Development of adjective frequencies across semantic classes

A growth curve analysis of child speech and child-directed speech

Elena Tribushinina[1], Huub van den Bergh[1], Dorit Ravid[2], Ayhan Aksu-Koç[3], Marianne Kilani-Schoch[4], Katharina Korecky-Kröll[5], Iris Leibovitch-Cohen[2], Sabine Laaha[5], Bracha Nir[6], Wolfgang Dressler[5] and Steven Gillis[7]
[1]Utrecht University / [2]Tel Aviv University / [3]Bogazici University / [4]University of Lausanne / [5]University of Vienna / [6]Haifa University / [7]University of Antwerp

This paper is a longitudinal investigation of adjective use by children aged 1;8–2;8, speaking Dutch, German, French, Hebrew, and Turkish, and by their caregivers. Each adjective token in transcripts of spontaneous speech was coded for semantic class. The development of adjective use in each semantic class was analysed by means of a multilevel logistic regression. The results show that toddlers and their parents use adjectives more often as the child grows older. However, this holds only for semantic classes denoting concrete concepts, such as physical properties, colour, and size. Adjectives denoting more abstract properties are barely used by children and parents throughout the first year of adjective acquisition. The correlations between adjective frequencies in child speech and child-directed speech are very strong at the beginning, but decrease with time as the child develops independent adjective use. The composition of early adjective lexicons is very similar in the five languages under study.

Keywords: adjective frequencies, semantic classes, audience design, order of emergence, cross-linguistic

1. Introduction

Adjectives are a secondary cognitive, lexical, and grammatical category in a number of respects. Semantically, they tend to adjust their meaning to that of a head

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noun (Ferris 1993; Lyons 1977; Sapir 1944; Siegel 1980; Taylor 1992; Vendler 1968), which means that the same adjective may have very different interpretations in combination with different nouns (e.g. *big mouse* vs. *big elephant*). Syntactically, adjectives are typically dependent on nouns, as indicated by the two major syntactic positions they occupy, predicate heads and NP modifiers (Bolinger 1967; Dixon & Aikhenvald 2004; Ferris 1993; Lewis 1976). In many languages, adjectives agree with head nouns in inflectional properties (number, gender, case, definiteness), particularly when they serve as modifiers within a noun-phrase. In addition, their less robust status is indicated by fuzzy boundaries with other categories, particularly with adverbs (Panagiotidis 2011), but also with nouns and verbs (Creissels 2005; Rusiecki 1985). Adjectives are not a universal category, as some languages map properties to nouns and some to verbs (Bhat 1994).

Adjectives emerge in child speech (CS) later than nouns and verbs (e.g. Barrett 1995; Berman 1988; Caselli, Bates, Casadio & Fenson 1995; Ninio 1988; Salerni, Assanelli, D'Odorico & Rossi 2007) and constitute a low-frequency class when compared to other content words in children's early lexicons in various languages (e.g. Behrens 2006; Dromi 1987; Marvin, Beukelman & Vanderhoof-Bilyeu 1994; Stolt, Haataja, Lapinleimu & Lehtonen 2008). Word-learning experiments demonstrate that 14-month-olds already have target-like expectations about the grammatical form NOUN, but not about the grammatical form ADJECTIVE (Booth & Waxman 2009; Waxman & Booth 2001).

Perhaps as a result of their secondary status and relatively low frequencies, adjectives have received much less attention in the language acquisition literature than other content-word classes. The existing research on adjective acquisition has largely focussed on the extension of novel adjectives to new objects (Graham, Cameron & Welder 2005; Klibanoff & Waxman 2000; Mintz 2005; Mintz & Gleitman 2002; Waxman & Klibanoff 2000) and on the comprehension of specific semantic classes, primarily colour terms (e.g. Andrick & Tager-Flusberg 1986; Bornstein 1985; Kowalski & Zimiles 2006; O'Hanlon & Roberson 2006; Pitchford & Mullen 2001; Soja 1994) and spatial adjectives (e.g. Barner & Snedeker 2008; Bartlett 1976; Brewer & Stone 1975; Ebeling & Gelman 1994; Harris, Morris & Terwogt 1986; Maratsos 1973; Smith, Cooney & McCord 1986). There have been only few attempts to explore the emergence of the adjective category using longitudinal transcripts of spontaneous CS (Aksu-Koç 2011; Blackwell 2005; Nelson 1976; Ravid & Nir 2000; Saylor 2000; Tribushinina & Gillis 2012; Tribushinina, Gillis & De Maeyer 2013).

The few longitudinal studies of early adjective vocabularies available so far indicate that two factors — distributions in child-directed speech (CDS) and conceptual properties of adjective classes — play an important role in shaping early adjective lexicons. Blackwell (2005) studied longitudinal speech samples from two

English-speaking children, Adam and Sarah (Brown corpus), between the ages 2;3 and 5;0. The results demonstrate that properties of the input — adjective frequencies and diversity of syntactic frames in which adjectives are used — are significant predictors of the age at which an adjective is acquired. Thus, distributions in CDS clearly influence the acquisition of adjectives.

However, children are not merely parroting what adults are saying. They also seem to have their own preferences as far as adjective use is concerned. Another factor that appears to play a role in the acquisition of the adjective category, along with the characteristics of parental input, concerns semantic properties of adjective classes. In Blackwell's study, the proportion of colour terms (e.g. *red, blue, green*) and adjectives denoting physical properties (e.g. *broken, heavy, soft*) was higher in CS than in CDS across all age periods studied, whereas the proportion of evaluative adjectives (e.g. *good, nice, interesting*) was higher in the input (see also Saylor 2000). Blackwell (2005) accounts for this result by appealing to different discourse functions of adjectives in CS and CDS. Children primarily use adjectives to identify referents or to comment on objects in their immediate environment, whereas parents more often use adjectives for evaluation.

Adjectives usually emerge in CS towards the end of the second year of life and are acquired at a high pace between ages two and three (Tribushinina & Gillis 2012; Voeikova 2011). It is crucial to conduct fine-grained analyses of adjective use in this period in order to get a better insight into the mechanisms of adjective acquisition. Hence, unlike prior research taking a more global perspective (e.g. Blackwell 2005; Stolt et al. 2008; Tribushinina & Gillis 2012; Tribushinina et al. 2013), this paper targets patterns of adjective use by children and their caregivers in the age range of 1;8 to 2;8, i.e. during the first year of adjective acquisition. The specific focus of this research is on changes in adjective (token) frequencies in CS and CDS, and on the impact of semantic properties of adjective classes on this development.

Although previous research, particularly by Blackwell (2005), provides useful insights into the mechanisms of adjective acquisition, it leaves several important questions unanswered. First, adjective frequencies in CS are likely to change as a function of age. It is, however, not known whether this effect would be different for adjectives from different semantic classes (e.g. colour terms *vs.* internal-state adjectives). There is growing evidence that nouns and verbs with concrete meanings are acquired before those with more abstract meanings (Bassano 1998, 2000; Behrens 2006; Gentner 1982, 2006; Gentner & Boroditsky 2001; Hirsh Pasek & Michnik Golinkoff 2006; Maouene, Laakso & Smith 2011). Likewise, it can be hypothesized that adjectives with more concrete (perceptually grounded) meanings emerge earlier than adjectives with a more abstract semantics. Further, it is plausible that changes in frequency of use also depend on semantic properties (e.g.

conceptual complexity) of adjective classes. Frequencies of some adjective classes are likely to increase between ages two and three, for example, because particular meanings (e.g. colour and shape concepts) become more accessible to children (Kowalski & Zimiles 2006; Pitchford & Mullen 2001). Alternatively, frequencies of adjective classes may change over time because children become increasingly involved in some kinds of activities (e.g. colouring, building block towers) stimulating the use of particular adjective classes, such as colour and size terms. By contrast, frequencies of adjectives denoting properties that are more abstract and, therefore, more complex and less relevant in the toddler's world, are more likely to remain relatively stable in the first year of adjective acquisition.

