Incremental Processing of Prenominal Modifiers by Three-Year-Olds: Effects of Prototypicality and Contrast

Elena Tribushinina, Marinka Willemsen, Esmee Kramer, and Pim Mak

Abstract Adults often use prenominal adjectives for predicting the upcoming referent, either based on one's knowledge of prototypical exemplars (e.g., elephants are always big) or based on the contrasting properties of objects (e.g., big box *vs.* small box). This paper seeks to determine whether Dutch-speaking three-year-olds can also process adjective-noun phrases incrementally and use the information provided in the adjective to identify the target referent even before the noun is pronounced. In order to test this, we conducted an eye-tracking experiment using the Visual World Paradigm. The results replicate previous research by showing that three-year-olds are able to identify the target referent through their knowledge of prototypical exemplars as fast as adults, even before the noun is pronounced. However, our results reveal that the ability to use contrastive information for referent identification is far more limited at that age, indicating that contrastive (relative) processing of prenominal adjectives is more demanding than prototype-based (absolute) interpretations.

Keywords Language processing · Adjective-noun phrases · Visual World Paradigm · Toddlers

1 Introduction

An important aspect of adult linguistic competence is the ability to process language incrementally by integrating incoming linguistic cues with the information available from the previous discourse, world knowledge and referential context.

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Furthermore, adults can predict the upcoming discourse based on the cues already available in the unfolding sentence. For example, adults hearing a sentence starting with *Could you pass me the tall …* in the visual context of a tall glass, a short glass, a tall pitcher and a key can predict that the speaker wants to have to tall glass even before the noun *glass* is pronounced (Sedivy et al., 1999). Since adjectives are often used to identify members of the same category based on their different properties (e.g., *Give me the blue beaker, not the red one*), adults assume that the speaker intends to ask for one of the glasses rather than another tall object (pitcher) that has no same-kind competitor in the visual scene. In languages such as English and Dutch, where attributive adjectives are always prenominal, adjectives play an important role in predicting the upcoming referent.

Anticipatory processing is of paramount importance to efficient communication. However, our understanding of how this ability develops in children is not sufficient. For one, we do not know whether toddlers can use contrastive information in the prenominal adjective for predicting the intended referent. The advent of eye-tracking research opened the possibility of examining rapid mental processes involved in language comprehension. The Visual World Paradigm is a particularly suitable method for research with young children, since it only relies on the listener's tendency to look at relevant parts of the display as the adjective-noun phrases are pronounced. This study uses eye-tracking in the Visual World Paradigm (VWP) in order to determine whether three-year-old children can use information conveyed by prenominal adjectives for rapid identification of the intended referent.

We focus on two kinds of adjective processing in two types of contexts: absolute uses in prototypical contexts as in *big elephant* (elephants are prototypically/intrinsically big, irrespective of contexts) and relative uses in contrastive contexts as in *big chair* (a chair is not intrinsically big, but can be called *big* compared to another chair in the visual array or to an average chair). Our focus is motivated by the recurrent findings that prototypical and contrastive uses play an important part in early adjective acquisition. In what follows we briefly review the literature demonstrating that adjective use in prototypical and contrastive contexts facilitates adjective acquisition in toddlers. After that, we discuss prior research on anticipatory adjective processing in children. Based on these two research lines, we formulate our research questions and hypotheses that are tested in a VWP experiment.

2 Adjectives in Child Language and Child-Directed Speech

2.1 Contrastive Uses

Adjectives, such as *red, big* and *round*, enable a child to make distinctions among referent objects and classes of objects on the basis of their properties (Nelson, 1976). Despite their communicative significance, they usually emerge in child speech later than nouns and verbs (Barrett, 1995; Ravid et al., 2003; Tribushinina et al., 2014), and have a protracted acquisition course throughout school years well

into adolescence (Ravid & Levie, 2010; Ravid & Schiff, 2012, 2021), especially when it comes to more abstract and morphologically complex adjectives (Ravid et al., 2016). Toddlers have been shown to have difficulty mapping adjectives onto relevant properties (Booth & Waxman, 2009; Klibanoff & Waxman, 2000; Tribushinina, 2017; Waxman & Markow, 1998). For example, if a child sees a rabbit and hears the mother saying *Look, the rabbit is blicky,* how does the child know which of the many properties of the rabbit are referred to? One useful strategy helping a child attend to a specific property is to provide contrastive information. For example, it is easier to understand the meaning of the adjective *big*, if two same-kind objects are contrasted in size (e.g., a big and a small teddy bear). An ideal situation for learning adjectives would be a contrastive context in which two objects are identical and differ only in the target dimension such as color (Au & Laframboise, 1990; Carey & Bartlett, 1978; Klibanoff & Waxman, 2000). Research by Waxman and associates shows that in the absence of such a within-category contrast, children as old as 3 years of age are not able to extend the meaning of a novel adjective across basic-level categories. For example, they can extend the meaning of *transparent plate* to another transparent plate, but not to a transparent cup. However, if the adjective is presented in a within-category contrast (e.g., a transparent plate *vs.* an opaque plate), three-year-olds are also able to extend the novel adjective across the basic-level category (Klibanoff & Waxman, 2000; Waxman & Klibanoff, 2000).

Longitudinal case studies of spontaneous conversations between parents and 2- to 3-year-old children (the age at which children acquire adjectives at a high pace) have shown that there are significant individual differences in the use of the *contrastive strategy* in child-directed speech (Murphy & Jones, 2008; Tribushinina et al., 2013; Tribushinina et al., 2015). Some parents often use adjectives in contrastive contexts such as *This ball is red and that one is blue*, whereas other parents barely use adjectives contrastively. Notably, a high frequency of contrastively used adjectives by the parents is associated with a higher rate of adjective learning by the children, which indicates that contrastive contexts facilitate adjective acquisition (Tribushinina et al., 2013). Facilitation through contrast appears to be a universal cognitive strategy that does not depend on the specific properties of adjectives in typologically different languages. Tribushinina et al. (2013) predicted that adjectives may be acquired faster in languages in which attributive adjectives are post-nominal (Hebrew and to some extent French), because it is easier to interpret an adjective relative to the noun if the noun has already been introduced (Yoshida & Hanania, 2013). However, no cross-linguistic differences in the pace of adjective acquisition were found between languages with A-N and N-A orders (Tribushinina et al., 2013).

