various embedded nominal phrases.

2.1. INTRODUCTION

2.1.1. *Relative clause processing in adults and children*

The acquisition of relative clauses has been studied extensively and in a large variety of languages (Brandt et al., 2009; Arnon, 2010; Adani, 2011; Arosio et al., 2012; Belletti et al., 2012; Adani et al., 2014, among others). The existing research focuses mainly on the asymmetry between child performance on subject-extracted relatives (SRs) and object-extracted relatives (ORs), examples of which are provided in (1) and (2), respectively. In the examples, the head of the relative clause is the noun it modifies (*The bunny*). The underscore marks the position in the embedded clause from which the head noun is extracted: subject position in SRs and object position in ORs.

(1) The bunny that __ is chasing the horse
(2) The bunny that the horse is chasing __

In head-initial languages, it is a robustly attested finding that young children have difficulties comprehending and producing ORs, but not SRs (see Gutierrez-Mangado, 2011 for a reversed pattern in Basque). Children's errors with ORs are mainly expressed by the interpretation of these sentences as SRs. An account that aims to explain the SR-OR

asymmetry in acquisition is proposed by Friedmann et al. (2009), following earlier work by Grillo (2005, 2009). This approach provides an explanation in terms of intervention locality, based on the syntactic principle of *Relativized Minimality* (RM; Rizzi, 1990 and subsequent work). We will refer to Friedmann et al.'s (2009) approach as the RM account.

Relativized Minimality is based on the configuration in (3), in which X is a constituent that moves from its original (gap) position Y crossing an intervening constituent Z.

(3) X … Z … Y

According to the RM Principle, a local relation between X and Y is impossible if Z is a potential candidate for that local relation. Such a case occurs when Z intervenes between X and Y and when Z is structurally similar to X. These two co-occurring conditions give rise to a locality intervention effect and, thus, to difficulties in parsing the structure. Friedmann et al. (2009) show how this configuration and the conditions that create intervention effects apply to the structure of SRs and ORs[1]. In the case of relative clauses, the authors identify the feature [+NP], or *lexical restriction*, as the one that, when present on both X and Z, makes them structurally similar. In (1) and (2), repeated as (4) and (5), both X and Z are lexically restricted, or in other words: they are both full DPs. But only in the OR Z intervenes between X and Y. For this reason, according to Friedmann et al. (2009) ORs with two full DPs are difficult for children whereas SRs with two full DPs are not.

(4) [The bunny] that __ is chasing [the horse]
X Y Z

(5) [The bunny] that [the horse] is chasing __
X Z Y

1 The RM principle was first developed to explain intervention locality effects in extraction from weak islands (Rizzi, 1990). The approach was later extended to explain intervention effects in ORs, assuming a structural proximity between the latter and the original island phenomena (Grillo, 2005, 2009; Friedmann et al., 2009; Rizzi, 2013).

The RM account predicts significant improvement in child comprehension of ORs when the head (X) is a full DP, whereas the embedded subject (Z) is not. Children are therefore predicted to perform more accurately on an OR with a full DP head and an embedded subject which is a personal pronoun, a DP that lacks the [+NP] feature. Friedmann et al. (2009, p. 75) tested this prediction examining child comprehension of Hebrew ORs with an embedded subject which is a null pronoun. The following example is taken from their paper.

(6) Tare li et ha-sus she- mesarkim oto
show to-me ACC the-horse that-*pro*-brush-3rd-pl him
'Show me the horse that someone is brushing'
(literally, 'the horse that they are brushing')

The Hebrew *pro* subject in (6) is an impersonal subject that agrees with the 3rd-person plural form, as evidenced by the Person and Number agreement marking on the embedded verb brush. This impersonal, or arbitrary *pro* is used to describe the action of an unspecified agent. Friedmann et al. (2009) found that children understood ORs like (6) more accurately than ORs with a full DP head noun and a full DP embedded subject. They explained the improved comprehension as due to the attenuation of the intervention locality effect, caused by the fact that the head of the OR is a full DP but not its embedded pronominal subject. Crucially, the prediction is that any type of pronoun in the embedded subject position will improve comprehension, since what matters is the lack of lexical restriction, a property shared by all personal pronouns. This prediction receives further support from studies that find relatively accurate child performance on ORs whose embedded subject is an overt 3rd-person pronoun (Brandt et al., 2009), a 2nd-person pronoun (Kidd et al., 2007) or a 1st-person pronoun (Arnon, 2010).

Other accounts that explain OR processing based on adult performance make similar predictions. Warren and Gibson (2002, 2005) propose that sentence processing is

determined by the number of new referents that intervene between a moved element (*filler*) and the gap site in which it is integrated into the structure. The greater the number of intervening referents (e.g., noun phrases, verbs) the harder it is to keep track of the filler until the gap site is encountered and the filler-gap dependency is resolved (a similar idea is advanced by O'Grady, 2011). Under this view, an intervening pronoun reduces processing cost since it does not introduce a new discourse referent: it serves as a link to an already given one. Indeed, adults have less difficulty with doubly nested ORs and object clefts whose embedded-most DP is a pronoun, as compared to cases in which all the nominal phrases in the structure are full DPs (Warren and Gibson, 2002, 2005). Other accounts explain the difficulty with ORs in terms of similarity between the DP head and the embedded subject DP. It has been found that an OR becomes easier to parse when these two constituents are sufficiently dissimilar. For instance, ORs with two full DPs are more costly to process than ORs in which the head is a full DP and the embedded subject is a proper name (Gordon et al., 2004), or a 2nd-person pronoun (Gordon et al., 2001). Other studies define the difficulties with OR processing in terms of *cue-based interference* (Lewis and Vasishth, 2005; Lewis et al., 2006; Van Dyke and McElree, 2006). Under this view, the similarity between the DP head and the embedded DP is defined by the cues that these two constituents bear. When a constituent (e.g., the DP head in an OR) is encountered it is encoded in memory. Later on, in the gap position, it has to be retrieved from memory in order to be integrated into the structure. At this point, its (syntactic, semantic, or other) cues are analyzed in order to decide whether the filler-gap dependency can be resolved. If another constituent (e.g., the embedded subject DP in an OR) shares similar cues with those of the encoded constituent this second set of cues will interfere with the processing of the first one, increasing the overall processing cost of the structure. In an OR with an embedded pronoun, the cues of the intervening pronoun are sufficiently different from those of the encoded head noun, thus reducing the processing cost.

As can be seen, there is an affinity between the RM account and the accounts reviewed in the last paragraph, although the former is the only one whose predictions have been tested in experiments with children. All these accounts appear to share the prediction that

an OR with an embedded pronominal subject is less costly for processing than an OR in which both the head noun and the embedded subject are full DPs. Moreover, at least some of these approaches (Gordon et al., 2001; Lewis et al., 2006), like the RM account, attribute the difficulties in OR processing to the (dis)similarity between the DP head and the embedded subject DP in terms of cues or features. Importantly, however, each of these studies tested the effect of only one pronoun type on OR processing. The only exception is Warren and Gibson's (2002) study with adults, to which we will return later. The present study is the first to assess the comprehension of ORs with different embedded pronominal subjects in children. That is, we will test the prediction that ORs with different pronouns in the embedded subject position should be equally easy for children, as compared to ORs with two full DPs. Comparing the effects of different pronoun types is particularly interesting given studies that show that pronouns with different referential properties affect sentence processing differently in adults (Warren and Gibson, 2002; Carminati, 2005).

We have recently shown (Haendler et al., 2015a) that there is a relation between children's performance on ORs with different types of embedded referring expressions (full DP, different personal pronouns)[2] and their language skills, as measured by standardized tests for receptive grammatical abilities. These language or grammatical skills (we will use the two terms interchangeably) were defined as the average score on three subtests from Siegmüller et al. (2010). The tests assessed the comprehension of (a) canonical and non-canonical declarative sentences (SVO and OVS); (b) sentences containing reflexives and pronouns; (c) various types of relative clauses (right-branching and center-embedded; SRs and ORs). In the discussion, we will elaborate on what grammatical skills are assumed to underlie children's performance on these three language tests. Concerning the results, we found that children were most accurate on ORs with an embedded 1st-person pronoun (OR+1pro; *The horse that **I** chase*), independently of their scores on the language tests. In ORs with an embedded 3rd-person pronoun (OR+3pro; *The*

2 We use the term *referring expression* to mean any linguistic form that relates to some discourse referent. This term thus includes both definite noun phrases (full DPs) and pronouns (see Fukumura and van Gompel, 2012; Serratrice, 2013).

*horse that **it** chases*) and ORs with a full DP head and an embedded full DP (OR+2DP; *The horse that **the bunny** chases*), which were overall more difficult, children's performance interacted with their grammatical skills: children with higher scores on the language tests were more accurate on these conditions than children with lower scores.

In the present paper, we extend this picture by looking at memory skills and assessing whether they interact with language abilities in the modulation of children's performance on the three OR types. In other words, we want to see whether both language and memory have an impact on children's OR processing, and whether their effects are independent of one another or whether they interact. In the latter case, we want to see what kind of relation between language and memory skills emerges during OR processing. This kind of analysis will help distinguish between effects that are purely due to children's language skills, effects that are purely memory-dependent and effects that are caused by both types of cognitive abilities.

2.1.2. *Memory and the processing of object relative clauses*

The relevance of memory for the processing of relative clauses has been vastly investigated. To begin with, Friedmann et al. (2009) speculate that the difficulty with an OR containing two full DPs lies in children's limited memory capacity. During the processing of such a structure, one needs to hold in memory the featural specifications of the DP head and the embedded DP and compare them in order to determine their (dis)similarity (see also Adani et al., 2010). When the features of the DP head and of the embedded DP are similar, such as when they are both full DPs, the comparison of the features is more costly and memory capacity is overloaded. However, when the features on the DP head and on the embedded DP are sufficiently different, as in the case of an OR with an embedded pronominal subject, comparing the features becomes less demanding for memory resources and the comprehension of the OR is facilitated.

The reviewed accounts on adult processing similarly suggest that memory abilities constrain the processing of ORs (for a comprehensive review, see Wagers and Phillips, 2014). According to Gibson (1998, 2000) and Warren and Gibson (2002, 2005; see also

O'Grady, 2011), the difficulty associated with keeping track of the filler while processing newly introduced discourse referents is related to available memory resources. The greater the number of new discourse referents that intervene between the filler and its gap site, the longer the filler has to be kept in memory until the filler-gap dependency is resolved. Therefore, people with strong memory capacity will be facilitated in maintaining the filler in memory while processing the sentence until the gap position is reached. Gordon et al.'s (2001, 2004) proposal that the processing cost of an OR is determined by the (dis)similarity between the DP head and the embedded DP is also related to memory capacity. The idea is that dissimilar DPs burden memory to a lesser extent, making the distinction of the two constituents during sentence processing easier. Finally, the processing mechanism assumed under the cue-based interference account (Lewis and Vasishth, 2005; Lewis et al., 2006; Van Dyke and McElree, 2006) similarly draws on memory resources. If the set of cues of a previously encoded constituent (the DP head of an OR) and that of the intervening DP are similar, memory capacity will be overloaded, resulting in an increased processing cost. If the two sets of cues are dissimilar, memory resources will be less burdened and the sentence will be easier to process.

The relation between children's memory abilities and their comprehension of syntactically complex sentences has been vastly studied. Different studies have used different kinds of tests to measure memory, yielding mixed results. Some studies found a relation between children's off-line response accuracy and their performance on listening span tasks (Montgomery et al., 2008; Montgomery and Evans, 2009; Weighall and Altmann, 2011), backward digit span tasks (Engel de Abreu et al., 2011; Boyle et al., 2013) and forward digit span tasks (Arosio et al., 2011, 2012; Engel de Abreu et al., 2011). An association has been found also between similar memory tasks and children's on-line sentence processing (Booth et al., 2000; Roberts et al., 2007). However, no systematic relation has been found between the score on any specific memory test and children's performance on any specific language task (Kidd, 2013). Particularly relevant for the present study is Arosio et al.'s (2012) work. Using a picture-selection task, they tested 7-years-old German-speaking children on the comprehension of SRs and ORs,

disambiguated either by Case marking on the determiner of the embedded DP or by Number marking on the embedded verb. The authors found that children were more accurate on case-disambiguated than on number-disambiguated ORs. Also relevant is their finding that children's score on a forward span test was a reliable predictor of their comprehension of ORs (but not SRs).

In the present study, we administered to children both a forward and a backward digit span task. The memory measure was calculated as the average score on the two tests. As we have seen, both the forward and the backward span tests have been widely used in studies with children. Moreover, these tasks are typically assumed to reflect two kinds of memory components in Baddeley's classical model (Baddeley, 1986; Baddeley et al., 2009): the forward digit span task is believed to reflect the operation of the phonological loop, a short-term storage of phonological information; the backward digit span task is assumed to reflect the operation of the central executive, which is responsible for the coordination and elaboration of the stored information. The former is often referred to as verbal short-term memory; the latter as verbal working memory (Kidd, 2013). The fact that no systematic relation has been demonstrated between any of these two tests and a specific performance pattern on language comprehension led us to combine the scores on the two tasks into one, more general measure of memory capacity. The disadvantage in doing so is that we cannot look at separate effects caused by the two kinds of memory abilities (short-term memory and working memory). The advantage is that such a general memory measure is more robust and reliable for the analysis, since it combines data collected in two different tasks. The mixed findings in the literature regarding the relation between the two span tasks and certain language abilities leaves the qualitative analysis of the role of memory highly speculative. Hence, by using the composite score, we gain a stronger measure for the quantitative analysis of children's memory capacity.

2.1.3. *Referential properties and discourse accessibility*

As we have seen, the prediction we are testing is that any type of embedded pronoun should facilitate children's performance on ORs to an equal extent. However, there is extensive

literature focusing on differences between pronouns in terms of their referential properties. A case in point is the different way of establishing reference of 1st- and 2nd-person pronouns on the one hand, and 3rd-person pronouns on the other hand. When a participant in a linguistic act constructs a discourse model, 1st- and 2nd-person pronouns are directly integrated into that model since they refer, respectively, to the speaker and the interlocutor, two discourse referents which are always available and highly accessible (Recanati, 1993; Erteschik-Shir, 1997; Ariel, 2001). Moreover, the referents of these pronouns are derived from the lexical meaning of the pronouns themselves: 1st-person pronoun ('I,' 'we') = speaker; 2nd-person pronoun ('you') = interlocutor. This is similar to the way in which a regular noun phrase (e.g., 'the horse') establishes reference. The discourse referent of the noun phrase is derived from its lexical meaning, despite the fact that it is marked with 3rd-person (unlike 1st- and 2nd-person pronouns) and although it is not referring to a participant in the linguistic act (like 'speaker' or 'interlocutor'). By contrast, the referent of a 3rd-person pronoun ('it,' 'they,' and demonstratives such as 'this,' 'that') is derived from the discourse, in a process of pronoun resolution in which the pronoun relates to an antecedent in the linguistic or extra-linguistic context (Heim, 1991; Legendre and Smolensky, 2012).

There is experimental evidence that such differences in discourse accessibility of pronouns affect the processing of sentences in which they occur. Warren and Gibson (2002) found that adults perceive doubly nested ORs with an embedded 1st- or 2nd-person pronoun as less complex, as compared to such structures with an embedded 3rd-person pronoun. Moreover, adult on-line processing of pronoun resolution in infrequent circumstances (when the pronoun antecedent is a previously mentioned object, rather than subject) is facilitated when that pronoun is marked with 1st- or 2nd-person, rather than 3rd-person (Carminati, 2005). These effects, assumed to be caused by the referential properties of pronouns, have not been tested yet in children. But a number of studies suggest children are sensitive to discourse properties of pronouns as well. First, in line with the pronoun asymmetry described above, children acquire the ability to correctly interpret 1st- and 2nd-person pronouns before 3rd-person pronouns (Brener, 1983; Girouard et al., 1997;

Legendre et al., 2011; Legendre and Smolensky, 2012). Moreover, there is substantial evidence indicating that children are sensitive to the discourse properties that determine pronoun usage and interpretation (Song and Fisher, 2005, 2007; Spenader et al., 2009; Pyykkönen et al., 2010; Koster et al., 2011; Hartshorne et al., 2015)[3]. For instance, Song and Fisher (2005) found that 3-year-olds, tested with a preferential-looking paradigm, looked more to the correct referent figure of a pronoun when it was made prominent in the discourse (in the preceding context it was the first-mentioned figure in a subject position and pronominalized once), than when the referent was not prominent. Children in Koster et al.'s (2011) study interpreted the pronoun as referring to the first-mentioned character in a context story, both when this character was consistently the discourse topic and when there was a shift in the topic of the story. Production studies also suggest that children are sensitive to referential properties of pronouns, as well as to the extra-sentential or extra-linguistic context, when they choose which referring expression to utter (see Serratrice, 2013 and references therein). Together, these studies suggest that, from early on, children are sensitive to discourse properties of pronouns such as topicality or order-of-mention. It appears that children can use these properties in order to construct a plausible discourse model and, based on that model, derive expectations regarding the usage of the referring expressions they encounter in the linguistic input (see a related discussion in Trueswell et al., 2011).

According to Goodluck (2010), who discusses data in contradiction with Friedmann et al.'s (2009) approach, children's performance on complex structures is determined by both syntactic and discourse accessibility operations (see also Goodluck, 1990, 2005 and Avrutin, 2000). Whereas the RM account predicts difficulties with object-extracted wh-questions in which both the moved constituent and the intervening one are full DPs (*Which*

3 Some studies have tested children's comprehension of intra-sentential anaphora. These are sentences in which the referent of the pronoun is inside the same sentence in which the pronoun appears (e.g., Sekerina et al., 2004; van Rij et al., 2010; Clackson et al., 2011). Here we concentrate only on extra-sentential anaphora, where the referent of the pronoun is in the extra-sentential or extra-linguistic (visual) context. This is the relevant case for the present study.

lion did the zebra kick?), Goodluck (2005) found that children perform more accurately when the moved constituent is a more generic name (*Which animal did the zebra kick?*). In explaining the data, Goodluck suggests that children's difficulty with object which-questions is related both to the syntactic factor of distance (*which lion* / *animal* is extracted from the more distant position as the object of the verb *kick*) and to the discourse factor of set-restriction (to interpret *which lion*, the child has to restrict the set of given lions and understand which one she is asked about; this operation is less costly when *lion* is replaced with the more generic *animal*). Although Goodluck's (2010, p. 1520) proposal is made in relation to structures that are slightly different from the ones dealt with here, the relevance of her work lies in the idea that "[…] children appear to have difficulty in general with grammatical phenomena that require access to discourse."

2.1.4. *The present study*

To summarize the goal of the present study, we test the prediction that ORs with different embedded pronominal subjects are easier than ORs with two full DPs. Moreover, no difference is predicted between the conditions with pronouns. We used right-branching ORs with various referring expressions in the embedded subject position. ORs with an embedded 1st-person pronoun (7) and with 3rd-person pronoun (8) were compared to a baseline condition of ORs in which both the head noun and the embedded subject are full DPs (9)[4]. Note that these ORs differ with respect to the referring expression that occupies the embedded subject position (in bold). Hence, we expect differences in performance on the ORs to reflect effects caused by these referring expressions.

4 In addition to these three conditions, we also tested a fourth condition in which the head noun was a demonstrative pronoun and the embedded subject was a full DP (*Welche Farbe hat der, den das Pferd jagt?* 'What color has that (the one) that the horse is chasing?'). The predictions regarding this condition are not straightforward, since existing literature is not explicit about whether such a demonstrative bears the [+NP] feature or not. Moreover, unlike this condition, all the others differed minimally by the referring expression in the embedded subject position. Upon suggestion from the two reviewers, we will neither present nor discuss the data from this condition.

(7)	OR+1pro:	Welche	Farbe	hat	der Hase,	den	**ich**	jage?
		what	color	has	the bunny	who	**I**	chase
(8)	OR+3pro:	Welche	Farbe	hat	der Hase,	den	**es**	jagt?
		what	color	has	the bunny	who	**it**	chases
(9)	OR+2DP:	Welche	Farbe	hat	der Hase,	den	**das Pferd**	jagt?
		what	color	has	the bunny	who	**the horse**	chases

Previous studies on children's OR comprehension have used only off-line methods. Here, we designed a visual-world experiment (Tanenhaus et al., 1995) and measured both off-line response accuracy and on-line eye-gaze during the inspection of a visual scene that accompanied each test sentence. The off-line accuracy was collected as a measure of explicit comprehension; the on-line eye-gaze as a measure of implicit parsing strategies. Many studies using on-line measures (e.g., eye-tracking) have found evidence for early processing of complex structures and/or a more fine-grained performance pattern that usually remains hidden in the explicit response (Brandt-Kobele and Höhle, 2010; Adani and Fritzsche, 2015). Thus, on-line gaze measures are arguably more sensitive in testing child language, yielding results that suggest that children might implicitly process a structure accurately even when their explicit response is inaccurate. For this reason, and since previous studies have found difficulties with ORs that persist until late in development (e.g., Friedmann et al., 2009; Arosio et al., 2012; Adani et al., 2014), we tested children at age 5. If the on-line eye-gaze measure is indeed more sensitive than the off-line response accuracy we might find evidence for correct processing of the harder condition(s) even as early as this age.

Let us now summarize the predictions regarding children's performance on the three conditions and the possible relation to language and memory abilities. The initial prediction is that children will be more accurate on OR+1pro and OR+3pro than on OR+2DP, and there should be no difference between performance on OR+1pro and OR+3pro. However,

if the different ways with which the 1st- and the 3rd-person pronouns establish reference influence children's performance, as found with adults (Warren and Gibson, 2002; Carminati, 2005), children should be more accurate on OR+1pro than on OR+3pro. We have already mentioned that stronger grammatical skills improve children's performance on two of the conditions. Given previous studies (Kidd, 2013), we might expect to find also an impact of memory that shows that stronger memory capacity improves performance on the task. We might also find that language and memory abilities modulate children's performance differently. This would result in different patterns of interaction between language/memory and response accuracy/eye-gaze.

Regarding the specific pattern expected in the two kinds of data we have collected, a higher proportion of correct responses (i.e., naming the color of the correct figure) will express a more accurate off-line performance. With respect to the eye-gaze data, there are several possibilities. We measure the proportion of looks to the target figure in the visual scene that accompanies each test sentence, within a time window defined in advance for the analysis. Accurate processing of the sentence within the analysis window will be expressed either by earlier looks to the target figure, or by longer looks to the target (higher proportion of target looks), or both. Therefore, the initial predictions regarding the performance pattern in the accuracy data and the eye-gaze data roughly correspond. However, we might find evidence for correct processing of the sentences, or a more fine-grained performance pattern, only in the eye-gaze data.

2.2. MATERIALS AND METHODS

2.2.1. *Participants*

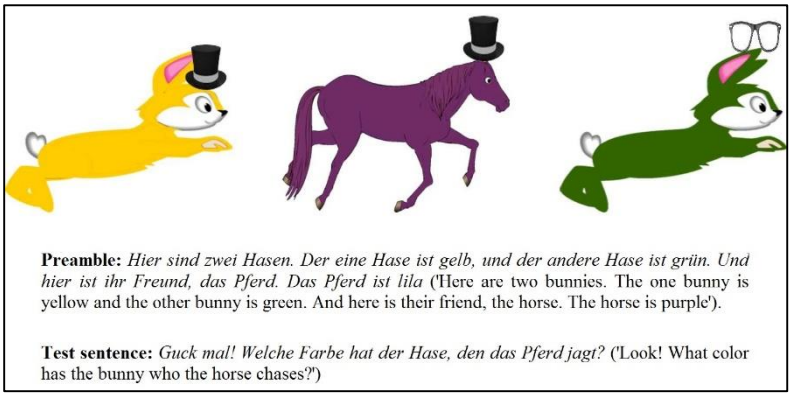
Forty-seven 5-years-old children (24 females, age range 5.0-5.11, M = 5.5) participated in the study. All children are growing up as monolingual speakers of German and none has reported history of linguistic, hearing or other cognitive developmental disorders. Parents gave their consent for the participation of their children. The study, approved by the ethics

commission of the University of Potsdam, was successfully piloted with a group of university students.

2.2.2. *Material*

2.2.2.1. *Visual stimuli*

In a setup inspired by Arnon (2010) and Adani (2011) participants watched in each trial an animated video with two identical animals on the sides (target and distractor animals) and a third different animal in the middle (middle animal). Each of these three regions of interest had the same size of 436 × 400 pixels. An example of a visual scene is provided in **Figure 2.1**. Employing two verbs, *chase* and *tickle*, the three animals in the scene were chasing each other on half of the trials and tickling one another with a feather on the other half. Each of the animals in the scene was colored differently. The three colors were combined such that similar colors did not appear within the same video, in order to facilitate color distinction and recognition (Pitchford and Mullen, 2003). Each of the animals carried a small object (hat, glasses, flower or heart–all clip art images) that was relevant for the fillers, but not for the experimental items. The target animal (i.e., the referent of the OR head noun) could be one of four masculine nouns–bear, bunny, lion, or monkey–each of which appeared an equal number of times as target, and in a balanced manner across conditions. The middle animal was on some trials a neuter noun (horse, camel, zebra, or sheep) and on others a feminine noun (duck, cow, cat, or mouse). In the OR+1pro condition, the middle animal was always the dog, established as referent for the 1st-person pronoun in an introduction story prior to the experiment (see *Procedure*). The direction of the scene was in half of the trials from left to right and in the other half from right to left. Depending on the action direction, the target animal was always either on the left or on the right side of the scene, but never in the middle. In the ORs, the target animal was always the last animal in the row; in the fillers, it was always the first animal in the row, to prevent participants from anticipating the side on which the target appeared.



Preamble: *Hier sind zwei Hasen. Der eine Hase ist gelb, und der andere Hase ist grün. Und hier ist ihr Freund, das Pferd. Das Pferd ist lila* ('Here are two bunnies. The one bunny is yellow and the other bunny is green. And here is their friend, the horse. The horse is purple').

Test sentence: *Guck mal! Welche Farbe hat der Hase, den das Pferd jagt?* ('Look! What color has the bunny who the horse chases?')

FIGURE 2.1. Example of a visual scene, a preamble and a test sentence.

2.2.2.2. *Linguistic stimuli*

The design consisted of three experimental conditions (examples 7–9 in the *Introduction*), with seven trials in each condition, and 12 fillers (e.g., *Welche Farbe hat der Hase mit dem Hut?* 'What color is the bunny with the hat?'). Piloting the experiment before the actual testing revealed that, with this amount of items, the duration of the experiment (~20 min) was adequate for 5-year-olds. The displayed videos were accompanied by the test sentences that were pre-recorded with a female German native speaker and integrated into the video file. These were questions about the color of one animal in the scene to be identified through a relative clause (in experimental items) or a small object (in fillers). Two lists were constructed, each containing a different pseudo-randomized order of the items. Half of the participants were exposed to the first list, and the other half were exposed to the second list. The full list of items is provided in **Appendix A.1**.

Since all the target animals (i.e., the OR head noun) were singular masculine nouns, the relative pronoun in all the ORs was always unambiguously accusative case-marked (*den* 'who_ACC_MASC'). This way, the sentence is revealed to be an OR already upon encountering the relative pronoun and children might be facilitated in processing the sentence (Arosio et al., 2012). However, in order for children to be able to make use of this information, they have to be able to recognize the accusative Case marking on the relative

pronoun. In particular, they have to be able to distinguish the accusative-marked *den* from the nominative-marked *der*. If children cannot tell apart the two minimally differing Case markings they might erroneously understand the sentence as a SR (e.g., *Welche Farbe hat der Hase, der das Pferd jagt?* 'What color has the bunny who_NOM_MASC the horse chases?'). This might mask the comprehension difficulties children typically have with the syntactic structure of the OR as such. In order to determine whether children were able to discern between the two case-markings, we looked at their performance on one of the language tests that were administered (from the TSVK battery, Siegmüller et al., 2010): the test on the comprehension of OVS sentences, which are grammatical but non-canonical in German. Successful performance on this test requires the distinction between nominative (*der*), accusative (*den*) and dative Case marking (*dem*), in order to understand that the pre-verbal noun is an accusative- or dative-marked object and that the post-verbal noun is a nominative-marked subject. When looking at the performance on this test it appears that 37 out of 41 children scored at or above 50% (answering correctly six or more out of the 12 questions in the test). Scatterplots showing the relation between individual performance on this test and the overall performance in the experiment (both in terms of off-line accuracy and on-line eye-gaze) are provided in the online supplementary material. Additional evidence that children in our study were able to tell apart nominative and accusative Case marking stems from independent studies that show that children as old as 4;6 can already distinguish nominative and accusative Case marking in German (Grünloh et al., 2011)[5].

2.2.2.3. *Memory*

We administered to the children a forward span test and a backward version of the same test. The sequences for the forward span test were taken from the *Intelligence and*

5 To be sure, we performed all the analyses after excluding the four children who scored lower than 50% on the test for comprehension of OVS sentences. The results were qualitatively similar to those of the analysis in which these children are included. We therefore report the results from the analysis that includes all children.

Development Scales battery (Grob et al., 2009). The forward span test was used to measure verbal short-term memory. To measure verbal working memory, we used the same sequences in a backward span test which is typically taken to measure this type of memory capacity. The sequences in the two memory tasks were of increasing length, ranging from 2 to 7 items in each sequence, and containing either digits or letters (for instance, 5-3-8 or C-O-G). For each sequence length (of two items, three items, and so on) there was one sequence of digits and one sequence of letters.

2.2.2.4. *Language*

The language tests were three subtests from Siegmüller et al.'s (2010) standardized battery for receptive grammatical abilities in German: subtest 3 for the comprehension of SVO and OVS sentences (e.g., *Die kinder zeichnet der Mann* 'The_ACC children draws the_NOM man'); subtest 5 for the comprehension of sentences containing reflexives and pronouns (*Der Papa wäscht ihn* 'The_NOM father washes him_ACC'); and subtest 6 for the comprehension of various types of relative clauses (right-branching SR: *Den Hasen schiebt der Esel, der weint* 'The_ACC bunny pushes the_NOM donkey that_NOM cries'; center-embedded OR: *Der Mann, den der Indianer trägt, liest* 'The_NOM man, that_ACC the_NOM Indian carries, reads'). In all these tests, the task is to point to one picture out of three that best corresponds to a sentence read aloud by the experimenter.

2.2.3. *Procedure*

The experiment was carried out at a university lab, in a quiet and child-friendly room. Participants were seated at a distance of 55–70 cm from a DELL laptop (screen resolution 1600 × 900, white background), connected to an SMI RED-m eye-tracker (sample rate 60Hz). The experiment was run over the SMI Experiment Center software. An experimenter sat next to the participant, observing the tracking quality on a separate monitor and moving from one trial to the next, or repeating a trial if necessary, by pressing keys on an external keyboard. The experimenter also registered by hand the participant's verbal response in each trial.

In an introduction video, displayed prior to the experiment, Nellie the dog appeared and explained she would like to have the child's help in learning the color names. She explained the task and gave three example questions that served as warm-up trials. Participants received feedback on their responses to the practice trials, but not during the actual experiment. After the warm-up items, Nellie showed and named all the animals as well as the actions (chasing and tickling) that would appear in the game. The story teller also said she would appear every now and then and play with her friends. This, together with the appearance of the dog as the middle animal in the relevant trials, established the referent for the 1st-person pronoun and made its usage felicitous.

In the experiment, each trial started with a preamble video in which the animals of the scene were presented and their colors were named. The referent of the 3rd-person pronoun was stressed prosodically in the preamble, in order to make it more salient in the discourse. The test question followed the preamble video immediately (**Figure 2.1** shows an example of a visual scene with the preamble text and the test sentence accompanying it. An example of a preamble text and a test sentence for each of the conditions is provided in **Appendix A.2**; a video exemplifying a trial can be found in the online supplementary material.). Upon hearing the question about the color of one of the animals, participants answered and the experimenter noted their response on a sheet. In case of no response the experimenter offered the participant to listen again to the question. In such cases, both the preamble and the test question were replayed and only the second response was counted in the analysis. A short break was taken after every 10 items. The entire duration of the experiment was approximately 20 min. Children, who were generally engaged and happy to participate, received stickers as a reward.

The forward and backward span tasks and the language tests were administered in a separate session, 1-3 weeks after the first appointment, at the same room at the university lab. The instructions for the forward span task were given following the protocol of this test (IDS, Grob et al., 2009). The instructions for the backward span task were based on those given in another such test that has norms from older children (HAWIK, Petermann and Petermann, 2008). In the forward span task, the experimenter read to the children the

sequences of digits and letters and the child was required to repeat each sequence in the order in which the items had been presented. In the backward span task, the child heard the same sequences read by the experimenter and was instructed to repeat each sequence in the exact opposite order. The task was interrupted if the child failed to correctly repeat three consecutive sequences. The order of testing was the same for all children: the forward digit span test was administered first, then the backward digit span test, followed by the three language tests (comprehension of (a) OVS sentences; (b) pronouns and reflexives; and (c) relative clauses).