Second, although properties of the input were shown to affect the time of adjective acquisition, it is not clear whether adjective frequencies in CDS remain stable or change over time. Based on the theory of audience design (Clark & Murphy 1982), we can assume that parents adjust their speech when speaking to young children. In line with this assumption, cross-linguistic research on noun plurals demonstrates that plural suffixes in CDS are much more transparent and regular than in the adult systems (Ravid, Dressler, Nir-Sagiv, Korecky-Kröll, Souman, Rehfeldt, Laaha, Bertl, Basbøll & Gillis 2008). Likewise, Maouene et al. (2011) report that verbs are used in CDS in less diverse contexts (i.e. with a more limited set of nouns) than what can be expected on the basis of adult verb-noun association data. A special kind of audience design is parental scaffolding, whereby parents progressively increase the complexity of their language as a function of children's age and by doing so invite the child to produce more complex words and constructions (Wood, Bruner & Ross 1976). For instance, there is evidence that frequency of maternal verbalizations in talk to children increases as children grow older (Stevens, Blake, Vitale & Macdonald 1998; Van de Weijer 1999). Furthermore, the types of parental utterances also appear to change over time. In a longitudinal study reported in Stevens et al. (1998), mothers used more labels, suggestions and comments when talking to their children at 15 months than at 9 months. As against this, the frequency of attention-getting verbalizations decreased between 9 and 15 months. Interestingly, parental scaffolding was shown to be correlated with vocabulary size at 15 months.

In a similar fashion, it can be predicted that frequencies of adjective use in CDS increase over time, either as an attempt to attune adjective use to the developing capacities of a child or as a result of the naturally changing types of activities in which children and caregivers become involved as the child grows older. Blackwell (2005: 552–553) reports raw frequencies of adjectives in CS and CDS at six age periods (2;6, 3;0, 3;6, 4;0, 4;6, 5;0) divided over six semantic classes. These data seem to suggest that both Adam and his mother come to use fewer adjectives with time, whereas adjective use in the speech of Sarah and her mother appears to

increase. However, a mere comparison of raw frequencies, without taking sample size (number of child and parent utterances per datapoint) into account, may give a distorted picture of development. In other words, we cannot be sure whether higher or lower adjective frequencies are due to changes in adjective use or due to talkativeness of the speakers at individual recordings. Therefore, the present study uses a statistical method that takes into account the differences between the corpora in the number of child and parent utterances, as well as the differences in the exact number and timing of recordings, and allows to trace changes in adjective use by both children and parents (see below).

In addition to studying overall adjective frequencies in CDS, this paper aims to provide a fine-grained analysis of changes in adjective frequencies in CDS across semantic classes. It is possible that the use of adjective categories denoting concepts that are of less significance in the world of parent-toddler interactions (e.g. temporal, quantitative, numeral adjectives) remains relatively stable, as parents (unconsciously) use these words on a regular basis for particular communicative needs at hand (cf. Van Veen 2011). However, there are also semantic classes of adjectives denoting concepts that are very prominent in daily parent-child interactions and perhaps become more relevant over time. For instance, parents may at a certain point notice that the child is acquiring the ability to conceptualize colour or size and is developing interest in these concepts. Consequently, caregivers may start using colour and size terms at higher rates than before as a kind of audience design.

This study also aims to provide new insights into the relation between adjective frequencies in CS and CDS and, importantly, into the developmental course of this relation. In Blackwell's (2005) study, cumulative adjective frequencies in the input, collapsed across the datapoints, were shown to predict the time at which a particular adjective would be acquired. Based on these data, we cannot say whether the relation between adjective use in CS and CDS remains stable throughout development or changes over time. It is reasonable to assume that adjective frequencies in CS are strongly dependent on frequencies in CDS at the onset of the acquisition process, but that this correlation decreases with time as children become more independent language users. In order to answer this question we need a method that would be more suitable for studying development than the traditional way of splitting the investigated period into phases (often arbitrarily defined) and comparing frequencies (or proportions) between these phases (cf. Blackwell's analysis of adjective frequencies across semantic classes). Therefore, in the present investigation, we will use a growth curve analysis by means of a multilevel logistic regression (Goldstein 1979, 1987). This approach allows to investigate a relation between a continuous independent variable (age) and a dichotomous dependent variable (presence *vs.* absence of adjectives). Van Veen, Evers-Vermeul, Sanders and Van

den Bergh (2009) applied the growth curve analysis to the study of connective use and found that there is a temporary relation between connective frequencies in CDS and CS. At the very beginning, there is little influence of CDS on CS because the child barely produces speech; and at the end of the investigated period connective frequencies in CS are hardly related to frequencies in CDS, since the child is already able to use connectives independently. Thus, input frequencies appear to be particularly important when children start producing a linguistic item in their speech. Hence, it can be hypothesized that adjective frequencies in CS are related to frequencies in CDS in early adjective productions, but this relation is likely to decrease over time. This trend ought to be observed for overall adjective frequencies, as well as for frequencies of specific semantic classes.

In this study, we target early acquisition of adjective vocabularies by ten children acquiring five languages (Netherlandic Dutch, Austrian German, Swiss French, Hebrew, and Turkish). These languages have an open adjective class and are largely similar in terms of adjective semantics. The only notable exception is the class of modal adjectives in Hebrew, which is a lot more frequent and diverse than in the other four languages (Ravid & Nir 2000). Hebrew uses adjectives to express meanings that are associated mainly with modal verbs (or inflections) in the other languages. Despite this exception and typological differences on the morphosyntactic level, we assume that early acquisition of adjective vocabularies takes a comparable course in the five languages targeted for analysis due to similarities in the constitution of adjective lexicons and in the general cognitive underpinnings of this process.

To summarize, three questions were targeted in this study: 1) Does early adjective use change over time as a function of age and does this development differ for various semantic classes of adjectives? 2) Does adjective use in CDS change with the child's age? 3) Is the development of adjective use in CS related to adjective use in CDS? Adjective use is operationalized in this study as token frequencies of adjectives. Other aspects of adjective acquisition (e.g. syntactic, morphological, pragmatic) fall beyond the scope of this paper.

2. Method

2.1 Data

The data in this study come from the "Cross-Linguistic Project on Pre- and Protomorphology in Language Acquisition" (cf. Bittner, Dressler & Kilani-Schoch 2003; Savickiene & Dressler 2007; Stephany & Voeikova 2009; Voeikova & Dressler 2002; Xanthos, Laaha, Gillis, Stephany et al. 2011). In this project, we investigate

various aspects of the development of the adjective category (morphology, syntactic functions, derivation, semantics) in five typologically different languages (Dutch, German, French, Hebrew, and Turkish). In the present paper, we focus on the development of semantic classes in early adjective lexicons, with a special focus on the frequency of adjective use across semantic classes.

We analyzed spontaneous speech samples from ten children (two per language) and their caregivers in the period between 1;8 and 2;8. Even though adjectives can emerge in CS as early as at 15 months, their frequency remains very low until the age of 20 months (Stolt et al. 2008; Voeikova 2011). Children acquire adjectives at a high pace between their second and third birthdays, and by age three, adjective frequency in CS reaches a plateau (Tribushinina & Gillis 2012). Not only type and token frequencies of adjectives grow fast between ages two and three; grammatical aspects of the adjective category are also acquired fast in that period. Tribushinina et al. (2013) report that around age two, children use adjectives primarily in non-syntactic frames (single-word utterances and telegraphic phrases), whereas typically developing three-year-old toddlers use adjectives in full syntactic constructions (primarily as predicates and NP modifiers) at adult rates. Thus, important developments in the formation and consolidation of the adjective category start around the age of 20 months and take about a year. This makes the period between 1;8 and 2;8 particularly interesting for studying early adjective use.

There were also empirical reasons for choosing the age range of 1;8–2;8. First, for most of the children in our sample (with the exception of Emma and Jan) no recordings were available before age 1;6. Second, as evidenced by Table 1, the first adjectives for most of the children were only attested around age 1;8. Third, before age 1;8 adjectives are too infrequent to capture subtle developments in the frequency of semantic classes.

All participants were monolingual speakers of the respective languages, from upper-middle class families. The corpora contain transcripts of audio recordings that were made once or twice a month in unstructured home settings (e.g. eating, washing, book reading, having a bath). A short description of the samples used in this study is given in Table 1.