In a recent study, Davies et al. (2020) used a large corpus of child-directed speech and found that caregivers mainly used adjectives in descriptive contexts, whereas contrastive uses were extremely rare in parental speech. Thus, despite the usefulness of contrastive contexts found both in the lab (Au & Laframboise, 1990; Carey & Bartlett, 1978; Klibanoff & Waxman, 2000) and in naturalistic acquisition (Tribushinina et al., 2013), most parents seem to be insensitive to the facilitating role of contrasts in adjective learning. Based on this result, Davies and colleagues

hypothesize that "hearing relatively few contrastive adjectives may delay the development of contrastive inference" (Davies et al., 2020: 176). This prediction will be tested in our experiment.

2.2 Prototypical Uses

A strategy that is attested in child-directed speech quite often is restricting adjective use mainly to best exemplars (or prototypes) of a property. Picture books aimed at teaching children adjectives often make use of prototypical exemplars. Across languages, the meaning of *big* is commonly illustrated by a picture of an elephant, *small* by a mouse, and *tall* by a tower. Such prototypes are also the most common referents of dimensional adjectives in interactions between parents and toddlers (Tribushinina, 2013b). It is interesting to note that such adjective-noun combinations are very infrequent in adult-directed speech, probably because it is redundant to call elephants *big* and towers *tall*. To illustrate, Tribushinina (2008) reports that only 1% of all tokens of *tall* in the British National Corpus (adult-directed speech) is used with reference to towers. In contrast, 32% of tokens of *tall* refer to towers in the Manchester corpus of parent-toddler conversations. Likewise, the Dutch adjective *hoog* 'high/tall' is used to describe towers in only 1% of its uses in the Spoken Dutch Corpus (adult-directed speech), in contrast to 36% in child-directed speech in the Groningen Corpus in the CHILDES archive.

Production data also suggest that toddlers are conservative adjective users; they keep track of adjective-noun pairings in the input and initially only use adjectives with reference to a restricted set of referents attested in child-directed speech. This explains why there are almost no incorrect adjective-noun combinations in the speech of 2-year-olds. The most frequent referents of adjectives in early child speech are best exemplars from the child-directed speech (Tribushinina, 2008, 2013b). Later on, children generalize over different adjectival uses and start using adjectives productively, applying them to a broader set of referents (Tribushinina, 2013b).

There is recent experimental evidence that three-year-olds also use their knowledge of prototypical exemplars in the online processing of adjective-noun phrases. Using the Visual World Paradigm, Tribushinina and Mak (2016) examined toddlers' processing of adjective-noun phrases and their ability to predict the upcoming noun on the basis of the meaning of a prenominal adjective. Dutch-speaking three-year-olds and adults heard adjective-noun phrases while two objects were displayed. On ambiguous trials, the adjective could refer to either of the objects (e.g., *green* in the visual context of a green house and a green candy). On informative trials, the participants saw a best exemplar of the property and another object. For example, they saw a pillow and a book, and heard *een zacht kussen* 'a soft pillow'. The reasoning was that if children were able to process the attributive meaning of the prenominal adjective, they would immediately link the adjective *soft* with the picture of the pillow, and thus look at the pillow before hearing the noun. Indeed, in the informative

condition, the proportion of looks to the target already increased upon hearing the adjective, whereas in the ambiguous condition it only happened after the noun was pronounced. Remarkably, three-year-olds were as fast as adults orienting towards the target upon hearing an informative adjective. These findings demonstrate that toddlers, like adults, interpret adjectives incrementally and use their knowledge of prototypical referents in the processing of adjective-noun phrases. Since attributes such as 'soft' were not visible in the pictures, prediction of the upcoming referent required the children in this experiment to rely on their knowledge of prototypical properties of objects, in this case the knowledge that pillows are prototypically soft, whereas books are not. Hence, learning adjectives through prototypical objects, as established by corpus-based studies, is also reflected in the online processing of adjective-noun phrases.

The current study will add to this research by establishing whether three-year-old children are also able to predict the upcoming noun based on contrastively used prenominal adjectives and by investigating whether toddlers would have a preference for one of the strategies (use of prototypical exemplars *vs.* contrastive information) when both are available in the visual context. Before reporting the experiment, we will briefly review relevant eye-tracking research on the processing of adjective-noun phrases by young children, with a focus on the ability to use contrastive information for processing prenominal adjectives.

3 Children's Ability to Use Contrastive Information for Referent Identification

In the study reported by Sekerina and Trueswell (2012), six-year-old Russian-speaking children saw displays with nine objects and were asked to drag one of the objects (e.g., red butterfly) to a container also depicted on the screen, as their eye gaze was tracked. The display included two red objects (e.g., a butterfly and a fox) and an object of a different color either from one of the categories (e.g., a purple butterfly), or from both categories (e.g., a purple butterfly and a grey fox). In the former case (one-contrast condition), it is possible to predict the noun based on the adjective if adjectives are interpreted contrastively, since there are two butterflies and only one of them is red. In the latter case (two-contrast condition), the participants have to wait until the noun is pronounced, since there are two possible referents of *red* (i.e., butterfly and fox), both of them contrasted with a same-kind object of a different color. In this experiment, adults indeed started looking at the target upon hearing the adjective in the one-contrast condition, but waited until the noun was pronounced in the two-contrast condition (Sekerina & Trueswell, 2011). However, the child results showed no anticipatory eye movements to the target object before the noun was pronounced (Sekerina & Trueswell, 2012). On the one hand, this seems to suggest that it might be too difficult for 6-year-olds to use contrasts to identify the referent when hearing a contrastively used prenominal

adjective. On the other hand, this finding might be a result of task complexity, as a visual-search task with nine different objects might be too demanding for 6-year-olds.