2.3. RESULTS

We analyzed the data using the *lme4* package (Bates et al., 2015) in the R environment (R Development Core Team, 2015). The categorical accuracy data were analyzed with logit mixed models (Jaeger, 2008). The eye-tracking data were analyzed using linear mixed models with empirical logit as dependent variable (Barr, 2008). The eye-gaze plots present the data after having removed the individual differences from the dependent variable, based on the outcome of the linear mixed model. This was done using the *remef* function (Hohenstein and Kliegl, 2014). The plots therefore present the results on which the statistical inferences are based, that is, the ones that are derived from the statistical model. Importantly, in the case of the data presented here, plotting the partial effects yielded patterns qualitatively similar to those of the observed data. This means that removing the individual differences did not alter the general pattern in the data. For each of the eye-gaze plots, a corresponding figure showing the observed data is provided in the online supplementary material, for the sake of comparison. MEMORY SCORE (average score on the two span tests) and LANGUAGE SCORE (average score on the three language tests) were inserted into the mixed-effects model analysis as continuous covariates, without splitting the group of participants. However, for the sake of presenting the data (either in a plot or in a table), the group was divided into children who scored higher vs. those who scored lower on the tests. This division was done with a median split. Scatterplots showing the

individual performance pattern (for both the accuracy and the eye-tracking data) in relation to the average score on the memory and language tests can be found in the online supplementary material. In this section, we report the most relevant results of the analyses. The complete output of each model is listed in **Appendix A.3** and **A.4**.

The data from six children who did not do the memory and language tests were excluded, so the analysis of the accuracy data is based on 41 children. For two among these, eye-tracking failed due to technical problems during the testing session. Thus, the analysis of the eye-tracking data is based on 39 children. In the eye-tracking data analysis, we excluded 35 trials (2.2% of the total trials available) in which there was more than 50% data loss. The excluded items were distributed across all conditions and several participants. Prior to the analysis, we checked whether the participants performed similarly on trials with the verb *jagen* 'chase' and on those with the verb *kitzeln* 'tickle.' There was no substantial difference in the performance on trials involving these two actions, neither in terms of response accuracy nor in terms of eye-gaze. Hence, all trials were analyzed together.

2.3.1. *Accuracy*

Response accuracy was calculated based on the color named by the participants (Arnon, 2010). Naming the color of the target animal was scored as 1; otherwise as 0. Without taking into account the individual differences of language and memory abilities, children performed on the OR+1pro condition 97% (SE = 0.03) accurately, on the OR+2DP condition 47% (SE = 0.02) and on the OR+3pro condition 44% (SE = 0.03). These accuracy percentages were compared to chance level using one-sample *t*-tests (chance level was set at 0.5 since, although there were three regions of interest in the visual scene, children never named the color of the middle animal, indicating that they never considered it a possible answer). Only performance on the OR+1pro condition was significantly above chance (t = 43.06). On the OR+2DP and OR+3pro conditions, performance was at chance (t = −0.59 and t = −1.16, respectively).

The results look different when language and memory abilities are considered. **Figure 2.2** shows the pattern of relation between children's scores on the language and memory tests, and how it is manifested in their performance on each of the three conditions. The ceiling performance on the OR+1pro condition was not influenced by language and memory abilities. The pattern that emerges in the OR+2DP condition is similar to that in the OR+3pro condition. A lower score on the language tests determined a below-chance performance on these two conditions, whereas a higher score on the language tests determined a more accurate performance on them.

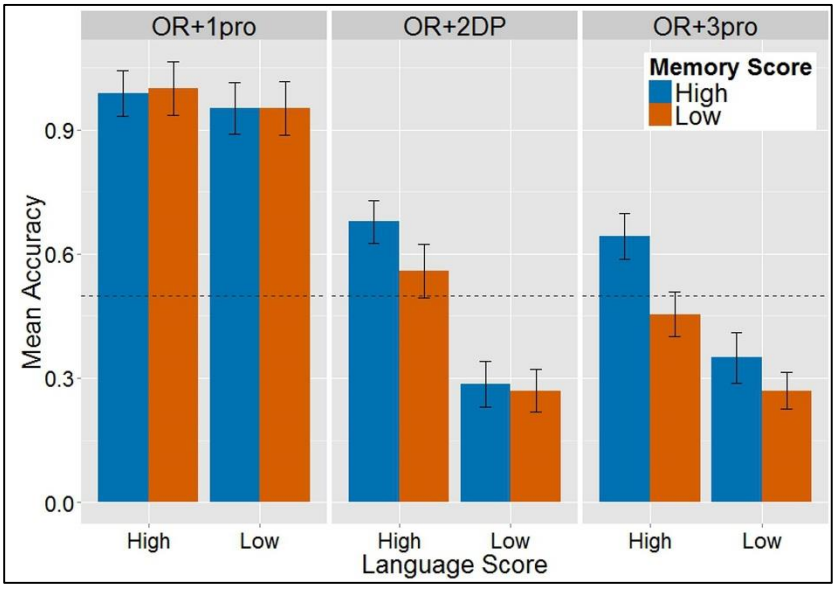


FIGURE 2.2. Mean response accuracy (±1 SE) on the three conditions, in relation to children's scores on the language tests (on the x-axis) and on the memory tests (blue = High Score; orange = Low Score). The horizontal dashed line marks the chance level of 0.5.

The accuracy data were fit into a logit mixed model, including CONDITION as fixed factor, LANGUAGE SCORE and MEMORY SCORE as two continuous covariates (without

splitting the participant group) and intercepts for random effects of subjects and items. The OR+1pro condition was excluded from the analysis to avoid the impact of extreme differences in task performance on the model outcome. All the terms that contain an interaction between LANGUAGE and MEMORY were included, since these two covariates did not correlate significantly (r = 0.08, t = 0.45). A table of correlations between the language measure, the memory measure and response accuracy is provided in the online supplementary material. The main effect CONDITION was not statistically significant (coef = -0.12, SE = 0.49, z = -0.25, p = 0.81), confirming that performance on OR+2DP and OR+3pro was overall similar. The main effect LANGUAGE SCORE was significant (coef = 0.36, SE = 0.16, z = 2.26, p = 0.02), and so was the interaction CONDITION by LANGUAGE SCORE (coef = -0.31, SE = 0.13, z = -2.34, p = 0.02). This interaction reflects the fact that, whereas performance on the OR+2DP and OR+3pro conditions was the same in children with lower language scores, children with higher language scores were significantly more accurate on OR+2DP than on OR+3pro. None of the terms that include MEMORY SCORE (main effect MEMORY and the interactions CONDITION by MEMORY, LANGUAGE by MEMORY as well as CONDITION by LANGUAGE by MEMORY) was statistically significant. Hence, we see that children's performance on OR+2DP and OR+3pro in the off-line data is modulated by language, but not by memory capacity.

2.3.2. *Eye-tracking*

Figure 2.3 shows, for each of the three conditions, the proportion of target looks of children with high and low scores on the memory tests, broken by their scores on the language tests in order to see the relation between the two cognitive measures. The plot shows the data within the relevant time window, defined *a priori* for the analysis, rather than for the entire trial duration. This window starts at the offset of the relative pronoun den (plus 200ms, the average time span necessary for programming and executing an eye movement; Trueswell, 2008). Note that the part that precedes the relative pronoun (*Welche Farbe hat der Hase,…* 'What color has the bunny…') is ambiguous about whether the sentence is a SR or an OR. However, based on the unambiguously accusative-marked relative pronoun, it is already

possible (and, indeed, very likely for adult speakers at least) to correctly predict that the sentence will turn out to be an OR. For these reasons, the beginning of the critical time window has been set at the beginning of the critical information in the sentence, that is, after the relative pronoun has been processed. This window ends after the 2-seconds long silence that followed the test question.

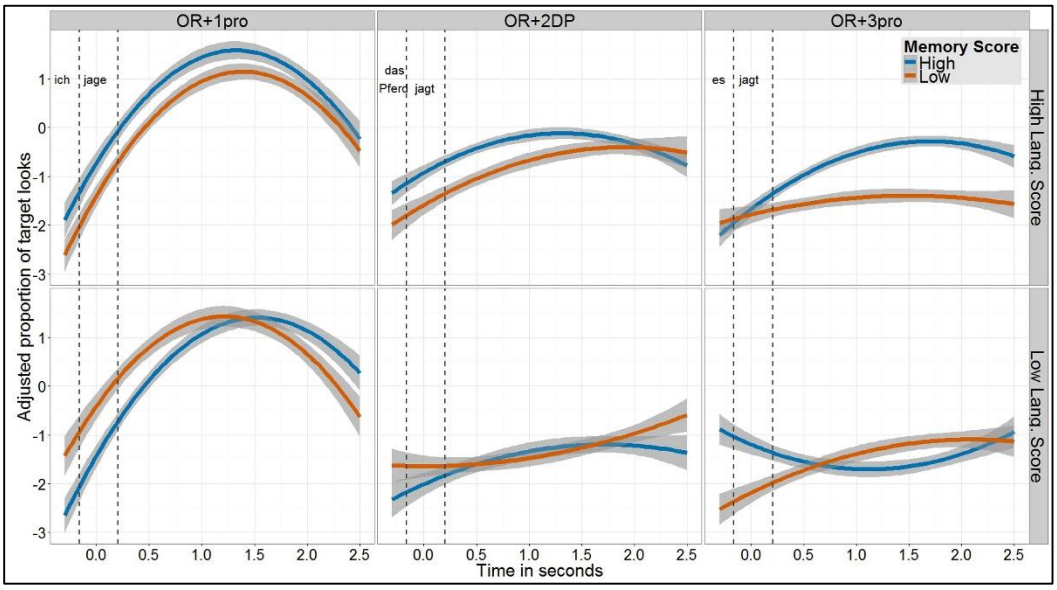


FIGURE 2.3. Proportion of target looks (transformed to empirical logit and adjusted after the removal of individual differences) within the time window relevant for analysis, shown separately for each condition, divided by children's score on the memory tests (blue line = High Score; orange line = Low Score) and broken by their score on the language tests (top row = High Score; bottom row = Low Score). On the x-axis Time ranges from the offset of the relative pronoun until the end of the 2-seconds long silence that followed the sentence. Two vertical dashed lines mark the critical chunks in the analysis window: (1) embedded subject DP (*ich* 'I'; *das Pferd* 'the horse'; *es* 'it'); (2) embedded verb (*jage*/*t* 'chase/s'); (3) post-sentential silence. The analysis of the eye-gaze data was performed on the entire time window shown in the plot (chunks 1-3).

Within this time window, the effects we are interested in might start from the onset of the embedded subject DP onward, while the embedded full DP or pronoun and the verb are processed. Another (perhaps more plausible) possibility is that the effects emerge also in the 2-seconds long silence following the test sentence. In other words, children might continue to process the structure even after the sentence offset (Brandt-Kobele and Höhle, 2010; Adani and Fritzsche, 2015). Importantly, by including the post-sentential silence in the analysis time window we account for effects that might occur upon processing the verb, which is the very last word in the sentence. This is relevant in the light of studies with adults that predict the effect to occur at the verb, the point in which the filler-gap dependency is resolved (e.g., Gibson, 2000; Gordon et al., 2001, 2002; Warren and Gibson, 2002; Lewis et al., 2006; O'Grady, 2011).

Within the critical time window, which was approximately 2800ms long, the dependent variable was the proportion of looks to the target figure, calculated as looks to the target animal divided by looks to all the three animals in the visual scene. An accurate processing of the sentence in terms of eye-gaze might be expressed by faster looks to the target (earlier increase in proportion of target looks, or PTL), by more target looks (higher PTL), or by both. Note that, in the analysis procedure adopted here (Barr, 2008), TIME is included in the model as a continuous covariate. Therefore, the analysis does not provide information about the specific point in which the effect occurs. For this reason, we will not be able to say how long exactly after the embedded subject DP or the embedded verb have been processed the effect starts. However, the advantage in such an analysis is that the time-related information is obtained in its entirety, without the necessity to cut time into chunks and lose information about the timely course of the gaze pattern. The time-related information is expressed here in the form of significant interactions with the TIME covariate. For instance, a significant interaction CONDITION by TIME would mean that, over time (without knowing where exactly during the analyzed window), target looks in one condition increase more than in another condition. For the analysis, each of the pronoun conditions was compared to the baseline condition with two full DPs, using sliding contrast specification (OR+1pro vs. OR+2DP vs. OR+3pro). The plot and analysis of the eye-gaze

data include all the trials in the experiment, independently of whether they were answered correctly or incorrectly.

Let us turn to the gaze pattern shown in **Figure 2.3**. In the OR+1pro condition, the increase in target looks is faster and the PTL is higher (peaking around 1200ms into the critical time window) than in the other two conditions, reflecting what we find in the accuracy data. Individual differences in language and memory skills do not appear to affect this pattern. In the OR+2DP condition, children with a low score on the language tests look less to the target independently of their memory score (lower middle panel in **Figure 2.3**). Children with a higher language score (upper middle panel) look faster to the target when their memory score is high (culminating at about 1500ms), as compared to when their memory score is low. These high-language but low-memory children eventually look to the target like their high-memory peers, but at a later point (around 1800ms). In the OR+3pro condition, children with a low language score again look less to the target independently of their memory score (lower right panel). However, a clear difference emerges between high-memory and low-memory children when their language score is high (upper right panel). Here, high-memory children look to the target faster and more than their low-memory peers.

Following Barr's (2008) procedure for the analysis of eye-tracking data in the visual-world paradigm, we performed only the by-subject analysis, aggregating the data across items. This was done due to the relatively small number of items per condition. The proportion of target looks was transformed to an empirical logit and used as the dependent variable in the model. TIME, divided into 50ms long bins, was centered around the point in which target looks started to increase when all conditions are collapsed together, based on a *Grand Mean* plot. We then fit a linear mixed model including CONDITION as fixed factor, TIME as covariate with linear and quadratic polynomials, LANGUAGE SCORE and MEMORY SCORE as additional continuous covariates (without group splitting) and an intercept for the random effect of subjects. As in the model for the accuracy data, all the terms that contain an interaction between LANGUAGE and MEMORY were included as well, due to the lack of correlation between the two measures. The inclusion of a quadratic term for TIME

was justified by a comparison to a model with a linear term only ($\chi 2 = 726.3$, difference in Df = 12, $p < 0.001$).

The main effect CONDITION was significant for both comparisons, but in opposite directions: PTL in the OR+1pro condition were significantly greater than those in the OR+2DP condition (coef = −0.82, SE = 0.03, t = −30.88); PTL in the OR+2DP condition were significantly greater than those in the OR+3pro condition (coef = −0.25, SE = 0.03, t = −9.46). These effects mean that children looked to the target in OR+1pro trials overall longer than in OR+2DP trials, and in these longer than in OR+3pro trials. The former effect reflects what we find in the accuracy data, but the advantage of OR+2DP over OR+3pro in terms of eye-gaze is absent in the accuracy data. Both the main effect of LANGUAGE (coef = 0.06, SE = 0.03, t = 1.98) and the main effect of MEMORY (coef = 0.09, SE = 0.05, t = 1.87) were only marginally significant. Also the interaction LANGUAGE by MEMORY was not statistically significant (coef = 0.07, SE = 0.04, t = 1.73). Most importantly, all the four-way interactions were significant. For the comparison OR+1pro vs. OR+2DP, the interaction TIME by CONDITION by LANGUAGE by MEMORY was significant (for the quadratic term of TIME: coef = 3.88, SE = 1.82, t = 2.13). This effect reflects the pattern observed in the two middle and the two left panels of **Figure 2.3**. No individual differences in language and memory emerge in the performance on the OR+1pro condition, whereas differences do emerge in the OR+2DP condition depending on language and memory scores. Also for the comparison OR+2DP vs. OR+3pro, the interaction TIME by CONDITION by LANGUAGE by MEMORY was significant (for the linear term of TIME: coef = 8.41, SE = 1.80, t = 4.66; for the quadratic term of TIME: coef = −6.39, SE = 1.76, t = −3.63). This effect reflects what we see in the two middle and the two right panels of **Figure 2.3**. When language score is low, the gaze pattern in the two conditions is the same independently of the memory score. But when language score is high, the differences between high-memory and low-memory children are more pronounced in the OR+3pro condition than in the OR+2DP condition: only in the latter the low-memory children eventually look to the target like their high-memory peers, albeit later.

2.3.3. *Looks to distractor*

Before discussing the results, let us examine the pattern of children's looks to the distractor animal. Recall that, in their off-line responses on incorrect trials, children named the color of the distractor animal, never that of the middle animal. **Figure 2.4** shows, for each of the three conditions, the proportion of distractor looks in children with high and low scores on the memory tests, broken by their language scores (again, we plot here the partial effects; the corresponding plot showing the observed data is provided in the online supplementary material). As expected, and reflecting children's off-line responses, on the OR+1pro condition their looks to the distractor are very low. By contrast, on the OR+2DP and OR+3pro conditions, the proportion of distractor looks throughout the critical time window is very high, mostly for children with lower memory scores. That is, children's errors were expressed by their systematic (off-line as well as on-line) interpretation of the OR as a SR, treating the DP head as the subject rather than the object of the embedded clause. This pattern of error is typically found in studies on children's comprehension of relative clauses.

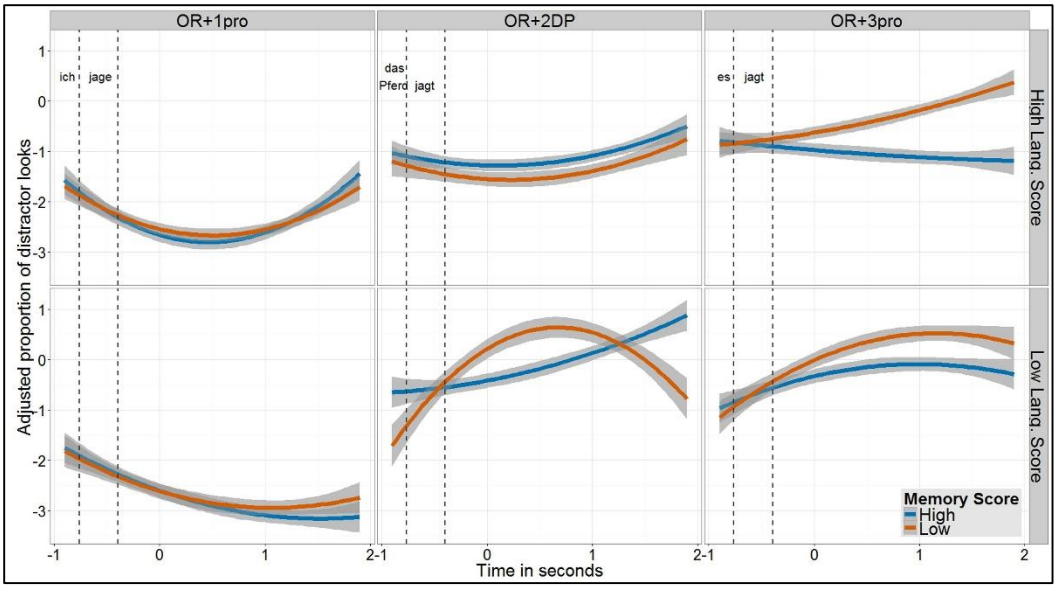


FIGURE 2.4. Proportion of looks to the distractor figure (transformed to empirical logit and adjusted after the removal of individual differences) within the time window relevant for analysis, shown separately for each condition, divided by children's score on the memory tests (blue line = High Score; orange line = Low Score) and broken by their score on the language tests (top row = High Score; bottom row = Low Score). On the x-axis Time ranges from the offset of the relative pronoun until the end of the 2-seconds long silence that followed the sentence. Two vertical dashed lines mark the critical chunks in the analysis window: (1) embedded subject DP (*ich* 'I'; *das Pferd* 'the horse'; *es* 'it'); (2) embedded verb (*jage*/*t* 'chase/s'); (3) post-sentential silence.

2.4. DISCUSSION

The aim of the study was to test the effects of various pronoun types on children's processing of ORs. We took as reference condition ORs with a full DP head and an embedded full DP subject, which are typically hard for children, and manipulated the embedded subject using personal pronouns. The three OR types were structured with a masculine noun as DP head, which had the advantage of facilitating, at least potentially, children's comprehension. This was achievable due to the possibility to recognize the

sentence as an OR rather early in the sentence, upon processing the accusative Case marking on the relative pronoun (*den*). There is evidence from previous studies on relative clause comprehension in German (Arosio et al., 2012) that children are facilitated when the relative clause (whether a SR or an OR) is disambiguated by case (as in our stimuli), as compared to when it is disambiguated by a singular or plural Number marking on the embedded verb (in our stimuli, the verb was always marked with singular). Another characteristic of the three conditions we tested is that they differ with respect to the referring expression in the embedded subject position–full DP, 1st- or 3rd-person pronoun. We therefore expect these referring expressions to trigger effects in task performance, if their referential properties play a role in determining OR processing. The initial prediction, as made by Friedmann et al. (2009) and by other accounts, is that ORs with embedded pronominal subjects are more accurately comprehended than ORs with two full DPs, independently of the pronoun type. Our findings support this prediction only partially.

First, we find that children are more accurate on ORs with an embedded 1st-person pronoun than ORs with two full DPs, both in terms of off-line accuracy and in terms of on-line eye-gaze, where we find more target looks in the OR+1pro than in the OR+2DP condition. This finding supports the initial prediction. It is also in line with other studies, both with children and with adults, showing that a 1st- or 2nd-person pronoun in the embedded subject position makes the OR easier to process (Gordon et al., 2001; Warren and Gibson, 2002, 2005; Arnon, 2010).

We also find that ORs with 1st-person pronoun are more accurately processed (again, both off-line and on-line) than ORs with 3rd-person pronoun. This result is not in line with the RM account, since the prediction is that different pronoun types in the embedded subject position facilitate ORs to an equal extent. The reason is that in both cases the full DP head, which contains the [+NP] feature, crosses an intervening pronoun, a constituent that lacks the [+NP] feature. This result appears to disagree also with other accounts that predict facilitated performance on ORs with an embedded pronoun, independently of the pronoun type (e.g., Gordon et al., 2001; Lewis et al., 2006). The pronoun asymmetry suggests that defining the (dis)similarity between the DP head and the embedded subject

DP only in terms of 'lexical restriction,' that is, in terms of a full DP vs. a personal pronoun, is not sufficient. This pronoun asymmetry is in line, however, with theoretical accounts on referential properties of pronouns (Heim, 1991; Recanati, 1993; Erteschik-Shir, 1997; Ariel, 2001; Legendre and Smolensky, 2012) as well as with previous experimental studies with adults. Both Warren and Gibson (2002) and Carminati (2005) found that the presence of a 1st-person pronoun facilitates adults' sentence processing more than the presence of a 3rd-person pronoun. These studies explain such an asymmetry in terms of the different referential properties of the pronouns. Since discourse referents of 1st-person pronouns are accessed directly, these pronouns are less costly for processing than 3rd-person pronouns, which need to be resolved via an antecedent (in the sentential or extra-sentential context), before the discourse referent of the pronoun is accessed. This is also the case in the present study: the discourse referent of the 3rd-person pronoun is accessed only after the pronoun has been resolved via an antecedent, which had to be retrieved from the linguistic context provided in the preamble video before the trial. Hence, the presence of the pronoun in itself does not necessarily facilitate OR processing. It seems that only pronouns that relate to their discourse referents directly, like 1st-person pronouns, do so[6]. The facilitation found by Friedmann et al. (2009) with Hebrew ORs containing an embedded arbitrary *pro* subject (example 6 in the *Introduction*) can be explained on similar terms. The Hebrew arbitrary *pro* is used when the agent of the action remains unspecified. It might well be that the facilitation was due to the discourse properties of *pro*–the fact that it does not relate to any specific discourse referent, thus reducing processing cost–rather than to its property of lacking the [+NP] feature, as suggested by the authors.

6 Recall that the middle animal in the visual scenes accompanying the OR+1pro condition was always the dog, the narrator. One reviewer pointed out that children's high performance on this condition might reflect their familiarity with this animal, rather than the effect caused by the pronoun itself. We have already addressed this issue in a follow-up study, yet to be published. Using similar material and methodology, we tested children on different types of relatives (SRs and ORs), in which the figure of the narrator appeared in various experimental conditions and in some fillers. In this setup, it was impossible to anticipate the type of sentence based on the visual presence of the narrator. Importantly, the results show that the 1st-person pronoun advantage over the 3rd-person pronoun persists, similarly to what we find in the present study.

A third pattern that emerges in the eye-gaze data is that ORs with a 3rd-person pronoun are actually harder for children than ORs with two full DPs. This finding is not in line with the prediction that any kind of pronoun in the embedded subject position facilitates OR comprehension (e.g., Gordon et al., 2001; Friedmann et al., 2009; Rizzi, 2013). It can be explained, again, if the referential properties of the referring expressions are taken into account. A 3rd-person pronoun can be interpreted only after it has been related to an antecedent, which needs to be located and retrieved from the linguistic or extra-linguistic context. This is not the case with a full DP, whose discourse referent is derived from its lexical meaning and accessed directly. Note that, just like in an OR with a 1st-person pronoun, also in an OR with 3rd-person pronoun the DP head crosses an intervening pronoun. The fact that the former condition is easier than the latter, compared to the baseline with two full DPs, supports further the claim that the presence of the pronoun on its own cannot account for children's performance. Rather, the type of pronoun–and more precisely, the referential properties of that pronoun–appear to play a major role in facilitating or not facilitating the processing of the OR.

Interestingly, Goodluck (2005, 2010) managed to separate intervention locality effects from complex discourse accessibility operations. Goodluck (2005) manipulated the discourse accessibility operation in object-extracted wh-questions by making it more demanding (*Which lion did the zebra kiss?*) or less demanding (*Which animal did the zebra kiss?*). Crucially, in both cases, the intervention locality effect was present (in both sentences, both the moved object DP and the intervening subject DP are lexically restricted). The fact that children were more accurate on the *which-animal* question than on the *which-lion* led the author to conclude that discourse accessibility determines children's performance on the structure independently of the syntactic complexity. This is reminiscent of what we find in the two pronoun conditions. Both in OR+1pro and in OR+3pro, the (reduced) syntactic complexity is kept constant due to the embedded pronoun. Therefore, children' higher accuracy rate on OR+1pro than on OR+3pro is likely due to the different referential properties of the pronouns. In other words, the direct discourse accessibility in the case of the 1st-person pronoun makes this condition easier

than the 3rd-person pronoun condition, in which discourse accessibility is indirect and therefore more demanding.

Note that the advantage of the OR+2DP condition over OR+3pro, in terms of main effect, is found only in the on-line eye-gaze data. An even more crucial finding is that the effects of memory only emerge in the on-line data, whereas they remain hidden when looking at the off-line accuracy data. These findings join a growing body of studies that show that children's performance sometimes appears different when tested by means of explicit or implicit responses. Specifically, measures of implicit processing (such as eye-tracking) often suggest that children accurately parse ORs even though their explicit performance on the same ORs remains poor (Adani and Fritzsche, 2015; see also discussion in Brandt-Kobele and Höhle, 2010). In the present study we show that children looked faster or longer to the target figure in conditions that they processed more accurately than in conditions that were harder for them. In other words, when children correctly processed a sentence their attention on the target figure was more stable in comparison to harder sentences.

These eye-gaze effects were found within the 2800ms long time window defined *a priori* for the analysis. A widespread assumption, supported by evidence from on-line processing studies with adults, is that such effects occur upon processing the embedded verb of an OR, the site in which the filler-gap dependency is resolved (e.g., Gibson, 2000; Gordon et al., 2001, 2002; Warren and Gibson, 2002; Lewis et al., 2006; O'Grady, 2011). Although Friedmann et al. (2009) do not make specific predictions regarding the exact point in which intervention effects occur, it seems they do so in subsequent work (Belletti et al., 2012), suggesting that intervention effects are detectable only when the two relevant DPs (the head noun and the embedded subject in an OR) are similar in terms of morphological features that are overtly marked on the embedded verb. Hence, it seems that also according to the RM account intervention effects in ORs are expected to occur at the embedded verb. This idea is entertained also in Franck et al. (2015).

Analyzing the eye-gaze data in the entire time window from the offset of the relative pronoun until the end of the post-sentential silence does not allow the detection of time-

locked effects. Nevertheless, it had several motivations and some evident advantages. First, the part of the sentence that precedes the relative pronoun, which was equal in the three conditions, is not informative enough to guide the participants toward the identification of the relevant referent. We therefore do not expect any gaze pattern prior to hearing the relative pronoun to be driven by the linguistic input. Second, processing the unambiguously accusative-marked relative pronoun is virtually enough to be able to identify the sentence as an OR and thus the correct referent. Even though we do not expect to find evidence for such rapid processing in 5-year-olds, the crucial point is that the relative pronoun is the first informative point in the sentence. Third, young children might be slow in processing the OR, and effects stemming from their eye-gaze might well emerge after the critical information has been processed. Several visual-world studies have even found effects occurring after the sentence ended (e.g., Brandt-Kobele and Höhle, 2010; Adani and Fritzsche, 2015). Crucially, the embedded verb in our stimuli is the last word in the sentence. Thus, post-sentential effects might be driven (also) by the filler-gap dependency resolution at the verb, as predicted, for instance, by Gibson (2000), Gordon et al. (2001, 2002), Warren and Gibson (2002), Lewis et al. (2006), O'Grady (2011) and other account. Finally, following Barr's (2008) analysis procedure, the inclusion of TIME as a continuous covariate appears to be more appropriate in a linear mixed-effects model analysis. The main reason is that the effect of time (the change in gaze pattern throughout the duration of the trial) is captured in its entirety, whereas by cutting it into chunks some information about the time course of the gaze pattern is lost.

Concerning language and memory abilities, we have looked at the role of children's memory capacity in their OR processing and at its relation to the role of their language skills. The goal was to test whether effects which are due to language and memory depend on each other or not and, if they do, in what manner. We had previously shown that, on the two harder conditions (OR+2DP and OR+3pro), children with stronger language abilities are significantly more accurate than children with weaker language skills (Haendler et al., 2015a). Given the linguistic material used in the three administered subtests, we reasoned that stronger language or grammatical skills meant a stronger ability to compute

movement-derived structures (subtests on sentences with canonical and non-canonical word order) and a stronger ability in discourse accessibility operations (subtest on reflexives and pronouns). It is therefore not surprising that children who had a higher average score on these tests were more accurate on ORs that were more difficult in terms of computing the syntactic movement (OR+2DP) and on ORs that were more difficult in terms of discourse accessibility (OR+3pro). On the OR+1pro condition, in which both the computation of the syntactic movement and discourse accessibility are facilitated, all children were accurate independently of their score on the grammatical tests.

In the present study, adding memory abilities to the picture reveals a more fine-grained pattern in the effects of language skills previously found. The analysis shows that language and memory have independent, additive effects that vary in relation to the experimental conditions. Children are most accurate on the OR+1pro condition, but neither their response accuracy nor their eye-gaze are influenced by individual differences in language and memory abilities. Individual differences in language and memory do affect, however, performance on the OR+2DP and OR+3pro conditions, but the effects of memory are observable only in the eye-gaze data, as mentioned earlier. Whether children with weaker grammatical skills have stronger or weaker memory does not seem to affect their performance substantially. By contrast, the gaze pattern of children with stronger grammatical skills clearly changes depending on their memory capacity. In the OR+2DP condition, low-memory (and high-language) children look to the target like their high-memory peers, but later, suggesting an accurate albeit delayed processing of the sentence. In the OR+3pro condition, low-memory (and high-language) children look to the target less than their high-memory peers up to the end of the trial, showing no evidence of correct processing of the sentence. **Table 2.1** summarizes these findings in a schematic way.

TABLE 2.1. A summary of the cases in which we find evidence for accurate processing (in terms of on-line target looks) of the different conditions, depending on language, and memory abilities.

		OR + 1pro	OR + 2DP	OR + 3pro
High-language	High-memory	YES	YES	YES
	Low-memory	YES	YES, but late	NO
Low-language	High-memory	YES	NO	NO
	Low-memory	YES	NO	NO

YES, there is such evidence; NO, there is no such evidence.