2.2 Procedure

The transcriptions were tagged with the CHILDES' MOR software tool (adapted for the five languages), producing inflectional decomposition and part-of-speech tagging. The resulting tags and codings were verified manually. A word was selected as an adjective if it satisfied the following criteria: a. being a content word; b. being an open-class word (thus, excluding pronouns, determiners, etc.); c. having

Table 1. The corpora

Corpus	Language	Source	N files analyzed	N utterances		N adjective tokens		N adjective types		First adjective attested in CS at age
				CS	CDS	CS	CDS	CS	CDS	
Peter (m)	Dutch	Bol (1995)	11	4197	12490	500	2652	55	360	1;8
Sarah (f)	Dutch	Van Kampen (1994)	10	4957	6972	312	1186	50	126	1;7
Jan (m)	German	Korecky-Kröll (2011)	26	5805	9969	565	3014	105	239	1;3
Lena (f)	German	Lettner (2008)	26	4394	8039	187	1274	47	160	1;7
Emma (f)	French	Kilani-Schoch (2003)	26	5169	5035	732	931	72	91	1;4
Sophie (f)	French	Kilani-Schoch (1997)	33	9725	12746	864	1602	71	86	1;6
Gil (f)	Hebrew	Herzberg (2010)	13	7513	11216	374	2219	71	142	1;8
Omer (f)	Hebrew	Herzberg (2010)	12	7295	13489	340	2940	66	180	1;9
Irem (f)	Turkish	Ural et al. (2009)	18	6863	16455	90	868	37	160	1;7
Mine (f)	Turkish	Aksu-Koç (1998)	13	1323	2076	99	183	39	53	1;10

adjectival semantics, i.e. denoting properties, attributes or states of noun referents (thus, excluding actions, objects, etc.); d. having adjectival inflectional morphology (in Dutch, German, French, and Hebrew); e. being used in adjectival syntactic positions (mainly, attributive and predicative).

Attributively used past participles (e.g. *broken arm*) and ordinal numerals (e.g. *second*) were included in the analysis due to having adjectival inflectional morphology and similar semantics. Adjectives in formulas (e.g. *good night*) were also counted. Particles were only counted if they had an adjectival form. Thus, for instance, the Dutch particle *open* 'open', which has an adjectival form, was counted, whereas its German counterpart *auf* 'open', which is based on a preposition, was not counted. Repetitions and direct imitations were excluded from analysis.

The morphological coding allowed an automatic extraction of adjectives. Overall adjective frequencies in tokens and types are listed in Table 1.

2.3 Coding

Each adjective in the CS and the CDS was coded for semantic class using the CLAN coding mode. The adjective classification introduced in Blackwell (2005) for research on English (based on Dixon 1982) was used as a starting point in the present study. Blackwell used seven main categories (dimension, colour, value, age, physical property, human propensity, other); the latter three were further divided into more specific subcategories, following Frawley (1992) and Roget (1965). For example, the 'other' category was subdivided into adjectives denoting endearment, similarity, sufficiency, conformity, absence, manifestation, succession, dearness, certainty, truth, difficulty, disjunction, necessity and knowledge. The main categories were used in the quantitative analyses, and the more specific subcategories were only included in the qualitative analyses targeting the order of adjective emergence.

In order to be able to conduct more fine-grained quantitative analyses, we have adjusted Blackwell's classification by splitting the 'human propensity' class into three more specific classes (behavioural properties, internal states and physical states) and by adding a few main categories that proved to be frequent in our data (conformity, modal, ordinal, quantitative, temporal). Most of these categories were partly subsumed under the 'other' category in the original classification. Temporal adjectives (e.g. *previous*, *last*) were added to the coding scheme because they constitute a very common adjectival category in the languages included in this study (this category includes, among other adjectives, Blackwell's 'succession' subcategory). For adjectives with a clear quantitative semantics, such as *alone*, *ample* and *whole*, a separate class 'quantitative characteristics' was added (this category subsumes, but is not restricted to, Blackwell's subcategories of 'sufficiency',

'absence' and 'dearness'). Modal adjectives were added because, as explained above, they are particularly frequent in Hebrew, but can also be found in other languages investigated here (e.g. *probable*, *needed*) (cf. Blackwell's 'necessity' and 'certainty' adjectives). A preliminary coding of the data demonstrated that a lot of adjectives in CS and CDS pertain to sameness, similarity and correspondence to a standard (e.g. *same, different, unusual*). Therefore, Blackwell's subcategories of 'similarity', 'conformity' and 'truth' (from the 'other' category) were collapsed into a single main category 'conformity to a standard'. Finally, as already mentioned earlier, ordinal numbers (e.g. *first*, *second*) were included in the dataset because in the languages under study they have adjectival agreement morphology (and a very

Table 2. Semantic classes in the coding scheme, based on Blackwell (2005)

Semantic class	Examples
Age	*old, new, young, adult*
Behavioural property	*wild, funny, cautious, awkward, talkative, naughty*
Colour	*blue, yellow, greenish, pink, ruby-red, snow-white*
Conformity (to a standard)	*similar, different, same, correct, false, normal, unusual*
Evaluation	*good, bad, fantastic, terrible, nasty, interesting, delicious*
Internal state	*angry, crazy, happy, afraid, cheerful, eager, confident*
Modal	*needed, necessary, forbidden, possible*
Ordinal number	*first, second, third*
Physical property	
– surface	*rough, smooth, sticky, dry, dirty*
– configuration/functionality	*open, closed, loose, tight, intact, broken*
– taste/edibility	*sweet, sour, bitter, salty, raw*
– smell	*fragrant, smelly*
– sound	*quiet, noisy, loud, monotonous, soft, brittle*
– shape	*round, square, flat, straight*
– light	*dark, light*
– consistency	*soft, rigid, thick*
– matter	*wooden, plastic*
– speed	*fast, slow, quick*
– temperature	*warm, cold, hot, freezing*
Physical state	*sick, ill, tired, sore, drunk, hungry, dizzy, dead*
Quantitative characteristics	*alone, scarce, ample, complete, whole, limited, empty*
Spatial property (size and position)	*big, tall, wide, gigantic, tiny, narrow, remote, high*
Temporal property	*eternal, final, previous, early, late, past, permanent, long*
Other	*electric, Japanese*

similar semantics). Since ordinal numbers are strictly speaking not an adjectival category, in contrast to quantitative adjectives, they were counted separately.

The resulting classification included fourteen semantic classes (see Table 2). This classification was detailed enough to conduct quantitative analyses of specific semantic classes and gave a relatively small 'other' category (2.5% of adjective tokens).

The coding of specific instances of an adjective was determined by contextual factors. This means that polysemous adjectives were assigned to a semantic class relevant in a given context. For example, the French adjective *petit* was coded as a spatial adjective in cases such as (1) and as an age term in contexts such as (2). Similarly, the Dutch adjective *lang* 'long' was coded as a spatial term in (3) and as temporal in (4). The German adjective *süß* 'sweet' was coded as a physical-property adjective in (5) and as an evaluative adjective in (6).

(1) *Un petit coeur.* (Emma, 2;4)
('A small heart.') (while drawing)

(2) *Petit garcon.* (Emma 2;1)
('Little boy.') (used with reference to a character in a picture book)

(3) *Ik heb langere armen.* (input to Peter, 2;2)
('I have longer arms.')

(4) *Het is ook zo lang geleden dat Frank je gezien heeft.* (input to Peter, 2;3)
('It's also so long ago that Frank saw you.')

(5) *Knusprig, süß und kalt.* (input to Jan, 2;3)
('Crispy, sweet and cold.')

(6) *Mein süßer Bub.* (input to Jan, 2;4)
('My sweet boy.')

Coding was done by the authors of this paper, at least one of whom was a native speaker of the language involved. Coding decisions were closely coordinated between the coders to make sure that the same codes were given to similar items across languages. Any disagreement was resolved by consensus.

2.4 Intra-coder agreement

Ten percent of the data were re-coded approximately eight months after the final coding. The percentage of items coded in the same way in the first and second rounds of coding was calculated per corpus. Subsequently, mean agreement rates per language were calculated. The intra-coder agreement was 99.2% for Dutch, 98.3% for French, 100% for German, 98.8% for Hebrew and 100% for Turkish.

2.5 Analyses

Observations of adjective use are nested within children. That is, adjective use on (randomly) selected occasions of the same child has more in common than adjective use of (randomly) selected children on these occasions. We therefore have two types of samples: adjective use by the same child at a different sample of recordings and a sample of children. Consequently, a multilevel model is in operation, with adjective use on different occasions nested within children (see Appendix 1 for model description). Changes in the use of adjectives with age can be modelled by means of so-called polynomials (a function of powers of age). Such polynomials are extremely flexible and can take almost any shape (depending on the number of powers and the size of the regression weights; see Goldstein 1979). In such a multilevel model, an average change (in adjective frequency) is estimated, as well as a deviation of the average change with age for each child (i.e. the variance between children). In fact, this boils down to the estimation of a growth curve for each individual child.