The study by Huang and Snedeker (2013) suggests that the latter explanation is more likely. They examined the ability of five-year-old English-speaking children to use referential contrast for identifying the referent based on an adjective cue. Their experiment included displays with four objects and the participants were asked to point to, for instance, *a big coin*. The experiment contained two- and one-referent trials, that is, trials in which the contrast item belonged to the same object category (two-referent), or to another object category (one-referent). Within two-referent trials, the visual array included two same-category objects of different sizes (e.g., a big and a small coin), a distractor of the same size as the target object (e.g., big stamp) and an irrelevant object (e.g., marshmallow). Only in the two-referent trials, i.e. when the visual context contained a contrasting object from the same category, the children started looking at the target earlier, even before the noun was pronounced. Thus, the five-year-olds inferred that the adjective *big* was more likely to be used with reference to the coins (rather than to the big stamp), since a contrast of a big and a small coin was present. However, the children were slower than adults to orient towards the target.

To the best of our knowledge, the only study that has compared the processing of contrastively used prenominal and postnominal modifiers is Arunachalam (2016). This study examined the processing of referential expressions within a mixed-age sample of three- and four-year old English children, by using their parents' language input. A visual array with six depicted objects was used and children were instructed to point to the correct object (e.g., a striped umbrella) as fast as possible. The experiment showed that children around age 3 looked faster to the target object when parents used postnominal modifiers (e.g., umbrella with stripes), compared to when they used prenominal adjectives (e.g., striped umbrella). This suggests that children this young may have difficulties processing prenominal adjectives. There was however no adjective competitor present in this experiment: There was only another umbrella but not another striped object. Hence, the participants did not need to hear the noun to identify the referent. There is evidence in the literature that three-year-olds look at the correct referent when hearing an informative adjective. For example, upon hearing *blue car* in the visual context of a red car and a blue car, they look at the blue car before the noun is pronounced (Fernald et al., 2010). The finding that the participants in Arunachalam's study did not look at the striped umbrella upon hearing the adjective might indicate that the adjective was too complex (or infrequent) for this age group. Thus, it is still unclear whether children this young are able to use contrastive information in the prenominal adjective for referent identification.

4 The Current Study

Prior research has shown that toddlers seem to have no trouble with the incremental and anticipatory processing of prenominal adjectives in their absolute use, i.e. in cases where adjectives denote intrinsic properties of objects (e.g., elephants are always *big*, towers are always *tall*). The first aim of the present study is to replicate the finding that three-year-olds use the knowledge of prototypes for predicting the upcoming noun based on the adjective, and are as fast as adults in doing so (Tribushinina & Mak, 2016).

The second aim of this research is to determine whether three-year-olds can also predict the upcoming noun in relative contexts, where adjectives do not denote intrinsic (context-independent) properties of objects, but rather depend on the contextual information. More specifically, we focus on relative contexts where adjective use is supported by a visual contrast. For instance, a glass is not intrinsically tall: the same glass can be described as *tall* if presented next to a shorter glass or *short* when the visual context contains a taller glass. Previous research (Huang & Snedeker, 2013) has shown that five-year-olds are able to identify a referent based on the adjective cue and the visual contrast. Our study aims to establish whether this ability is already present at an earlier age.

Even though contrastive contexts facilitate adjective learning, relative (contrast-based) interpretations are supposedly more demanding than absolute (prototype-based) interpretations because relative processing is flexible and context-dependent, whereas absolute interpretations hinge on context-independent noun-adjective (or object-property) associations (Smith et al., 1986; Smith et al., 1988; Tribushinina, 2013a). Accordingly, the eye-tracking experiment performed by Sekerina and Trueswell (2012) suggests that rapid use of contrastive information for referent identification might be demanding for children as old as six years of age. In a similar vein, the findings reported by Arunachalam (2016) reveal that anticipatory processing of referential contrast may not be available to three-year-olds. For this reason, we opted for a design that is less complex than the one commonly used in the literature on the processing of referential contrast. Typically, in such studies there are two same-category objects (e.g., a tall glass and a short glass) and a number of other objects including a competitor that is (on its own) also compatible with the adjective (e.g., a tall pitcher). Adult-like use of referential contrast involves the ability to predict the target noun (in this case *glass*) based on the fact that there are two glasses and only one pitcher in the visual array. We reckoned that this design might be too demanding for three-year-olds. Furthermore, we do not yet know whether three-year olds possess a more basic ability to use contrastive information in the anticipatory processing of adjectives. In other words, are they able to apply a relative interpretation to an adjective when presented with a pair of same-kind entities differing in the target property? To test this more basic ability to use contrastive

information for anticipatory processing, we adopted a simpler design with only three objects in the visual array, including two objects of different sizes (the target object and its contrastive counterpart) and an unrelated object that is not associated with the target property at all. This means that in our design there is no other object that might in principle be described by the adjective in the given visual context (like the big stamp in Huang and Snedeker's study or the tall pitcher in Sedivy et al.'s experiment).

If three-year-olds can successfully predict the target object in contrastive contexts, then it is also relevant to investigate whether the children use contrastive information to the same extent as prototypicality. Since relative interpretations are generally more complex than absolute interpretations, it is reasonable to assume that prototype-based anticipatory processing could be more readily available to children. The third question addressed by this study is how three-year-olds identify referent objects in an ambiguous context where both a prototype match and a contrast match are present.

The three research questions were examined by means of the Visual World Paradigm, in which children each time saw three objects and heard an adjective-noun phrase. The displays included either a prototypical target (research question 1), or a contrastive target (research question 2), or an ambiguous context in which a prototypical and a contrastive target were present (research question 3). Adult controls were included in the experiment in order to determine a baseline for the children's performance.

5 Method

5.1 Participants

In total 60 monolingual Dutch children participated in the experiment. Data of 15 children were not included in the analyses based on the quality of the eye-tracking record (see below), resulting in a final sample of 45 children (60% female). Their mean age was 3 years and 5 months (*SD* = 3.53 months, range 36–47 months). The children were recruited by contacting a preschool in a small city in a rural area in The Netherlands.