To account for these results, we will now explain what might cause the qualitative differences among the conditions and how language and memory abilities might play a role in creating the effects we find. The three conditions are similar in their syntactic structure, in the sense that they are all ORs in which the DP head moves from the embedded object position. Processing this movement, and resolving the filler-gap dependency, is assumed to be facilitated in the two pronoun conditions. According to the RM account, the syntactic complexity of OR+1pro and OR+3pro is reduced due to the attenuation of the intervention locality effect, since the full DP head crosses an intervening pronoun rather than another full DP (Friedmann et al., 2009; Rizzi, 2013). The syntactic complexity of ORs with pronouns is reduced also from the perspective of the integration cost metric account (Gibson, 1998, 2000; Warren and Gibson, 2002, 2005) and according to the *similarity-based* and *cue-based interference* approach (Gordon et al., 2001, 2002, 2004; Lewis and Vasishth, 2005; Lewis et al., 2006; Van Dyke and McElree, 2006, 2011). All these accounts argue that facilitated processing of ORs with embedded pronouns is due to reduced burden on memory resources (see also Sheppard et al., 2015). The three conditions differ, however, with respect to the referring expression in the embedded subject position: these referring expressions require different levels of processing cost in terms of discourse accessibility. The 1st-person pronoun and the full DP relate to their discourse referents directly, deriving them from their lexical meanings, whereas the 3rd-person pronoun relates to its discourse

referent indirectly, deriving it from the meaning of the antecedent to which it relates. This implies that referring expressions (such as 1st-person pronouns and full DPs) whose discourse referent is accessed directly overload memory resources less than referring expressions (such as 3rd-person pronouns) whose discourse referent has to be retrieved from the previously encoded context (Warren and Gibson, 2002; van Rij et al., 2013).

These syntactic and discourse characteristics of the conditions appear to explain the pattern we find in the data. In particular, they might account for the role of memory capacity and its additive effects to those of language skills. Language skills, as defined by the average score on the three language tests, appear to be the underlying constraint on children's performance. If children score low on these tests–in other words, if they are less proficient in processing movement-derived structures and in accessing discourse (these are the two relevant operations assessed by the language tests, as we have seen)–then we find no evidence for accurate processing of the two conditions that are hard either due to syntactic movement (OR+2DP, in which a full DP moves over another full DP) or due to discourse accessibility (OR+3pro, in which accessing the discourse referent of the 3rd-person pronoun is more demanding). It seems that, in the case of low-language children, some basic grammatical skills are weaker and therefore their memory capacity does not make any difference. Not surprisingly, even low-language children succeed on the OR+1pro condition, which is less demanding both in terms of its syntactic movement and in terms of discourse accessibility. But also here memory capacity does not make any difference: this condition is equally easy for all children independently of their memory skills. What happens in children who score high on the three language tests? Just like their low-language peers, they perform at ceiling on the easiest OR+1pro condition, independently of their memory capacity. A different pattern, modulated by memory, emerges in the two harder conditions (OR+2DP and OR+3pro). In OR+2DP, high-memory children correctly process the structure, whereas low-memory children do so as well, but rather late. In OR+3pro, there is evidence that only high-memory children correctly process the structure, whereas low-memory children are substantially less accurate.

Thus, memory capacity appears to be crucial when discourse accessibility is demanding (as when 3rd-person pronouns need to be resolved), but only if general linguistic abilities, such as computing syntactic movements and accessing discourse referents of pronouns and reflexives, are sufficiently strong. In the OR+2DP condition, in which retrieving the referent of a full DP is less costly, even low-memory children eventually look to the target, although later than their high-memory peers. In the OR+3pro condition, in which the retrieval of the referent of the 3rd-person pronoun is more costly, low-memory children do not catch up with their high-memory peers and there is no evidence that they accurately process the structure.

Our findings resemble, at least partly, those of Warren and Gibson (2002), who elaborate on the idea that memory resources are crucial for processing structures that require both filler-gap dependency resolution and accessing discourse referents of various referring expressions. These authors found the same asymmetry between 1st-person pronouns and 3rd-person pronouns, with the former facilitating OR processing more than the latter, an asymmetry which is explained in the light of Gibson's (1998, 2000) integration cost metric. According to the authors, the processing cost of a certain structure increases with the number of discourse referents that intervene between the filler and the gap site in which it is integrated. The reason is that each of the intervening discourse referents has to be integrated as well, thus reducing the memory resources available to process the structure. When one of the intervening discourse referents is a 1st-person pronoun, whose integration is done straightforwardly, the available memory resources are less burdened than in the case in which the intervening constituent is a 3rd-person pronoun, whose integration is more costly. Note, however, that in Warren and Gibson (2002) adults judged ORs with an embedded 3rd-person pronoun as less complex than ORs with two full DPs. This pattern is unlike what we find with children. In the present study, OR+3pro appears to be the condition on which memory has the strongest impact. Given that children's memory abilities are underdeveloped, compared to adults,' it is not surprising that children with weaker memory skills struggle while processing ORs with an embedded

3rd-person pronoun, even if their ability to perform on the language tests we used is already strong.

2.5. Conclusion

Our data support only in part a purely syntax-based account such as Friedmann et al.'s (2009), or the *similarity-/cue-based interference* accounts of relative clause processing. While we do find that an embedded 1st-person pronoun facilitates OR processing, we also find that an embedded 3rd-person pronoun does not. It appears that OR processing is constrained not only by the syntactic complexity of the structure, but also by the referential properties of the involved constituents. Both require memory resources and might thus determine difficulties in processing the OR, as has been suggested for adults. The results suggest that both language and memory abilities play a role in modulating these syntactic and discourse accessibility constraints, and that they do so in an independent, additive fashion.

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Supplementary material

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CHAPTER 3

PRONOUN FACILITATION IN RELATIVE CLAUSE PROCESSING: CONTRASTING DIFFERENT APPROACHES

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ABSTRACT

Unlike subject relative clauses, object relatives are easier to process when the embedded constituent is a pronoun. This pronoun facilitation is stronger with 1st-person than with 3rd-person pronouns, an asymmetry attributed to the cognitive demand associated with discourse accessibility, defined as the level of ease or difficulty in identifying a pronoun's referent. Evaluating the predictions of different theoretical approaches, we test the effects of embedded 1st- and 3rd-person pronouns on relative clause processing. Italian subject and object relatives with identical word order were used for a more controlled analysis. Data from two experiments (eye-tracking and self-paced reading) with adults and 5-year-olds, pitted against the outcome of a corpus analysis, indicate that both relative clause types are equally affected by the pronoun asymmetry. The results support a structure-discourse approach according to which processing cost is modulated by the number, and discourse

accessibility, of referents that need to be integrated while a long-distance dependency is being processed.

3.1. INTRODUCTION

Within the vast literature investigating the well-known subject-object asymmetry in relative clauses, a particular line of research has looked at how embedded pronouns affect relative clause processing, both in adults (Gordon et al., 2001; Heider et al., 2014; Kaan, 2001; Mak et al., 2008; Reali & Christiansen, 2007; Warren & Gibson, 2002) and in children (Arnon, 2010; Brandt et al., 2009; Brandt et al., 2016; Friedmann et al., 2009; Kidd et al., 2007; Lassotta et al., 2015). Processing difficulties with object relatives (1b), as compared to subject relatives (1a), are widely attested when both the head noun (*The man*) and the embedded noun (*the actor*) are lexical noun phrases. However, when the embedded constituent is a pronoun, this subject-object asymmetry disappears and object relatives (2b) become easy to process as much as, or even more than, subject relatives (2a).

(1) a. The man that __ encountered the actor has crossed the street.
b. The man that the actor encountered __ has crossed the street.

(2) a. The man that __ encountered you has crossed the street.
b. The man that you encountered __ has crossed the street.

Different theoretical accounts can explain why embedded pronouns facilitate the processing of object relatives, but not of subject relatives. According to *similarity-based approaches* (e.g., Gordon et al., 2001; Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & McElree, 2006; 2011; see also Belletti et al., 2012 and Friedmann et al., 2009), the head noun of an object relative (*The man*) is encoded in memory until the embedded verb (*encountered*) is encountered. At this point the head noun is retrieved from memory and the long-distance dependency is resolved. The appearance of intermediate constituents (*the actor*/*you*) before the dependency resolution makes processing harder, if the intermediate

constituent bears retrieval cues that are similar to those of the head noun. At the retrieval site–the embedded verb–this similarity in cues triggers an interference effect in memory. The interference is reduced in the case of an embedded pronoun (2b), whose retrieval cues are sufficiently different from those of a lexical noun phrase. In subject relatives there is no interference in memory, since the long-distance dependency is resolved before the embedded constituent is encountered. Hence, the embedded pronoun should not affect subject relative processing.

Discourse-based approaches (e.g., Fox & Thompson, 1990; Kaan, 2001; Mak et al., 2008) highlight the role of discourse-related factors underlying the usage and processing of relative clauses. Object relatives are typically used to describe a discourse-new entity (the head noun) whereas the embedded noun phrase, which is the subject of the embedded clause, is used to refer to a discourse-old entity. Since pronouns typically refer to previously mentioned subjects (Fukumura & van Gompel, 2015; Gordon & Hendrick, 1998; Song & Fisher, 2005), the appearance of the pronoun in the embedded subject position of an object relative is preferred and its processing is therefore facilitated. By contrast, the head noun of subject relatives is typically a discourse-old entity, whereas the embedded object refers to a discourse-new one. An embedded object pronoun in a subject relative clause would violate this assumption, resulting in increased processing cost.

According to *experience-based approaches* (Brandt et al., 2009; Kidd et al., 2007; MacDonald, 2013; Reali & Christiansen, 2007; Roland et al., 2012), the frequency of occurrence of certain linguistic structures plays a prominent role in sentence processing. Corpus analyses (Heider et al., 2014; Reali & Christiansen, 2007; Roland et al., 2012) show that object relatives are mostly used with an embedded pronoun, whereas subject relatives are mostly used with an embedded lexical noun phrase. Under the assumption that sentence processing is affected by distributional properties exhibited in language production (MacDonald, 2013; Hsiao & MacDonald, 2016), this asymmetry is expected to be reflected during relative clause processing. Therefore, when the embedded constituent is a lexical noun phrase subject relatives should be easier than object relatives, but the reversed pattern is predicted when the embedded constituent is a pronoun.

Finally, some studies adopt a combination of more than one of these ideas in order to explain the pronoun effects. Heider et al. (2014) suggest that processing difficulties at different points in the sentence arise for different reasons. If the embedded subject is a lexical noun phrase, difficulties at this point reflect the parser's dashed expectation to find a pronoun, given the frequency or discourse factors. By contrast, difficulties at the relative clause verb reflect memory interference due to the fact that both the head noun and the embedded subject are lexical noun phrases.

Another hybrid approach is the *Storage and Integration Cost Metric* (Warren & Gibson, 2002), based on Gibson's (1998; 2000) *Dependency Locality Theory*. According to this approach, factors related to structural complexity and to discourse status combine to determine relative clause processing. Specifically, the processing of long-distance dependencies is modulated by the memory load associated with the storage and integration of discourse referents in a given sentence. Due to limited memory capacity, processing load increases with each newly introduced referent that appears between a displaced constituent (*The man*, in examples 1b and 2b) and the embedded verb (*encountered*), where the long-distance dependency is resolved. When an intervening constituent introduces a new discourse referent (*the actor*, in 1b) processing is more costly. But when the intervening referent is discourse-old or highly salient, as pronouns' referents typically are (2b), processing is facilitated. The hybrid aspect of this approach lies in the relation between structural complexity, measured by the number of referents that remain to be processed, and the discourse status of these referents, measured by the level of ease or difficulty with which they are accessed in the discourse context and integrated into the structure. For simplicity, we will term this approach the *structure-discourse approach*.

In the present study, we test the effects of embedded pronouns on relative clause processing. We use a more controlled experimental design, compared to previous studies, and contribute novel results that are best explained by the *structure-discourse approach*. We address several issues that were left open in previous research. We ask whether embedded pronouns affect the processing not only of object relatives, but also of subject relatives, and if yes in what manner. Moreover, we ask whether pronoun effects in subject

and object relatives depend on the type of pronoun that is used, specifically in relation to the discourse properties of the pronoun. In addition, we extend previous research on the topic by comparing the performance of young children and adults.

3.1.1. *Comparing pronoun effects in subject and object relatives*

Whereas all the approaches reviewed above predict object relatives to be easier when the embedded constituent is a pronoun, there is no agreement concerning the effect of embedded pronouns on subject relatives. The *similarity-based approach predicts* that an embedded pronoun should have no effect on the processing of subject relatives, since it does not appear between the head noun and the embedded verb. By contrast, the *experience-* and *discourse-based approaches* predict subject relatives with an embedded pronoun to become hard, either because they are less frequent or due to the increased processing cost of pronouns that refer to objects.

Experimental findings so far have been mixed. In a complexity rating task, Warren & Gibson (2002) found that the comprehension of subject relatives was not influenced by whether they contained a pronoun or not; they were always rated as less complex than object relatives. Importantly, however, the subject and object relatives in this study were not entirely comparable. Object relatives were doubly nested and the pronoun was the embedded-most subject (3); by contrast, subject relatives were right-branching and the pronoun was not embedded within the relative clause (4).

(3) The old lady who the government assistance program which <u>you</u> praised had saved did not have enough money to heat her house.

(4) <u>You</u> praised the government assistance program which had saved the old lady who did not have enough money to heat her house.

Other studies found that subject relatives with an embedded pronoun are actually harder than analogous object relatives. Both Reali & Christiansen (2007) and Roland et al. (2012) found that reading times at the two words following the complementizer *that* (underlined in examples 5a-b) were faster when the sentence was an object relative (5b), as compared

to a subject relative (5a). The same result was found also when the pronoun was 2nd-person (*you*) or 3rd-person (*they*).

(5) a. The lady that visited me enjoyed the meal.
b. The lady that I visited enjoyed the meal.

Mak et al. (2008) tested similar sentences in Dutch, using a plural 2nd-person pronoun that is case- and number-ambiguous (*jullie* 'you'). They found that subject relatives were harder to process than object relatives, as indicated by slower reading times at the lexical verb (*heeft*/*hebben* in examples 6a-b). When the pronoun was unambiguously case- and number-marked (*wij*/*ons* 'we/us') the object relative advantage was evident already at the second word following the pronoun region (*het* in examples 7a-b).

(6) a. … de hardloper, die jullie in het park gegroet heeft …
the jogger who you-PL in the park greeted has
'… the jogger, who has greeted you in the park, …'

b. … de hardloper, die jullie in het park gegroet hebben …
the jogger who you-SG in the park greeted have
'… the jogger, whom you have greeted in the park, …'

(7) a. … de hardloper, die ons in het park gegroet heeft …
the jogger who us in the park greeted has
'… the jogger, who has greeted us in the park, …'

b. … de hardloper, die wij in het park gegroet hebben …
the jogger who we in the park greeted have
'… the jogger, whom we have greeted in the park, …'

Finally, some studies do not find any reliable difference between the processing of subject relatives with an embedded pronoun and analogous object relatives. Tested on subject relatives with a 1st-person pronoun (Arnon, 2010) or a 3rd-person pronoun (Brandt et al., 2009), children were as accurate as on object relatives with the same embedded pronouns. As for adults, Kaan (2001) found no reliable difference in reading times of

subject and object relatives like the ones in examples (6a-b). Similarly, Gordon et al. (2001) tested sentences like (5a-b) with the 2nd-person pronoun *you*, finding no difference in reading times at the verb of the matrix clause between subject and object relatives.

The inconsistency of the results concerning pronoun effects in subject relatives might be due to the usage of different tasks and/or material across experiments. For instance, the discrepancy between Kaan's (2001) and Mak et al.'s (2008) findings, despite their usage of similar sentences, was left unexplained. Another plausible explanation for the different results across studies is related to word order properties of English, the language used in most of these studies. In English, word order is a reliable indicator for the identity of a relative clause as a subject or an object relative, whether with or without a pronoun. When a relative pronoun (*who*) or a complementizer (*that*) is encountered the parser can try to predict, based on the following word, whether the structure is a subject or an object relative. As a consequence, there is no consensus as to where to measure effects in such sentences. For instance, Gordon et al. (2001) measured reading times at the verb of the matrix clause (*enjoyed*, in 5a-b), which was always the first word following the relative clause. Claiming to propose an improved analysis, Reali & Christiansen (2007) measured the effect in the region comprising the embedded pronoun and the embedded verb (underlined words in examples 5a-b). Whether analyzing this region is indeed preferred remains controversial, though, as we will go on to explain.

The data presented for the pronouns *you* (Reali & Christiansen, 2007; Figure 3 on page 10), I (Figure 5 on page 12) and they (Figure 7 on page 14) suggest that the effect found by these authors is mainly driven by shorter reading times at the first word of object relatives (*I* in 5b), as compared to the same word position in subject relatives (*visited* in 5a). But this effect might merely reflect the fact that pronouns are read faster than verbs, since they are short words on which relatively little processing time is spent. The shorter reading times at the second word of the object relative (*visited* in 5b) might therefore be a spill-over effect from the preceding word. Hence, it is not clear why this analysis is preferable to Gordon et al.'s (2001). In fact, at the matrix verb both studies found the same result, namely no difference between subject and object relatives with the same embedded

pronoun. Moreover, the role of word order in relative clause processing in English makes it hard to explain, based on the experience-based approach, the finding that the object relative advantage occurs already at first word following the complementizer *that*. In subject relatives, the first word after the complementizer is typically a verb, whether the embedded constituent is a pronoun or not. Given that the frequency of subject relatives without an embedded pronoun is as high as the frequency of object relatives with an embedded pronoun (Reali & Christiansen, 2007), the reader should not have more processing difficulties upon encountering the verb *visited* in (5a) than upon encountering the pronoun *I* in (5b). This supports the idea that the difference simply reflected faster reading times for the pronouns than for the verbs.

An additional general problem related to word order is that subject relatives display the more common arguments order in English, Agent-Verb-Patient, whereas the order of Patient-Agent-Verb in object relatives is less common. Thus, difficulties in processing object relatives might also be related to encountering an uncommon arguments order, assuming that the language parsing system relies to some extent on a heuristic strategy such as *agent-first*, according to which the first encountered noun is presumed to be an agent (Adani & Fritzsche, 2015; Jackendoff & Wittenberg, 2014). Particular effects in relative clause processing, like those of embedded pronouns, might thus be confounded with effects that are driven by the commonness of arguments order.

To address these word order issues we used Italian. Similar to English, Italian subject and object relatives with an embedded lexical noun phrase have different word order. However, when the embedded constituent is a pronoun subject relatives (8) and object relatives (9) display the same word order: the object pronoun in subject relatives and the subject pronoun in object relatives occupy the same pre-verbal position. Therefore, the comparison of effects that occur at and after the pronoun is more appropriate than in English. Another characteristic of these Italian sentences is that the arguments order is non-canonical both in subject relatives (Subject-Object-Verb) and in object relatives (Object-Subject-Verb). Thus, in these sentences the parser cannot rely on the commonness of arguments order. These characteristics make the comparison between subject and object

relatives in Italian more reliable, and they allow a better interpretation of the effect of embedded pronouns.

(8)	La signora	che	mi	ha visitato	ha preparato	la	cena.
	the lady	that	me	has visited	has prepared	the	dinner

'The lady that visited me prepared the dinner.'

(9)	La signora	che	(io)	ho visitato	ha preparato	la	cena.
	the lady	that	(I)	have visited	has prepared	the	dinner

'The lady that I visited prepared the dinner.'

3.1.2. *Comparing different types of pronouns*

In assessing the effect of pronouns on relative clause processing, a central question is whether these effects depend on the type of embedded pronoun or not. Pronouns differ, among other things, in the way in which they establish reference (Ariel, 1990; 2001; Chafe, 1987; Erteschik-Shir, 1997; Köder & Maier, 2016; Recanati, 1993). Referents of 1st- and 2nd-person pronouns (the speaker and the hearer, respectively) are identified more straightforwardly than referents of 3rd-person pronouns. The latter can be correctly interpreted only if their referents are known to all the participants engaged in the linguistic act (e.g., conversation), and they need to satisfy certain assumptions, such as being uniquely identifiable and salient (Ariel, 2001; Gundel et al., 1993).

There is reason to postulate that linking a given pronoun to its referent–a process that we will term *discourse accessibility* (following Haendler et al., 2015b)–is a cognitive operation whose cost reflects the type of pronoun-referent linking. In other words, 1st- or 2nd-person pronouns are expected to burden processing to a lesser extent than 3rd-person pronouns because of their different discourse accessibility mechanisms. This prediction is supported by experimental findings showing that adults' reading times are faster when the sentence contains a 1st-person pronoun, as compared to an analogous sentence with a 3rd-person pronoun (Carminati, 2005).

In relative clauses, however, the comparison of pronouns with different discourse accessibility mechanisms has been scarce so far. Many of the studies that tested relative

clauses with pronouns looked at only one pronoun type: 1st-person (Arnon, 2010; Brandt et al., 2016; Roland et al., 2012), 2nd-person (Gordon et al., 2001) or 3rd-person (Brandt et al., 2009; Friedmann et al., 2009; Heider et al., 2014; Kaan, 2001; Lassotta et al., 2015). Some studies tested more than one type of pronoun, but they were not designed to compare their effects (Reali & Christiansen, 2007; Mak et al., 2008 tested 1st- and 2nd-person pronouns, whose discourse accessibility properties are assumed to be similar). Two studies, however, did look specifically at the difference between 1st- and 3rd-person pronouns in relative clause processing, one in adults (Warren & Gibson, 2002) and one in children (Haendler et al., 2015b). Both found that object relatives whose embedded subject is a 1st-person pronoun are processed more accurately than comparable object relatives with an embedded 3rd-person pronoun. In both studies, the 1st-/3rd-person asymmetry was interpreted as due to the difference in processing cost that is driven by the pronouns' discourse accessibility mechanism.

Crucially, however, this pronoun asymmetry can be explained also by experience-based approaches. Corpus analyses in English show that object relatives with an embedded 1st-person pronoun occur more frequently than with a 3rd-person pronoun (Heider et al., 2014; Reali & Christiansen, 2007). By using subject and object relative with a similar word order and testing the effects of both 1st- and 3rd-person pronoun on them, we can tease apart the frequency explanation from the discourse accessibility one, based on the predictions of these approaches. This point will become clear in the last section of the *Introduction*, and when discussing the results of the corpus analysis (cf. *Experiment 1*).

Concerning the comparison of 1st- and 3rd-person pronouns, we introduce another improvement with respect to previous studies. Since pronouns have different discourse accessibility properties, their effects can be properly compared only when the context in which the referents appear is controlled. In previous studies different types of contexts were used. In Reali & Christiansen (2007), the relative clauses with 1st- and 2nd-person pronouns were introduced without a context (which, in itself, is appropriate, given that these pronouns do not necessarily require a preceding context). By contrast, the referent of the 3rd-person pronoun was introduced in a context within the same sentence (*According*

to the Taylors, the landlord that they telephoned offered a nice apartment), whereas the referent of the impersonal 3rd-person pronoun *it* was provided in a separate sentence (*The research was very illuminating. The studies that motivated it converged to similar results*). Also Warren & Gibson (2002) used different contexts across conditions. If different contexts are given within or outside the test sentence, or if there is no context at all, effects related to memory load might emerge when the pronoun is encountered and interpreted. This makes the comparison across conditions problematic. To avoid this problem, in our experiments each sentence was preceded by a context that appeared before the sentence and introduced the referent of the pronoun, be it 1st- or 3rd-person.

3.1.3. *Comparing adults and children*

As mentioned above, the 1st-/3rd-person pronoun asymmetry in object relative processing was found both in adults and children. Despite the affinity in the results, these studies did not directly compare adults and children on the same task. Hence, little can be said about whether pronoun discourse accessibility affects adults' and children's processing similarly or not. We find it important to make such a comparison in the light of a body of research supporting the so-called *Continuity Hypothesis*. This term conveys the idea that there is a continuity between children's and adults' sentence processing, meaning that they process language in a qualitatively similar manner (Adani & Fritzsche, 2015; Contemori & Marinis, 2014; Felser et al., 2003; Love, 2007; Roberts et al., 2007; Trueswell & Gleitman, 2007). In fact, young children appear to be generally sensitive to discourse-related factors that affect sentence processing, like the felicity of a given discourse-pragmatic context (Thomsen & Poulsen, 2015). Concerning pronouns, there is evidence that children from early on attend to discourse characteristics that constraint the usage of pronouns, like cognitive accessibility to the referent, its prior mention and salience (Allen et al., 2015; Hartshorne et al., 2015; Pyykkönen et al., 2010; Song & Fisher, 2005). It is therefore highly important to test adults and children using the same task and material, in order to determine whether their processing strategies differ, and if they do to what extent.

3.1.4. *The present study – predictions*

To test how the processing of subject and object relatives is affected by embedded pronouns with different discourse accessibility mechanisms, we look at the following four types of sentences: subject relatives with a 1st-person pronoun (10) or with a 3rd-person pronoun (11), and object relatives with a 1st-person pronoun (12) or with a 3rd-person pronoun (13).

(10) Il cavallo che **mi** sta lavando.
the horse that me is washing
'The horse that is washing me.'

(11) Il cavallo che **la** sta lavando.
the horse that her is washing
'The horse that is washing her.'

(12) Il cavallo che **io** sto lavando.
the horse that I am washing
'The horse that I am washing.'

(13) Il cavallo che **lei** sta lavando.
the horse that she is washing
'The horse that she is washing.'

The predictions of each of the theoretical approaches are as follows. For the *similarity-based approach* the typical subject-object asymmetry is expected, with object relatives being harder than subject relatives, even though the Italian sentences have the same word order. In object relatives, both the head noun (*The horse*) and the embedded pronoun (*I*/*she*) function as grammatical subjects. The fact that this retrieval cue is shared by both constituents is expected to increase interference in memory and make the sentence harder (Nicenboim et al., submitted; Van Dyke, 2007). In subject relatives, differently from the head noun, the embedded pronoun functions as a grammatical object. Thus, the interference effect in subject relatives is expected to be smaller. Concerning the 1st-/3rd-person pronoun asymmetry, current models in this approach do not take into account differences in terms

of discourse accessibility. But the Person cue might play a role: in (12) the head noun is marked as [+3rd-person] and the embedded pronoun as [+1st-person], whereas in (13) the person-marking is [+3rd-person] on both constituents. Thus, there should be stronger interference in (13), making object relatives with an embedded 3rd-person pronoun harder than those with a 1st-person pronoun.

Both the *discourse-based* and the *experience-based approaches* predict subject relatives with pronouns (10)-(11) to be harder than object relatives with the same pronouns (12)-(13). Concerning the 1st-/3rd-person asymmetry, the experience-based approach makes predictions depending on the distribution of such sentences in the language. If the pattern is like in English, with object relatives appearing more often with a 1st- than with a 3rd-person pronoun, we will expect the former to be easier than the latter. We will report the results of a corpus analysis based on which these predictions will be formulated.

Finally, the *structure-discourse approach* predicts no difference between Italian subject and object relatives. The reason is that word order is identical in both sentence types and the distance between the head noun and the finite verb (*sta*/*sto*), where the long-distance dependency is resolved, is the same. As for the 1st-/3rd-person asymmetry, the prediction is that 1st-person pronouns should facilitate processing more than 3rd-person pronouns, due to the less costly discourse accessibility mechanism of the former type of pronoun. This pronoun asymmetry is therefore predicted to emerge both in subject and in object relatives.

The four conditions (examples 10-13) were tested in an eye-tracking visual-world experiment with 5-year-old children and adults. We then conducted a follow-up self-paced reading experiment with adults that allowed a more precise testing of the predictions. But first we report the results of a corpus analysis that was carried out in order to determine the distribution of subject and object relatives with embedded pronouns in Italian.

3.2. EXPERIMENT 1: CORPUS ANALYSIS

Previous corpus analyses in English found that when the embedded constituent is a lexical noun phrase, subject relatives occur more frequently than object relatives. By contrast, object relatives outnumber subject relatives when the embedded constituent is a pronoun. This pattern holds when the pronoun is either 1st-, 2nd- or 3rd-person (Heider et al., 2014; Reali & Christiansen, 2007; see Arnon, 2010 for similar results in Hebrew; see also Roland et al., 2012). From Heider et al.'s and Reali & Christiansen's findings it also emerges that object relatives with a 1st-person pronoun are more frequent than object relatives with a 3rd-person pronoun. However, since this pronoun comparison was not in their focus of research it was not analyzed or tested. Here, we are interested first in the extent to which subject and object relatives occur with embedded pronouns in Italian. Second, we are interested in their distribution in relation to the Person marking on the pronoun. We will look at Italian corpora containing child speech as well as child-directed speech, assuming that they reflect the language to which children are exposed. Subsequently, we will formulate the predictions of experience-based approaches regarding adults' and children's performance on the experiment that will follow.

3.2.1. METHOD

We analyzed 8 Italian corpora in CHILDES (MacWhinney, 2000): Antelmi, Calambrone, D'Odorico, Klammler, Roma, Tonelli Elisa, Tonelli Gregorio and Tonelli Marco. For the identification of relative clauses, we used a method similar to Belletti & Chesi (2011). We first extracted all sentences with *che* 'that', and then selected only the ones in which *che* is used as a complementizer introducing a relative clause. We coded the relative clauses based on the properties that were relevant for our analysis: speaker (adults vs. children); type of relative clause (subject vs. object); type of embedded constituent (lexical noun phrase vs. pronoun); and in relative clauses with pronouns, the type of pronoun and Person marking.

3.2.2. RESULTS AND DISCUSSION

We extracted a total of 5542 utterances containing *che* 'that'. Of these, 1108 were identified as relative clauses. For subject relatives we also counted relatives in which the embedded verb was a copula (e.g., *I bimbi che sono bagnati* 'The children who are wet', child production, age 1;11) and subject relatives in the passive voice (e.g., *Uno che non è stato mai gonfiato* 'One that has never been inflated', adult production). The division between the two relative clause types shows that both populations produce subject relatives significantly more than object relatives. For the adults there were 708 subject relatives and 300 object relatives (χ^2>100, p<.001); for children 85 subject relatives and 15 object relatives (χ^2=78.42, p<.001).

Next, we divided the relative clauses based on two types of embedded constituents that are relevant for our purpose: either a pronoun (specifically, one of four types of pronouns) or a lexical noun phrase. Other expressions that are irrelevant here (e.g., a proper name) were excluded, leaving us with 504 utterances. The distribution based on the type of embedded constituent is summarized in **Table 3.1**. Adults produce subject relatives with an embedded lexical noun phrase significantly more than with a pronoun (χ^2=89.81, p<.001). By contrast, their object relatives more often have embedded pronouns rather than embedded lexical noun phrases, a difference that is also significant (χ^2>100, p<.001). Although children produce overall less relative clauses than adults, the same pattern emerges. Children's subject relatives mostly have an embedded noun phrase, rather than a pronoun (χ^2=12.46, p<.001), and the opposite is true for their object relatives (χ^2=5.33, p=.02). So far, the two patterns that we find–the higher frequency of subject relatives as compared to object relatives, and the asymmetry with respect to the type of embedded constituent–correspond to the findings of previous corpus analyses, whether in Italian (Belletti & Chesi, 2011) or in other languages (Arnon, 2010; Diessel & Tomasello, 2000; Heider et al., 2014; Reali & Christiansen, 2007).

TABLE 3.1. Number of uttered subject and object relatives, divided by the type of embedded constituent.

Relative clause type	Embedded constituent		Adults	Children
Subject relatives	Pronoun	Demonstrative	1	0
		Overt pronoun	1	0
		Null pronoun	0	0
		Clitic	28	4
	Lexical noun phrase		163	22
Object relatives	Pronoun	Demonstrative	1	0
		Overt pronoun	40	1
		Null pronoun	183	9
		Clitic	0	0
	Lexical noun phrase		49	2

In the next step we looked only at relative clauses with embedded pronouns (34 subject relatives and 234 object relatives), dividing the pronouns based on their Person marking. The numbers are reported in **Table 3.2**. This division reduces substantially the amount of data we have from children since, as we have seen, children produce more subject relatives, which tend to be without an embedded pronoun. Therefore, only the data from adults can be submitted to a statistical analysis.

TABLE 3.2. Number of uttered subject and object relatives with an embedded pronoun, divided by the type and Person marking of the pronoun.

Relative clause type	**Pronoun type**	**Adults**			**Children**		
		1st-person	**2nd-person**	**3rd-person**	**1st-person**	**2nd-person**	**3rd-person**
Subject relatives	Demonstrative	0	0	1	0	0	0
	Overt pronoun	0	0	1	0	0	0
	Null pronoun	0	0	0	0	0	0
	Clitic	2	6	20	3	0	1
	Total:	**2**	**6**	**22**	**3**	**0**	**1**
Object relatives	Demonstrative	0	0	1	0	0	0
	Overt pronoun	15	23	2	0	1	0
	Null pronoun	36	111	36	4	1	4
	Clitic	0	0	0	0	0	0
	Total:	**51**	**134**	**39**	**4**	**2**	**4**

As can be seen, in most of the subject relatives with pronouns produced by adults, and in all of those produced by children, the embedded pronoun is a clitic. In object relatives, the pronoun is a null pronoun in most of the cases (e.g., *Ecco, ci sono tutti gli animaletti che conosci* 'There you go, here are all the animals that (you) know'), but there are also numerous object relative with an embedded overt pronoun, in many of them the pronoun appears in a post-verbal position (e.g., *E qui c'hanno l'albero come quello che c'avevi te* 'And here they have a tree like the one that you had').