Not only adjective use differs between recordings, so does the number of utterances. The dependent variable in order to take the number of utterances into account is the logit of adjective frequency. That is, $\text{Logit}[F] = \ln\left[\frac{F}{N-F}\right]$ is used as a criterion to assess differences between children with age. Hence, the frequency of adjectives is seen as an occurrence of F in a sample of N observations. Such logits can take any value between $-\infty$ and $+\infty$ (these logits can be transformed to probabilities of occurrence: $p(x) = \frac{1}{1+e^{-x}}$, which are easier to interpret).

Note that polynomials can be used to describe changes with age in adjective use in CS as well as changes in adjective use in CDS. Once the parameters for changes with age for both children and parents are estimated, the correlation between adjective use of children and parents can be approximated (see Appendix 1).

3. Results

3.1 Frequency of adjective use in CS and CDS

Table 3 shows the parameter estimates for changes in token frequency of adjectives with age. A second order polynomial proved necessary in order to describe the average change over time. This model fits quite well to the observed data; the correlation between the observed frequencies and the predictions of the model equals 0.892.

At the age of 805 days, the likelihood that children use adjectives is estimated as ($\frac{1}{1+e^{-(-2.490)}}$ =) 0.08. This means that at the age of 805 days, children on average

Table 3. Fixed and random parameter estimates for change in adjective frequency with age (in logits; age rescaled as (age – 805)/100)

Parameter	Fixed		Parameter	Random	
	Estimate	(se)		Estimate	(se)
$\beta_0 * Age^0$	−2.490	(.199)	$S^2(\beta_0)$	0.389	(.176)
$\beta_1 * Age^1$	0.314	(.092)	$S(\beta_0, \beta_1)$	−.0125	(.060)
$\beta_2 * Age^2$	−0.112	(.017)	$S^2(\beta_1)$	0.080	(.037)

use an adjective in 8 of every hundred utterances. On average, there is an increase in adjective use with age ($\beta_1 = 0.314$), but a decrease with age^2 ($\beta_2 = -0.112$). This shows that average change in adjective frequency is not linear; in particular, changes in frequency of adjective use are smaller at the beginning and at the end of the investigated period than around the average age of 805 days. Based on the fixed parameter estimates in Table 3, the (average) likelihood of adjective use can be approximated for each age. For instance, for the age of 605 days the explanatory variable age has a value of [(605 – 805)/100 =] −2.0. Therefore, the logit of the likelihood of adjective use is estimated as: $(-2.490 + 0.314 * -2.00 - 0.112 * -2.00^2 =)$ −3.566. Transforming the estimated logit back to a proportion (or probability, $\frac{1}{1+e^{-(-3.566)}}$) shows that at the age of 605 days, children use adjectives (on average) in 2.7 out of every hundred utterances. At the age of 905 days, the average probability of adjective use has increased to 0.092; i.e. an adjective is used in 9.2 utterances out of every hundred utterances.

However, the average development in the use of adjectives does not account for the individual differences between children in the development of adjective use. The random parameters in Table 3 quantify the differences in development between children. Table 3 shows that children differ in adjective use at the age of 805 days (i.e. $S^2_{\beta 0}$). At this age the (logit of the) average equals −2.490, and the variance in adjective use at this age equals 0.389. Therefore, the 68% confidence interval for adjective use in CS at this age varies from ($\frac{1}{1+e^{-(-2.490-\sqrt{0.389})}}$ =) 4% to ($\frac{1}{1+e^{-(-2.490+\sqrt{0.389})}}$ =) 13% of utterances.

Not only the average adjective frequency differs between children, but also the change in adjective frequency with age. On average, the change with age equals 0.314. However, this parameter has a variance between children ($S^2 = 0.080$). The 68% confidence interval for change in adjective use varies from $(0.314 - \sqrt{0.080} =)$ 0.031 to $(0.314 + - \sqrt{0.080} =)$ 0.597. So, in terms of logits, the change in the frequency of adjective use with age varies from 0.031 to 0.597.

For the effect of Age^2, we were not able to show a (significant) difference between children. Therefore we have to assume that children do not differ in the effect of Age^2.

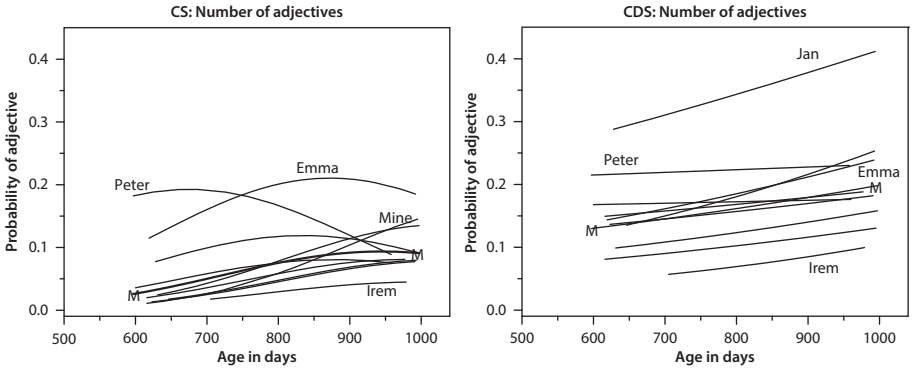

Figure 1. Estimated growth curves of adjective use in CS and CDS, M: average change over time

Individual growth curves can be approximated from the individual growth parameters. Figure 1 presents individual growth curves (changes in the probability of adjective occurrence) for each child. Exactly the same model was applied to the CDS (see Appendix 2 for parameter estimates). As can be seen, there are large deviations from the average curve (M). This holds both for children and their caregivers.

In both CS and CDS, there is a significant increase in the probability of adjective occurrence with age. A second order polynomial (with powers of age^0, age^1 and age^2) fits the data best for both children and adults. Furthermore, all three parameters appear to vary (significantly) between children and parents. On average, parents use adjectives more often than children.

Each line in Figure 1 represents the probability of adjective use by an individual child/parent (throughout the paper, child names are given in the graphs for the curves that are markedly different from the rest). We can observe development in adjective frequencies by individual children/parents, but also differences in development between children/parents. For example, Peter uses adjectives relatively often around the age of 600 days (1;8), but comes to use adjectives less frequently with age, whereas for the other children, a clear increase is observed. Also, the extent of increase in the probability of adjective occurrence differs for parents. Adjective use in the speech of some caregivers (e.g. the parents of Peter and Sarah) remains relatively constant, whereas for others (e.g. the parents of Jan, Emma and Omer) the increase is significant.

The model also provides information about the relation between CS and CDS. For both CS and CDS, the variance in adjective occurrence depends on age. Hence, the correlation between CS and CDS is also contingent on age. The estimated random parameters for overall adjective frequencies are presented in Table 4.

Table 4. Covariance matrix between CS and CDS

	CS_β_0	$CS\_\beta_1 * t^1_{ij}$	CDS_β_0	$CDS\_\beta_1 * t^1_{ij}$
CS_β_0	.389			
CS_β_1	−.125	.080		
CDS_β_0	.199	−.090	.249	
CDS_β_1	−.014	.009	−.011	.005

From the random estimates, the variance for CS and CDS can be approximated for every age in the investigated period. For instance, at the age of 605 days the variance in CS equals $(.389 + 2 * -2 * -.125 + .080 * -2^2 =)$ 1.209, whereas for CDS the variance at this age equals $(.249 + 2 * -2 * -0.11 + .005 * -2^2 =)$ 0.313. The covariance at this time point equals $(.199 - 2 * (-.090 - .014) + -2^2 * .009 =)$ 0.443. Hence, the correlation between CS and CDS at the age of 605 days is estimated as $(\frac{0.443}{\sqrt{1.209 * 0.313}} =)$ 0.72. At the age of 805 days, the correlation is estimated as $(\frac{0.199}{\sqrt{0.389 * 0.249}} =)$ 0.64.