In addition, 38 adults (63.2% female) participated in the experiment as a comparison group. A diverse sample of adults was recruited by means of convenience sampling, varying in age, educational level and living environment (both rural and urban area). The mean age of the adults was 36 years (*SD* = 15.60 years, range 19–63 years).

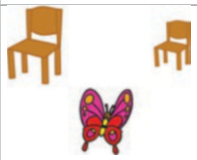
5.2 Materials and Design

The materials were displayed in three different conditions: (a) prototypical, (b) contrastive, and (c) ambiguous (see Table 1). A within-subjects design was used in which each participant took part in all three conditions. As will be described below, three lists with trials were created to which participants were assigned randomly.

Twenty-one items were designed in which three objects were displayed in a triangle shape while simultaneously a pre-recorded adjective-noun phrase was heard. Each adjective-noun phrase consisted of a definite article, an adjective and a noun, for instance *de hoge toren* 'the tall tower'. Of each item there were three versions, corresponding with the three different conditions. See Table 1 for an overview of the kind of objects that were displayed in each condition, with example displays of the three different versions of one item. The complete list of items is attached in the Appendix.

Three different lists with 21 items each were created in such a way that each list contained one version of each item. Participants were randomly assigned to one of the three lists, so that each participant saw only one version of an item. For example, participants saw the high chair in either the prototypical, contrastive, or ambiguous condition. The position of the target object was randomized for all the items in every list. The three lists contained seven items from each condition.

Table 1 Overview of the three conditions with example displays

Condition	Object 1	Object 2	Object 3	Example display and pronounced phrase
Prototypical	Prototype	Non-prototype	Unrelated	 *de hoge toren* 'the high tower'
Contrastive	Contrast target	Opposite contrast	Unrelated	 *de hoge stoel* 'the high chair'
Ambiguous	Contrast target	Prototype	Opposite contrast	 *de hoge stoel/toren* 'the high chair/tower'

Note. Object 1 is in the upper-left corner, the other objects follow clock-wise

Conditions In the prototypical condition, participants could identify the target object based on their knowledge of prototypical properties of objects. In this condition, the following three objects were depicted: (a) a best exemplar (prototype) of the property denoted by the adjective (e.g., a big hippo), (b) a non-prototypical object, that is, an object that is not intrinsically related to the adjective used but can be described by this adjective, (e.g., a big present), and (c) an unrelated object, that is, an entity for which the adjective is not a fitting attribute (e.g., sand).

In the contrastive condition, there were two same-kind objects differing in size (e.g., big present and small present) and an unrelated entity of a different category (e.g., sand). The unrelated entity was not associated with the property in question (e.g., sand cannot be big or small).

In the ambiguous condition, which is a combination of the prototypical and the contrastive condition, two possible target objects were present. This condition consisted of the following three objects: The best exemplar from the prototypical condition (e.g., a big hippo), and the two contrasting objects of the contrastive condition (e.g., a big present and a small present). There were thus two possible targets that both corresponded to the adjective (e.g., a big hippo and a big present, equally-sized in the pictures), and on the basis of the adjective it was impossible to predict which one was the target. The noun that was pronounced corresponded half of the time with the prototypical object and half of the time with the competing contrast object. The goal of the ambiguous condition was to examine what information the participants would use to predict the referent: the prototypical properties of objects or the contrastive information, or possibly both.

Visual Stimuli Picture books for children were scanned for familiar objects from the experiential world of young children and child-friendly images were created using clipart and graphic programs. For the contrastive objects, the same picture was used twice, only the property denoted by the adjective (e.g., size) was different. Since Dutch definite articles give away information about the gender of the upcoming noun, the three objects always corresponded to same-gender nouns. In this way, participants could not establish reference based on the article used. The adjectives *hoog* ‘high/tall’, *groot* ‘big’, *klein* ‘little’, *lang* ‘long’, *dik* ‘thick’, and *dun* ‘thin’ were used, since these are among the first adjectives acquired by young children (Tribushinina, 2013b) and the ones commonly used for referent identification (Nelson, 1976).

Auditory Stimuli Adjective-noun phrases pronounced by a native female Dutch speaker were pre-recorded. In each sound file, the onset of the adjective was set at 3 s, so that children had enough time to get familiarized with the displayed objects. The onset of the noun was always at 4.5 s. The total duration of each sound file was 7 s.

5.3 Apparatus

The portable Tobii X2–60 eye-tracker was used to record the eye movements of participants. The sampling rate was 60 Hz. The Tobii Studio 3.4.5 software was used for the presentation of the items and for the recording of the eye-movements.

5.4 Procedure

For the children, the experiment took place in a small and quiet room at their own daycare. The stimuli were presented on a laptop to which the eye-tracker was connected. The children were seated on a comfortable chair in front of the laptop. Then, a child-friendly calibration procedure was performed, consisting of five calibration points. After successful calibration, the experimenter gave a neutral instruction "Listen and look carefully". Then, the experiment started and the 21 items were presented one after another. Although no task was given to search for the target referents, some children spontaneously started to talk or point to the screen. This was not discouraged, unless it compromised their looks at the screen. The experiment lasted in total approximately 5 min per participant. All children were thanked afterwards and received a small reward.

For the adults, the experiment followed a similar procedure. The experiment took place in different locations, in both home and university settings. In each setting, a quiet room was used for testing. For the calibration procedure, also consisting of five calibration points, adult settings were used.

5.5 Analysis

Preparation of the Data For each trial, three areas of interest (AOIs) were defined that covered the fixation patterns of participants to the three objects of the display. The locations of fixations were determined in 100-ms steps from the eye-tracking data. For each time-step it was determined which AOI a participant looked at. Fixations outside the AOIs were not included in the analyses. Trials were excluded when there was more than 25% missing data within the critical time interval from the onset of the adjective until the onset of the noun (3–4.5 s). In addition, for each participant a minimum of 4 trials per condition had to remain in order to include that participant in the final data sample. Data of fifteen children were excluded based on this criterion.