Concerning the Person marking, the data from adults reveal that in subject relatives the clitic is mostly 3rd-person. The difference between subject relatives with 1st- and with 3rd-person clitics, which is relevant for our next experiment, is significant (χ^2=16.67, p<.001). It is also in line with other findings on Italian clitics (Bellucci & Lorusso, 2015) and on English subject relatives with embedded pronouns (Heider et al., 2014). In object relatives, the embedded pronoun is mainly 2nd-person, followed by 1st-person and then by 3rd-person. The higher frequency of 1st- vs. 3rd-person pronouns in object relatives results as

non-significant (χ^2=1.6, p=.21). Nevertheless, it corresponds to findings in English by Heider et al. (2014) and Reali & Christiansen (2007).

In light of the corpus analysis, whose results are generally similar to previous ones, we can formulate the predictions of the *experience-based approach* concerning adults' and children's performance in the experimental task. First, object relatives with pronouns should be easier to process than subject relatives with pronouns (Heider et al., 2014; Mak et al., 2008; Reali & Christiansen, 2007; Roland et al., 2012). Second, concerning the comparison of 1st- and 3rd-person pronouns, we would expect to find an interaction between relative clause type and pronoun type. Subject relatives with a 3rd-person pronoun are expected to be easier to process than subject relatives with a 1st-person pronoun. For object relatives the opposite pattern is expected.

3.3. EXPERIMENT 2: EYE-TRACKING EXPERIMENT WITH CHILDREN AND ADULT CONTROLS

The test sentences in the eye-tracking experiment (examples 10-13) were constructed to suit young children. These four conditions were interspersed among sentences which are not relative clauses, as well as subject and object relatives with an embedded lexical noun phrase (examples 14 and 15, respectively). These sentences were included in order to prevent participants from anticipating the type of the upcoming sentence.

(14) Il cavallo che sta lavando le pecore.
the horse that is washing the sheep.PL.
'The horse that is washing the sheep.PL.'

(15) I cavalli che la pecora sta lavando.
the horses that the sheep.SG is washing.
'The horses that the sheep is washing.'

In all the relative clauses there was a mismatch in Number between the head noun and the embedded constituent: either the head noun was singular and the embedded constituent

plural (as in example 14), or vice versa (15). The reason is that Italian subject relatives with two lexical noun phrases that match in Number are ambiguous. If the embedded noun phrase in (14), *le pecore*, were singular (*la pecora*) the sentence could be either a subject relative or an object relative with a post-verbal subject (Arosio et al., 2005; Adani, 2011). Such an ambiguous sentence is likely to be interpreted by adults as a subject relative clause, as suggested by a number of studies (Carminati et al., 2006; Nitschke et al., 2010). Children would probably do the same, given that the comprehension of object relatives with post-verbal subjects, even when they are unambiguous, emerges late in development (Adani, 2011). Nevertheless, in order to avoid such an ambiguity we constructed all the items with a Number mismatch. The mismatching Number is expected to facilitate children's performance, as compared to previous studies in which object relative with a Number match were used (Adani et al., 2010; 2014). But the pronoun effects we are interested in should emerge also within an overall high accuracy rate.

Another characteristic of our material that should be considered is the fact that in subject relatives the embedded pronoun is a clitic whereas in object relatives it is a strong pronoun. Various studies have shown that the acquisition of object clitics is delayed as compared to strong pronouns (Cardinaletti & Starke, 2000; Hamann, 2000; Pirvulescu & Strik, 2014; Schmitz & Müller, 2008). However, Varlokosta et al. (2016) found that 5-year-old Italian-speaking children produce clitics 90% of the times in contexts that require their usage. We therefore assume that our 5-year-old participants have already acquired the correct usage and comprehension of clitics.

Using strong pronouns in object relatives has discourse-related implications that are independent of discourse accessibility. Italian allows the omission of subjects, with whom the verb agrees both in Number and in Person (e.g., *Il cavallo che sto lavando* 'The horse that (I) am washing'). The use of an overt pronoun often means that its referent is particularly salient or somehow in the focus of attention (Belletti & Guasti, 2015). If different effects of clitics and strong pronouns emerge we will have to consider the role of their discourse status as a potentially determining factor. Note that in our material the type of pronoun overlaps with the type of relative clause type: all subject relatives have clitics

and all object relatives have overt pronouns. Therefore, a relative clause type asymmetry could also reflect the difference between discourse status of clitics and of strong pronouns.

3.3.1. METHOD

3.3.1.1. *Participants*

A total of 71 monolingual Italian-speaking children (of which 43 girls) participated. To make sure children's language development was typical, we administered a standardized test for grammatical comprehension (TCGB; Chilosi & Cipriani, 2006) and included only children whose total score on the test was within the norm range corresponding to their age. One child was excluded because of poor performance on this test. Eye-tracking data were missing for two more children due to technical problems. The analysis is thus based on the remaining 68 children, whose age ranges from 4;1 to 5;11 (mean age = 5;3, SD = 6.6 months). Children were recruited in two kindergartens in the area of Florence, in which the testing sessions took place. According to questionnaires filled by the parents, none of the children had any hearing or cognitive disorders, and none of them was color blind. Children had either normal or corrected-to-normal vision. Children's participation was approved by written parental consent. As a thank-you gift for their participation, children received colorful stickers.

Twenty monolingual native speakers of Italian participated as controls (16 women; age range 20-38; mean age = 26.6; SD = 4.6 years). Eye-tracking failed for one adult who was therefore excluded from the analysis. Adults were recruited among personal acquaintances and via social networks either in Italy or in Berlin (Germany), where most of the participants lived by the time the experiment was carried out. They all filled a questionnaire providing information about their linguistic background in order to make sure they had grown up as monolingual speakers of Italian (participants living in Berlin arrived there as adults for studying or working purposes) and without any history of language, hearing or other cognitive disorders. Additionally, adults signed a form approving their participation in the study and declaring the accuracy of the information reported in the questionnaire.

They were tested in a quiet room, either in the private home of the participant or in that of the experimenter. All the adult participants had either normal or corrected-to-normal vision, and they were paid €5 for participating.

3.3.1.2. *Material*

The items were constructed with animate nouns referring to twelve different animals: 6 masculine (cat / horse / mouse / bear / bunny / lion) and 6 feminine (duck / frog / cow / sheep / goat / monkey). Another participating animal was Lilli the dog, who served as a referent for the 1st-person pronoun. In some trials Lilli appeared alone, to satisfy the usage of *I*/*me*, and in others she appeared together with her sister, where *we*/*us* was used. There were three verbs: *rincorrere* 'chase', *acchiappare* 'catch' and *lavare* 'wash'. In each of the four experimental conditions, the non-relatives and the relatives with lexical noun phrases there were 6 items, resulting in a total of 42 items and an experiment duration of approximately 20 minutes. A full list of the items is provided in **Appendix B.1**. The items were arranged in a different order in two lists. Half of the participants were tested with the first list and the other half with the second. In both lists there were no two consecutive trials from the same condition.

All the sentences were embedded within a question about the color of one or two animals, for example: *What color is the horse that the sheep are washing?* (Arnon, 2010; Haendler et al., 2015b). In non-relatives, the identification of the target animal was based on small objects that the animals had, for instance: *What color is the horse with the heart?* Each item was accompanied by a visual scene depicting colored animals that were performing some action on each other (**Figure 3.1**). The animals were either running after each other (for 'chase'), catching each other with a net ('catch') or washing each other with a brush ('wash'). The movement of the action was from right to left on half of the trials, and from left to right on the other half. The position of the target, either on the left or the right side, was counterbalanced and it was never the same in more than two consecutive trials. In all the videos the size of each of the three regions of interest (left, middle and right) was always 360 by 315 pixels. The three colors in each video were chosen carefully

to make them easily distinguishable, based on research on color perception in young children (Pitchford & Mullen, 2003). All sentences were recorded by a female native speaker of Italian, originally from the area of Florence, and integrated into the video file with Flash Adobe.

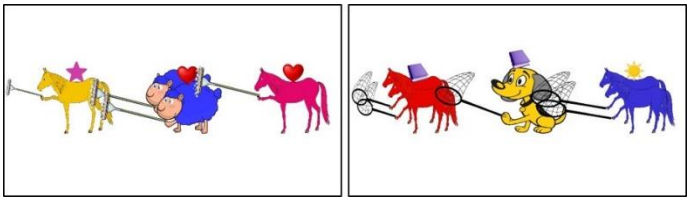

FIGURE 3.1. Examples of the visual material. Two snapshot examples of visual scenes that accompanied the sentences. For instance, the scene in the left panel corresponded to a subject relative like *Di che colore è il cavallo che le sta lavando?* 'What color is the horse that is washing them?' and the scene in the right panel corresponded to an object relative like *Di che colore sono i cavalli che io sto acchiappando?* 'What color are the horses that I am catching?'

Each trial was preceded by a preamble, the purpose of which was to present the animals that were going to appear in the trial and let the participants inspect the visual scene before the linguistic input was heard. The preamble was always composed of two sentences. The first sentence introduced the animals on the sides (16a), which appeared in the scene along with it. Then the middle animal(s) appeared and the second preamble sentence was heard (16b for items with a 1st-person pronoun; 16c for items with other referents).

(16) a. *Qui ci sono dei cavalli*.
'Here there are horses.'

b. *Ed eccomi qui con loro*.
'And here I am with them.'

c. *Ed ecco le loro amiche, le pecore*.
'And here are their friends, the sheep.'

Due to this preamble, at the beginning of the test question participants were fixating the middle part of the screen, which was never the target area of interest. Another function of the preamble was to provide the context for the referents of the pronouns. In the second preamble sentence, the referent was the subject of the sentence and, for 3rd-person pronouns, the referent was also the last mentioned word, thus satisfying the common characteristics of pronoun referents (Fukumura & van Gompel, 2015; Gordon & Hendrick, 1998; Song & Fisher, 2005). The referent of the 1st-person pronoun, which was also mentioned in the preamble, was the story narrator who explained the game at the beginning and whose voice was used to ask all the questions in the experiment. To prevent participants from predicting the upcoming type of sentence based on the preamble or the visual scene alone, also items without pronouns were preceded by a similar preamble. Moreover, in some non-relatives the dog narrator appeared as the middle figure.

3.3.1.3. *Procedure*

Children were tested individually in their kindergartens, in a quiet room where only the experimenter (the first author) was present with them. Children sat in front of a DELL laptop with a screen resolution of 1600x900 and white background, at a distance of approximately 55-70cm, allowing successful tracking of the eyes. An SMI RED-m remote eye-tracker, connected to the laptop, recorded eye movements at a sample rate of 120Hz. The SMI Experiment Center software was used to run the experiment. Moving from one trial to the next was done manually by the experimenter. Participants were required to answer the question, naming the color of what they think is the correct the animal or pair of animals. This was done in order to engage the participants in the task and keep their interest and attention on the experiment.

At the beginning of the experiment, children watched an introductory video in which the story teller, Lilli the dog, appeared and explained the color-naming game. She gave three examples that served as practice trials on which children received feedback and, if necessary, were corrected. Lilli also showed all the animals that were about to appear in the game and named them. Similarly, the three actions of chasing, washing and catching were shown and named. Finally, Lilli mentioned that she would appear every now and then throughout the game and play as well with the other animals, either on her own or together with her sister. The introduction video did not contain relative clauses.

Adults were tested in a quiet room, either at the University of Siena, at the experimenter's, or at the participant's private home. The same procedure was used as with children.

3.3.1.4. *Analysis*

We analyzed the eye-tracking data with mixed-effects models (Baayen et al., 2008) in which the dependent variable was the proportion of looks to the target area of interest, transformed into an empirical logit (Barr, 2008). We thus looked at how hard or easy it is to correctly identify the relative clause head noun as subject in subject relatives, or object in object relatives. This identification depends on accurately resolving the long-distance dependency in the sentence, which in turn is predicted to be affected by the type of embedded pronoun. In the analysis all trials were included, whether they were answered correctly or not. Moreover, we analyzed the two items lists together, since the performance patterns in them did not differ.

We followed the analysis procedure provided in Barr (2008), in which a by-subject and by-item analyses are performed separately, due to an aggregation that allows to have more data points within each time stamp. We first identified a time window in which the data were analyzed (see next section). We then divided the TIME variable into 50ms bins and centered it on the point in which target looks start increasing when the four experimental conditions are collapsed together, using a *Grand Mean* plot. This ensures that centering time does not derive from any initial theoretical assumption regarding participants'

performance. The factors RELATIVE CLAUSE TYPE and PRONOUN TYPE were coded as follows: subject relatives were coded as -0.5 and object relatives as 0.5; 1st-person pronoun was coded as -0.5 and 3rd-person pronoun as 0.5. The fixed effects part of the models included all main effects and interactions of RELATIVE CLAUSE TYPE and PRONOUN TYPE, as well as TIME, entered as a continuous covariate with third-order polynomials (Mirman et al., 2008) that resulted as statistically preferable. The random effects parts included an intercept for participants or for items, but no random slopes, since they resulted in failed convergence or a degenerate correlation matrix (Bates et al., submitted). In all the models the *bobyqa* optimizier was used, and they were fitted with the *lme4* package, version 1.1-12 (Bates et al., 2015) in R (R Core Team, 2016). For the t-statistics, we take absolute values of at least 2 to be significant at α=.05.

3.3.1.5. *Defining the time window for analysis*

Table 3.3 shows the temporal windows in the average trial. In Chunk 1, the animals were moving (i.e., performing the action of chasing, catching or washing), but no linguistic input was heard. This allowed the participants to visually analyze the scene before the linguistic input starts guiding the eyes towards any specific region on the screen. Chunks 2-3, containing the matrix clause and the complementizer *che*, were the same across conditions, making it impossible to identify the target animal(s) based on this part of the sentence. The critical linguistic input was heard in Chunk 4, in which the pronoun, auxiliary and lexical verb were heard. In all items, the complementizer *che* started at exactly the same point in time, 3560ms after the onset of the video. In Chunk 5, like in the first one, the animals kept moving without linguistic input. This post-sentential silence was included in order to capture late effects that occur after the sentence offset. This could be necessary with young children, whose sentence processing might be slower than adults' (Adani and Fritzsche, 2015; Brandt-Kobele and Höhle, 2010; Haendler et al., 2015b). The total duration of each item video was 7000ms on average (SD=137ms).

TABLE 3.3. Division of the average trial into temporal windows and their duration in milliseconds.

	Chunk 1 (1900ms)	Chunk 2 (1660ms)	Chunk 3 (130ms)	Chunk 4 (1160ms)		Chunk 5 (2150ms)
SR:1pro	SILENCE	*Di che colore è il cavallo* 'What color is the horse	*che* that	*mi* me	*sta* is	*lavando?* washing?'	SILENCE
SR:3pro				*la* her	*sta* is		
OR:1pro				*io* I	*sto* am		
OR:3pro				*lei* she	*sta* is		

SR = subject relatives; OR = object relatives; 1pro = 1st-person pronoun; 3pro = 3rd-person pronoun.

The beginning of the time window in which the data were analyzed was defined as the onset of Chunk 4 which contains the critical linguistic information. The onset of the window was shifted 200ms forwards, in order to account for the time it takes to program and execute an eye movement (Huettig & Altmann, 2005; Snedeker & Trueswell, 2004; Trueswell, 2008). Adults' target looks across conditions peaked slightly before the sentence offset, whereas children's peaked about 650ms after the sentence offset, reflecting their slower processing. Therefore, the end of the analysis window was the sentence offset for adults, and 650ms after the sentence offset for children. The length of the analysis window was 960ms for adults, and 1610ms for children.

3.3.2. RESULTS AND DISCUSSION

Response accuracy on the questions was at ceiling. Across conditions, children had an accuracy rate above 90% on average, and adults were 100% accurate on all conditions. Pronoun effects in subject and object relatives, as a function of time, are shown in **Figure 3.2** for adults and in **Figure 3.3** for children. We are plotting the partial effects, that is, the data from which between-subject variance has been removed using the *remef* function

(Hohenstein & Kliegl, 2014). The statistical model output for the adult data is given in **Table 3.4** and for children in **Table 3.5**.

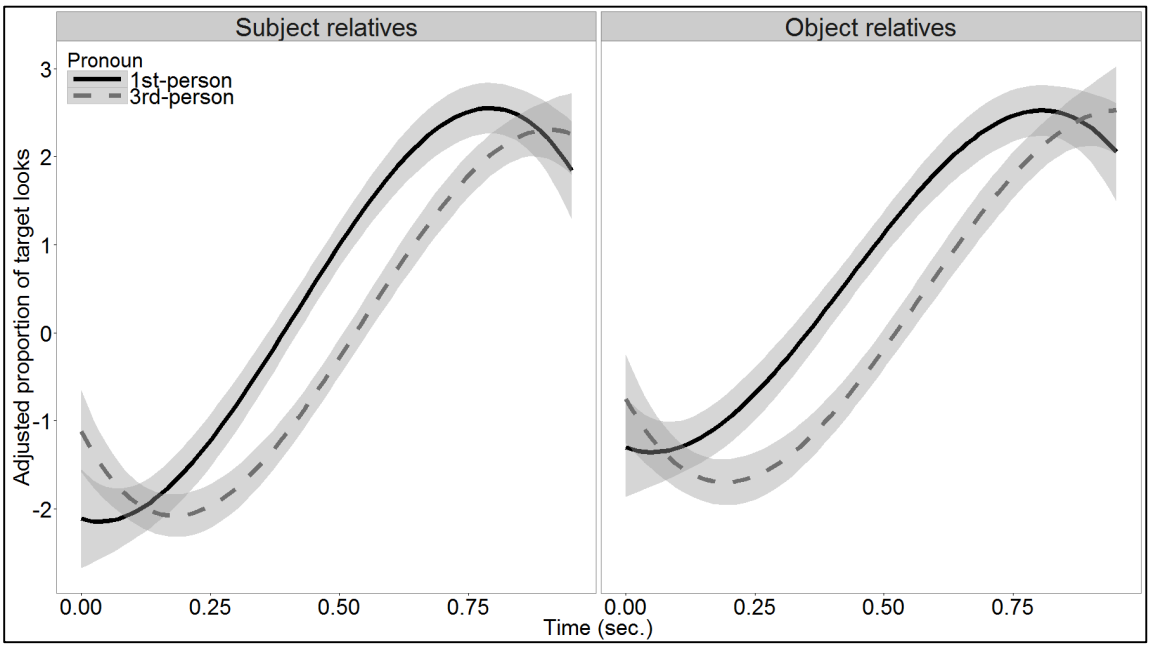

FIGURE 3.2. Adults' eye-movement pattern. Proportion of looks to the target (after removal of individual differences) within the analysis time window, from 200ms following the onset of the complementizer *che* 'that' until the end of the sentence. On the x-axis, TIME is represented in seconds. Sentences with an embedded 1st-person pronoun are marked with black solid lines; sentences with a 3rd-person pronoun are marked with dashed gray lines. The shaded area represents 95% confidence intervals.

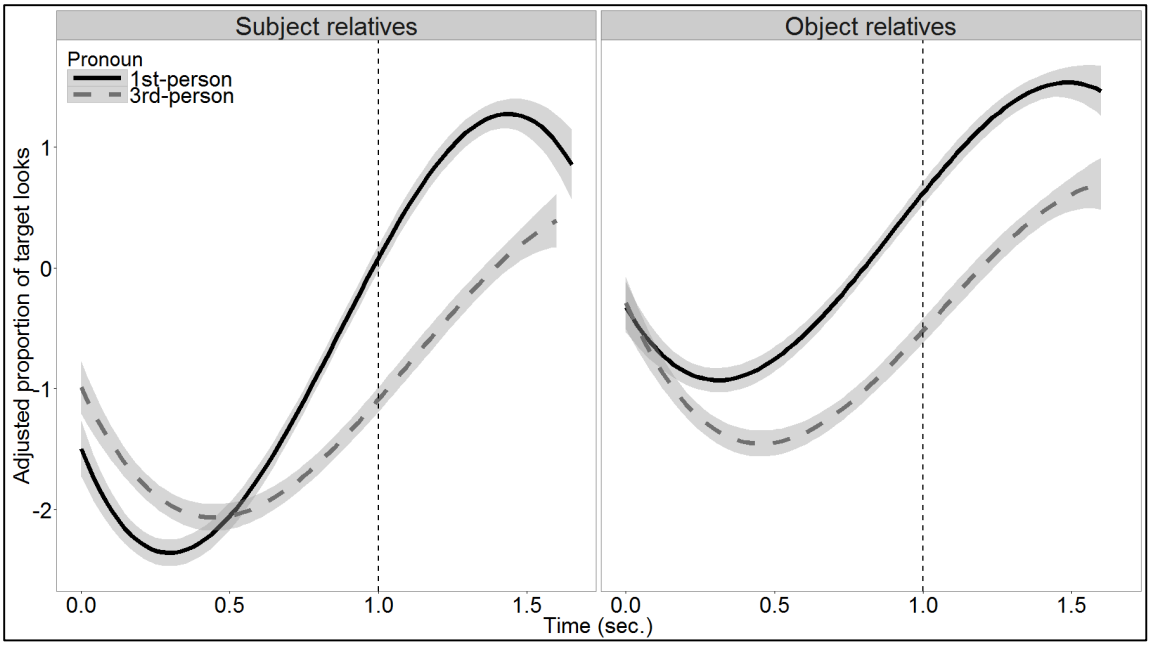

FIGURE 3.3. Children's eye-movement pattern. Proportion of looks to the target (after removal of individual differences) within the analysis time window, from 200ms following the onset of the complementizer *che* 'that' until 650ms after the end of the sentence, marked with a vertical dashed line. On the x-axis, TIME is represented in seconds. Sentences with an embedded 1st-person pronoun are marked with black solid lines; sentences with a 3rd-person pronoun are marked with dashed gray lines. The shaded area represents 95% confidence intervals.

TABLE 3.4. Fixed effects in the by-subject and by-item analyses of adults' eye-movement data.

	By-subject			By-item		
Effect	**Coef.**	**SE**	***t***	**Coef.**	**SE**	***t***
time[1]	29.21	1.02	28.72	22.5	0.6	37.38
time[2]	2	0.98	2.03	0.11	0.58	0.19
time[3]	-7	1.01	-6.95	-4.86	0.6	-8.13
relative_clause_type	0.1	0.05	2.04	0.15	0.16	0.91
pronoun_type	-0.41	0.05	-8.72	-0.37	0.16	-2.29
time[1] : relative_clause_type	-4.98	2.03	-2.45	-5.48	1.2	-4.55
time[2] : relative_clause_type	-0.6	1.95	-0.31	1.66	1.16	1.43
time[3] : relative_clause_type	3.46	2.01	1.72	0.69	1.2	0.57
time[1] : pronoun_type	-1.75	2.03	-0.86	-1.94	1.2	-1.61
time[2] : pronoun_type	8.25	1.95	4.23	9.37	1.16	8.1
time[3] : pronoun_type	-3.19	2.01	-1.59	-0.96	1.2	-0.81
relative_clause_type : pronoun_type	-0.14	0.09	-1.45	-0.16	0.32	-0.49
time[1] : relative_clause_type : pronoun_type	-5.82	4.05	-1.44	4.26	2.41	1.77
time[2] : relative_clause_type : pronoun_type	-2.92	3.91	-0.75	-1.4	2.32	-0.6
time[3] : relative_clause_type : pronoun_type	2.17	4.01	0.54	0.69	2.39	0.29

Coef. = coefficient; SE = standard error; time[1] = linear trend of time; time[2] = quadratic trend of time; time[3] = cubic trend of time. Effects that are significant (at $t > |2|$) in both analyses are shaded with gray.

TABLE 3.5. Fixed effects in the by-subject and by-item analyses of children's eye-movement data.

	By-subject			By-item		
Effect	**Coef.**	**SE**	***t***	**Coef.**	**SE**	***t***
time[1]	41.17	0.89	46.01	48.88	1.07	45.87
time[2]	13.01	0.91	14.36	15.85	1.08	14.72
time[3]	-13.16	0.91	-14.4	-17.39	1.08	-16.04
relative_clause_type	0.26	0.02	14.31	0.31	0.1	2.99
pronoun_type	-0.28	0.02	-15.19	-0.27	0.1	-2.61
time[1] : relative_clause_type	-13.31	1.79	-7.45	-19.4	2.13	-9.1
time[2] : relative_clause_type	-0.7	1.81	-0.39	-1.59	2.15	-0.74
time[3] : relative_clause_type	-0.14	1.83	-0.08	2.47	2.17	1.14
time[1] : pronoun_type	-17.27	1.78	-9.67	-29.84	2.13	-14
time[2] : pronoun_type	6.73	1.81	3.72	15.47	2.15	7.18
time[3] : pronoun_type	5.95	1.83	3.25	6.21	2.17	2.86
relative_clause_type : pronoun_type	-0.07	0.04	-2.02	-0.09	0.2	-0.44
time[1] : relative_clause_type : pronoun_type	8.19	3.57	2.3	25.12	4.26	5.89
time[2] : relative_clause_type : pronoun_type	8.83	3.62	2.44	6.42	4.31	1.49
time[3] : relative_clause_type : pronoun_type	3.03	3.66	0.83	-10.21	4.34	-2.35

Coef. = coefficient; SE = standard error; time[1] = linear trend of time; time[2] = quadratic trend of time; time[3] = cubic trend of time. Effects that are significant (at $t > |2|$) in both analyses are shaded with gray.

When the embedded pronoun was a 1st-person pronoun, adults looked to the target more than when it was a 3rd-person pronoun. This was the case independently of whether the sentence was a subject or an object relative, as indicated by the main effect of PRONOUN TYPE and its interaction with TIME (both significant in the by-subject and by-item analyses), as well as by the lack of a significant interaction of RELATIVE CLAUSE TYPE by PRONOUN TYPE. Target looks did not differ substantially between subject and object relatives overall, as the main effect of RELATIVE CLAUSE TYPE was significant only in the by-subject analysis. However, the interaction of RELATIVE CLAUSE TYPE by TIME was significant in both analyses, reflecting a higher proportion of target looks in object relatives than in subject relatives at the beginning of the analysis window. This pattern changed

when, about 200ms later, the difference in target looks between the two relative clause types disappeared.

Also children's target looks increased in 1st-person pronoun trials more and faster than in 3rd-person pronoun ones, as indicated by the main effect of PRONOUN TYPE and its interaction with TIME, significant in both analyses. Unlike adults, though, a main effect of RELATIVE CLAUSE TYPE and its interaction with TIME (both significant in the two analyses) reflect a higher proportion of target looks in object relatives than in subject relatives. Children looked to the target in object relatives more than in subject relatives already at the beginning of the analysis window. But, once the auxiliary and the verb were processed and children started to direct their gaze to the target, the difference between the two relative clause types disappeared. The bias to look at the target in object relatives prior to the critical linguistic input is also reflected in a significant three-way interaction of RELATIVE CLAUSE TYPE, PRONOUN TYPE and TIME (and, at least partially, by the interaction of RELATIVE CLAUSE TYPE by PRONOUN TYPE that was significant only in the by-subject analysis). This interaction indicates that, after there were initially more target looks in object than in subject relatives independently of the type of embedded pronoun, subsequently there were more target looks in 1st- than in 3rd-person pronoun trials, independently of the relative clause type.

To sum up, two main patterns emerge. First, both adults and children look more to the target when the embedded pronoun is a 1st-person pronoun than when it is a 3rd-person pronoun. Second, this pronoun asymmetry occurs similarly in subject and object relative clauses. We will first discuss these patterns and then proceed to deal with the advantage for object relatives in terms of target looks, which emerged, we believe, due to visual properties of the material.

The results are only partially in line with the *similarity-based approach* (Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & McElree, 2006; 2011). This approach can explain the advantage of the 1st-person pronoun over the 3rd-person pronoun without recurring to discourse accessibility. In relatives with a 1st-person pronoun, the interference of the embedded pronoun is smaller because of the mismatching Person cue on the head

noun (3rd-person) and the pronoun (1st-person). By contrast, there is greater interference in the case of a 3rd-person pronoun, which is marked with the same Person cue as the head noun. However, the similarity-based approach falls short of accounting for the lack of relative clause type asymmetry, since a processing advantage for subject relatives would be expected in any case. In object relatives, interference is stronger because both the head noun and the embedded pronoun are marked as grammatical subjects. Subject relatives should be easier because the interference is smaller, given that the head noun is marked as grammatical subject whereas the embedded pronoun as grammatical object (Nicenboim et al., submitted; Van Dyke, 2007).

Both the *discourse-based approach* (Fox & Thompson, 1990; Kaan, 2001; Mak et al., 2008) and the *experience-based approach* (Brandt et al., 2009; Kidd et al., 2007; MacDonald, 2013; Reali & Christiansen, 2007; Roland et al., 2012)–as indicated also by the results of our corpus analysis–predict subject relatives with an embedded pronoun to be harder than comparable object relatives, independently of the type of pronoun. Whereas some previous studies indeed found greater processing difficulty for subject relatives with pronouns (Heider et al., 2014; Mak et al., 2008; Reali & Christiansen, 2007; Roland et al., 2012), we find no such relative clause type asymmetry, in line with other studies (Arnon, 2010; Brandt et al., 2009; Kaan, 2001; Gordon et al., 2001; see also the pattern at the matrix verb found by Reali & Christiansen, 2007). The discrepancy between the various studies can be explained, at least partly, as due to word order. In our study, the use of Italian relatives with a similar word order allowed a more precise detection of the pronoun effect immediately upon encountering the pronoun, the first word that differentiated our conditions. The fact that this was the case in both relative clause types makes the comparison across conditions more reliable. Moreover, we did not incur into confounding effects of commonness of the arguments order, which was non-canonical in both relative clause types.

Our results are different from those obtained by Mak et al. (2008), who used Dutch, another language in which subject and object relatives have a similar word. These authors found that, with embedded pronouns that are case-marked (*ons* 'us' / *wij* 'we'), object

relatives were read faster than subject relatives, as measured at the second word following the pronoun (*het*, in 17a-b). This is unlike the lack of difference we find between subject and object relatives, in which the pronoun was also case-marked (e.g., *mi* 'me' / *io* 'I', or *la* 'her' / *lei* 'she'). We do not have a definitive explanation for this discrepancy. But perhaps one possibility is that the effects differ with respect to how far from the pronoun the long-distance dependency is resolved. In the Dutch material, the locus of the long-distance dependency resolution was at the fifth word following the pronoun (the auxiliary, underlined in examples 17a-b). In the Italian sentences, the auxiliary, at which the dependency resolution occurred, immediately followed the pronoun. At any rate, further research is required to clarify when a subject-object relative clause asymmetry arises in languages in which the embedded pronoun occupies the same position in both relative clause types.

(17) a. … de hardloper, die ons in het park gegroet <u>heeft</u> …
the jogger who us in the park greeted has
'… the jogger, who has greeted us in the park, …'

b. … de hardloper, die wij in het park gegroet <u>hebben</u> …
the jogger who we in the park greeted have
'… the jogger, whom we have greeted in the park, …'

The different 1st- and 3rd-person pronoun effects that we find are also not in line with the predictions of the *experience-based approach*. Based on the corpus analysis we conducted, we would expect to find an interaction of RELATIVE CLAUSE TYPE by PRONOUN TYPE, with subject relatives being easier with a 3rd-person pronoun than with a 1st-person pronoun, and object relatives being easier with a 1st-person pronoun than with a 3rd-person pronoun. However, what we find is the same pronoun asymmetry–with 1st-person pronoun trials being more accurately processed than 3rd-person pronoun ones–in both relative clause types.

The theoretical account that best captures our results is the *structure-discourse approach*. It predicts no asymmetry between our subject and object relatives, since the distance between the head noun and the auxiliary, where the long-distance dependency is

resolved, is similar across conditions. The 1st-person pronoun advantage is explained by the relatively small cognitive demand associated with its discourse accessibility mechanism, as compared to a 3rd-person pronoun (Haendler et al., 2015b; Warren & Gibson, 2002). The fact that Warren & Gibson (2002) did not find the same 1st-/3rd-person pronoun asymmetry in subject and object relatives is most probably due to two properties of their sentences. First, their subject relatives were right-branching and their object relatives doubly nested, thus having two different loci of the dependency resolution. Second, the pronouns were not located in the same place in the sentence: in object relatives the pronoun was the embedded-most constituent, whereas in subject relatives the pronoun appeared outside the relative clause.