Figure 2 shows the correlation between adjective use in CS and CDS. Notably, the correlation changes over time, i.e. it decreases steadily from almost 0.72 at the beginning of the study to 0.16 at the age of 995 days (2;6). For younger children, there is a strong correlation between the occurrence of adjectives in CS and CDS, while adjective use in the speech of older children barely reflects that of the CDS. Put differently, if parents use adjectives (relatively) frequently, then younger children are likely to use adjectives frequently as well, whereas for older children, no relation with the adjective use of parents can be shown.

Until now, we have only looked at the overall probability of adjective occurrence in CS and CDS. However, this development need not be identical for all semantic classes of adjectives. The estimated growth curves of adjective use in the

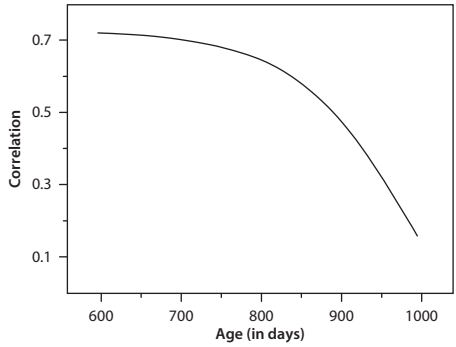

Figure 2. Correlation between probability of adjective occurrence in CS and CDS with age

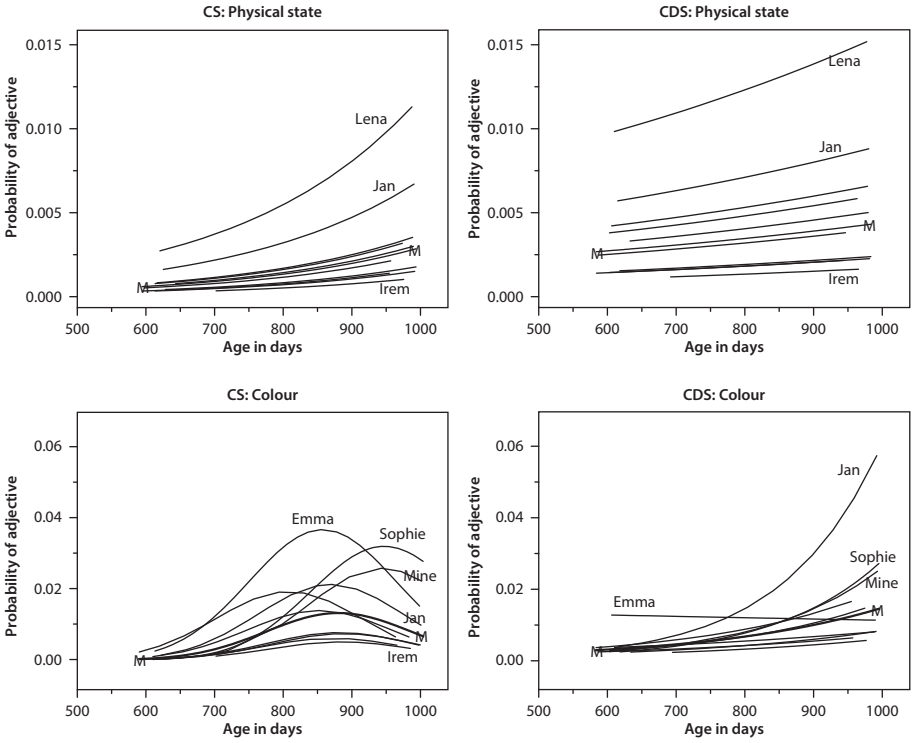

Figure 3. Estimated growth curves of physical-state and colour adjectives in CS and CDS, M: average change over time

semantic categories of 'physical states' and 'colour' are illustrated in Figure 3 (see Appendix 2 for parameter estimates per semantic class).

In the class of physical-state adjectives, there is a steady increase in the probability of adjective occurrence in both CS and CDS. The increase over time is larger for children (parents) who are already likely to use physical-state adjectives at the beginning of the study (Jan and Lena).

The colour category displays a more diverse picture. For some children (e.g. Irem) the probability of colour term use hardly changes during the period covered by the study, while other children's developmental path exhibits a sharp increase. For some children (e.g. Peter and Emma), this increase occurs in the initial stage of adjective acquisition, while for others (e.g. Sophie, Jan and Mine), the increase in the use of colour terms occurs markedly later. Most parents show an increase in the (relative) amount of colour adjectives. Only the use of colour adjectives in the input to Emma remains relatively stable over the investigated period.

The correlations between adjective use in CS and CDS do not show the same pattern across the semantic classes of adjectives. For example, for physical-state

adjectives (PH), the correlation remains constant and high across the whole period, indicating that there is a large correspondence between CS and CDS (see Figure 5). Children who are likely to use physical-state terms have parents who are likely to use these terms as well. For colour adjectives (C), on the other hand,

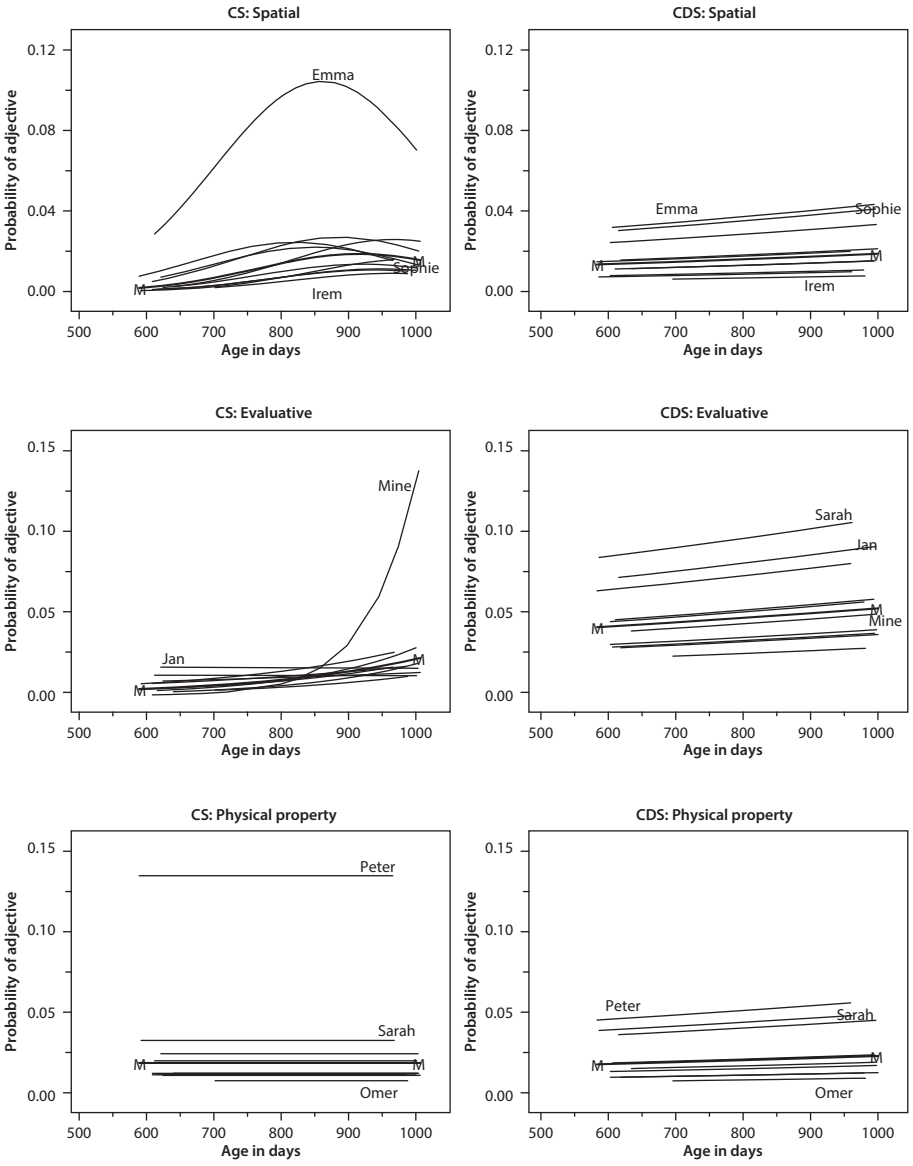

Figure 4. Estimated growth curves of spatial, evaluative and physical-property adjectives in CS and CDS, M: average change over time

the correlation develops through time, first increasing (from 0.63 to 0.89) and then decreasing, after around 800 days (2;2) to 0.58 at the age of 1000 days (2;7).