Before analysis, necessary assumptions were checked. Scatterplots indicated that assumptions of homoscedasticity and logit linearity were met.

Statistical Analysis The final dataset was analyzed by means of multilevel binary logistic regression (Barr, 2008). Since a multinominal type of multilevel logistic regression was not feasible considering current methodological advancements, binary analyses were conducted: the dependent variable was whether the participant fixated the target referent or fixated elsewhere. The analysis was performed in R (version 3.3.2), using the lme4 package (Bates et al., 2015). Time was included as a predictor to be able to model change over time. The model predicted the probability of fixating on the target picture. Participants and items were included as random factors, and Time and Group (child/adult) as fixed factors. In each condition, the proportions of looks at two different objects were compared. For the prototypical condition, the outcome measure was defined by the probability that the participants fixated on the prototypical object (e.g., high tower) compared to the non-prototypical object (e.g., high chair). Similarly, in the contrastive condition, the looks at the contrast target (e.g., high chair) were compared to the looks at the opposite contrast (e.g., low chair). In the ambiguous condition, the following three pairwise comparisons were performed: (1) the contrast target versus the prototypical object, (2) the prototypical object versus the opposite contrast and (3) the contrast target versus the opposite contrast. Because we performed multiple comparisons, a Bonferroni correction was applied, resulting in an alpha-level of .017. All analyses were performed on the critical time interval from the onset of the adjective until the onset of the noun (3–4.5 s), which we named the adjective time window. The children were the reference group in each analysis.

6 Results

6.1 Prototypical Condition

The proportions of looks (henceforth, *looks*) at the three different objects over the duration of the trials are shown in Fig. 1a for the children and Fig. 1b for the adults (the lines present averages across participants). The first vertical line indicates the onset of the adjective and the second vertical line indicates the onset of the noun.

At the start of the adjective window (at 3 seconds) the division of looks at the three objects was roughly equal in both groups. When the adjective was pronounced, however, the looks at the different objects started to diverge, for both children and adults. The model is presented in Table 2.

There was a significant positive effect of Time for the children. During the adjective window, their looks at the prototype increased significantly over time compared to the looks at the non-prototypical object. There was no interaction effect of Group by Time, indicating that the increase in looks at the prototype compared to the non-prototypical object for the adults was similar to that of the children.

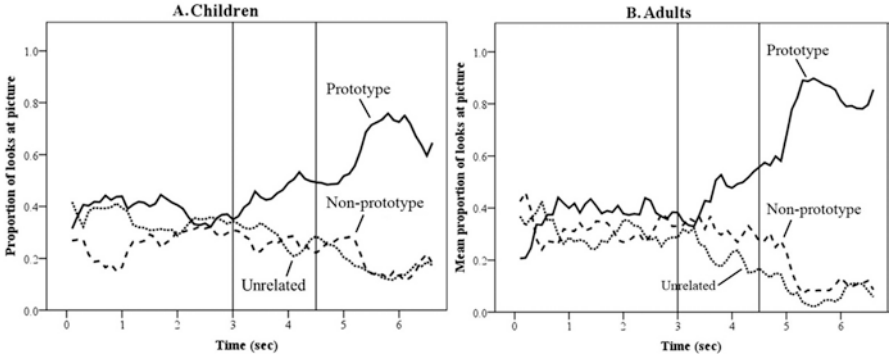


Fig. 1 (**a** and **b**) Proportion of looks at the objects over time in the prototypical condition, by group

Table 2 Parameter estimates for the prototypical condition

	Fixed effects		
Parameters	*Estimate (SE)*	*z*	***p***
Intercept	0.59 (0.13)	4.51	< .001
Time[a]	0.42 (0.10)	4.33	< .001
Group (Adults)	−0.24 (0.16)	−1.53	0.13
Time * Group	0.13 (0.14)	0.93	0.35
	Random effects		
Parameters	*Variance*	*SD*	
Participant	0.41	0.64	
Item	0.11	0.33	

[a] Children were used as reference group

6.2 Contrastive Condition

For the contrastive condition, Fig. 2a displays the looks at the different objects over the duration of the trial for the children, and Fig. 2b for the adults. For both children and adults, the division of looks at the three objects was not equal in the baseline time window (before adjective onset). For both groups, the one different-kind object (e.g., a butterfly) attracted more attention than the two objects of the same kind (e.g., two chairs).

The model is presented in Table 3. There was no effect of Time for the children, indicating that looks at the Contrast Target did not increase faster than the looks at the Opposite Contrast in the adjective window. The significant interaction shows that looks at the Contrast Target did increase for the adults.

To summarize the results thus far, the behavior of the three-year-olds was comparable to that of the adults in the prototypical condition, but the children were not able to discern the target referent on the basis of the adjective in the contrastive condition.

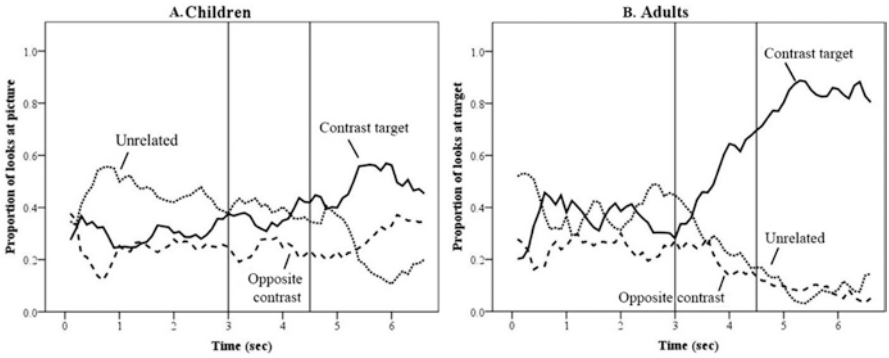


Fig. 2 (**a** and **b**) Proportion of looks at the objects over time in the contrastive condition, by group

Table 3 Parameter estimates for the contrastive condition

	Fixed effects		
Parameters	*Estimate (SE)*	*z*	*p*
Intercept	0.47 (0.13)	3.48	.001
Time[a]	0.17 (0.10)	1.72	.09
Group (Adults)	0.54 (0.15)	3.68	< .001
Time * Group	1.10 (0.15)	7.46	< .001
	Random effects		
Parameters	*Variance*	*SD*	
Participant	0.34	0.59	
Item	0.16	0.41	

[a] Children were used as reference group

6.3 Ambiguous Condition

For the ambiguous condition, the looks at the three different objects over the duration of the trials are displayed in Fig. 3a and b for respectively children and adults.