The results, and specifically the lack of relative clause type asymmetry, also indicate that processing was affected by whether the pronouns were 1st- or 3rd-person ones, but not by whether they were clitics or strong pronouns. In other words, there were no discourse effects related to the usage of clitics in subject relatives vs. strong pronouns in object relatives.

Regarding the comparison of adults and children, the same pattern emerged in both groups, although children were somewhat slower. This is line with the idea of continuity and with related research suggesting that young children generally deploy the same processing strategies used by adults (Adani & Fritzsche, 2015; Contemori & Marinis, 2014; Felser et al., 2003; Love, 2007; Trueswell & Gleitman, 2007). Whereas previous research has shown that children are sensitive to discourse factors that underlie the interpretation and usage of pronouns (Allen et al., 2015; Hartshorne et al., 2015; Pyykkönen et al., 2010; Song & Fisher, 2005; Thomsen & Poulsen, 2015), our results extend these findings by showing that children's relative clause processing–similarly to adults'–is affected by the discourse accessibility mechanisms of different pronoun types.

Finally, we turn to discuss the unexpected outcome of object relative advantage. In both adults and children, there was at the beginning of the analysis time window a higher proportion of target looks in object relatives than in subject relatives, independently of the pronoun type. This caused a strong relative clause type asymmetry throughout the entire

analysis window, despite the consequent pronoun effects. We therefore think that the higher proportion of target looks in object relatives does not reflect a more accurate processing. Rather, there seems to be a bias to look more to the patient of the action at the beginning of each video, before the sentence is heard and processed.

This pattern is clearly visible when looking at the raw data of the eye movements (cf. **Figure 3.4** for adults and **Figure 3.5** for children). From the beginning of the trial, children looked to the patient more than to the agent animal(s). Adults do so to some extent as well, but children persist in this bias longer. Importantly, however, once the critical linguistic input (the embedded pronoun, auxiliary and verb) was processed, eye movements were driven by it towards the target: they remained on the patient in the case of object relatives, and moved to the agent in the case of subject relatives. As pointed out by Barr et al. (2011), both keeping the eyes on the object that is currently being looked at and shifting the eyes away from it to look at another object are cognitive choices that are meaningful for the linking hypothesis between eye movements and linguistic processing. Since we think this patient-looks bias is independent of the linguistic material, we find no reason to withdraw our interpretation of the subsequent gaze effects as being caused by the experimental manipulations. It is worth mentioning that this kind of initial bias to look at the patient was found elsewhere as well. Lassotta et al. (2015) tested relative clause processing using similar setup to ours, but with slightly different visual stimuli. Also in their study children looked at the patient animal even before the sentence started and, subsequently, the gaze pattern changed due to the experimental manipulations.

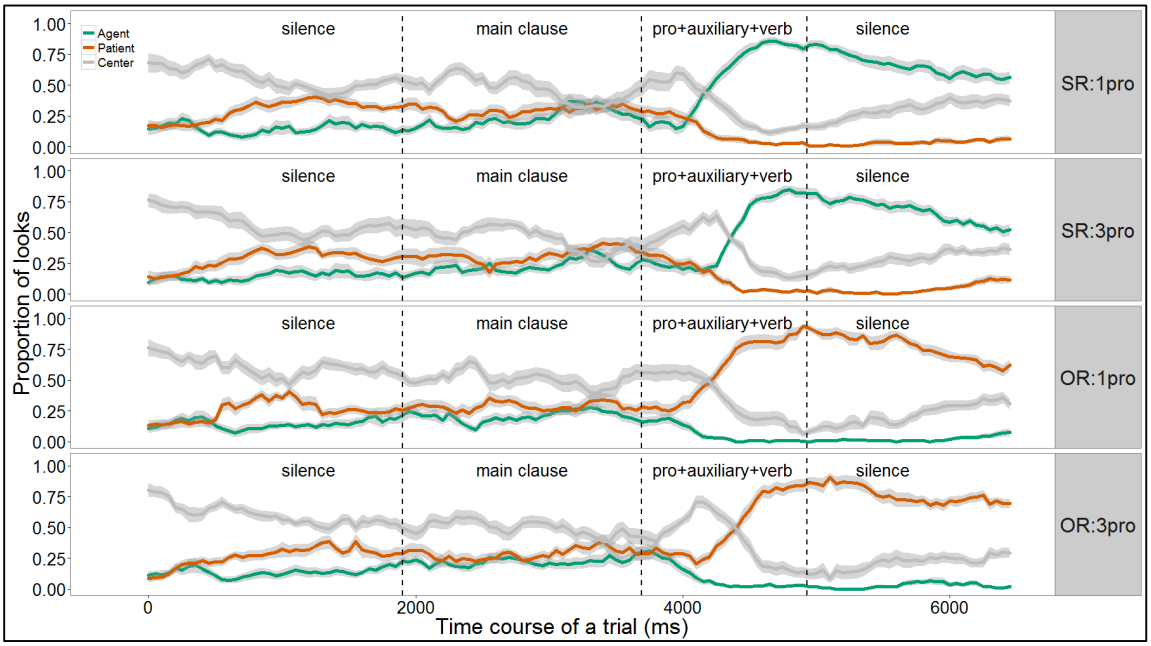

FIGURE 3.4. Adults' gaze pattern–raw data. Looks in each condition to the three areas of interest: AGENT (green line), PATIENT (orange line) and CENTER (gray line). SR = subject relatives; OR = object relatives; 1pro = 1st-person pronoun; 3pro = 3rd-person pronoun. The shaded area represents 95% confidence intervals.

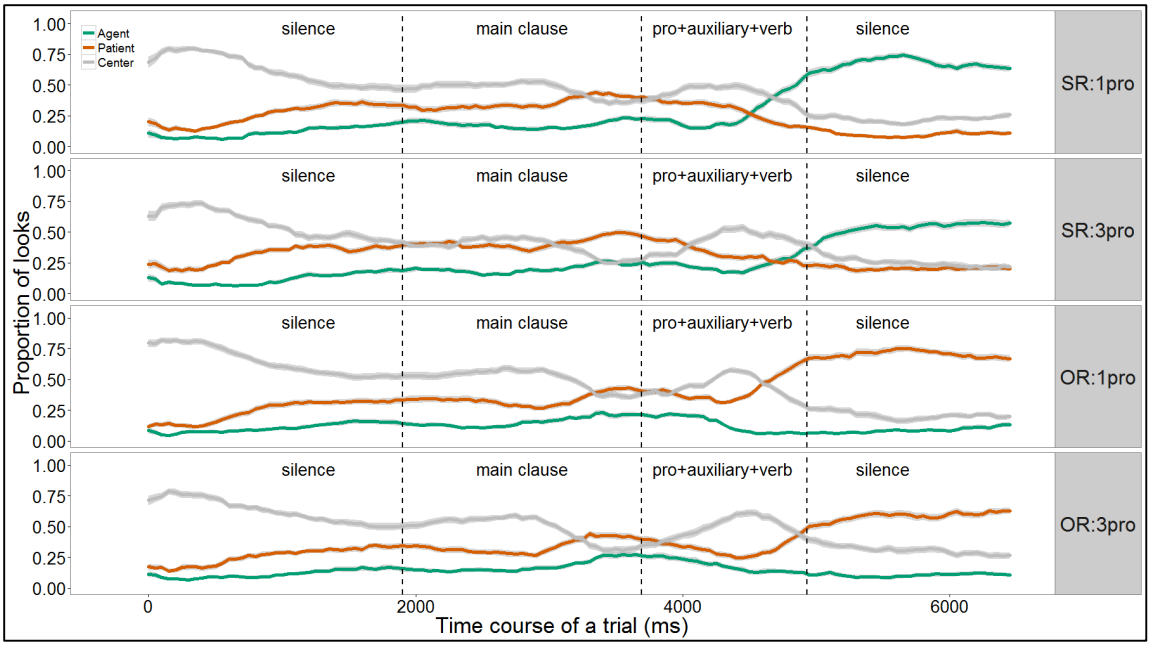

FIGURE 3.5. Children's gaze pattern–raw data. Looks in each condition to the three areas of interest: AGENT (green line), PATIENT (orange line) and CENTER (gray line). SR = subject relatives; OR = object relatives; 1pro = 1st-person pronoun; 3pro = 3rd-person pronoun. The shaded area represents 95% confidence intervals.

Some questions still remain open. First, the experiment was extremely easy for adults. The material included animated videos, simple test questions pronounced in a child-friendly tone, and the task itself was an easy color-naming game. Also, in order to make the duration of the experiment suitable for young children's limited attention span, it was not possible to increase much the number of items. In fact, although we observed meaningful effects in adults' eye movements, their accuracy rate was 100% across all conditions. Another important factor is the mismatch in Number that very likely made the sentences particularly easy, also for children (Adani et al., 2010; 2014; Contemori & Marinis, 2014). Finally, perhaps it could be argued that we should not draw firm conclusions about the pronoun effects because of the bias to look at the patient animal(s) at the beginning of each trial. Using another testing methodology, with a dependent

variable that is unrelated to visual input, might be helpful in order to see whether the results are reliable. All these issues were addressed in a follow-up self-paced reading experiment, carried out with adults only.

3.4. EXPERIMENT 3: SELF-PACED READING EXPERIMENT WITH ADULTS

This experiment was designed to test the same types of sentences as in the eye-tracking experiment, albeit with several changes. We eliminated from the sentences the mismatch in Number between the head noun and the embedded pronoun: all constituents were singular. The sentences were also longer and each sentence, including fillers, was followed by a comprehension question. Moreover, dealing with adults only, we created a larger variability in the items, interspersing the test sentences randomly among numerous fillers (as is standard in self-paced reading), many of which were constructed especially to prevent participants from recognizing the test items.

An example of a test item is provided in (18). The first and the last segments were identical across all conditions. The critical segment (a)-(d) included the embedded pronoun, which differed across conditions, and the verbal phrase composed of the auxiliary and the lexical verb. This three-words segment, which corresponds to the time window in which effects in the eye-tracking data occurred, yielded the same four conditions: subject relatives with a 1st-person pronoun (a); subject relatives with a 3rd-person pronoun (b); object relatives with a 1st-person pronoun (c); and object relatives with a 3rd-person pronoun (d).

We predict any effects to occur either at the pronoun itself or, perhaps more likely, at the auxiliary. This is in the light of previous studies that found effects of relative clause processing at the embedded finite verb, where the long-distance dependency is resolved (Gordon et al., 2001; Just & Carpenter, 1992; King & Just, 1991; Warren & Gibson, 2002).

(18)		Alessandro	era	divertito	dal	buffo	vecchietto	che ...
		Alessandro	was	amused	by-the	funny	old man	who
	a.	… **mi**	stava	bloccando …				
		me	was	blocking				
	b.	… **la**	stava	bloccando …				
		her	was	blocking				
	c.	… **io**	stavo	bloccando …				
		I	was	blocking				
	d.	… **lei**	stava	bloccando …				
		she	was	blocking				
		… col	carrello	pieno	di	roba.		
		with-the	cart	full	of	stuff		

Each test sentence was preceded by two context sentences that provided a referent for the pronoun. The first context sentence presented the person that would be the subject of the matrix clause (*Alessandro*), followed by the referent of the embedded pronoun (*Tina*). The second preamble sentence had the pronoun referent as subject, such that the subsequent reference to it with a pronoun is appropriate, or even expected (Fukumura & van Gompel, 2015; Gordon & Hendrick, 1998; Song & Fisher, 2005). An example of the context sentences for relatives with a 1st-person pronoun (18a & 18c) is given in (19); an example of the context sentences for relatives with a 3rd-person pronoun (18b & 18d) is shown in (20):

(19)	a.	Alessandro	faceva	la	spesa	con	me.
		Alessandro	did	the	shopping	with	me.
		‘Alessandro was shopping with me.’					
	b.	Io	volevo	andare	a	prendere	il latte.
		I	wanted	go	to	take	the milk
		‘I wanted to go get some milk.’					

(20) a. Alessandro faceva la spesa con Tina.
Alessandro did the shopping with Tina.
'Alessandro was shopping with Tina.'

b. Tina voleva andare a prendere il latte.
Tina wanted go to take the milk
'Tina wanted to go get some milk.'

3.4.1. METHOD

3.4.1.1. *Participants*

Sixty-eight Italian-native speakers (39 women; age range 20-44; mean age = 28; SD = 4.97) were recruited among personal acquaintances and via social networks. All of them were living in Berlin (Germany) at the time of testing, but all had lived in Italy at least until age 18, and all had attended primary and secondary school in Italy. All the participants had grown up speaking only Italian at home, some being exposed to local dialects as well. The participants' places of origin varied from the extreme South to the extreme North of Italy. Information about the participants was obtained by a personal questionnaire. Participants signed a statement to confirm the accuracy of the information provided, as well as a consent form for taking part in the experiment. They were paid €5 for participating.

3.4.1.2. *Material*

We constructed 32 items, each appearing in each of the four conditions (18a-d). The items had approximately the same length, and all the verbs used in the relative clause were 3-syllables long. Additionally, the embedded verbs were chosen such that the thematic roles of their subject and object were semantically reversible. Thus, verb semantics could not help in understanding 'who did what to whom' while reading the segments that precede the embedded pronoun. The scenes described in the context sentences were also chosen in a way that avoided a bias to interpret the sentence in advance, based on a bigger likelihood that one character did something to the other character, rather than the contrary. The experimental items were arranged in a standard Latin square design, in which each participant was exposed to only one instance of a certain item. There were 102 fillers. Most

of the fillers were especially constructed to prevent the participants from identifying the experimental items. For instance, there were sentences containing the complementizer *che* 'that' which are not relative clauses, like complement clauses or pseudo-relatives. There were also indirect questions that contained proper names taken from the test items and pronouns. Some fillers were taken from two experiments by De Vincenzi & Job (1996) about the processing of late closure sentences in Italian. Most of the fillers were preceded, like the test items, by one or two context sentences.

Each trial ended with a comprehension yes/no question. In the test items, the questions were always on the event described in the relative clause. The form of the question alternated between active and passive across the four conditions of the same item. For instance: *Il vecchio ha bloccato Tina col carrello della spesa?* 'Did the old man block Tina with the shopping cart?' or *Il vecchio è stato bloccato col carrello della spesa?* 'Was the old man blocked with the shopping cart?' This way, for each item the correct answer to the comprehension question alternated equally between 'yes' and 'no', depending on whether the sentence was a subject or an object relative. A full list of the test items is provided in **Appendix B.2**.

3.4.1.3. *Procedure*

The sentences were presented using a non-cumulative self-paced reading method (Just et al., 1982). Douglas Rohde's Linger software (http://tedlab.mit.edu/~dr/Linger/), version 2.94, was used to run the experiment on a Toshiba laptop with a 1366x768 screen resolution. Both the context and the test sentences were masked with strings of hyphens and the hidden words were revealed by pressing the space bar. The context sentences were revealed entirely with one key press for each sentence; the words of the test sentence were revealed one by one, with each key press unveiling the upcoming word and reverting the previous one into a hyphen. Reading times of each of the segments in the test sentence were measured in milliseconds and taken as an indicator of processing difficulty. To answer the comprehension question, participants had to press either the *c*-key for 'yes' or the *n*-key for 'no'. At the beginning of the experiment, participants read on the screen an

introduction that explained the task, followed by six practice items with questions. The software randomized the order of presentation of the items for each participant. The experiment contained two built-in breaks and the participants were required to take them for a couple of minutes. The experiment was carried out in private homes, either of the participant or of the experimenter, and always in a quiet room in which only these two persons were present. Participants were instructed to perform the task with their two middle fingers on the *c*- and *n*-keys and with the index finger of their stronger hand on the space key, so that they would not look at the keyboard during the experiment. The experiment took on average 40-45 minutes to complete.

3.4.1.4. *Analysis*

The reading times data were analyzed in R (R Core Team, 2016), using the *lme4* package, version 1.1-10 (Bates et al., 2015). The accuracy data, derived from the correct or incorrect responses on the comprehension questions, were analyzed with a generalized mixed-effects model with a logistic link function (Jaeger, 2008). The reading times data were analyzed with linear mixed-effects models (Baayen et al., 2008) whose dependent variable was the negative reciprocal reading times, to achieve approximately normally distributed residuals (Box & Cox, 1964). In all the models, the "bobyqa" optimizer was used. The *qqPlot* function was used to visually check the residuals normality, identify outliers and remove them. In each segment that was analyzed either 1 or 2 data points of outliers were removed, equivalent to 0.05-0.09% of the data. All the models included in the fixed effects part the main effects for the factor RELATIVE CLAUSE TYPE (subject relatives were coded as -0.5; object relatives as 0.5), the factor PRONOUN TYPE (1st-person pronouns were coded as -0.5; 3rd-person pronouns as 0.5) and their interaction. All the models included in the random effects part intercepts for subjects and items only, since adding random slopes often resulted either in convergence failure or in the estimation of some random effects with zero variability (Bates et al., submitted). For the linear mixed-effects models' outcome we took as significance threshold *t*-values of at least |2| at α=.05.

3.4.2. RESULTS AND DISCUSSION

3.4.2.1. *Accuracy*

Adults were highly accurate on all four conditions, but their response accuracy here was more informative than in the eye-tracking experiment. Response accuracy on subject relatives was 91% when the pronoun was 1st-person and 90% when it was 3rd-person. On object relatives, adults were 93% accurate when the pronoun was 1st-person and 88% when it was 3rd-person. The statistical analysis showed no effect of RELATIVE CLAUSE TYPE (β=.06, SE=.15, z=.41, p=.68), indicating that accuracy was overall similar on subject and object relatives. The main effect of PRONOUN TYPE was significant (β=-.39, SE=.15, z=-2.57, p=.01), indicating that participants were more accurate on 1st-person pronoun trials than on 3rd-person pronoun ones, independently of the type of relative clause. The interaction did not reach significance (β=-.57, SE=.30, z=-1.89, p=.059).

3.4.2.2. *Reading times*

Figure 3.6 shows the mean reading times in the test sentence. We analyzed the reading times at each of the three words in the critical segment: the pronoun, the auxiliary and the lexical verb. In addition, we also analyzed the word preceding the pronoun as a sanity check, and the word following the lexical verb checking for spill-over effects.

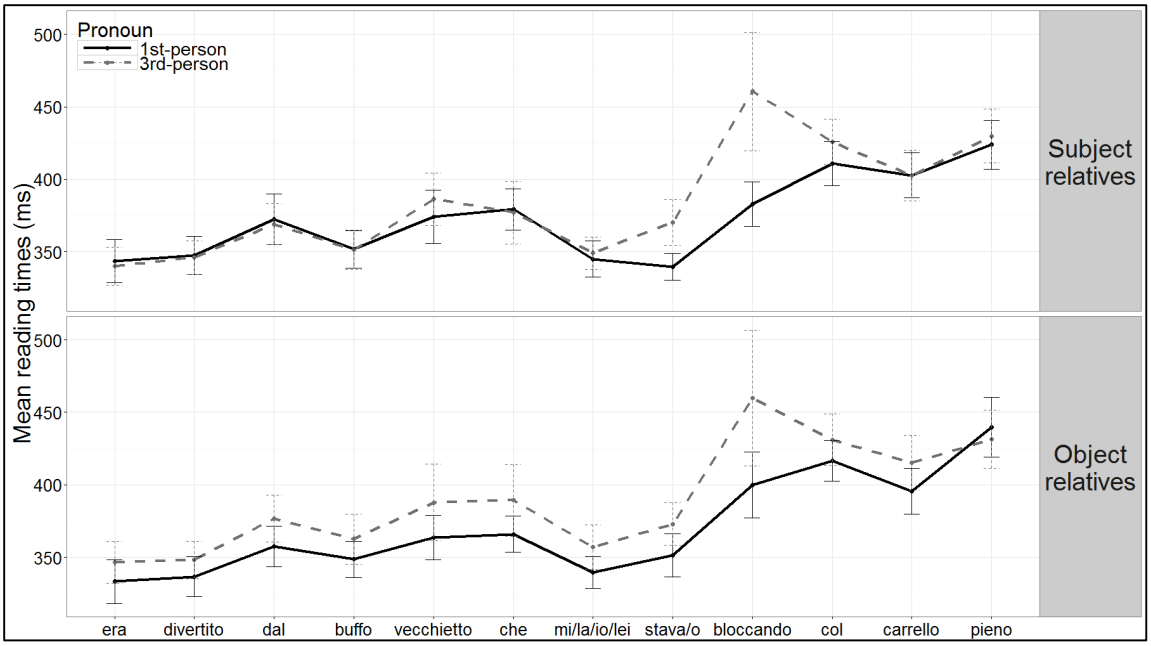

FIGURE 3.6. Mean reading times in the self-paced reading experiment. Sentences with an embedded 1st-person pronoun are marked with black solid lines; sentences with a 3rd-person pronoun are marked with dashed gray lines. The error bars represent 95% confidence intervals.

At the word preceding the pronoun (the complementizer *che* 'that') the main effects of RELATIVE CLAUSE TYPE and of PRONOUN TYPE were not significant, but their interaction was (β=.15, SE=.06, t=2.45). In object relatives with a 3rd-person pronoun, the complementizer took longer to read than in object relatives with a 1st-person pronoun, whereas there was no such difference in subject relatives. This unexpected effect is hard to explain, given that at this point the sentence is still ambiguous between a subject and an object relative clause, and the pronoun has not been encountered yet. To make sure this early effect was a single case, we analyzed also the two words preceding the complementizer–the relative clause head noun (*vecchietto* 'old man') and the word before it (*il* 'the'). None of the model terms in these words was significant. Moreover, we carried out a post-hoc analysis of the sentence segments, including the order of presentation of the

items as predictor. We reasoned that, if we find a significant interaction between any of the conditions and this predictor, it might suggest that participants were capable of predicting the type of structure they were reading even before encountering the disambiguating pronoun. In all these additional analyses, the main effect of order of items was significant, but the interactions with the conditions were not. This indicates that, throughout the experiment, participants were reading faster (perhaps because they got increasingly familiar with reading word by word). But, importantly, these faster reading times were not related to any specific condition(s). Therefore, the interaction at the complementizer, rather than reflecting an effect driven by the experimental manipulations, seems likely to be spurious.

The analysis at the pronoun showed no significant effects. Thus, the pronoun itself was read at an equal speed independently of whether it was a 1st- or a 3rd-person pronoun, and whether it was a strong pronoun (in object relatives) or a clitic (in subject relatives). Also the fact that the pronoun was sometimes two-letters long (*la/lo/mi/io*) and sometimes three-letters long (*lei/lui*) did not influence the time it took to be read.

By contrast, both the auxiliary and the lexical verb were read faster when appearing after a 1st-person pronoun than after a 3rd-person pronoun. This effect was similar in subject and object relatives, as reflected by the main effect of PRONOUN TYPE at these two words (auxiliary: β=.09, SE=.03, t=2.78; lexical verb: β=.15, SE=.04, t=4.24). The main effect of RELATIVE CLAUSE TYPE and the interaction were not significant at any of these two words. There were no spill-over effects at the word following the lexical verb (*col* 'with-the').

The effect we find at the auxiliary and the lexical verb is similar to the results of the eye-tracking experiment. The 1st-person pronoun prompted faster reading times than the 3rd-person pronoun, a pattern that occurred to a similar extent in both subject and object relative clauses. As discussed in *Experiment 2*, these findings are best explained by the *structure-discourse* approach (Gibson, 2000; Warren & Gibson, 2002). The outcome of the self-paced reading experiment strengthens even more the interpretation of the results of the eye-tracking one, since we used material that was more suitable for adults, numerous and

various filler sentences, and given that the Number mismatch between the head noun and the embedded pronoun was eliminated. It is therefore very likely that the different reading times at the auxiliary and the verb are due to the type of embedded pronoun and, specifically, due to the pronouns' different discourse accessibility mechanisms.

3.5. GENERAL DISCUSSION

In this study, we extended previous research on the processing of relative clauses with embedded pronouns. We tested whether pronouns affect subject and object relatives similarly or not, and whether the effect of pronouns can be explained by their discourse accessibility properties. The sentences we used–Italian subject and object relatives with similar word order–allowed us to avoid potential confounds due to the commonness of the order of arguments in the sentence. Moreover, we were able to conduct a more reliable analysis in which the same sentence regions were compared across conditions.

Although we found similar results in the eye-tracking and the self-paced reading experiments, we have to be careful not to draw strong conclusions from their comparison. In these two methodologies we collected different measures (target looks vs. reading times) and used different tasks (color naming vs. reading for comprehension). Nevertheless, it is reassuring that we found these strikingly similar effects, in that they provide converging evidence for the same linguistic phenomenon.

We compared several theoretical approaches and evaluated the extent to which their predictions can account for our findings. According to the *similarity-based approach* (Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & McElree, 2006; 2011), a processing advantage in subject relatives was expected, contrary to our findings. Also the *discourse-based approach* (Fox & Thompson, 1990; Kaan, 2001; Mak et al., 2008) and the *experience-based approach* (Brandt et al., 2009; Kidd et al., 2007; Reali & Christiansen, 2007; Roland et al., 2012; see also Heider et al., 2014), both predicting subject relatives with an embedded pronoun to be harder than comparable object relatives, fail to account for the lack of relative clause type asymmetry. The *experience-based approach* is also

incompatible with our findings concerning the 1st-/3rd-person pronoun asymmetry. A central assumption of this approach is that sentence comprehension reflects the distribution of certain language properties in natural speech (MacDonald, 1999; 2013; Hsiao & MacDonald, 2013; 2016). Based on our corpus analysis, we would expect subject relatives to be facilitated more with a 3rd-person pronoun than with a 1st-person pronoun and, by contrast, object relatives to be facilitated more with a 1st-person pronoun than with a 3rd-person pronoun. However, what we find is that both subject and object relatives are easier to process when the embedded pronoun is a 1st-person pronoun. This indicates that adults' and children's experience with certain linguistic patterns cannot always explain their performance in carefully controlled experimental settings.

As we have seen, our findings are explained best by the *structure-discourse approach* (or *Storage and Integration Cost Metric*; Gibson, 1998; 2000; Warren & Gibson, 2002). According to this approach, the embedded pronoun reduces memory load and facilitates processing. Since in our subject and object relatives the word order was the same and the pronoun appeared in exactly the same position, its effect in both sentence types was the same. The greater facilitation of the 1st-person pronoun, compared to the 3rd-person pronoun, is explained as due to the cognitively less demanding discourse accessibility mechanism of the former.

The key idea behind this approach is that sentence processing is affected not only by structural characteristics, such as syntactic complexity or the distance between a displaced constituent and the site of the long-distance dependency resolution, but also by discourse-related factors (cf. Hwang & Kaiser, 2015; Myachykov et al., 2012; Prat-Sala & Branigan, 2000). Although they are presumably independent in essence, these structural and discourse factors can interact with each other in a way that affects sentence processing. For instance, Yang et al. (2013) found that the classical subject-object asymmetry in relative clause processing (without pronouns) can be eliminated following certain manipulations of the discourse context. These authors tested subject and object relatives, presented in isolation or with a preceding context that made the referent of the relative clause head noun

particularly salient in the discourse. They found that participants read object relatives faster than subject relatives, when the context favored the usage of the former sentence type.

The assumption underlying the *structure-discourse* approach is that limited memory resources are the cause for processing difficulties in structures in which newly introduced referents appear while a long-distance dependency has not yet been resolved (Gibson, 1998; 2000; Gibson & Wu, 2013; Grodner & Gibson, 2005; Hsiao & Gibson, 2003). In fact, also discourse accessibility is a cognitive operation related strongly, if not mainly, to memory resources (Haendler et al., 2015b; van Rij et al., 2013). The ability to correctly link a 3rd-person pronoun to its referent depends on formulating a plausible discourse model, keeping it active in memory and retrieving from it the correct referent for the pronoun. This operation is less demanding in the case of a 1st-person pronoun: its referent is more readily available and memory resources are thus burdened to a lesser extent. It therefore seems important for models that take memory resources as the main determiner of sentence processing, but that currently do not account for effects of discourse accessibility (e.g., Lewis & Vasishth, 2005; Jäger et al., 2015), to incorporate these into their framework.

Another contribution of this paper to the study of pronoun effects in sentence processing is the comparison of young children and adults. Whereas previous research has looked either at adults or at children, we compared the performance of both populations and found that 5-year-olds' relative clause processing is affected by the pronouns in a qualitatively similar way to the adults'. We thus find support for the *Continuity Hypothesis* of language acquisition (Adani & Fritzsche, 2015; Contemori & Marinis, 2014; Felser et al., 2003; Love, 2007; Roberts et al., 2007; Trueswell & Gleitman, 2007). This highlights the importance of comparing children's performance to that of adult controls, as well as the advantage of using sensitive on-line methods in order to reveal young children's implicit processing strategies.

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CHAPTER 4

TESTING THE EFFECT OF IMPERSONAL ARBITRARY SUBJECT PRONOUN ON RELATIVE CLAUSE COMPREHENSION: A STUDY WITH HEBREW-SPEAKING CHILDREN

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ABSTRACT

Friedmann et al. (2009) claim that object relatives (OR) are hard when the head and embedded nouns both bear an NP-feature. As evidence, Hebrew-speaking children were shown to be accurate on ORs with an embedded impersonal pro, a non-referential pronoun with arbitrary interpretation lacking an NP-feature. This facilitation, however, might be driven by a mismatch in grammatical features between the head noun and impersonal pro, or by the pronoun's undemanding non-referentiality. We controlled for these possibilities by comparing ORs whose embedded subject is either impersonal pro, a full DP or a referential pronoun. In all conditions, grammatical features on the relevant constituents were similar. In a referent-identification task, the matching features made ORs with

embedded pronouns hard for 5-year-olds. Accuracy was particularly low when the embedded pronoun was referential. These results indicate that an NP-feature-mismatch does not facilitate ORs across the board, and that pronouns' discourse-related properties affect OR processing.

4.1. INTRODUCTION

Much research has been dedicated to the acquisition of restrictive relative clauses. These are subordinate clauses that describe a nominal phrase by restricting it from a given set of tokens of the same sort (Adani, 2011; Heim & Kratzer, 1998). Thus, the information conveyed by the relative clause is the basis on which the referent of the modified noun phrase can be identified. Previous research has mainly concentrated on the comparison of subject-extracted relatives (SR) and object-extracted relatives (OR). In a SR (1) the noun phrase modified by the relative clause, also called the head noun, is extracted from the subject position inside the relative clause. In other words, the head noun is the subject of the embedded verb. In an OR (2), the head noun is extracted from the object position of the embedded verb. In the examples, we put the constituent in the extraction site in angle brackets, representing it as a silent copy of the displaced head noun (Chomsky, 1995).

(1) The horse that <the horse> is catching the rhino
(2) The horse that the rhino is catching <the horse>

Previous work has shown that SRs emerge earlier than ORs in spontaneous speech production (e.g., Diessel & Tomasello, 2000). Reflecting this asymmetry, numerous studies in a variety of languages have found that ORs are harder to process than SRs, both for children and adults (Adani, 2011; Adani, Forgiarini, Guasti & van der Lely, 2014; Adani & Fritzsche, 2015; Arnon, 2010; Arosio, Yatsushiro, Forgiarini & Guasti, 2012; Belletti, Friedmann, Brunato & Rizzi, 2012; Friedmann, Belletti & Rizzi, 2009; Friedmann & Novogrodsky, 2004; Gibson, 2000; Gordon, Hendrick & Johnson, 2001; Hu, Gavarró,

Vernice & Guasti, 2016; Lewis, Vasishth & Van Dyke, 2006; MacDonald, 2013; Reali & Christiansen, 2007; Van Dyke & McElree, 2011, among others). To account for the observed difficulties with ORs, several theoretical approaches have been advanced. Among these, the account that stands at the focus of the present paper will be referred to as the *intervention locality approach* (Belletti et al., 2012; Friedmann et al., 2009; Grillo, 2009; Rizzi, 2013).

This approach is based on *Relativized Minimality* (RM), a syntactic principle first developed to explain degraded acceptability of sentences with extraction from islands (Rizzi, 1990). Later on, the RM principle was applied to the structure of relative clauses to explain the SR-OR asymmetry (Belletti et al., 2012; Friedmann et al., 2009; Grillo, 2009). According to RM, the configuration X…Z…Y represents a structure in which X undergoes a syntactic movement from its gap site Y and Z intervenes, such that Z c-commands Y but it does not c-command X. In such a configuration, the local relation between X and its gap in Y is disrupted if Z is of the same structural type as X. Applied to an OR like (2), X represents the head noun (*The horse*), Y the gap site *(<the horse>*) and Z the intervening embedded subject (*the rhino*). According to the intervention locality approach, if the head noun and the embedded subject are structurally similar, the disruption in the relation between the head noun and its gap leads to difficulties with the OR.