In the case of colour terms and physical-state adjectives, the growth in the probability of adjective use differs between children, as well as between parents. As against this, for spatial and evaluative adjectives, differences in growth can be shown only for CS, but not for CDS. Although the probability of spatial and evaluative adjectives in CDS changes over time, the difference between parents remains constant (see Figure 4). As demonstrated by Figure 5, the correlation between the probability of spatial adjectives (S) in CS and CDS first remains constant and then decreases from 0.84 to 0.61 after around 900 days (2;6). For evaluatives (V), the correlation initially increases from 0.36 to 0.60 (around 805 days, 2;2) and later drops to 0.07 (not significant).

For the class of physical-property adjectives, no growth can be assessed for CS. The probability of adjective use in this category remains constant for each child. In CDS, a small increase can be demonstrated, but the differences between parents remain constant across the investigated period (see Figure 4). The correlation between CS and CDS is high and appears not to change over time (see Figure 5).

The high correlations in Figure 5 show that for each category there is a strong relation between the ranking of CS and CDS. For example, as shown in Figure 3, the parents of the German-speaking children, Lena and Jan, use physical-state adjectives more often than the parents of the other children in our database. Similarly, Lena and Jan use adjectives of this class more often than the other children. In contrast, both Irem and her caregivers use physical-state adjectives less often than the other children and parents, respectively. Similar observations can be made about the rank order for other semantic classes, as evidenced by Figures 3 and 4 (e.g. relatively high frequencies of colour terms in the speech of Emma, Sophie, Mine,

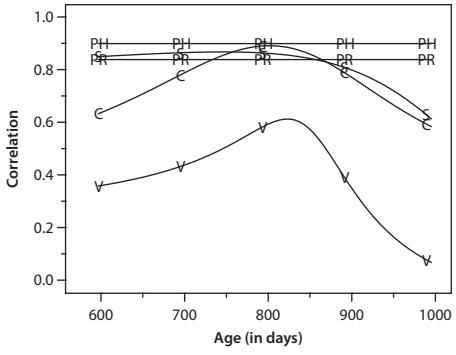

Figure 5. Correlation between probability of adjective occurrence in CS and CDS with age for colour (C), physical-state (PH), spatial (S), physical-property (PR) and evaluative (V) adjectives

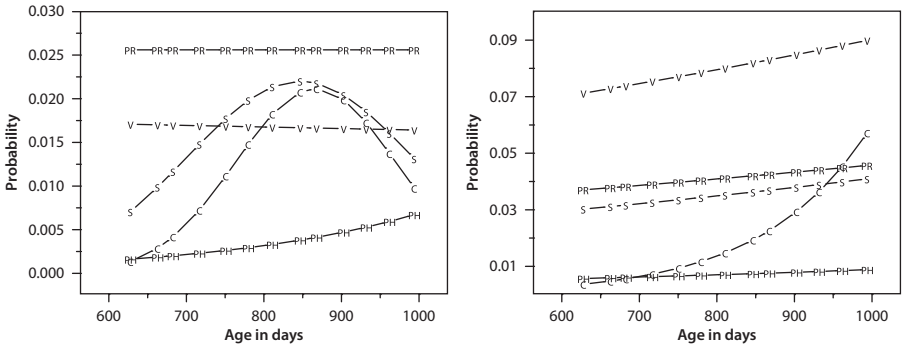

Figure 6. Estimated growth curves for colour (C), physical-state (PH), spatial (S), physical-property (PR) and evaluative (V) adjectives in the speech of Jan (left) and his caregivers (right)

Jan and their parents; relatively low frequencies of spatial adjectives in the Irem corpus and of physical-property terms in the Omer corpus). Hence, if parents are likely to use adjectives of a certain semantic class (relatively) frequently, their children are also likely to use adjectives of that semantic class (relatively) frequently. This by no means suggests that the ranking of semantic classes in the speech of a particular child mirrors that of her caregivers. By way of illustration, consider Figure 6, showing changes in the speech of the German-speaking boy, Jan, and in the speech of his parents for the adjective classes discussed above. The most frequently used adjective class in the speech of Jan are physical-property terms (e.g *heiss* 'hot', *kaputt* 'broken', *schnell* 'fast'), whereas in his parents' speech, evaluative adjectives (e.g. *gut* 'good', *toll* 'great', *schön* 'beautiful') are more common.

The semantic classes that have not been discussed in this section are hardly used by children and their caregivers in our database (estimated probabilities of occurrence are around zero for CS and CDS). Age adjectives were only used relatively often by the French-speaking girl, Emma, and her parents. The Dutch-speaking girl, Sarah, is the only child who uses behavioural adjectives relatively often, due to high token frequencies of the adjective *stout* 'naughty'; her mother also uses adjectives of this semantic class more often than the other caregivers (*stout* being the most frequent lemma). Sarah is also the only child using internal-state adjectives such as *boos* 'angry'. The other Dutch-speaking child, Peter, is the only child using a fair number of conformity adjectives, which is determined by the frequent use of the word *ander* 'other'. Temporal adjectives (e.g. *spät* 'late', *letzt* 'last', *weiter* 'further') are sometimes used by the German-speaker Jan and his mother, but barely by other children and parents. It is noteworthy that the adjective classes rarely used by the children and parents in this study denote quite abstract properties and, therefore, appear too complex for two-year-olds.

3.2 Language-specific tendencies

At the outset of this study we hypothesized that the development of adjective frequencies across semantic classes would be very similar in the five languages under study, since the adjective lexicons in Dutch, German, French, Hebrew, and Turkish are very similar in terms of semantic composition. The only difference that can be predicted on the basis of adjective semantics in adult language is a relatively high frequency of modal adjectives in Hebrew. As explained in Section 1, almost all basic modal meanings associated with verbs in the other languages are expressed by adjectives in Hebrew. In line with this typological property of Hebrew, the two Hebrew-speaking caregivers use significantly more modal adjectives than the parents with other language backgrounds, as evidenced by Figure 7. Likewise, the likelihood of modal adjective occurrence increases over time only for the Hebrew-speaking children (Omer and Gil). In the other languages, modal adjectives are barely used in CDS and CS.

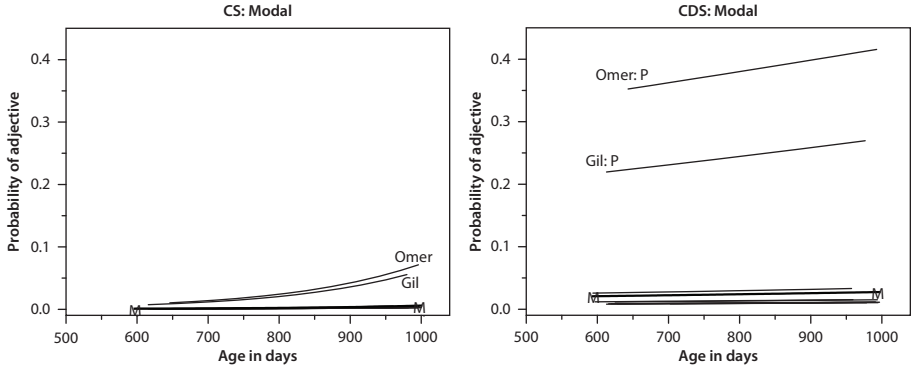

Figure 7. Estimated growth curves of modal adjectives in CS and CDS, M: average change over time

It is also noteworthy that the Dutch-speaking children (Peter and Sarah) and their caregivers use physical-property adjectives more often than speakers of the other languages in our database (see Figure 4). Upon closer scrutiny, we found that the high-token frequencies of this semantic class are due to two lemmas, *open* 'open' and *dicht* 'closed'. The token frequency of these two terms accounts for 62% of physical-property adjectives in the speech of Peter and 57% in the speech of Sarah. The reason why *open* and *dicht* are used so frequently compared to their counterparts in the other languages is that these adjectives can denote both the state of being open/closed, as in (7), and the process/action of opening/closing something, as in (8).

(7) *Open laten*. (Sarah, 2;3)
('Leave open.')

(8) *Magnetron gaat open*. (Peter, 2;1)
('Microwave goes open.')