In the ambiguous condition, two objects were possible referents on the basis of the adjective (either the prototype or the contrast target). Therefore, three pairwise comparisons were performed. Firstly, the looks at the prototype (e.g., high tower) were compared with the looks at the opposite contrast (e.g., low chair). Secondly, the looks at the contrast target (e.g., high chair) and the opposite contrast (e.g., low chair) were compared. These two comparisons examine whether children filter out the opposite contrast and focus on the target object. Next, a third comparison was conducted in which the looks at the prototype (e.g., high tower) were compared with the looks at the contrast target (e.g., high chair), thus the two possible referents. With this comparison it could be examined whether participants prefer one strategy over another: using prototypical exemplars or visual contrast. Table 4 displays the parameter estimates of the three pairwise comparisons.

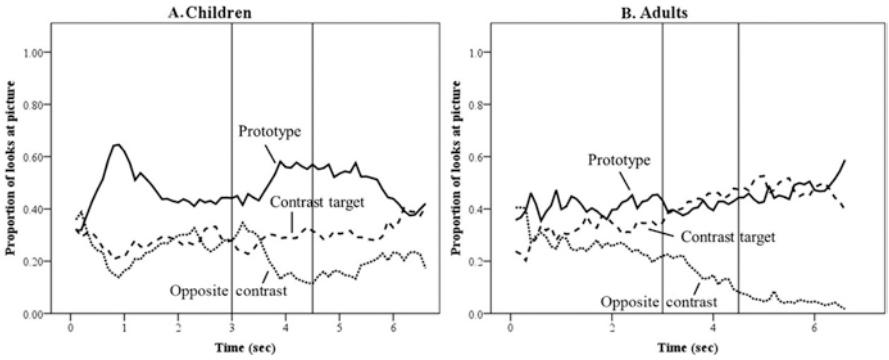


Fig. 3 (**a** and **b**) Proportion of looks at the objects over time in the ambiguous condition, by group

Table 4 Parameter estimates for the three pairwise comparisons of the ambiguous condition

	Prototype versus opposite contrast			Contrast target versus opposite contrast			Prototype versus contrast target		
Fixed effects									
Parameter	Estimate (SE)	*z*	*p*	Estimate (SE)	*z*	*p*	Estimate (SE)	*z*	*p*
Intercept	1.14 (0.19)	6.08	< .001	0.43 (0.19)	2.32	.02	−0.73 (0.16)	−4.62	< .001
Time	1.15 (0.11)	10.87	< .001	1.07 (0.12)	8.87	< .001	−0.04 (0.09)	−0.40	0.69
Group (Adults)	0.04 (0.19)	0.18	.85	0.76 (0.21)	3.69	< .001	0.78 (0.18)	4.36	< .001
Time * Group	−0.43 (0.16)	−2.61	.009	−0.01 (0.18)	−0.09	.93	0.13 (0.13)	1.06	.29
Random effects									
Parameter	*Variance*	*SD*		*Variance*	*SD*		*Variance*	*SD*	
Participant	0.63	0.79		0.71	0.84		0.57	0.75	
Item	0.36	0.60		0.30	0.55		0.20	0.45	

Prototype Versus Opposite Contrast When comparing the prototype to the opposite contrast, we found a main effect of time for children. There was an increase of looks at the prototypical object compared to the opposite contrast. The interaction shows that this effect was weaker for the adults. The latter effect is probably due to the fact that the looks at both possible targets for the adults already increased before the adjective was pronounced: the adults probably realized that these were the two possible referents given the three objects in the picture and divided their attention between them.

Contrast Target Versus Opposite Contrast When comparing the contrast target and the opposite contrast, there was also an effect of Time for the children: whereas the proportion of looks at the opposite contrast decreased, the looks at the contrast target remained stable. There was no interaction, indicating that the effect for the adults was similar to that of the children.

Contrast Target Versus Prototype The third comparison examined the proportion of looks at the two possible referents in order to see whether children make more use of visual contrast or of their knowledge of prototypical exemplars in establishing reference. The dependent variable was the probability of looking at the contrast target. No significant main effect of time was found for children. This means that during the adjective window, the increase of looks at the prototypical target was not significantly stronger than for the contrastive target. Note that although the slope does not significantly differ, there is a difference in the intercepts, due to the increased attention to the prototypical object in the baseline time window. There was no significant interaction effect of Group by Time. This means that the increase of looks at the prototypical target compared to the contrastive target does not differ between adults and children.

7 Conclusion and Discussion

Previous research has shown that early adjective acquisition may be facilitated by two strategies: learning adjectives through prototypical instances of a property (e.g., elephant for *big*) and learning through contrastive information (e.g., big plate *vs.* small plate). Tribushinina and Mak (2016) have shown that three-year-olds can predict a referent based on the prototypical associations between a prenominal adjective and a noun. The present study aimed to replicate this finding and to determine whether three-year-olds can also use visual contrast for predicting the upcoming noun. In addition, an ambiguous context was included in which both types of information could be used to identify the referent, in order to explore possible preferences or differences in strategy use. We will discuss the findings for each context below.

7.1 Prototypical Context: Three-Year-Olds' Reliance on Prototypes

The results of the prototypical condition demonstrate that three-year-olds process adjective-noun phrases incrementally and use their knowledge of prototypes to predict the upcoming referent. Before the noun was even pronounced, children looked at the target referent (e.g., elephant) based on the prenominal adjective (e.g., 'big'),

even though at least one other object in the visual array could potentially be described by means of the adjective (e.g., a dog, which was as big as the elephant in the picture). This result replicates an earlier finding reported by Tribushinina and Mak (2016) and extends it to a more complex visual array (of three rather than two objects). Both in the current study and in Tribushinina and Mak (2016), children were as fast as adults in attending to the target picture.