The structural similarity that makes OR processing hard is defined by Friedmann et al. (2009) in terms of the NP-feature. When both the head noun and the embedded subject of an OR bear an NP-feature, that is, when they are full DPs (or, to use the authors' terminology, when they are lexically restricted), the OR is hard to parse. As evidence, Friedmann et al. found that Hebrew-speaking 5-year-olds' OR comprehension improved significantly when only one of the relevant constituents was a full DP. Thus, children were highly accurate on free ORs (3), in which the wh-word head noun is not a full DP but the embedded subject is, and on ORs whose embedded subject is an impersonal *pro*, an unpronounced pronoun with arbitrary interpretation (4). In these ORs, the head noun is a full DP but not the embedded pronominal subject.

(3) Tare li et mi she-ha-yeled menadned.
show to-me ACC who that-the-boy swings
'Show me who the boy is swinging.'

(4) Tare li et ha-sus she- mesarkim oto.
show to-me ACC the-horse that-*pro*-comb$_{PL.MASC}$ him
Literally: 'Show me the horse that (they) are combing.'
Actual meaning: 'Show me the horse that someone is combing.'

Production studies in Hebrew confirm the facilitation of ORs with an embedded impersonal *pro*: children often produce such ORs as a strategy to avoid the production of ORs with two full DPs (Arnon, 2010; Friedmann et al., 2009; Guenzberg-Kerbel Shvimer & Friedmann, 2008; Novogrodsky & Friedmann, 2006).

Other studies, in which different kinds of pronouns were placed in the embedded subject position, found similar results. For instance, children are more accurate on ORs with an embedded 1st- or 2nd-person pronoun (*I*/*you*) than on ORs with two full DPs (Arnon, 2010; Brandt, Lieven & Tomasello 2016; Haendler, Kliegl & Adani, 2015b). Similarly, Brandt, Kidd, Lieven & Tomasello (2009) and Lassotta, Adelt, Stadie, Burchert & Adani (2015) found that children's comprehension improved also on ORs with an embedded 3rd-person pronoun like he or they. Although impersonal *pro* and the other pronouns used across studies differ in their characteristics and usage, they all share the property of lacking an NP-feature. Thus, taken together, these studies seem to support the idea that OR comprehension becomes easier when the head noun and the embedded subject differ in terms of the NP-feature.

Crucially, however, the facilitation of ORs with an embedded impersonal *pro* can be explained in more than one way. The mismatch in the NP-feature, as suggested by Friedmann et al., is one possibility. Another one is the mismatch in the feature Number between the singular head noun (*the horse*) and the inherently plural embedded pronoun (*pro*). The grammatical features characterizing impersonal *pro* are evident in the agreement marking (plural, masculine) on the embedded verb *mesarkim* 'comb.PL.MASC' in (4). Also the facilitation of ORs with an embedded 1st- or 2nd-person pronoun is not necessarily due to the mismatch in the NP-feature. It can be explained as due to a mismatch

in the feature Person between the head noun (3rd-person) and the embedded pronoun (1st- or 2nd-person). Let us explain in detail the basis for these claims.

Recent findings show that children are accurate on ORs whose head noun and embedded subject are both full DPs, albeit differing with regard to their grammatical features. Adani and colleagues found that a mismatch in the grammatical feature Number between the head noun and the embedded subject leads to improved performance in Italian-speaking children (Adani, van der Lely, Forgiarini & Guasti, 2010) and English-speaking ones (Adani et al., 2014). They found that children's comprehension improves when the head noun is singular and the embedded subject is plural, or vice versa, as compared to when both are singular or plural. Belletti et al., (2012) found a similar effect in Hebrew, concerning a match or a mismatch in the grammatical feature Gender. The *intervention locality approach* has been further developed to account for these findings, and the definition of structural similarity between the head and the embedded nouns has been refined. The idea is that what determines whether X and Z are similar, is any grammatical feature that serves as an attractor of syntactic movement. That is, if X and Z bear the same movement-attracting features the OR will be hard to process; whenever there is a mismatch in even one such feature the OR will become easier (Belletti et al., 2012; Rizzi, 2013; Starke, 2001). One relevant feature is Number, which is part of the set of features that attract movement in Italian, English and also Hebrew. This is why a mismatch in Number drives an improvement in comprehension in these languages. By contrast, Gender is an attractor of movement in Hebrew, but not in Italian. Therefore, a mismatch in Gender has a strong facilitation effect in ORs in the former language, but not in the latter (Adani et al., 2010; Belletti et al., 2012).

Concerning the feature Person, the *intervention locality approach* so far has not tested its effects. Nevertheless, it is likely to be relevant for determining the similarity between the head and the embedded nouns, given that it is a movement-attracting feature. An indication for this property lies in the overt marking of Person on verbs, just like Number, or Gender in Hebrew (Belletti et al., 2012). This is shown in examples (5)-(6). In all three examples, the verb *tfs* / *acchiappare* 'catch' is marked with Person (3rd-person) and

Number (singular). However, whereas the Hebrew verb is also marked with Gender, the Italian verb is not. This can be seen in the comparison between (5) and (6), where the Hebrew verb, but not the Italian one, is marked differently for masculine and feminine.

(5) Ha-sus she-hu tafas. (Hebrew)
the-horse that-he caught$_{3P.SG.MASC}$

Il cavallo che (lui) ha acchiappato. (Italian)
the horse that (he) has$_{3P.SG}$ caught

'The horse that he has caught.'

(6) Ha-sus she-hi tafsa. (Hebrew)
the-horse that-she caught$_{3P.SG.FEM}$

Il cavallo che (lei) ha acchiappato. (Italian)
the horse that (she) has$_{3P.SG}$ caught

'The horse that she has caught.'

In the light of this refined definition of structural similarity, the Number mismatch in previously tested ORs with impersonal *pro* might well be a cause for the attested facilitation. Similarly, in studies that used 1st- or 2nd-person pronouns in the embedded subject position, the mismatch in Person between the head noun (a full DP marked with 3rd-person) and the embedded pronoun could also be the source of improvement in children's performance. Thus, in all these cases we do not know whether the observed high accuracy is because the head noun and the embedded subject differ in terms of the NP-feature, given that the embedded subject is a pronoun, or in terms of the features Number or Person. Of course, the facilitation might also be the result of a cumulative effect driven by the mismatch in more than one feature. The first goal of the current study is to test whether Hebrew ORs with impersonal *pro* are easy for children also when other relevant grammatical features on the head noun and the embedded pronoun, such as Person, Number and Gender, are controlled. In other words, we want to see whether the dissimilarity in

terms of the NP-feature alone facilitates OR comprehension, as predicted by the *intervention locality approach*.

There is yet another potential source of facilitation of ORs with impersonal *pro*, which lies in the referential properties of this specific pronoun. As mentioned, impersonal *pro* has an arbitrary interpretation, in the sense that it is non-referential (Shlonsky, 2014). It is used to refer to an arbitrary subject in cases in which the identity of the agent of the action is not, or does not need to be, known. Note that impersonal *pro* is invariable: although it takes a plural and masculine agreement marking, its referent–the agent that is performing the action–does not necessarily have to be plural or masculine. To better capture the non-referentiality of impersonal *pro*, compare it with a referential 3rd-person pronoun like *hem* 'they' (or 'he', 'she' and so on, for that matter). Such a pronoun takes as discourse referent a specific entity that is highly salient in the discourse, for example by being previously mentioned as a subject or a topic (Fukumura & van Gompel, 2015; Song & Fisher, 2005). This is illustrated in (7b), where the pronoun *hem* refers to the people mentioned in (7a). By contrast, a non-referential pronoun like impersonal *pro* does not relate to any specific discourse referent. Hence, its referent does not need to be mentioned in a previous context, as shown in (8). In fact, if a sentence like (8) were to follow the one in (7a) it would sound odd (or, at least, it would sound as an unrelated sentence, not as a continuation of the first one). Since (7a) establishes a specific referent of the agent that is outside the door, it would be inappropriate to refer to it with impersonal *pro*.

(7) a. Yesh anashim baxuc.
there (are) people outside
'There are people outside.'

b. Hem dofkim b-a-delet.
they knock$_{.PL}$ at-the-door
'They are knocking at the door.'

(8) Dofkim b-a-delet.
pro knock.PL at-the-door
Literally: '(They) are knocking at the door.'
Actual meaning: 'Someone is knocking at the door.'

These two pronouns, with their different referential properties, are assumed to differ also with respect to the cognitive load associated with their processing. A referential pronoun like *hem* imposes an additional processing cost due to the requirement of establishing a link with its antecedent. By contrast, a non-referential pronoun such as impersonal *pro* is likely to burden the language parsing system to a lesser extent. The rationale behind this assumption is simple: when we encounter a referential 3rd-person pronoun we need to look for an antecedent in the discourse context and retrieve it for the purpose of processing the sentence, an operation that might demand more cognitive resources; by contrast, a non-referential pronoun like impersonal *pro* does not require this additional step during sentence processing and is therefore less resource-demanding.

Evidence that sentence processing–and relative clause processing in particular–is constrained by referential properties of pronouns has emerged in several studies. In particular, previous research has looked at the effect of 1st- and 3rd-person pronouns on sentence processing. In a visual-world study, Haendler et al. (2015b) recorded German-speaking 5-year-olds' eye movements during the processing of ORs with an embedded 1st- or 3rd-person pronoun. The 1st-person pronoun facilitated processing more than the 3rd-person pronoun, as indicated by a higher proportion of looks to the target in the visual scene that accompanied the sentence. Similar results have been found also with adults. Warren & Gibson (2002) measured English-speaking adults' complexity rating of doubly embedded ORs in which the embedded-most subject was either a 1st- or a 3rd-person pronoun. ORs with an embedded 1st-person pronoun were rated as significantly less complex than comparable ORs with an embedded 3rd-person pronoun. Additionally, Carminati (2005) tested Italian adults' processing of sentences other than relative clauses and found the same 1st- vs. 3rd-person pronoun asymmetry.

In all of these studies, the advantage of the 1st-person pronoun over the 3rd-person pronoun was interpreted as due to the pronouns' referential properties. The idea is that

processing was affected by the level of difficulty with which the referent of a pronoun is retrieved from discourse. The search and retrieval of a discourse referent is less costly in the case of a 1st-person pronoun. Its referent, which is part of the linguistic act (it is the speaker), is accessed more straightforwardly than the referent of a 3rd-person pronoun, which is not part of the linguistic act and is therefore retrieved less directly from the discourse (Ariel, 2001; Erteschik-Shir, 1997; Heim, 1991; Köder & Maier, 2016; Recanati, 1993). Taken together, these studies point to effects during sentence processing that are caused by referential properties of different types of pronouns, and to which also young children are sensitive (see also Hartshorne, Nappa & Snedeker, 2015; Legendre & Smolensky, 2012; Song & Fisher, 2005). Therefore, the possibility that children find ORs with impersonal *pro* easy because the pronoun is non-referential needs to be assessed. This constitutes another goal in the present study.

The advantage of using impersonal *pro* to test effects of pronouns' referential properties is emphasized in the light of the arguments made earlier about the Person feature. The asymmetry between 1st- and 3rd-person pronouns in previously tested ORs could be explained not only based on the pronouns' referential properties, but also on the different Person feature that marks them. In ORs with an embedded 1st-person pronoun (*The horse that I am chasing*), the head noun is marked with 3rd-person and the embedded pronoun with 1st-person. By contrast, in ORs with an embedded 3rd-person pronoun (*The horse that she is chasing*), both constituents are marked with 3rd-person. The mismatch in Person in the former case might have facilitated comprehension more than the match in the latter. Thus, the comparison of 1st- and 3rd-person pronouns in terms of their referential properties is confounded with the (mis)match in the Person feature. In the present study, we avoid this confound by comparing two pronouns that bear the same grammatical features (Person, Number and Gender) and differ only with respect to their referential properties.

In this study we will also look at the relation between children's performance on the tested ORs and their memory abilities. Friedmann et al. (2009) briefly suggest that difficulties in cases of intervention locality might be related to memory load. The idea is

that memory is required to compare the head and the embedded nouns, based on their characterizing features, while processing the OR. When the two constituents bear similar features this operation consumes more memory resources, resulting in greater processing cost. But when they differ with respect to their features memory is burdened to a much lesser extent (see related proposals by Gordon et al., 2001; Lewis et al., 2006; Lewis & Vasishth, 2005; Van Dyke & McElree, 2011[7]). If memory is overloaded more during the processing of ORs in which the head and the embedded nouns bear the same features, then we might find that children with stronger memory skills are also more accurate on these ORs (Bentea, Durrleman & Rizzi, 2016; for detailed reviews on the role of memory in sentence processing, see Kidd, 2013 and Wagers & Phillips, 2014).

In sum, although there is evidence that children perform well on ORs with an embedded impersonal *pro*, we do not know whether this is due to the feature specification on the pronoun–be it the NP-feature or the grammatical features Person, Number etc.–or whether it is due to the undemanding referential properties of impersonal *pro*. In the present study we address these open questions. First, in an attempt to replicate previous findings, we test whether children are more accurate on ORs with impersonal *pro* than on ORs with two full DPs. However, contrary to previously used sentences, we structure the ORs in a way that controls for potential effects that are due to grammatical features other than the NP-feature. To do this, the head noun and the embedded subject had similar grammatical features (Person, Number and Gender). If the mismatch in NP-feature facilitates comprehension, as predicted by the *intervention locality approach*, children should be more accurate on ORs with impersonal *pro* than on ORs with two full DPs, despite the match in the other features. Second, we test whether the non-referentiality of impersonal *pro* affects OR comprehension. To do this, we compare ORs with impersonal *pro* to ORs with an embedded referential pronoun *hem* 'they', in which all relevant grammatical features are

7 Like the *intervention locality approach*, these *similarity-based*, or *cue-based*, frameworks currently do not account for effects of referential properties of pronouns on sentence processing. Here we are concentrating only on the *intervention locality approach*, since its proponents have tested the effect of Hebrew impersonal *pro* on OR comprehension and formulated explicit predictions about it.

again controlled. The *intervention locality approach* predicts no difference between these two OR types, because the embedded subject in both is a pronoun lacking an NP-feature, and the relevant grammatical features are controlled. However, if the pronouns' referentiality matters the less costly referential characteristics of impersonal *pro* might facilitate comprehension more than the more demanding referential properties of *hem*. Finally, the *intervention locality approach* assumes that memory is overloaded more when the head and the embedded nouns bear the same features. Therefore, the prediction is that children's memory skills will be related to their performance on ORs with two full DPs more than on ORs with embedded pronouns, in which the two relevant constituents differ with respect to the NP-feature.

4.2. METHOD

4.2.1. *Participants*

Thirty-six children (18 girls, age range = 3;11-6;4, mean age = 5;1) were recruited among personal acquaintances or in private kindergartens in the area of Jerusalem. Six children (of which 2 girls) were excluded from the sample for the following reasons: 1 child failed to understand the task, 3 children were growing up as bilinguals and 2 children received speech therapy around the period of testing. The remaining 30 children were all growing up as monolingual speakers of Hebrew, without history or evidence of language, hearing or other communication disorders. This information was obtained through a questionnaire signed by the parents or by the teachers (with a parents' authorization). In addition, parents signed a consent form to allow the participation of their child.

4.2.2. *Material*

The conditions are shown with examples and translation in **Table 4.1**. For each of the three OR types we constructed 7 items. As can be seen in the examples, the head noun (*Ha-susim* 'The-horses') and the embedded subject (*ha-karnafim* 'the-rhinos' / impersonal *pro* / *hem*

'they') always had the same grammatical features of Person (3rd-person), Number (plural) and Gender (masculine).

It can be noticed that ORs with impersonal *pro* and with *hem* differ with respect to the appearance of the reumptive pronoun *otam* 'them' at the end of the sentence. It is resumptive in the sense that, while referring to the raised head noun, it is stranded within the relative clause (Boeckx, 2003; Friedmann et al., 2009). This resumptive pronoun is obligatory in ORs with an embedded impersonal *pro*, but it substantially degrades the acceptability of ORs with an embedded *hem* pronoun, based on the judgment of three native speakers. ORs with two full DPs, by contrast, can either contain or not a resumptive pronoun at the end. Although both versions are grammatical (Doron, 1982; Shlonsky, 1992), ORs with two full DPs containing a resumptive pronoun are less frequent in natural speech (Ariel, 1999) and they are harder to process than comparable ORs without a resumptive pronoun, even for adults (Meltzer-Asscher, Fadlon, Goldstein & Holan, 2015). In order to account for any potential effects of the resumptive pronoun *otam*, some of the ORs with two full DPs contained it and some did not (four with, three without).

In addition to ORs, there were 8 subject relative clauses and 8 non-relatives (e.g., *Ha-susim im ha-perax* 'the-horses with the-flower'), used as fillers with the aim of preventing participants from developing response strategies during the experiment. Each of these utterances was embedded within a matrix sentence, repeated equally for each item, which asked about the color of a pair of animals: for instance, *Ma ha-ceva shel ha-susim she-ha-karnafim tofsim?* 'What (is) the-color of the-horses that-the-rhinos catch?' Adapted from Arnon (2010), this method allowed us to introduce the task as a color-naming game and mask the actual goal of the experiment at least to some extent. All the noun phrases were animals familiar to young children. We used 3 verbs–*rxc* 'wash' (using a brush), *dgdg* 'tickle' (using a feather) and *tfs* 'catch' (using a net)–each appeared an equal number of times throughout the entire experiment. The sentences, recorded with a female native speaker of Hebrew, were integrated into the accompanying visual scene using Flash Adobe.

The visual scenes were animated videos that depicted animals performing the described action (cf. **Figure 4.1**). On half of the trials the direction of the action was from the right

to the left side of the scene, and on the other half it was from left to right. The items were arranged in two pseudo-randomized lists. All items appeared in both lists, but in a different order, such that no two consecutive trials were of the same condition. Half of the children were exposed to the first list and the other half to the second list. A full list of the items is provided in **Appendix C.1**.

TABLE 4.1. A summary of the conditions with examples.

Sentence type	**Embedded DP type**	**Example**
		Ma ha-ceva shel… What (is) the-color of…
OR	full DP	*... ha-susim she-ha-karnafim tofsim (otam)?* the-horses.**3P.PL.MASC** that-the-rhinos.**3P.PL.MASC** catch (them) '… the horses that the rhinos are catching?'
	impersonal *pro*	*... ha-susim she- tofsim otam?* the-horses.**3P.PL.MASC** that-*pro*-catch.**3P.PL.MASC** them '… the horses that someone is catching'
	hem	*... ha-susim she-hem tofsim?* the-horses.**3P.PL.MASC** that-they.**3P.PL.MASC** catch '… the horses that they are catching?'
SR		*... ha-susim she-tofsim et ha-karnafim?* the-horses that-catch ACC the rhinos '… the horses that are catching the rhinos?'
Non-relatives		*... ha-susim im ha-perax?* the-horses with the-flower '… the horses with the flower?'

OR = object relatives; SR = subject relatives; 3P = 3rd-person marking; PL = plural marking; MASC = masculine marking.

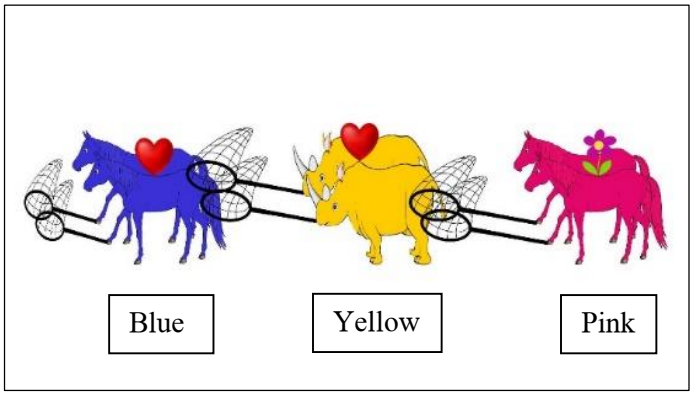

FIGURE 4.1. A snapshot from an example video (the color names indicated in boxes did not appear in the original videos).

4.2.3. *Procedure*

Two participants were tested in their private homes, with one or both parents present in the room. The rest of the children were tested in a quiet room in their kindergartens, either in the presence of the experimenter alone, or together with a teacher. Each child was encountered twice by the experimenter, with a distance of 1-2 weeks between the two appointments. Each session was approximately 20-25 minutes long. Children received colorful stickers as a thank-you gift at the end of each of the two sessions. They were generally happy to participate and very much engaged in all the tasks.

In the first session, prior to the experiment, children played a preparation game designed to make sure they know impersonal *pro*. This pronoun, with its specific function and lacking a phonological realization, is rather peculiar. Although children's active use of ORs with impersonal *pro* is attested from age 3;6 in experimental settings that elicit relative clause production (Arnon, 2010; Guenzberg-Kerbel et al., 2008; Novogrodsky & Friedmann, 2006), their comprehension of this pronoun has not been widely investigated in Hebrew. At the time of conducting the study, we were only aware of Friedmann et al.'s (2009) Experiment 4 as a study in which the comprehension of impersonal *pro*, embedded in ORs, was tested. The goal of the preparation game was therefore to assess children's

awareness of impersonal *pro* in general, not in relative clauses. For this reason, and in order to avoid influencing the performance in the actual experiment, no relative clauses were used in the game. Moreover, the verbs/actions in the game were not the ones used in the experiment. Note that children's performance in the game was not a precondition for their participation in the experiment. Rather, we aimed to create a context in which impersonal *pro* was used, and make sure children understand and use it appropriately. The game confirmed that children had no difficulties performing the tasks included. The procedure of the preparation game is detailed in **Appendix C.2**.

Right after the game, children were seated in front of a DELL laptop with a screen resolution of 1600x900. The SMI Experiment Center software was used to display the videos[8]. The experimenter, sitting next to the child, pressed a button to move from one trial to the next. After each question, the child named aloud the color of the pair of animals she thought were the correct ones, and the experimenter noted down the response on a sheet. After each 9-10 trials there was a short break of approximately 1-2 minutes in which the experimenter briefly interacted with the child, giving her a positive feedback.

At the beginning of the experiment the child watched on the computer an introduction video in which a dog named Guli appeared and explained the task. He said he would like to have the child's help in learning the color names. The narrator then showed examples of the three actions that were about to appear in the experiment–wash, tickle and catch–and named them. Five practice trials were integrated into the introduction video and the experimenter, if necessary, provided feedback for the response on them (but not during the actual experiment). The animals that appeared in these practice trials did not appear later in the test items. At the end of the story, Guli presented and named each of the animals that were going to participate in the experiment. The trials with the questions then followed.

In the second session, the experimenter administered to the child a forward and a backward digit span test (Armon-Lotem & Meir, 2016, adapted from the *Wechsler*

8 An SMI eye-tracker recorded eye movements during the experiment. We will not present these data since the pattern they reveal is parallel to the response accuracy and as such, in our understanding, it does not add new information or insight. The eye-tracking data are available from the first author.

Intelligence Scales for Children-revised: WISC-R95, Wechsler, 1998). In each test, the child heard sequences of digits of increasing length (from 2 to 9 digits), read aloud by a recorded female voice on a laptop. For each span length there were two trials. The test was interrupted when the child failed to answer on two trials of the same span length. The score was the highest span for which the child answered correctly on both trials. We took as a measure of memory skills the average score on the two digit span tests. By doing so, we have a more robust measure that accounts for the cognitive abilities required to perform on these two types of memory tests (Haendler et al., 2015b).

4.3. RESULTS

All children were 100% accurate on the subject relatives and non-relative sentences. On ORs, children were most accurate when the embedded subject was a full DP, followed by ORs with impersonal *pro*, and least accurate on ORs with *hem*, as shown in **Table 4.2**.

TABLE 4.2. Proportion of correct responses on object relatives, divided by the type of embedded DP (95% confidence intervals in parentheses).

Embedded DP	Proportion of correct responses
full DP	.58 (.11)
impersonal *pro*	.28 (.10)
hem	.09 (.09)

Before the analysis, we checked whether there was a difference between ORs with two full DPs with and without the resumptive pronoun *otam*. This pronoun led to a slightly lower accuracy rate on the two-DP condition. Children were more accurate on ORs with two full DPs without the resumptive pronoun (63%) than on those with (54%). This difference, although non-significant statistically (t=-1.02, p=.31), is in line with previous studies on resumption in Hebrew relative clauses (Ariel, 1999; Meltzer-Asscher et al., 2015; see also in Friedmann et al., 2009 Experiment 2, results of the picture task).

Importantly, though, the accuracy rate on ORs with two full DPs was the highest whether these sentences contained or not a resumptive pronoun. Thus, since the presence or absence of the resumptive pronoun in two-DP ORs did not matter for the comparison to the pronoun conditions, all the items with two full DPs were collapsed together in the analysis.

We also included in the analysis children's age as a covariate. Note that the age range and its mean in our participants group roughly correspond to those in previous studies on relative clause comprehension in Hebrew (Belletti et al., 2012; Friedmann et al., 2009; Friedmann & Novogrodsky, 2004). Nevertheless, with this relatively wide age range it is important to check for possible effects of age. This is even more crucial when testing memory, since effects of memory skills and of age are expected to be highly correlated.

We analyzed the data with a generalized linear mixed model (Baayen, Davidson & Bates, 2008; Jaeger, 2008), using the *lme4* package (Bates, Maechler, Bolker & Walker, 2015) in R (R Core Team, 2016). The dependent variable was the correct or incorrect response, defined as 1 or 0 respectively. The fixed effects part included the three OR types, with the three types of embedded DP, to which we applied contrast coding in the following manner: IMPERSONAL *PRO* was compared to FULL DP, and *HEM* was compared to IMPERSONAL *PRO*. In addition, we included in the fixed effects part the average score on the two memory tests as well as the age in months. Both were used as centered, continuous covariates (without group division). All the main effects and interactions of EMBEDDED DP, MEMORY SCORE and AGE were estimated, except for the terms containing an interaction between MEMORY SCORE and AGE. These terms were excluded since, predictably, the two covariates correlated significantly (r=.53, p=.04). In the random effects part, we included an intercept over subjects and one over items. There was not enough data to include random slopes. A summary of the fixed effects part in the model is provided in **Table 4.3**.

TABLE 4.3. A summary of the fixed effects part in the mixed-effects model.

Effect	**Coefficient**	**Std. Error**	***z***	***p***
Intercept	-1.24	.25	-5.06	<.001
EMBEDDED DP: IMPERSONAL *PRO* VS. FULL DP	-1.77	.30	-5.88	<.001
EMBEDDED DP: *HEM* VS. IMPERSONAL *PRO*	-1.50	.36	-4.16	<.001
MEMORY SCORE	.62	.27	2.31	.02
AGE	-.11	.26	-.41	.68
MEMORY SCORE X IMPERSONAL *PRO* VS. FULL DP	-.37	.39	-.96	.34
MEMORY SCORE X *HEM* VS. IMPERSONAL *PRO*	-1.31	.41	-3.19	.001
AGE X IMPERSONAL *PRO* VS. FULL DP	.58	.29	1.96	.05
AGE X *HEM* VS. IMPERSONAL *PRO*	-.16	.35	-.48	.63

Consider the first comparison we aimed for, namely between ORs with impersonal *pro* and ORs with two full DPs. As indicated by the main effect, accuracy rate on ORs with two full DPs was significantly higher. This condition comparison did not interact significantly with MEMORY SCORE. The second comparison we were interested in, the one between the two pronoun conditions, was also significant. Children were more accurate on ORs with impersonal *pro* than on ORs with *hem*. Here there was also a significant interaction with MEMORY SCORE. Whereas children's accuracy rate on ORs with *hem* remained low independently of their memory skills, stronger memory improved children's performance on ORs with impersonal *pro*. As for the main effect of MEMORY SCORE, it was significant, indicating that across all conditions performance improved with stronger memory skills. The main effect of AGE and its interactions with the OR types were not significant.

The relation between memory and mean accuracy on the three OR types is plotted in **Figure 4.2**. It can be seen that accuracy rate both on ORs with two full DPs and on ORs with impersonal *pro* increase with higher memory score, thus reflecting a lack of interaction with this measure (although the increase in accuracy is slightly steeper for two-DP ORs, it is not significantly different from ORs with impersonal *pro*). By contrast, accuracy rate on ORs with hem remains unaffected by the memory score. This reflects the

significant interaction with memory for the difference between this condition and ORs with impersonal *pro*.

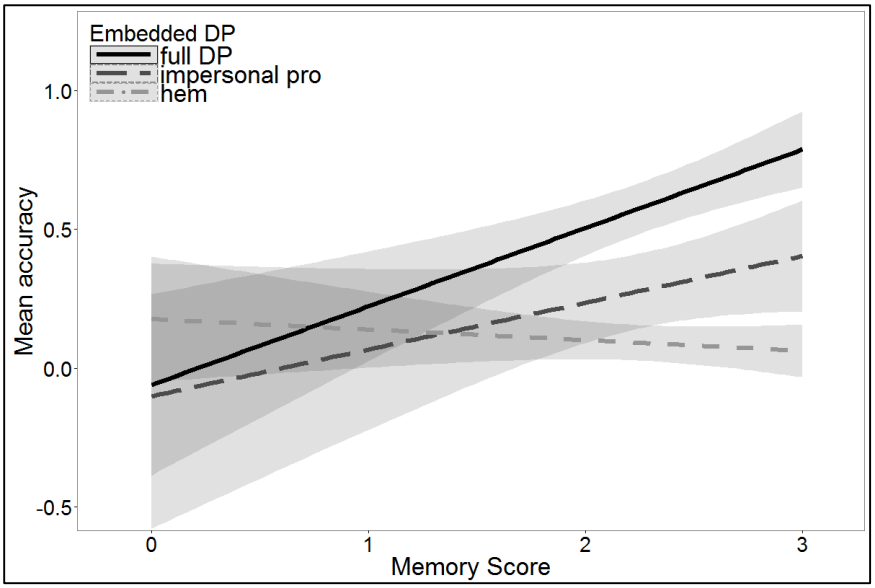

FIGURE 4.2. The relation between MEMORY SCORE and mean accuracy on the object relatives, divided by the type of embedded DP.

4.4. DISCUSSION

In this study we asked whether children comprehend ORs with an embedded impersonal *pro* accurately, after controlling for other potentially facilitating factors that characterized the material in previous research. We find that, unlike in previous studies, ORs with impersonal *pro* were hard for children. Moreover, we aimed at testing whether the comprehension of ORs with impersonal *pro* might be affected specifically by the referential properties of this pronoun. The results suggest this is the case. Children were more accurate on ORs with impersonal *pro*, a non-referential pronoun that is less costly for processing, than on ORs with *hem*, a referential pronoun that is cognitively more resource-

demanding. Finally, we tested the assumption that memory abilities support the processing of ORs in which the head and the embedded nouns bear the same features. From the data it emerges that memory was not related to whether the constituents shared a similar features set. Rather, it appears to be related to the referential properties of the various constituents (full DPs and pronouns) and, in particular, it emphasizes the asymmetry between the two pronoun conditions.

4.4.1. *ORs with impersonal pro vs. ORs with two full DPs*

Previous studies have found that children accurately comprehend ORs with an embedded impersonal *pro*, and that they often produce them as a strategy to avoid ORs with two full DPs (Arnon, 2010; Friedmann et al., 2009; Guenzberg-Kerbel et al., 2008; Novogrodsky & Friedmann, 2006). However, in all of these studies, ORs with impersonal *pro* were characterized by a mismatch both in the NP-feature and in Number between the head noun and the embedded impersonal *pro*. Given findings that confirm the facilitation effect of Number on OR comprehension (Adani et al., 2010; 2014), it is impossible to conclude which type of feature mismatch enhanced performance on ORs with impersonal *pro*.

In the present study, we controlled for the possibility that ORs with impersonal *pro* are facilitated due to a mismatch in Number, or any other feature other than the NP-feature. We compared ORs with impersonal *pro* to ORs with two full DPs, in which all the potentially facilitating features in Hebrew–Person, Number and Gender–were the same on the full DP head noun and on impersonal *pro*. Once these features matched, we found that ORs with impersonal *pro* were not easier than ORs with two full DPs. In fact, children were most accurate on the latter condition. This result indicates that previously attested high accuracy on ORs with impersonal *pro* is not due to the mismatch in the NP-feature *per se*. It might be driven by the Number mismatch, or perhaps by a combined effect due to both kinds of mismatch.

Importantly, the accuracy rate on ORs with two full DPs is roughly comparable to the one found in previous studies with Hebrew-speaking children of the same age range (e.g., Friedmann et al., 2009). We thus replicated previous findings on this OR type. The failure

to replicate the previously found high accuracy on ORs with impersonal *pro* is therefore likely because these ORs did not have a mismatch in other grammatical features, notably Number, between the head noun and impersonal *pro*. In other words, the presence of impersonal *pro* in the embedded subject position, and thus the dissimilarity in terms of the NP-feature alone, were not sufficient to facilitate comprehension in our study.