In German, the same broad semantics is associated with the non-adjectival particles *zu* 'close(d)' and *auf* 'open', which are a lot more frequent than the adjectives *geschlossen* 'closed' and *offen* 'open' in the CS and CDS. For example, Jan's speech contains 35 tokens of *auf* and 25 tokens of *zu*, but not a single token of the adjectives *geschlossen* and *offen*. Similarly, there are 47 instances of *auf* and 26 instances of *zu* in Lena's speech, and only one token of *offen*. Thus, unlike in Dutch, the adjectives for 'open' and 'closed' in German (but also in French, Hebrew, and Turkish) can only denote the state of being open/closed, but not the process of opening/closing, which explains relatively high frequencies of physical-property terms in Dutch compared to the other languages under study.

As shown in Figure 4, the French-speaking caregivers use spatial adjectives more often than adult speakers of other languages. This tendency is attributable to the frequent use of *petit* 'small/little'. In French this adjective is commonly used not only in the dimensional sense as in (9), but also with pragmatic meanings (e.g. affective, mitigating) as in (10). Both French-speaking girls in this study reveal early sensitivity to the pragmatic uses of *petit*, as illustrated in (11) and (12). The frequency of *petit* accounts for 70% of spatial adjective tokens in Emma's speech and 85% in Sophie's speech. However, as shown in Figure 4, only Emma uses markedly more spatial adjectives than the other children in this study. The higher probability of age adjectives in the Emma corpus is also due to the frequent use of *petit*.

(9) *Les éléphants d'Inde ils ont des petites oreilles.* (input to Emma, 2;5)
('The elephants from India (lit. they) have small ears.')

(10) *J'aimerais un petit thé.* (input to Sophie, 2;4)
('I would like a little tea.')

(11) *Ça va petit Troumf? [:Schtroumpf]* (Emma, 2;1)
('How are you little Schtroumpf?') (toy, plastic figure)

(12) *J'ai un petit biscuit.* (Sophie, 2;8)
('I have a little cookie.') (while playing dinner)

The relatively frequent use of German physical-state terms (mainly *weh* 'sore', but also *müde* 'tired', *gesund* 'healthy' and *krank* 'ill') in the speech of Jan, Lena and their caregivers, evidenced by Figure 3, is probably due to the extra-linguistic contexts of the recordings. For example, Lena is very ill in one recording, and Jan has a severe cold in another.

Hence, there appear to be only marginal differences between children acquiring different languages as far as frequencies of semantic classes in development are concerned. This finding is consonant with the properties of the adult adjective systems in the five languages. As noted above, adjectives in Dutch, German, French, Hebrew, and Turkish differ in morphosyntactic properties of the adjective class, but largely concur in terms of semantics. However, in view of the small sample size per language, this conclusion should be treated with caution.

3.3 Order of adjective emergence

We hypothesized that children's early adjective productions are restricted to lemmas having concrete meanings grounded in immediate perceptions, and gradually move towards lemmas with a more abstract semantics. In order to test this prediction, we discuss the order in which adjectives emerge in spontaneous CS across the five languages.

3.3.1 *Dutch*

It is noteworthy that both Peter and Sarah start acquiring the adjective lexicon with physical-property terms. The Dutch-speaking children and their caregivers use adjectives of this semantic class more often than the speakers of the other languages in our database (see Figure 4), due to the frequent use of two lemmas, *open* 'open' and *dicht* 'closed'. As explained above, the relatively high frequency of these words compared to their counterparts in the other languages can be explained by their broader semantics, which includes not only the state of being open/closed, but also the act of opening/closing something (often used in requests).

Other semantic classes appearing quite early in Dutch CS include spatial, quantitative and evaluative adjectives, as well as conformity and colour terms. Sarah uses the behavioural adjective *stout* 'naughty' (which is also frequent in her input) from the very first recording. The first occurrence of a behavioural adjective in Peter's speech (*rustig* 'quiet') was only attested at age 2;7. Among the semantic classes acquired later by both children are modal adjectives (Peter: 2;2, Sarah: 2;1), internal-state terms (Peter: 2;7, Sarah: 2;3) and ordinal numerals (Peter: 2;3, Sarah: 2;4). Temporal adjectives emerge in Peter's speech only at the very end of the investigated period (2;7) and were not attested in Sarah's speech at all. Thus, the order of emergence in Dutch confirms the prediction that adjectives with more abstract meanings would emerge later than adjectives with concrete semantics.

3.3.2 *German*

Both Jan and Lena start productive adjective use with physical-property and conformity terms. Evaluative adjectives also emerge quite early (Jan: 1;8, Lena: 1;11).

Additionally, only Jan's speech is characterized by early emergence of the behavioural adjective *sportlich* 'sporty' (1;8), the physical-state term *weh* 'sore' (1;9) and the temporal adjectives *spät* 'late' (1;9) and *weiter* 'further' (1;10). Early emergence of these adjectives appears to be contrary to the prediction that abstract adjectives would be acquired later. This finding is probably related to the fact that Jan is an early talker, which is also manifested in the presence of quite complex adjective lemmas in his speech from early on. In contrast, Lena is a late talker; in her speech, these adjectives appear relatively late (physical state: 2;3, temporal: 2;6). The category of ordinal numbers is one of the last semantic classes acquired within the period investigated in this study (Jan: 2;1, Lena: 2;7). The last semantic class that emerged in Jan's speech are adjectives denoting internal states (age 2;2). No adjectives from this class were attested in Lena's speech. Her speech also does not contain any adjectives denoting age, behavioural and modal properties. Crucially, these are the most complex adjectives with abstract denotations. Furthermore, their understanding requires a more developed Theory of Mind (internal states, behavioural properties), as well as some understanding of scalarity (age) and intentionality (modals). Therefore, it does not come as a surprise that these words are acquired later than adjectives with a more accessible semantics.

3.3.3 *French*

Both Emma and Sophie start with a variety of adjective classes, including physical-property terms, evaluative and quantitative adjectives. Other classes emerging in their speech relatively early are conformity (Emma: 1;8, Sophie: 1;10), age (Emma: 1;8, Sophie: 1;10), colour (Emma: 1;8, Sophie: 1;11) and spatial adjectives (Emma: 1;8, Sophie: 1;10), as well as adjectives denoting internal states (Emma: 1;10, Sophie: 1;9). Semantic classes emerging later in the speech of both girls are temporal adjectives (both at 2;1) and modal terms (Emma: 2;6, not yet attested in Sophie's speech). Adjectives denoting physical states appear earlier in Emma's (age 1;9) than in Sophie's speech (age 2;5). Ordinal numerals were not attested in the speech of the French-speaking children.

As explained in Section 3.2, the most frequent adjective lemma in the speech of Emma and Sophie is *petit* 'small/little'. The adjective *autre* 'other' is the next preferred adjective in the French children's data (Emma 98%, Sophie 90% of the conformity class). This preference can be attributed to the formal and functional properties of *autre*. As it is a vowel-initial adjective triggering resyllabification with the preceding determiner and often occurring in a head function, *autre* seems to be learned by children as an amalgam or a single unit (*un autre* 'another', *l'autre* 'the other'). It appears as a useful means of individuating the referent without specifying its distinct properties (see Aksu-Koç 2011 on *öbür* 'other' in Turkish). The quantitative class is dominated by *seul* 'alone', used in reference to a familiar figure.

Finally, temporal adjectives centre on a few collocations (*dernière fois* 'last time', *semaine prochaine* 'next week'), the first one conveying a frequent request.

Overall, the development of these particular classes over time supports the hypothesis of a change from perceptually salient to more abstract adjectives. However, the picture becomes clearer once we set apart the lemmas that have the highest token frequency and occur quite early in the classes denoting age, conformity and quantitative characteristics (*petit* 'little', *autre* 'other', *seul* 'alone'). In fact, the diversification of classes in terms of new lemmas occurs much later than the early uses of adjectives: at 2;4 (Emma) and 2;6 (Sophie) for age, 2;3 (Emma) and 2;6 (Sophie) for conformity and 2;2 (Emma) and 2;3 (Sophie) for quantitative characteristics. In Emma's data, the internal-state adjectives display a parallel pattern of late (from 2;5 on) and regular diversification of lemmas after a long period across which the three first examples are scattered. There is no similar temporal gap in the distribution of the more perceptually salient adjectives of colour and space; these words are regularly distributed throughout the period studied. But, as expected, in the more abstract temporal class, the emergence of lemmas is relatively late too (both children at 2;2). Finally, the three internal-state adjective lemmas in Sophie's corpus occur during a specific period (between 1;9 and 2;5) and seem closely related to some features of the interaction and a larger extra-linguistic context experienced by the child.