The results of these two eye-tracking studies corroborate the findings from prior corpus research demonstrating that best exemplars are among the most frequent referents of adjectives both in early child speech (between ages 2 and 3) and in child-directed speech (Tribushinina, 2008, 2013b). Frequent exposure to best exemplars of a property through child-directed speech and stories/pictures in children's books probably leads to the development of this strong knowledge of (and reliance on) prototypes already at a young age.

7.2 Use of Contrastive Information

In this section, the results of the contrastive and ambiguous condition are discussed together because of the coherence of the findings. Previous research by Huang and Snedeker (2013) demonstrated that five-year-olds can use referential contrast (e.g., big coin *vs.* small coin) to predict the upcoming referent, even in the presence of a competitor that shares the property with the target (e.g., big stamp), but lacks a contrastive counterpart. The contrastive condition in our experiment aimed to determine whether the prerequisite of this ability, i.e., anticipatory processing of contrastively used adjectives in an array without a plausible competitor, is present at age 3.

The results of the contrastive condition show no evidence that three-year-olds can use visual contrast for predicting the target referent. When the visual array contained two same-kind objects that differed only in the aspect described by the adjective (e.g., high chair *vs.* low chair), the children did not narrow the set of possible target objects before hearing the noun, contrary to the adults whose looking patterns showed strong sensitivity to contrasts. There are several possible explanations for this result. First, this finding might indicate that three-year-olds are not able to use contrastive information in online adjective processing; so this capacity develops somewhere between ages 3 and 5. A second possibility is that toddlers *are* sensitive to contrastive information, but need more time to integrate visual contrasts in adjective processing. If this is the case, a larger time window between the adjective and the noun might have resulted in anticipatory looking.

Finally, it is possible that three-year-olds are to a certain extent able to use visual contrast for referent identification, but have difficulty inhibiting the difference bias. In the contrastive condition, both the target and the contrast belong to the same category (e.g., both chairs), whereas the third (unrelated) object (e.g., butterfly) is more interesting by virtue of belonging to a different category. Such different-category pictures attracted more attention, already in the window preceding the

adjective. The same pattern was observed in the ambiguous condition, where the prototypical target (e.g., tower) was of a different category than the contrast target (high chair) and the opposite contrast (low chair). At the moment the adjective was pronounced, the proportion of looks to the prototypical object was significantly higher than the proportion of looks to the two same-kind objects. This difference in intercept may explain why the increase in the proportion of looks to the prototype and the contrastive target was the same; in this case growth was relatively small for the prototypical objects because many children already focused on the prototype in the baseline time window.

It is noteworthy that upon hearing the adjective (e.g., *hoog* 'high/tall') in the ambiguous condition, the children were able to filter out the opposite contrast object (low chair): The proportion of looks to the opposite contrast object decreased in the critical time window, which was not the case for the contrast target (high chair). This finding indicates that children might, at least to a certain extent, make use of the visual contrast for referent identification. The looking patterns of the adults in the ambiguous condition showed strong signs of sensitivity to contrasts, since they already filtered out the third object in the first seconds of the baseline window. Regarding the performance of adults in the ambiguous condition, it is noteworthy that prototypical interpretations were as frequent as contrastive interpretations, even though contrastive uses appear more natural and more informative from a pragmatic point of view (avoidance of redundancy and maximal informativeness for referent identification). This pattern might be due to the fact that the participants were not given a task to find a referent, and the contexts might have been interpreted as purely descriptive. Furthermore, there is recent evidence suggesting that over-specification in adjective use (as in *tall tower*) does not hinder comprehension and may even facilitate it under certain conditions (Tourtouri et al., 2019). Also, the adult participants might have developed certain looking patterns (or strategies) after repeated exposure to both contrastive and prototypical contexts of adjective use in the experiment. In other words, they might have figured out that in half of the trials the adjective would redundantly refer to a best exemplar of the property.

7.3 First Prototypes, Then Contrasts

The results of this study clearly show that the developing ability to use contrastive information in adjective processing lags behind the capacity to process adjectives based on knowledge of prototypes. Three-year-olds are as good as adults in predicting the upcoming referent based on their knowledge of best exemplars of the property. However, their ability to use visual contrast for adjective interpretation is far more limited. With contrasts, they perform significantly worse than adults and only reveal some signs of the emerging ability to rely on contrastive information for referent identification.

Why is contrastive processing of prenominal adjectives more demanding than prototype-based interpretations? Difficulty with contrastive interpretations may be related to the paucity of contrastively used adjectives in child-directed speech (Davies et al., 2020). As against this, parental speech contains plenty of descriptive uses highlighting prototypical adjective-noun or adjective-object associations (Tribushinina, 2008, 2013b). It is plausible to assume that the early-emerging ability to use knowledge of best exemplars in online adjective processing and the protracted acquisition of contrastive inference is related to this asymmetry.

It is also possible that this difference is related to the complexity level of relative versus absolute interpretations, respectively. Absolute interpretations are not context-dependent or, at least, significantly less context-dependent than relative interpretations. Developmental work on the interpretation of relative adjectives using offline comprehension experiments has repeatedly shown that children younger than age 4 tend to apply relative adjectives only to the extremes of a visual array (Ehri, 1976; Smith et al., 1986, 1988; Tribushinina, 2013a). Such interpretations are inherently absolute, because they are not based on context-dependent comparative judgments. Only around age 4, children seem to discover the common reference point for antonymous adjectives and start using a relative standard located around the midpoint of a series in their judgments; and from age 5 onwards they adjust the position of such a reference point to the properties of a specific reference class (Smith et al., 1986; Tribushinina, 2013a).