This point is highlighted further when considering the structure of our ORs with impersonal *pro*. Since impersonal *pro* is unpronounced, on the surface this kind of OR seems identical to a SR with an embedded object pronoun, although the underlying syntactic structure of these two sentence types differs substantially. This is illustrated in examples (9)-(10). In the OR in (9), the embedded verb *tfs* 'catch' takes as subject impersonal *pro* and as object the head noun *ha-susim* 'the-horses', whereas *otam* 'them' is interpreted as a resumptive pronoun that refers to the head noun. By contrast, the embedded verb in the SR in (10) takes as subject the head noun and the pronoun *otam* is interpreted as the object of the embedded verb, referring to some discourse referent *i*.

(9) Ha-susim she- tofsim otam.
the-horses.PL.MASC that-*pro*-catch.PL.MASC them.PL.MASC
Literally: 'The horses that (they) are catching.'
Actual meaning: 'The horses that someone is catching.'

(10) Ha-susim she-tofsim otam$_i$.
the-horses.PL.MASC that-catch.PL.MASC them.PL.MASC
'The horses that are catching them$_i$.'

The similarity between these two sentence types stems from the fact that in (9) the head noun and impersonal *pro* are marked with the same grammatical features of Person, Number and Gender. In fact, with a mismatch in even one of these features the similarity to a SR disappears. In (11) the head noun is marked with singular, and as a consequence also the resumptive pronoun takes a singular marking. In (12) the head noun and the resumptive pronoun are plural but feminine. As can be seen, these ORs with differing grammatical features are clearly distinguishable from the SR in (10).

(11) Ha-sus she- tofsim oto.
the-horse.SG.MASC that-*pro*-catch.PL.MASC him.SG.MASC
Literally: 'The horse that (they) are catching.'
Actual meaning: 'The horse that someone is catching.'

(12) Ha-susot she- tofsim otan.
the-horses.PL.FEM that-*pro*-catch.PL.MASC them.PL.FEM
Literally: 'The mares that (they) are catching.'
Actual meaning: 'The mares that someone is catching.'

Note, however, that our ORs with impersonal *pro* (9) are by no means ambiguous. In the context in which these sentences were presented, interpreting them as SRs with an embedded object pronoun would be completely inappropriate. The reason is that no referent for the object pronoun *otam* 'them' has been explicitly mentioned in the previous context or made salient in the discourse in some other way. Indeed, adults with whom the experiment was piloted were 100% accurate on ORs with impersonal *pro*, indicating that they never considered interpreting this structure as a SR. Nevertheless, it is possible that children's high accuracy in previous studies was driven, or at least supported, by the Number mismatch (example 11 is comparable to previously used ORs with impersonal *pro*, as in Friedmann et al., 2009). Such ORs with impersonal *pro* can hardly be confused with SRs. In the present study, by contrast, children might have been confused by the apparent similarity between ORs impersonal *pro* (9) and SRs like (10). This possibility emphasizes even more the claim that impersonal *pro* on its own is not sufficient to facilitate OR comprehension; a mismatch in one or more grammatical features is required as well.

4.4.2. *ORs with embedded pronouns*

Impersonal *pro* is not the only kind of pronoun whose effects on OR comprehension have been tested. Other studies have argued for a facilitation caused by an embedded 1st-person or 2nd-person pronoun (Arnon, 2010; Brandt et al., 2016; Gordon et al., 2001; Haendler et al., 2015b). How can this be reconciled with the lack of pronoun facilitation in our study, as evinced by the low accuracy on ORs with either impersonal *pro* or *hem*? A plausible

explanation is that in the present study, Person was among the features whose effects were controlled. Just like the effect of impersonal *pro* in previous studies is confounded with a mismatch in Number, the effect of 1st- and 2nd-person pronouns is confounded with a mismatch in Person. As we have argued, this feature is likely to be relevant for intervention locality due to its overt marking on verbs. Our findings show that a match in Person (and other features) results in a lack of facilitation, despite the fact that the embedded subject was a pronoun.

Other studies with children have rather used a 3rd-person pronoun as the embedded subject, yielding mixed results: some found that 3rd-person pronouns facilitate OR comprehension (Brandt et al., 2009; Lassotta et al., 2015) and some found they do not (Coyer, 2009; Haendler et al., 2015b). Our findings are in line with the studies that fail to find a 3rd-person pronoun facilitation, which is explained as driven by the match in the feature Person. In Coyer (2009) and Haendler et al. (2015b) the head noun and the embedded pronoun were singular and marked with 3rd-person, whereas in the present study the two constituents were plural and marked with 3rd-person (both in ORs with impersonal *pro* and in ORs with *hem*). So we see that in those cases in which there is a full match in the set of relevant features, the OR is hard for children despite the presence of a pronoun in the embedded subject position. In all these cases, the mismatch in NP-feature between the head noun and the embedded pronoun was not sufficient to facilitate OR comprehension.

So what could explain the 3rd-person pronoun facilitation found in some studies? We believe children's performance on those ORs could have been enhanced by discourse effects that are due to task-specific characteristics. Contrary to the present study, in these studies the pronoun was not encountered for the first time inside the test sentence. Rather, each test sentence was preceded by a context in which the pronoun was mentioned in relation to its referent (the context corresponded to the visual material in the experiment). For instance: *Look, here's Pater again. Let's see what he's doing now… He's washing this frog* (Brandt et al., 2009). Similarly, the items in Lassotta et al. (2015) were preceded by an introductory phrase such as *Here is a chick, here is another chick and here are two*

frogs; they both have a flower. In both studies, the explicit mention of the pronoun in the preceding context could have made its referent highly salient in the discourse context. This in turn is likely to facilitate the processing of the pronoun and the sentence in which it is embedded. In addition, the sentences in Lassotta et al.'s study were also characterized by a Number mismatch between a singular head noun (e.g., *a chick*) and a plural embedded pronoun (*they*). This is another factor that might have improved children's accuracy, as compared to the present study.

In short, it appears that the mere presence of a pronoun in the embedded subject position does not facilitate OR comprehension across the board. When the head noun and the embedded pronoun are marked with the same grammatical features performance is poor, and children are even more accurate on ORs with two full DPs (see Haendler et al., 2015b for an extended discussion on this issue).

4.4.3. *The role of pronouns' referential properties*

Despite the overall low accuracy rate on the two pronoun conditions, we also found that children were relatively more accurate on ORs with impersonal *pro* than on ORs with *hem*. This pronoun asymmetry is not related to (dis)similarity in grammatical features, given that both OR types had a pronoun in the embedded subject position, and all the relevant constituents had the same features. This asymmetry can be explained, though, by the different referential properties of the pronouns.

The pronoun *hem* is a referential pronoun that can be interpreted only if the link to its referent in the discourse is correctly identified and processed. By contrast, impersonal *pro* is non-referential (Shlonsky, 2014). As such, its interpretation does not depend on a linking process with a specific referent in the discourse. It is conceivable that what makes ORs with impersonal *pro* easier to process than ORs with *hem* is the fact that the referential properties of the former require less cognitive resources during sentence processing. The idea that discourse-related properties of pronouns–specifically, how easy or hard it is to retrieve the pronoun's referent from discourse–is supported by previous work that has looked at the difference between 1st- and 3rd-person pronouns (Ariel, 2001; Carminati,

2005; Erteschik-Shir, 1997; Haendler et al., 2015b; Heim, 1991; Köder & Maier, 2016; Legendre & Smolensky, 2012; Recanati, 1993; Warren & Gibson, 2002). These studies have argued that a less demanding pronoun-referent linking (1st-person pronouns) facilitates processing more than a more demanding pronoun-referent linking (3rd-person pronouns). The present study extends this idea by pointing to different effects between a case of demanding pronoun-referent linking (*hem*) and a case in which there is no such linking whatsoever (impersonal *pro*). In fact, the present results provide even more straightforward evidence for the idea that pronouns' referential properties constrain OR processing, since in our material the pronouns had the same features, in particular Person.

It could be argued that ORs with *hem* were particularly hard for children in the present study because the sentences were not preceded by a linguistic context in which the pronoun's referent was explicitly mentioned (although the referent, the middle pair of animals, was visually present in the video that accompanied the sentence). First, note that in previous studies in which children had difficulties with ORs with a 3rd-person pronoun, the sentences were preceded by a context in which the referent was mentioned (Coyer, 2009; Haendler et al., 2015b). This shows that difficulties with 3rd-person pronouns do not arise only in the absence of a context. Second, it is crucial to note that any comparison between impersonal *pro* and *hem* in Hebrew would raise the question of what context can be used, or whether it can be used at all. On the one hand, a pronoun like *hem* requires being linked to a highly salient discourse referent, ideally mentioned explicitly in the context. But such a context would be problematic for the usage of impersonal *pro* that, due to its arbitrary interpretation, cannot be linked to any specific referent. On the other hand, it is evident that the lack of an explicit mention of the referent in a preceding context, as in the present study, is more problematic for *hem* than for impersonal *pro*. Crucially, however, this fact actually highlights even more the constraints imposed by the referential properties of the two pronouns during OR processing: in the absence of an explicit mention of a referent, the interpretation of the referential pronoun *hem* was more error-prone than that of the non-referential impersonal *pro*.

Concerning the assumption that the non-referentiality of impersonal *pro* is cognitively less demanding, it is legitimate to ask why ORs with this pronoun were harder for children than ORs with two full DPs. If impersonal *pro* is easier to process than *hem* because of its non-referentiality, then intuitively this should also be the case in comparison to a full DP. Unlike impersonal *pro*, but similar to a referential 3rd-person pronoun, a full DP does have a specific referent, albeit one that is retrieved from discourse more directly than the referent of a 3rd-person pronoun (Epstein, 2002; Heim, 1982). Hence, we would have expected the effect of referentiality to create a hierarchy in which OR comprehension is easiest with impersonal *pro*, then with a full DP whose referent is accessed with relative straightforwardness, then with a referential 3rd-person pronoun whose referent is less directly accessed. This is not what we find. Unfortunately, our results do not allow us to fully understand the underlying mechanisms of referentiality and how it affects OR processing in depth. The pattern that seems to emerge is that the non-referentiality of impersonal *pro* is not sufficient, on its own, to facilitate OR comprehension when the grammatical features (Person, Number and Gender) match. This is why the children in our study performed poorly on ORs with an impersonal *pro*. However, non-referentiality is still enough to facilitate comprehension relative to the case of a referential pronoun like *hem*. This is why, despite the overall low accuracy rate on the two pronoun conditions, children were still more accurate on ORs with impersonal *pro* than on ORs with *hem*, a difference that the statistical analysis confirmed as significant. What exactly the conditions are under which pronoun referentiality affects sentence processing, and in what manner it does so, are issues that will have to be further studied in the future.

One possible direction to pursue might be to follow up on previous studies and compare ORs with impersonal *pro* and ORs with two full DPs in which there is also a mismatch in a grammatical feature, like Number. Unlike in previous studies, though, both OR types should have the same Number marking on the head (singular) and on the embedded subject (plural). For instance, *Ha-sus she-ha-karnafim tofsim* 'The-horse that-the-rhinos are catching' and *Ha-sus she-tofsim oto* 'The-horse that-*pro*-catch him'. ORs with impersonal *pro*, expected to be easier for children due to the Number mismatch, would be more

comparable to the ORs with two full DPs because of the singular head and plural embedded subject. Would we find in this case that ORs with impersonal *pro* are harder or easier than ORs with two full DPs? This question is left open for now.

4.4.4. *The relation to memory*

Finally, consider the issue of memory. The initial assumption was that intervention locality structures are hard because the similarity between the head noun and the intervening embedded subject overloads memory resources (Friedmann et al., 2009; see also Gordon et al., 2001; Lewis et al., 2006; Lewis & Vasishth, 2005; Van Dyke & McElree, 2011). Hence, memory skills should support the comprehension of ORs whose head and embedded nouns share a full set of features more than ORs with differing features (under the prediction that the latter should be anyway easier). We found that stronger memory skills support children's performance on ORs with two full DPs and on ORs with impersonal *pro*, but not on ORs with *hem*. Among our conditions only ORs with two full DPs presented a case in which the head noun and the embedded subject were similar in terms of all of the relevant features (NP-feature, Person, Number and Gender). Thus, the pattern of relations between response accuracy and memory score confirms only partially the initial assumption. Rather, it appears from the presented findings that strong memory skills support OR processing, but only in cases in which there is direct linking between the embedded constituent and its referent, like with full DPs (Haendler et al., 2015b), or when such linking is not required at all, as in the arbitrary interpretation of impersonal *pro*.

The relation with memory also highlights the asymmetry between the two pronoun conditions. ORs with *hem* were hard across the board. That is, all children had difficulties with them, independently of their memory ability. By contrast, despite the low accuracy rate on ORs with impersonal *pro* on the group level, some children–those with stronger memory skills–were highly accurate on these ORs. Specifically, not all the children with strong memory skills performed well on ORs with impersonal *pro*; but all the children who were highly accurate on this condition also scored high on the memory tests. Thus, although both pronoun conditions were overall hard for children, the individual differences

in memory skills emphasize the strong asymmetry between the effects of impersonal *pro* and of *hem* on OR comprehension.

4.5. CONCLUSION

The reported findings do not lend support to the idea that OR comprehension is facilitated by the lack of NP-feature of an embedded pronoun. If the head noun and the embedded pronoun are marked with the same grammatical features children find the sentence hard, despite the mismatch in NP-feature. Moreover, OR comprehension is also constrained to some extent by the referential properties of the embedded pronoun. Together, the results point to the possibility that OR processing is influenced not only by grammatical factors, such as feature specification on the relevant constituents, but also by discourse-related factors such as pronoun referentiality. These discourse effects appear to occur independently of grammatical ones and to be strongly related to children's memory abilities.

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CHAPTER 5

CONCLUSIONS

This thesis deals with the effects of embedded pronouns on relative clause processing. These effects were explored in three studies, each carried out in a different language. In the German study, I find evidence that the expected facilitation of embedded pronouns on children's OR processing depends on the pronoun type. As compared to a lexical noun phrase, the 1st-person pronoun facilitated processing more than the 3rd-person pronoun, which in fact made processing harder. The pronoun asymmetry was also evident in the relation to memory and grammatical skills, which modulated performance only on ORs with the harder 3rd-person pronoun, but not with the 1st-person pronoun. In the Italian study, the same 1st-/3rd-person pronoun asymmetry was found in both OR and SR, whose word order was kept the same. No relative clause type asymmetry was found. The same performance pattern was evident in children's and adults' eye-movements, as well as in the reading times of an additional group of adults. In the Hebrew study, I find that the previously attested facilitation of the impersonal *pro* pronoun on children's OR comprehension does not hold across the board. Rather, this pronoun was found to facilitate performance most likely because of other characteristics of the sentence (e.g., mismatch in Number). Despite children's difficulties, they were still relatively more accurate on ORs when the embedded pronoun was the non-referential impersonal *pro* as compared to the referential pronoun *hem* 'they'. The asymmetry between these two pronouns was highlighted by the relation between children's response accuracy and their memory abilities.

Together, the data presented in this thesis suggest that relative clause processing, and sentence processing in general, is not affected only by syntactic or other characteristics pertinent to the sentence structure. Rather, discourse-related factors, such as the discourse accessibility, or other referential properties, of the constituents that compose the sentence appear to play a prominent role in the modulation of processing patterns. Current theoretical approaches that explain sentence processing in terms of similarity between constituents need to account for these discourse effects. For instance, according to the *Intervention Locality Approach* (Belletti et al., 2012; Bentea et al., 2016; Friedmann et al., 2009), the pronoun facilitates OR processing because it lacks an NP-feature. This approach needs to account for the fact that different pronouns, with different referential properties, affect processing differently. *Similarity-Based Approaches*, such as cue-based retrieval processing (Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006; 2011), explain processing in terms of greater or smaller memory load that is driven by an interfering constituent that shares with another constituent in memory the same retrieval cues. This approach needs to incorporate an explanation of cases of increased processing load which depends on discourse properties of the constituents.

In sum, in order to account for discourse-related effects a comprehensive theory of human sentence processing would have to describe some kind of a combination between factors of various nature–both structural ones that are pertinent to the syntactic structure of the sentence and to the structure of its constituents, and discourse-related ones.

One such combination of factors is proposed by the *Storage and Integration Cost Metric Approach* (Gibson, 1998; 2000; Warren & Gibson, 2002; 2005). Importantly, I do not wish to make the claim that this approach is capable of explaining sentence processing in its entirety. In fact, the scope of its predictions extends well beyond the effects found in the presented experiments, and these predictions are at the center of on-going debate and research. However, the attempt of this approach to describe sentence processing both from

a structural perspective and from a discourse-related one is definitely welcome. Similar attempts should be made by other processing accounts as well.

Another important point that emerges from the presented data is that discourse-related effects, just like structural ones, are related to–and modulated by–memory capacity. This is in line with other studies on discourse-related phenomena in psycholinguistics, in which the role of memory and other cognitive abilities is demonstrated (e.g., Hendriks et al., 2014; Warren and Gibson, 2002; van Rij et al., 2013; Vogels et al., 2015). These findings point to the idea that memory provides support on various levels of sentence processing.

Finally, the comparison of children's and adults' performance joins a body of studies whose results support the *Continuity Hypothesis* (e.g., Adani & Fritzsche, 2015; Contemori & Marinis, 2014; Felser et al., 2003; Love, 2007; Roberts et al., 2007; Trueswell & Gleitman, 2007). The data show that children's sentence processing is influenced by the discourse accessibility or referentiality of pronouns in a fashion that is qualitatively similar to the adult one. Thus, I find evidence that children are as sensitive as adults to the interaction of structural and discourse-related factors.

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APPENDIX A:

Discourse accessibility constraints in children's processing of object relative clauses

A.1 Full list of items in the experiment

Fillers

1. Welche Farbe hat der Bär mit dem Hut?
What color has the bear with the hat?

2. Welche Farbe hat der Löwe mit der Brille?
What color is the lion with the glasses?

3. Welche Farbe hat der Affe mit dem Herzen?
What color has the monkey with the heart?

4. Welche Farbe hat der Hase mit der Blume?
What color has the bunny with the flower?

5. Welche Farbe hat der Bär mit der Brille?
What color has the bear with the glasses?

6. Welche Farbe hat der Löwe mit dem Hut?
What color has the lion with the hat?

7. Welche Farbe hat der Affe mit der Blume?
What color has the monkey with the flower?

8. Welche Farbe hat der Hase mit dem Herzen?
What color has the bunny with the heart?

9. Welche Farbe hat der Bär mit der Blume?
What color has the bear with the flower?

10. Welche Farbe hat der Löwe mit dem Herzen?
What color has the lion with the heart?

11. Welche Farbe hat der Affe mit der Brille?
What color has the monkey with the glasses?

12. Welche Farbe hat der Hase mit dem Hut?
What color has the bunny with the hat?

OR+2DP

1. Welche Farbe hat der Bär, den das Kamel kitzelt?
What color has the bear who the camel tickles?

2. Welche Farbe hat der Löwe, den das Zebra jagt?
What color has the lion who the zebra chases?

3. Welche Farbe hat der Affe, den das Schaf kitzelt?
What color has the monkey who the sheep tickles?

4. Welche Farbe hat der Bär, den die Ente jagt?

What color has the bear who the duck chases?

5. Welche Farbe hat der Löwe, den die Maus kitzelt?
What color has the lion who the mouse tickles?

6. Welche Farbe hat der Affe, den die Katze jagt?
What color has the monkey who the cat chases?

7. Welche Farbe hat der Hase, den das Pferd kitzelt?
What color has the bunny who the horse tickles?

OR+1pro

1. Welche Farbe hat der Bär, den ich jage?
What color has the bear who I chase?

2. Welche Farbe hat der Löwe, den ich kitzle?
What color has the lion who I tickle?

3. Welche Farbe hat der Affe, den ich jage?
What color has the monkey who I chase?

4. Welche Farbe hat der Bär, den ich kitzle?
What color has the bear who I tickle?

5. Welche Farbe hat der Löwe, den ich jage?
What color has the lion who I chase?

6. Welche Farbe hat der Affe, den ich kitzle?
What color has the monkey who I tickle?

7. Welche Farbe hat der Hase, den ich jage?
What color has the bunny who I chase?

OR+3pro

1. Welche Farbe hat der Bär, den es jagt?
What color has the bear who it chases?

2. Welche Farbe hat der Löwe, den es kitzelt?
What color has the lion who it tickles?

3. Welche Farbe hat der Affe, den es jagt?
What color has the monkey who it chases?

4. Welche Farbe hat der Bär, den sie kitzelt?
What color has the bear who she tickles?

5. Welche Farbe hat der Löwe, den sie jagt?
What color has the lion who she chases?

6. Welche Farbe hat der Affe, den sie kitzelt?
What color has the monkey who she tickles?

7. Welche Farbe hat der Hase, den es jagt?
What color has the bunny who it chases?

OR+dem

1. Welche Farbe hat der, den das Kamel kitzelt?
What color has DEM who the camel tickles?

2. Welche Farbe hat der, den das Zebra jagt?
What color has DEM who the zebra chases?

3. Welche Farbe hat der, den das Schaf kitzelt?
What color has DEM who the sheep tickles?

4. Welche Farbe hat der, den die Ente jagt?
What color has DEM who the duck chases?

5. Welche Farbe hat der, den die Maus kitzelt?
What color has DEM who the mouse tickles?

6. Welche Farbe hat der, den die Katze jagt?
What color has DEM who the cat chases?

7. Welche Farbe hat der, den das Pferd kitzelt?
What color has DEM who the horse tickles?

A.2 Example of a preamble text and test sentence for each condition

Condition	Preamble text	Test sentence
Fillers	Hier sind zwei Bären. Der eine Bär ist lila und der andere Bär ist gelb. Und hier ist ihr Freund, das Kamel. Das Kamel ist grün. Here are two bears. One bear is purple and the other bear is yellow. And here is their friend, the camel. The camel is green	Guck mal! Welche Farbe hat der Bär mit dem Hut? Look! What color is the bear with the hat?
OR+2DP	Hier sind zwei Löwen. Der eine Löwe ist rot und der andere Löwe ist gelb. Und hier ist ihr Freund, das Zebra. Das Zebra ist blau. Here are two lions. One lion is red and the other lion is yellow. And here is their friend, the zebra. The zebra is blue.	Guck mal! Welche Farbe hat der Löwe, den das Zebra jagt? Look! What color is the lion that the zebra chases?
OR+1pro	Hier sind zwei Affen. Der eine Affe ist gelb und der andere Affe ist rot. Und ich bin auch da. Hier bin ich blau. Here are two monkeys. One monkey is yellow and the other monkey is red. And I'm also here. Here I'm blue.	Guck mal! Welche Farbe hat der Affe, den ich kitzle? Look! What color is the monkey that I tickle?

OR+3pro	Hier sind zwei Bären. Der eine Bär ist blau und der andere Bär ist gelb. Und hier ist ihre Freundin, die Ente. Die ENTE ist pink. Here are two bears. One bear is blue and the other bear is yellow. And here is their friend, the duck. The DUCK is pink.	Guck mal! Welche Farbe hat der Bär, den sie kitzelt? Look! What color is the bear that she tickles?
OR+dem	Hier ist ein pinkes Schaf. Und hier sind seine Freunde, die Affen. Der EINE Affe ist gelb, und der ANDERE Affe ist blau. Here is a pink sheep. And here are its two friends, the monkeys. ONE monkey is yellow, and the OTHER monkey is blue.	Guck mal! Welche Farbe hat der, den das Schaf kitzelt? Look! What color is the one that the sheep tickles

A.3 Fixed effects of generalized linear mixed-effects model

Fixed effect	**Coef.**	**SE**	**z-value**	**p-value**
Intercept	-.26	.34	-.75	.45
Condition OR+2DP vs. OR+3pro	-.12	.49	-.24	.81
Language Score	.36	.16	2.26	.02
Memory Score	.32	.23	1.39	.16
Language Score : Condition OR+2DP vs. OR+3pro	-.31	.13	-2.34	.02
Memory Score : Condition OR+2DP vs. OR+3pro	.13	.19	.67	.50
Language : Memory	-.18	.18	-1.04	.29
Language : Memory : Condition OR+2DP vs. OR+3pro	.10	.15	.67	.50

A.4 Fixed effects of linear mixed-effects model

Fixed effect	**Coef.**	**SE**	**t-value**
Intercept	-.39	.05	-7.91
Time	17.51	.88	19.85
Time2	-17.73	.89	-19.95
Condition OR+1pro vs. OR+2DP	-.82	.03	-30.88
Condition OR+2DP vs. OR+3pro	-.25	.03	-9.46
Memory Score	.09	.05	1.87
Language Score	.06	.03	1.98
Time : Condition OR+1pro vs. OR+2DP	-6.46	2.15	-2.99
Time2 : Condition OR+1pro vs. OR+2DP	31.89	2.18	14.65
Time : Condition OR+2DP vs. OR+3pro	-1.74	2.18	-.79
Time2 : Condition OR+2DP vs. OR+3pro	-.72	2.17	-.33
Time : Memory	-.85	.89	-.96
Time2 : Memory	-2.08	.88	-2.36
Memory : Condition OR+1pro vs. OR+2DP	-.13	.02	-5.07
Memory : Condition OR+2DP vs. OR+3pro	.04	.03	1.50
Time : Language	.14	.57	.25
Time2 : Language	-3.59	.58	-6.19
Language : Condition OR+1pro vs. OR+2DP	.08	.02	4.49
Language : Condition OR+2DP vs. OR+3pro	-.09	.02	-5.03
Memory : Language	.07	.04	1.73
Time : Memory: Condition OR+1pro vs. OR+2DP	-14.41	2.13	-6.75
Time2 : Memory: Condition OR+1pro vs. OR+2DP	-2.88	2.17	-1.33
Time : Memory: Condition OR+2DP vs. OR+3pro	8.86	2.19	4.04
Time2 : Memory: Condition OR+2DP vs. OR+3pro	3.37	2.11	1.59
Time : Language: Condition OR+1pro vs. OR+2DP	7.85	1.42	5.54
Time2 : Language: Condition OR+1pro vs. OR+2DP	-1.75	1.44	-1.21
Time : Language: Condition OR+2DP vs. OR+3pro	-4.56	1.43	-3.18
Time2 : Language: Condition OR+2DP vs. OR+3pro	5.41	1.45	3.74
Time : Memory: Language	.75	.74	1.02

Time2 : Memory: Language	-.44	.75	-.59
Memory: Language : Condition OR+1pro vs. OR+2DP	.05	.02	-2.19
Memory : Language: Condition OR+2DP vs. OR+3pro	.04	.02	1.70
Time : Memory: Language: Condition OR+1pro vs. OR+2DP	.72	1.77	.41
Time2 : Memory: Language: Condition OR+1pro vs. OR+2DP	3.88	1.82	2.13
Time : Memory: Language: Condition OR+2DP vs. OR+3pro	8.41	1.80	4.66
Time2 : Memory: Language: Condition OR+2DP vs. OR+3pro	-6.39	1.76	-3.63

APPENDIX B:

Pronoun facilitation in relative clause processing

B.1 Full list of items in the eye-tracking experiment

Subject relatives with a 1st-person pronoun

(1) Qui ci sono dei gatti. Ed eccoci qui con loro.
Di che colore è il gatto che ci sta rincorrendo?

(2) Qui ci sono dei cavalli. Ed eccoci qui con loro.
Di che colore è il cavallo che ci sta lavando?

(3) Qui ci sono dei topi. Ed eccoci qui con loro.
Di che colore è il topo che ci sta acchiappando?

(4) Ecco delle papere. E qui ci sono io con loro.
Di che colore sono le papere che mi stanno rincorrendo?

(5) Ecco delle rane. E qui ci sono io con loro.
Di che colore sono le rane che mi stanno lavando?

(6) Ecco delle mucche. E qui ci sono io con loro.
Di che colore sono le mucche che mi stanno acchiappando?

Subject relatives with a 3rd-person pronoun

(1) Qui ci sono dei gatti. Ed ecco le loro amiche, le capre.
Di che colore è il gatto che le sta rincorrendo?

(2) Qui ci sono dei cavalli. Ed ecco le loro amiche, le pecore.
Di che colore è il cavallo che le sta lavando?

(3) Qui ci sono dei topi. Ed ecco le loro amiche, le scimmie.
Di che colore è il topo che le sta acchiappando?

(4) Ecco delle papere. E qui c'è il loro amico, l'orso.
Di che colore sono le papere che lo stanno rincorrendo?

(5) Ecco delle rane. E qui c'è il loro amico, il coniglio.
Di che colore sono le rane che lo stanno lavando?

(6) Ecco delle mucche. E qui c'è il loro amico, il leone.
Di che colore sono le mucche che lo stanno acchiappando?

Object relatives with a 1st-person pronoun

(1) Ecco dei gatti. E qui ci sono io con loro.
Di che colore sono i gatti che io sto lavando?

(2) Ecco dei cavalli. E qui ci sono io con loro.
Di che colore sono i cavalli che io sto acchiappando?

(3) Ecco dei topi. E qui ci sono io con loro.
Di che colore sono i topi che io sto rincorrendo?

(4) Qui ci sono delle papere. Ed eccoci qui con loro.
Di che colore è la papera che noi stiamo lavando?

(5) Qui ci sono delle rane. Ed eccoci qui con loro.
Di che colore è la rana che noi stiamo acchiappando?

(6) Qui ci sono delle mucche. Ed eccoci qui con loro.
Di che colore è la mucca che noi stiamo rincorrendo?

Object relatives with a 3rd-person pronoun

(1) Ecco dei gatti. E qui c'è la loro amica, la capra.
Di che colore sono i gatti che lei sta lavando?

(2) Ecco dei cavalli. E qui c'è la loro amica, la pecora.
Di che colore sono i cavalli che lei sta acchiappando?

(3) Ecco dei topi. E qui c'è la loro amica, la scimmia.
Di che colore sono i topi che lei sta rincorrendo?

(4) Qui ci sono delle papere. Ed ecco i loro amici, gli orsi.
Di che colore è la papera che loro stanno lavando?

(5) Qui ci sono delle rane. Ed ecco i loro amici, i conigli.
Di che colore è la rana che loro stanno acchiappando?

(6) Qui ci sono delle mucche. Ed ecco i loro amici, i leoni.
Di che colore è la mucca che loro stanno rincorrendo?

Subject relatives with two lexical noun phrases

(1) Qui ci sono dei gatti. Ed ecco le loro amiche, le capre.
Di che colore è il gatto che sta rincorrendo le capre?

(2) Qui ci sono dei cavalli. Ed ecco le loro amiche, le pecore.
Di che colore è il cavallo che sta lavando le pecore?

(3) Qui ci sono dei topi. Ed ecco le loro amiche, le scimmie.
Di che colore è il topo che sta acchiappando le scimmie?

(4) Ecco delle papere. E qui c'è il loro amico, l'orso.
Di che colore sono le papere che stanno rincorrendo l'orso?

(5) Ecco delle rane. E qui c'è il loro amico, il coniglio.
Di che colore sono le rane che stanno lavando il coniglio?

(6) Ecco delle mucche. E qui c'è il loro amico, il leone.
Di che colore sono le mucche che stanno acchiappando il leone?

Object relatives with two lexical noun phrases

(1) Ecco dei gatti. E qui c'è la loro amica, la capra.
Di che colore sono i gatti che la capra sta lavando?

(2) Ecco dei cavalli. E qui c'è la loro amica, la pecora.
Di che colore sono i cavalli che la pecora sta acchiappando?

(3) Ecco dei topi. E qui c'è la loro amica, la scimmia.
Di che colore sono i topi che la scimmia sta rincorrendo?

(4) Qui ci sono delle papere. Ed ecco i loro amici, gli orsi.
Di che colore è la papera che gli orsi stanno lavando?

(5) Qui ci sono delle rane. Ed ecco i loro amici, i conigli.
Di che colore è la rana che i conigli stanno acchiappando?

(6) Qui ci sono delle mucche. Ed ecco i loro amici, i leoni.
Di che colore è la mucca che i leoni stanno rincorrendo?

Non-relatives

(1) Qui ci sono dei gatti. Ed eccoci qui con loro.
Di che colore è il gatto con la nuvola?

(2) Ecco dei cavalli. E qui c'è la loro amica, la scimmia.
Di che colore sono i cavalli con il libro?

(3) Qui ci sono dei topi. Ed ecco le loro amiche, le capre.
Di che colore è il topo con il cuore?

(4) Ecco delle papere. E qui ci sono io con loro.
Di che colore sono le papere con la stella?

(5) Qui ci sono delle rane. Ed ecco i loro amici, gli orsi.
Di che colore è la rana con il fiore?

(6) Ecco delle mucche. E qui ci sono io con loro.
Di che colore sono le mucche con il sole?