Adjective processing based on prototypes is an example of absolute interpretations (e.g., tallness is an inherent property of towers). In contrast, non-prototypical entities, such as dogs, may only be dubbed *big* in a relative way (e.g., compared to another dog or compared to an average dog). Contrastive information is not automatically available, but needs to be derived relative to a context-dependent reference point. These differences provide a plausible explanation for the developmental pattern observed in our study: Processing in prototypical (absolute) contexts appears fully-developed at age 3, whereas the development of relative/contrastive processing is still ongoing.

It is plausible to assume that three-year-olds would be more successful in processing contrastive inference if we had used regular intersective (absolute) adjectives that are less context-sensitive than the scalar relative adjectives used in our study. For example, toddlers might be more successful in anticipatory processing of the adjective *red* when presented with a visual array containing a blue car and two red objects (a red bike and a red car). Even though anticipatory processing of contrastive reference is still demanding, the processing of intersective adjectives is presumably less taxing than the processing of intrinsically relative size terms whose interpretation heavily depends on context and comparison class (cf. *a tall lamppost* vs. *a tall boy*).

7.4 Limitations and Directions for Future Research

In this study, we did not focus on individual processing strategies. However, it is possible that some children are more prone (and/or better able) to use contrastive information in adjective processing. Longitudinal studies of contrastive adjective use have revealed remarkable individual differences between children and between caregivers. Some parents favor heavy antonym use, whereas other parents barely use opposites when talking to children (Murphy & Jones, 2008; Tribushinina et al., 2013). There is a positive correlation between antonym use in child speech and child-directed speech (children of heavy antonym users also often use adjectives in contrastive contexts), but the source of this correlation is unclear. It is plausible to assume that the individual differences in contrast use by children and their caregivers may have consequences for adjective processing in real time. Children of heavy antonym users and/or children who favor the use of antonyms may have an advantage in the use of visual contrast for adjective processing. These individual differences are an interesting avenue to explore in future research. Other possibly interesting individual differences pertain to selective attention and vocabulary size (cf. Yoshida et al., 2011).

The findings of the current study are in line with the results of Huang and Snedeker (2013) demonstrating that adults display a stronger tendency to use contrastive information than children. Yet, in their study five-year-olds were able to identify the referent based on referential contrast, whereas our three-year-olds were not able to predict the target referent even though the task was much easier. Future research could focus on contrastive processing in 4-year-old children in order to further examine the developmental phase in which the use of contrastive information becomes more available to children. Relatedly, future research might look into factors that facilitate the use of contrastive information in the incremental processing of adjective-noun phrases. For instance, it could be the case that highlighting the relevant contrast in preceding discourse (cf. Sekerina & Trueswell, 2012) could have enhanced the performance of the three-year-olds in our experiment.

It would also be theoretically interesting to compare the processing of contrastive and prototypical adjective uses in languages with different adjective-noun orders. Obviously, anticipatory adjective processing is not relevant in languages such as Hebrew where attributive adjectives are usually placed after the noun. Evidence from novel word learning studies seems to indicate that the postnominal position facilitates adjective mapping to relevant properties (Yoshida & Hanania, 2013). However, there is evidence that Hebrew-speaking toddlers also have difficulty integrating the meaning of the adjective with that of the noun, even though attributive adjectives always follow the noun. When asked to find the *big teddy* in a visual scene showing a big teddy (correct attribute; correct noun), a small teddy (wrong attribute; correct noun), a big clock (correct attribute; wrong noun) and a small clock (wrong attribute; wrong noun), Hebrew-speaking toddlers would often make choices based on the noun alone (Ninio, 2004). Hence, a possible advantage of the postnominal position (Yoshida & Hanania, 2013) might be counterbalanced

by a reduced salience of the adjective which is "overshadowed" by the NP-initial noun: A child may choose a referent based on the noun alone and then fail to repair her initial interpretation upon hearing the adjective. It would be worthwhile to investigate whether and how the postnominal position might influence adjective processing in contrastive and prototypical contexts. Elliptic constructions and nominalized adjectives (e.g., 'the tall one') might be particularly informative in this respect because they do not reveal the referent by using the noun before the adjective.

Another interesting path for future research would involve a paradigm, in which children's adjective processing would be studied in a more naturalistic setting, with real input provided by the child's caregiver (as in Arunachalam, 2016). This contextual methodology, in which language processes of children can be related to parental speech, is a valuable addition to adjective research in experimental settings.

Appendix: List of Items

	Adjective	Prototype	Non-prototype/contrast	Unrelated
1	tall (hoog)	tower (toren)	chair (stoel)	butterfly (vlinder)
2	"	house (huis)	glass (glas)	ladybug (lieveheersbeestje)
3	"	mountain (berg)	table (tafel)	dress (jurk)
4	"	tree (boom)	bicycle (fiets)	watering can (gieter)
5	"	apartment building (flatgebouw)	fence (hek)	ice cream (ijsje)
6	big (groot)	elephant (olifant)	dog (hond)	pen (pen)
7	"	hippo (nijlpaard)	gift (cadeau)	sand (zand)
8	"	whale (walvis)	monkey (aap)	modder (mud)
9	"	bus	teddy bear (knuffelbeer)	flower (bloem)
10	"	giant (reus)	cloud (wolk)	chocolate sprinkles (hagelslag)
11	small (klein)	gnome (kabouter)	window (raam)	policeman (politieagent)
12	"	chick (kuiken)	bath (bad)	hair (haar)
13	"	mouse (muis)	ball (bal)	doctor (dokter)
14	long (lang)	snake (slang)	candy stick (zuurstok)	computer
15	"	train (trein)	ladder	princess (prinses)
16	"	garden hose (tuinslang)	twig (tak)	pan
17	"	rope (touw)	pencil (potlood)	t-shirt
18	"	garland (slinger)	necklace (ketting)	alarm (wekker)
19	"	giraffe	road (weg)	frog (kikker)
20	thick/fat (dik)	elephant (olifant)	candle (kaars)	drawer (kast)
21	thin (dun)	pencil (potlood)	ice cream (ijsje)	book (boek)

Note. The words in parentheses are the Dutch translations

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