B.2 Full list of items in the self-paced reading experiment

(1)

[3rd-person pronoun]

Maria era al mare con il fratello Paolo.

Paolo si è messo ad azzuffarsi con i vicini di ombrellone.

Maria | era | preoccupata | per | la | ragazza | che | lo/lui | stava | spingendo | con | cattiveria | dentro | l'acqua.

La ragazza dell'ombrellone accanto ha buttato Paolo in acqua? / La ragazza dell'ombrellone accanto è stata buttata in acqua?

[1st-person pronoun]

Maria era al mare con me.

Io mi sono messo ad azzuffarmi con i vicini di ombrellone.

Maria | era | preoccupata | per | la | ragazza | che | mi/io | stava/stavo | spingendo | con | cattiveria | dentro | l'acqua.

La ragazza dell'ombrellone accanto mi ha buttato in acqua? / La ragazza dell'ombrellone accanto è stata buttata in acqua?

(2)

[3rd-person pronoun]

Elena era nel parco a leggere un libro.

Il figlio Andrea giocava con altri bambini sul prato.

Elena | si | intenerì | dalla | dolce | bambina | che | lo/lui | stava | stringendo | con | evidente | affetto | naturale.

Andrea è stato abbracciato con affetto? / Andrea ha abbracciato la bambina con affetto?

[1st-person pronoun]
Elena era nel parco a leggere un libro.
Io giocavao con altri bambini sul prato.

Elena | si | intenerì | dalla | dolce | bambina | che | mi/io | stava/stavo | stringendo | con | evidente | affetto | naturale.

Sono stato abbracciato con affetto? / Ho abbracciato la bambina con affetto?

(3)
[3rd-person pronoun]
Luciana era in coda al salumificio.
Adriano era con lei e aspettava paziente.

Luciana | era | imbarazzata | per | la | signora | che | lo/lui | stava | scrutando | con | curiosità | tanto | palese.

La signora al salumificio ha osservato Adriano? / La signora al salumificio è stata osservata?

[1st-person pronoun]
Luciana era in coda al salumificio.
Io ero con lei e aspettavo paziente.

Luciana | era | imbarazzata | per | la | signora | che | mi/io | stava/stavo | scrutando | con | curiosità | tanto | palese.

La signora al salumificio mi ha osservato? / La signora al salumificio è stata osservata?

(4)

[3rd-person pronoun]

Donatella offriva una terapia contro la depressione tramite l'incontro tra uomo e animale.
Leo ha fatto una sessione terapeutica allo zoo con una scimmia.

Donatella | poté | osservare | soddisfatta | la | scimmia | che | lo/lui | stava | tastando | con | una | grande | sensibilità.

Leo è stato toccato con sensibilità? / Leo ha toccato la scimmia con sensibilità?

[1st-person pronoun]

Donatella offriva una terapia contro la depressione tramite l'incontro tra uomo e animale.
Io ho fatto una sessione terapeutica allo zoo con una scimmia.

Donatella | poté | osservare | soddisfatta | la | scimmia | che | mi/io | stava/stavo | tastando | con | una | grande | sensibilità.

Sono stato toccato con sensibilità? / Ho toccato la scimmia con sensibilità?

(5)

[3rd-person pronoun]

Stefano e Valentina hanno festeggiato la fine dell'anno con persone dell'ufficio.
Valentina e uno dei colleghi si sono complimentati a vicenda sul lavoro svolto.

Stefano | s'è | proprio | irritato | dal | collega | che | la/lei | stava | lodando | senza | risparmiare | esagerate | lusinghe.

Il collega ha fatto a Valentina complimenti esagerati? / Al collega sono stati fatti complimenti esagerati?

[1st-person pronoun]
Stefano e io abbiamo festeggiato la fine dell'anno con persone dell'ufficio.
Io e uno dei colleghi ci siamo complimentati a vicenda sul lavoro svolto.

Stefano | s'è | proprio | irritato | dal | collega | che | mi/io | stava/stavo | lodando | senza | risparmiare | esagerate | lusinghe.

Il collega mi ha fatto complimenti esagerati? / Al collega sono stati fatti complimenti esagerati?

(6)
[3rd-person pronoun]
Giuseppe analizzava un nido di scarafaggi con altri studenti di biologia.
Monica, insieme ad altri colleghi, non voleva però stare vicino a quegli animali.

Giuseppe | era | veramente | infastidito | dallo | studente | che | la/lei | stava | tirando | via | dal | nido | repellente.

Monica è stata allontanata dal nido di scarafaggi? / Monica ha allontanato lo studente dal nido di scarafaggi?

[1st-person pronoun]

Giuseppe analizzava un nido di scarafaggi con altri studenti di biologia.

Io, insieme ad altri colleghi, non volevo però stare vicino a quegli animali.

Giuseppe | era | veramente | infastidito | dallo | studente | che | mi/io | stava/stavo | tirando | via | dal | nido | repellente.

Sono stata allontanata dal nido di scarafaggi? / Ho allontanato lo studente dal nido di scarafaggi?

(7)

[3rd-person pronoun]

Ettore visitava Claudia all'ospedale psichiatrico.

Claudia, così come un altro ricoverato, era a volte difficile da controllare.

Ettore | non | poté | ignorare | il | paziente | che | la/lei | stava | spogliando | velocemente | e | senza | passione.

Il paziente ha tolto a Claudia i vestiti? / Al paziente sono stati tolti i vestiti?

[1st-person pronoun]

Ettore mi visitava all'ospedale psichiatrico.

Io, così come un altro ricoverato, ero a volte difficile da controllare.

Ettore | non | poté | ignorare | il | paziente | che | mi/io | stava/stavo | spogliando | velocemente | e | senza | passione.

Il paziente mi ha tolto i vestiti? / Al paziente sono stati tolti i vestiti?

(8)

[3rd-person pronoun]

Michele è passato a trovare Angelica e suo padre, colpiti da una brutta influenza.
Angelica assisteva il padre e riceveva a sua volta tanto aiuto da lui.

Michele | provò | tenerezza | per | il | padre | che | la/lei | stava | curando | con | erbe | medicinali | naturali.

Ad Angelica sono state date medicine omeopatiche? / Angelica ha dato a suo padre medicine omeopatiche?

[1st-person pronoun]

Michele è passato a trovare me e mio padre, colpiti da una brutta influenza.
Io assistevo il padre e ricevevo a mia volta tanto aiuto da lui.

Michele | provò | tenerezza | per | il | padre | che | mi/io | stava/stavo | curando | con | erbe | medicinali | naturali.

Mi sono state date medicine omeopatiche? / Ho dato a mio padre medicine omeopatiche?

(9)

[3rd-person pronoun]

Laura ha voluto fare un salto al bar con il suo fidanzato Giulio.
Giulio si è subito presentato a tutti i clienti del bar.

Laura | si | ingelosì | molto | della | ragazza | che | lo/lui | stava | baciando | su | entrambe | le | guance.

La ragazza ha dato un bacio a Giulio? / La ragazza è stata baciata?

[1st-person pronoun]

Laura ha voluto fare un salto al bar con me.

Io mi sono subito presentato a tutti i clienti del bar.

Laura | si | ingelosì | molto | della | ragazza | che | mi/io | stava/stavo | baciando | su | entrambe | le | guance.

La ragazza mi ha dato un bacio? / La ragazza è stata baciata?

(10)

[3rd-person pronoun]

Gianna era in sala d'attesa con il fratello Marco.

Marco all'improvviso è diventato tutto rosso.

Gianna | allora | s'è | accorta | della | dottoressa | che | lo/lui | stava | fissando | con | un | notevole | interesse.

Marco è stato osservato? / Marco ha osservato la dottoressa?

[1st-person pronoun]

Gianna era in sala d'attesa con me.

Io all'improvviso sono diventato tutto rosso.

Gianna | allora | s'è | accorta | della | dottoressa | che | mi/io | stava/stavo | fissando | con | un | notevole | interesse.

Sono stato osservato? / Ho osservato la dottoressa?

(11)

[3rd-person pronoun]

Gioia ha giocato a nascondino con Luigi e altri ragazzini.
Luigi ha dato il via al primo round del gioco.

Gioia | venne | distratta | dalla | sorridente | bambina | che | lo/lui | stava | cercando | con | determinazione | e | tenacia.

La bambina ha cercato Luigi con fermezza? / La bambina è stata cercata con fermezza?

[1st-person pronoun]

Gioia ha giocato a nascondino con me e altri ragazzini.
Io ho dato il via al primo round del gioco.

Gioia | venne | distratta | dalla | sorridente | bambina | che | mi/io | stava/stavo | cercando | con | determinazione | e | tenacia.

La bambina mi ha cercato con fermezza? / La bambina è stata cercata con fermezza?

(12)

[3rd-person pronoun]

Antonella sorvegliava il figlio Raffaele e i suoi amici.
Raffaele prese dei colori per giocarci con gli altri.

Antonella | guardò | disperata | la | rossa | fanciulla | che | lo/lui | stava | macchiando | con | colori | accesi | e vivaci.

Raffaele è stato sporcato con dei colori? / Raffaele ha sporcato la bambina con dei colori?

[1st-person pronoun]

Antonella sorvegliava me, suo figlio, e i miei amici.

Io presi dei colori per giocarci con gli altri.

Antonella | guardò | disperata | la | rossa | fanciulla | che | mi/io | stava/stavo | macchiando | con | colori | accesi | e vivaci.

Sono stato sporcato con dei colori? / Ho sporcato la bambina con dei colori?

(13)

[3rd-person pronoun]

Mattia leggeva il giornale in salotto.

Sara nel frattempo parlava su skype con alcuni amici di scuola.

Mattia | s'è | alquanto | innervosito | dal | compagno | che | la/lei | stava | sgridando | per | aver | copiato | all'esame.

Il compagno ha rimproverato Sara per via dell'esame? / Il compagno è stato rimproverato per via dell'esame?

[1st-person pronoun]

Mattia leggeva il giornale in salotto.

Io nel frattempo parlavo su skype con alcuni amici di scuola.

Mattia | s'è | alquanto | innervosito | dal | compagno | che | mi/io | stava/stavo | sgridando | per | aver | copiato | all'esame.

Il compagno mi ha rimproverato per via dell'esame? / Il compagno è stato rimproverato per via dell'esame?

(14)

[3rd-person pronoun]

Alex era in compagnia della sorella Lea e di alcuni suoi amici.
Lea tirò fuori dalla borsa dei trucchi.

Alex | era | davvero | incuriosito | dal | ragazzo | che | la/lei | stava | truccando | per | poi | riderci | sopra.

Lea è stata truccata in modo burlesco? / Lea ha truccato il ragazzo in modo burlesco?

[1st-person pronoun]

Alex era in mia compagnia e di alcuni miei amici.
Io tirai fuori dalla borsa dei trucchi.

Alex | era | davvero | incuriosito | dal | ragazzo | che | mi/io | stava/stavo | truccando | per | poi | riderci | sopra.

Sono stata truccata in modo burlesco? / Ho truccato il ragazzo in modo burlesco?

(15)

[3rd-person pronoun]

Luca ha dovuto accompagnare la figlia Valeria in palestra.
Valeria si è messa a parlare con alcuni amici all'entrata.

Luca | s'è | intimorito | molto | dal | teppistello | che | la/lei | stava | guardando | con | un'aria | da | folle.

Il teppistello ha fissato Valeria? / Il teppistello è stato fissato?

[1st-person pronoun]
Luca ha dovuto accompagnarmi in palestra.
Io mi sono messa a parlare con alcuni amici all'entrata.

Luca | s'è | intimorito | molto | dal | teppistello | che | mi/io | stava/stavo | guardando | con | un'aria | da | folle.

Il teppistello mi ha fissato? / Il teppistello è stato fissato?

(16)
[3rd-person pronoun]
Dario ha invitato i suoi cuginetti a giocare con Francesca, la loro amica preferita.
Francesca giocava volentieri con i piccoli.

Dario | s'è | rallegrato | seriamente | del | cuginetto | che | la/lui | stava | seguendo | in | casa | con | risolutezza.

Francesca è stata inseguita per tutta la casa? / Francesca ha inseguito il cugino per tutta la casa?

[1st-person pronoun]
Dario ha invitato i suoi cuginetti a giocare con me, la loro amica preferita.
Io giocavo volentieri con i piccoli.

Dario | s'è | rallegrato | seriamente | del | cuginetto | che | mi/io | stava/stavo | seguendo | in | casa | con | risolutezza.

Sono stata inseguita per tutta la casa? / Ho inseguito il cugino per tutta la casa?

(17)

[3rd-person pronoun]

Emma ha trovato suo figlio Jacopo e i suoi amici completamente sporchi di fango.
Jacopo ha portato tutti i bambini con sé in cortile.

Emma | rimase | proprio | contenta | della | ragazzina | che | lo/lui | stava | sciacquando | con | l'acqua | della | fontanella.

Jacopo ha lavato la ragazzina in cortile? / Jacopo è stato lavato in cortile?

[1st-person pronoun]

Emma ha trovato me, suo figlio, e i miei amici completamente sporchi di fango.
Io ho portato tutti i bambini con me in cortile.

Emma | rimase | proprio | contenta | della | ragazzina | che | mi/io | stava/stavo | sciacquando | con | l'acqua | della | fontanella.

Ho lavato la ragazzina in cortile? / Sono stato lavato in cortile?

(18)

[3rd-person pronoun]

Petra faceva una gita in montagna con Almo e altri amici.
Almo, così come la sua consorte, soffriva spesso di vertigini.

Petra | trovò | realmente | ridicola | quella | donna | che | lo/lui | stava | tenendo | forte | per | paura | di cascare.

La moglie di Almo è stata afferrata? / La moglie di Almo lo ha afferrato?

[1st-person pronoun]

Petra faceva una gita in montagna con me e altri amici.

Io, così come la mia consorte, soffrivo spesso di vertigini.

Petra | trovò | realmente | ridicola | quella | donna | che | mi/io | stava/stavo | tenendo | forte | per | paura | di cascare.

Mia moglie è stata afferrata? / Mia moglie mi ha afferrato?

(19)

[3rd-person pronoun]

Giulia usciva da scuola con l'amico Alberto.

Alberto rimase indietro immobilizzandosi inaspettatamente.

Giulia | si | rese | conto | della | signora | che | lo/lui | stava | spiando | da | dietro | ad un | albero.

Alberto ha osservato la signora di nascosto? / Alberto è stato osservato di nascosto?

[1st-person pronoun]

Giulia usciva da scuola con me.

Io rimasi indietro immobilizzandomi inaspettatamente.

Giulia | si | rese | conto | della | signora | che | mi/io | stava/stavo | spiando | da | dietro | ad un | albero.

Ho osservato la signora di nascosto? / Sono stato osservato di nascosto?

(20)

[3rd-person pronoun]

Simona faceva il bagno al suo nipotino Dani.
Dani non voleva assolutamente fare la doccia da solo.

Simona | s'è | emozionata | tanto | dalla | sorellina | che | lo/lui | stava | lavando | con | naturalezza | quasi | materna.

La sorella è stata sciacquata con naturalezza? / La sorella ha sciacquato Dani con naturalezza?

[1st-person pronoun]

Simona faceva il bagno a me, il suo nipotino.
Io non volevo assolutamente fare la doccia da solo.

Simona | s'è | emozionata | tanto | dalla | sorellina | che | mi/io | stava/stavo | lavando | con | naturalezza | quasi | materna.

La sorella è stata sciacquata con naturalezza? / La sorella mi ha sciacquato con naturalezza?

(21)

[3rd-person pronoun]

Edoardo e Ludovica sono andati con alcuni amici in montagna.
Ludovica e altri del gruppo hanno messo i piedi in un ruscello.

Edoardo | ha | riso | tantissimo | per | l'amico | che | la/lei | stava | schizzando | come | in un | benevolo | gioco.

Ludovica ha bagnato l'amico scherzosamente? / Ludovica è stata bagnata scherzosamente?

[1st-person pronoun]
Edoardo e io siamo andati con alcuni amici in montagna.
Io e altri del gruppo abbiamo messo i piedi in un ruscello.

Edoardo | ha | riso | tantissimo | per | l'amico | che | mi/io | stava/stavo | schizzando | come | in un | benevolo | gioco.

Ho bagnato l'amico scherzosamente? / Sono stata bagnata scherzosamente?

(22)
[3rd-person pronoun]
Alessio e Giuditta incontrano regolarmente un gruppo di persone al fine di farsi a vicenda un massaggio rilassante.
Giuditta stavolta ha fatto coppia con il belloccio del gruppo.

Alessio | ha | osservato | con | gelosia | l'uomo | che | la/lei | stava | toccando | in | una | maniera | sospettosa.

Il bell'uomo è stato massaggiato? / Il bell'uomo ha massaggiato Giuditta?

[1st-person pronoun]
Alessio e io incontriamo regolarmente un gruppo di persone al fine di farci a vicenda un massaggio rilassante.
Io stavolta ho fatto coppia con il belloccio del gruppo.

Alessio | ha | osservato | con | gelosia | l'uomo | che | mi/io | stava/stavo | toccando | in | una | maniera | sospettosa.

Il bell'uomo è stato massaggiato? / Il bell'uomo mi ha massaggiato?

(23)

[3rd-person pronoun]

Antonio ha portato al mare sua figlia Paola.

Paola ha subito trovato un gruppo di bambini con cui giocare.

Antonio | s'è | infuriato | per | il | bambino | che | la/lei | stava | colpendo | sulla | schiena | scottata | dal sole.

Paola ha picchiato il bambino sulla schiena? / Paola è stata picchiata sulla schiena?

[1st-person pronoun]

Antonio ha portato al mare me, sua figlia.

Io ho subito trovato un gruppo di bambini con cui giocare.

Antonio | s'è | infuriato | per | il | bambino | che | mi/io | stava/stavo | colpendo | sulla | schiena | scottata | dal sole.

Ho picchiato il bambino sulla schiena? / Sono stata picchiata sulla schiena?

(24)

[3rd-person pronoun]

Alessandro faceva la spesa con Tina.

Tina voleva andare a prendere il latte.

Alessandro | era | divertito | dal | buffo | vecchietto | che | la/lei | stava | bloccando | col | carrello | pieno | di roba.

Il vecchio è stato bloccato col carrello della spesa? / Il vecchio ha bloccato Tina col carrello della spesa?

[1st-person pronoun]
Alessandro faceva la spesa con me.
Io volevo andare a prendere il latte.

Alessandro | era | divertito | dal | buffo | vecchietto | che | mi/io | stava/stavo | bloccando | col | carrello | pieno | di roba.

Il vecchio è stato bloccato col carrello della spesa? / Il vecchio mi ha bloccato col carrello della spesa?

(25)
[3rd-person pronoun]
Sofia è andata in spiaggia con Eugenio e i loro compagni di classe.
Eugenio e gli amici hanno deciso di seppellirsi a vicenda nella sabbia.

Sofia | osservò | con | attenzione | la | compagna | che | lo/lui | stava | coprendo | di | sabbia | molto | lentamente.

Eugenio ha seppellito l'amica sotto la sabbia? / Eugenio è stato seppellito sotto la sabbia?

[1st-person pronoun]
Sofia è andata in spiaggia con me e i nostri compagni di classe.
Io e gli amici abbiamo deciso di seppellirci a vicenda nella sabbia.

Sofia | osservò | con | attenzione | la | compagna | che | mi/io | stava/stavo | coprendo | di | sabbia | molto | lentamente.

Ho seppellito l'amica sotto la sabbia? / Sono stato seppellito sotto la sabbia?

(26)

[3rd-person pronoun]

Regina e Raimondo erano al bar a prendere un caffè.
Raimondo s'è messo a litigare con la barista per via dei pasticcini troppo cari.

Regina | teneva | sotto | controllo | la | proprietaria | che | lo/lui | stava | picchiando | con | ceffoni | molto | pesanti.

La proprietaria del bar è stata colpita con forza? / La proprietaria del bar ha colpito Raimondo con forza?

[1st-person pronoun]

Regina e io eravamo al bar a prendere un caffè.
Io mi sono messo a litigare con la barista per via dei pasticcini troppo cari.

Regina | teneva | sotto | controllo | la | proprietaria | che | mi/io | stava/stavo | picchiando | con | ceffoni | molto | pesanti.

La proprietaria del bar è stata colpita con forza? / La proprietaria del bar mi ha colpito con forza?

(27)

[3rd-person pronoun]

Daniela è andata al negozio dove lavora Remo.

Remo e una sua collega bisticciavano su chi avesse rubato dei soldi dalla cassa.

Daniela | s'è | arrabbiata | con | la | commessa | che | lo/lui | stava | cacciando | a | calci | fuori | dal negozio.

Remo ha mandato via la commessa? / Remo è stato mandato via?

[1st-person pronoun]

Daniela è andata al negozio dove lavoro.

Io e una mia collega bisticciavamo su chi avesse rubato dei soldi dalla cassa.

Daniela | s'è | arrabbiata | con | la | commessa | che | mi/io | stava/stavo | cacciando | a | calci | fuori | dal negozio.

Ho mandato via la commessa? / Sono stato mandato via?

(28)

[3rd-person pronoun]

Cecilia e Lucio erano in centro quando è iniziato il terremoto.

Lucio preferiva stare per strada vicino ad altre persone sopraffatte dallo spavento.

Cecilia | era | veramente | gelosa | della | giovane | che | lo/lui | stava | calmando | con | soffici | e dolci | carezze.

La giovane è stata accarezzata? / La giovane ha accarezzato Lucio?

[1st-person pronoun]

Cecilia e io eravamo in centro quando è iniziato il terremoto.

Io preferivo stare per strada vicino ad altre persone sopraffatte dallo spavento.

Cecilia | era | veramente | gelosa | della | giovane | che | mi/io | stava/stavo | calmando | con | soffici | e dolci | carezze.

La giovane è stata accarezzata? / La giovane mi ha accarezzato?

(29)

[3rd-person pronoun]

Filippo e Patrizia chiacchieravano su skype con dei parenti all'estero.

Patrizia raccontava di avere nostalgia di casa.

Filippo | era | terribilmente | seccato | dallo | zio | che | la/lei | stava | chiamando | con | dei | soprannomi | affettuosi.

Patrizia ha dato dei soprannomi allo zio? / A Patrizia sono stati dati dei soprannomi?

[1st-person pronoun]

Filippo e io chiacchieravamo su skype con dei parenti all'estero.

Io raccontavo di avere nostalgia di casa.

Filippo | era | terribilmente | seccato | dallo | zio | che | mi/io | stava/stavo | chiamando | con | dei | soprannomi | affettuosi.

Ho dato dei soprannomi allo zio? / Mi sono stati dati dei soprannomi?

(30)

[3rd-person pronoun]

Roberto ha incontrato la sua vecchia zia Eleonora per strada.

Eleonora è andata a fare una passeggiata pomeridiana.

Roberto | s'è | commosso | dal | vecchio | signore | che | la/lei | stava | guidando | con | garbo | a | braccetto.

Il vecchio signore è stato accompagnato? / Il vecchio signore ha accompagnato Eleonora?

[1st-person pronoun]

Roberto ha incontrato me, la sua vecchia zia, per strada.

Io sono andata a fare una passeggiata pomeridiana.

Roberto | s'è | commosso | dal | vecchio | signore | che | mi/io | stava/stavo | guidando | con | garbo | a | braccetto.

Il vecchio signore è stato accompagnato? / Il vecchio signore mi ha accompagnato?

(31)

[3rd-person pronoun]

Matteo e Rita sono scesi in piazza.

Rita voleva bere dalla fontana dove alcuni ragazzi giocavano.

Matteo | ha | fissato | perplesso | il | ragazzo | che | la/lei | stava | bagnando | per | pura | profonda | cattiveria.

Rita ha bagnato il ragazzo con cattiveria? / Rita è stata bagnata con cattiveria?

[1st-person pronoun]
Matteo e io siamo scesi in piazza.
Io volevo bere dalla fontana dove alcuni ragazzi giocavano.

Matteo | ha | fissato | perplesso | il | ragazzo | che | mi/io | stava/stavo | bagnando | per | pura | profonda | cattiveria.

Ho bagnato il ragazzo con cattiveria? / Sono stata bagnata con cattiveria?

(32)
[3rd-person pronoun]
Emanuele e sua figlia, Rachele, sono entrati in un negozio di costumi.
Rachele ha giocato col figlio del proprietario.

Emanuele | ha | guardato | stupito | il | bambino | che | la/lei | stava | vestendo | di | abiti | colorati | e festosi.

Al figlio del proprietario sono stati messi abiti colorati? / Il figlio del proprietario ha messo a Rachele abiti colorati?

[1st-person pronoun]
Emanuele e io siamo entrati in un negozio di costumi.
Io ho giocato col figlio del proprietario.

Emanuele | ha | guardato | stupito | il | bambino | che | mi/io | stava/stavo | vestendo | di | abiti | colorati | e festosi.

Al figlio del proprietario sono stati messi abiti colorati? / Il figlio del proprietario mi ha messo abiti colorati?

APPENDIX C:

Testing the effect of impersonal arbitrary subject pronoun on relative clause comprehension

C.1 Full list of items in the experiment

Condition	Item	Sentence
Non-relatives	1	*Ma ha-ceva shel ha-dubim im ha-anan?* What (is) the-color of the-bears with the-cloud What color are the bears with the cloud?
	2	*Ma ha-ceva shel ha-susim im ha-perax?* What (is) the-color of the-horses with the-flower What color are the horses with the flower?
	3	*Ma ha-ceva shel ha-xatulim im ha-sefer?* What (is) the-color of the-cats with the-book What color are the cats with the book?
	4	*Ma ha-ceva shel ha-barvazim im ha-shemesh?* What (is) the-color of the-ducks with the-sun What color are the ducks with the sun?
	5	*Ma ha-ceva shel ha-axbarim im ha-lev?* What (is) the-color of the-mice with the-heart What color are the mice with the heart?
	6	*Ma ha-ceva shel ha-kofim im ha-shemesh?* What (is) the-color of the-monkeys with the-sun What color are the monkeys with the sun?
	7	*Ma ha-ceva shel ha-arayot im ha-koxav?* What (is) the-color of the-lions with the-star What color are the lions with the star?
	8	*Ma ha-ceva shel ha-dubim im ha-koxav?* What (is) the-color of the-bears with the-star What color are the bears with the star?

Subject relatives	1	*Ma ha-ceva shel ha-susim she-roxacim et ha-gmalim?* What (is) the-color of the-horses that-wash ACC the-camels What color are the horses that are washing the camels?
	2	*Ma ha-ceva shel ha-xatulim she-tofsim et ha-xazironim?* What (is) the-color of the-cats that-catch ACC the-piggies What color are the cats that are catching the piggies?
	3	*Ma ha-ceva shel ha-barvazim she-medagdegim et ha-karnafim?* What (is) the-color of the-ducks that-tickle ACC the-rhinos What color are the ducks that are tickling the rhinos?
	4	*Ma ha-ceva shel ha-axbarim she-medagdegim et ha-xazironim?* What (is) the-color of the-mice that-tickle ACC the-piggies What color are the mice that are tickling the piggies?
	5	*Ma ha-ceva shel ha-kofim she-roxacim et ha-karnafim?* What (is) the-color of the-monkeys that-wash ACC the-rhinos What color are the monkeys that are washing the rhinos?
	6	*Ma ha-ceva shel ha-arayot she-tofsim et ha-arnavim?* What (is) the-color of the-lions that-catch ACC the-bunnies What color are the lions that are catching the bunnies?
	7	*Ma ha-ceva shel ha-dubim she-tofsim et ha-gmalim?* What (is) the-color of the-bears that-catch ACC the-camels What color are the bears that are catching the camels?
	8	*Ma ha-ceva shel ha-susim she-medagdegim et ha-arnavim?* What (is) the-color of the-horses that-tickle ACC the-bunnies What color are the horses that are tickling the bunnies?

Object relatives with two full DPs	1	*Ma ha-ceva shel ha-dubim she-ha-xazironim roxacim otam?* What (is) the-color of the-bears that-the-piggies wash them What color are the bears that the piggies are washing?
	2	*Ma ha-ceva shel ha-susim she-ha-karnafim tofsim otam?* What (is) the-color of the-horses that-the-rhinos catch them What color are the horses that the rhinos are catching?
	3	*Ma ha-ceva shel ha-xatulim she-ha-gmalim medagdegim otam?* What (is) the-color of the-cats that-the-camels tickle them What color are the cats that the camels are tickling?
	4	*Ma ha-ceva shel ha-barvazim she-ha-arnavim roxacim otam?* What (is) the-color of the-ducks that-the-bunnies wash them What color are the ducks that the bunnies are washing?
	5	*Ma ha-ceva shel ha-axbarim she-ha-karnafim tofsim?* What (is) the-color of the-mice that-the-rhinos catch What color are the mice that the rhinos are catching?
	6	*Ma ha-ceva shel ha-kofim she-ha-arnavim medagdegim?* What (is) the-color of the-monkeys that-the-bunnies tickle What color are the monkeys that the bunnies are tickling?
	7	*Ma ha-ceva shel ha-arayot she-ha-gmalim roxacim?* What (is) the-color of the-lions that-the-camels wash What color are the lions that the camels are washing?

Object relatives with an embedded impersonal *pro*	1	*Ma ha-ceva shel ha-dubim she-roxacim otam?* What (is) the-color of the-bears that-*pro*-wash them What color are the bears that someone is washing?
	2	*Ma ha-ceva shel ha-susim she-tofsim otam?* What (is) the-color of the-horses that-*pro*-catch them What color are the horses that someone is catching?
	3	*Ma ha-ceva shel ha-xatulim she-medagdegim otam?* What (is) the-color of the-cats that-*pro*-tickle them What color are the cats that someone is tickling?
	4	*Ma ha-ceva shel ha-barvazim she-roxacim otam?* What (is) the-color of the-ducks that-*pro*-wash them What color are the ducks that someone is washing?
	5	*Ma ha-ceva shel ha-axbarim she-tofsim otam?* What (is) the-color of the-mice that-*pro*-catch them What color are the mice that someone is catching?
	6	*Ma ha-ceva shel ha-kofim she-medagdegim otam?* What (is) the-color of the-monkeys that-*pro*-tickle them What color are the monkeys that someone is tickling?
	7	*Ma ha-ceva shel ha-arayot she-roxacim otam?* What (is) the-color of the-lions that-*pro*-wash them What color are the lions that someone is washing?
Object relatives with an embedded *hem*	1	*Ma ha-ceva shel ha-dubim she-hem roxacim?* What (is) the-color of the-bears that-they wash What color are the bears that they are washing?
	2	*Ma ha-ceva shel ha-susim she-hem tofsim?* What (is) the-color of the-horses that-they catch What color are the horses that they are catching?
	3	*Ma ha-ceva shel ha-xatulim she-hem medagdegim?* What (is) the-color of the-cats that-they tickle What color are the cats that they are tickling?
	4	*Ma ha-ceva shel ha-barvazim she-hem roxacim?* What (is) the-color of the-ducks that-they wash What color are the ducks that they are washing?
	5	*Ma ha-ceva shel ha-axbarim she-hem tofsim?* What (is) the-color of the-mice that-they catch What color are the mice that they are catching?
	6	*Ma ha-ceva shel ha-kofim she-hem medagdegim?* What (is) the-color of the-monkeys that-they tickle What color are the monkeys that they are tickling?
	7	*Ma ha-ceva shel ha-arayot she-hem roxacim?* What (is) the-color of the-lions that-they wash What color are the lions that they are washing?

C.2 Procedure of the preparation game

The preparation game consisted of three trials, always in the same order: act-out, passive listening and elicited production of impersonal *pro*.

First trial: act-out
The experimenter shows the child toy animals, for example a tiger and a monkey, and says a sentence like *Tari li she-menashkim et ha-namer* 'Show me that *pro* are kissing the tiger'.
The child then has to act-out the scene based on the instruction.

Second trial: passive listening
The experimenter acts-out a scene with the toy animals, saying a corresponding sentence like *Ani roe she-doxafim et ha-dov; at roa she-doxafim et ha-dov?* 'I see that *pro* are pushing the bear; do you see that *pro* are pushing the bear?'
The child has to watch and listen.

Third trial: elicited production
The experimenter acts-out a scene with the toy animals, saying a corresponding sentence like *Tiri ma osim axshav l-a-pil; ma osim l-a-pil?* 'Look what *pro* are now doing to the elephant; what are *pro* doing to the elephant?'
The child is expected to answer something like *Menashkim oto* '*pro* are kissing it'.

The third trial was repeated if the child did not produce a sentence containing the impersonal *pro*, but rather said something like *Ha-kof menashek oto* 'the monkey is kissing it', or just *Neshika* 'kiss' (both of these answers are inappropriate given the question of the experimenter). In the vast majority of the cases, children answered appropriately in this task.