3.3.4 *Hebrew*

Both Gil and Omer start acquiring the adjective lexicon with a restricted set of semantic classes, mainly denoting perceptually salient properties, such as physical property, colour and spatial properties. As in the other languages considered above, evaluative adjectives also appear in CS very early (Gil: 1;9, Omer: 1;11). Due to the prominent role of modal adjectives in Hebrew CDS, adjectives from this semantic class also emerge in the speech of Gil and Omer quite early (Gil: 1;11, Omer: 1;10), despite the conceptual complexity of modal words (see Figure 7). The exceptional status of modal adjectives in early CS represents the fact that adjectives are the best representatives of the modal class in Hebrew. Apart from the modal verbs *yaxol* 'can' and *roce* 'want', all of the basic modal notions are expressed by modal adjectives (and adverbs) *carix* 'need', *muxan* 'ready', *mutar* 'allowed', *asur* 'forbidden', *xayav* 'must', *efSar* 'possible' and *kday* 'worthwhile', among others.

The last semantic classes emerging in the speech of Gil are internal-state adjectives (age 2;8). For Omer, behavioural adjectives are the last to emerge (age 2;5). No temporal adjectives were attested in the speech of the Hebrew-speaking children; the number of temporal adjectives in the CDS is also very low (one in the Gil corpus and two in the input to Omer).

3.3.5 *Turkish*

Both Irem and Mine mainly use physical-property adjectives at the outset of this study. Mine also uses spatial adjectives and colour terms from early on. These classes emerge in Irem's speech somewhat later (colour: 2;3, spatial: 2;4). Evaluative adjectives appear in their speech at age 2;1. The last semantic classes emerging in Mine's speech are temporal (2;4) and quantitative (2;6) adjectives. Several categories have not been attested in Mine's speech at all (age, behavioural, modal, numeral, physical state). Notice that all these classes are relatively complex due to abstractness of their denotations. For Irem, the last category to emerge within the investigated period are adjectives denoting age (2;7), but their frequencies remain extremely low. Adjectives designating internal states, ordinal numerals, physical states and temporal properties have not been attested in Irem's speech. These are the most complex semantic categories denoting abstract properties.

The relatively high frequency of evaluatives in the speech of Mine (see Figure 4) is mostly due to their use in formulas (e.g. *iyi günler* 'good day') and also due to the frequent use of *kötü+kalpli* 'bad hearted' in reference to Big Bad Wolf, whose story she insists on telling.

4. Conclusion and discussion

This study set out to explore the development of adjective lexicons in children aged 1;8 to 2;8. Three questions were addressed: 1) Does early adjective use change over time as a function of age and does this development differ for various semantic classes of adjectives? 2) Does adjective use in the CDS change with the child's age? 3) Is the development of adjective use in CS related to adjective use in CDS? Based on the results, all these questions can be answered affirmatively.

First, as expected, children are likely to use more adjectives as they grow older. However, this does not hold for all adjective classes to the same extent. By and large, two groups of categories can be identified in the data. The use of some adjective classes in CS (e.g. age, behavioural, conformity, internal states, quantitative) remains constant over the period covered by this study. Notice, however, that adjectives from these classes are barely used by the children in the investigated age range, and are hardly used by their parents either. These adjective classes denote quite abstract properties and, therefore, are still too complex for a two-year-old child.

Another group of categories are adjectives that are used relatively frequently by the children in our database (e.g. colour, physical state, spatial, evaluative terms). Children use adjectives from these semantic classes increasingly more often between two and three years of age. Not surprisingly, these are adjective classes

denoting concepts that are quite prominent in the world of a two-year-old toddler. Children of this age are known to rely on colour and size for referent identification (Nelson 1976), which explains the prominent role of colour terms and spatial adjectives in early adjective lexicons. Physical-state terms, such as *hungry* and *tired*, describe essential states of a child that toddlers may often need to communicate to their parents. Evaluative adjectives, the most frequently used semantic class in the CDS, are presumably important in early adjective vocabularies due to the importance of the affective component in parent-child interactions.

A semantic class that does not seem to fit either of these categories are physical-property terms. As in prior studies on English (Blackwell 2005; Saylor 2000), physical-property terms constitute the most frequently used semantic class of adjectives in CS, and the second largest class in CDS, after evaluative adjectives. This pattern is consistent with the idea that young children primarily use adjectives to comment on perceptually salient properties of objects in their immediate environment (Blackwell 2005). However, unlike for other frequently used classes, we did not observe any increase in the probability of adjective occurrence (in CS) for physical-property terms. It might be the case that adjectives from this semantic class emerge in CS earlier and that the sample used in this study does not capture the initial stage in the acquisition of these words. However, this explanation does not seem plausible, given the ages of adjective emergence (see Table 1) and in view of the fact that adjectives are highly infrequent in CS before age 1;8 (see Figure 1, cf. Stolt et al. 2008; Voeikova 2011).

An alternative explanation might be that this semantic class is too large and too diverse, including a range of characteristics, such as surface, taste, smell, sound, shape, temperature, light, consistency and speed. It is reasonable to assume that the real developmental patterns in this case are obscured by the heterogeneity of the category. It is worthwhile to split this class into several smaller categories in future investigations and to trace their development in CS separately. However, in order to do this, larger samples will be needed than the ones available now, since adjectives are relatively infrequent and dividing them into even smaller categories can increase the chance of a sampling error.

As far as the order of emergence is concerned, children in this study started acquiring the adjective category with adjectives that have very concrete semantics anchored in immediate perceptions. Physical-property terms and adjectives of space and colour are among the first semantic classes represented in CS across all the languages studied in this paper. Evaluatives also tend to emerge early, presumably due to being highly frequent in the input, and possibly also due to the importance of the emotional component in parent-child interactions. In contrast, temporal, modal and behavioural terms, as well as adjectives denoting internal states, ordinal numbers and age, are among the last categories emerging (or not emerging

at all) within the period covered by the present investigation. These adjectives are complex by virtue of their abstract semantics. The pattern observed in our sample is consistent with the semantic theories postulating a basicness and higher accessibility of words with perceptible referents (e.g. Barsalou 1999; Johnson 1987) and theories of language acquisition positing the primacy of perceptual information early in development (e.g. Clark 1973; Gentner 1982; Smith, Jones & Landau 1996). In this respect, our results also replicate earlier findings on the acquisition of nouns and verbs (Bassano 1998, 2000; Behrens 2006; Gentner 1982, 2006; Gentner & Boroditsky 2001; Hirsh et al. 2006; Maouene et al. 2011).

As explained in Section 1, the only remarkable difference between the languages under study, as far as the composition of the adjective vocabularies is concerned, is that Hebrew associates modal meanings primarily with adjectives, whereas in the other languages these meanings are largely mapped onto verbs (or inflections). The probability of adjective use in this category increased only for two children, Gil and Omer, both acquiring Hebrew. Therefore, the difference in the acquisition paths between the two Hebrew-speaking children and all the other children in our database is probably attributable to this typological feature of Hebrew rather than to differences between children.

We have also seen that the use of physical-property terms is higher in the speech of the Dutch participants (children and caregivers) compared to other children and parents in our database. This tendency is probably related to the fact that adjectives are often used in Dutch as parts of separable verbs. More specifically, the frequent use of *open* 'open' and *dicht* 'closed/close', i.e. adjectival forms that can denote both the state of being open/closed and the act of opening/closing, makes this category rather frequent in Dutch CS and CDS. In the other languages under study, adjectives are used specifically for the state of being open/closed, but not for the act of opening/closing. The latter meaning is associated either with non-adjectival particles (e.g. German *zu* and *auf*) or with verbs.

Finally, the French CDS contains more tokens of spatial adjectives than CDS in the other four languages. This pattern is related to the higher frequency of the adjective *petit* 'small/little' which is abundantly used in French with pragmatic meanings. Research by Kilani-Schoch and Xanthos (2013) shows that *petit* is the first adjective to be inflected and to be used productively in French child language. In line with these earlier results, the French-speaking children in this study started using *petit* very early, in both the dimensional and the pragmatic sense, although only Emma's speech contained significantly more tokens of spatial adjectives than the speech of the other children in our sample.

Apart from the few cases of language-specific trends discussed above, adjective use across semantic classes appears to be very similar in the languages investigated here. As explained in Section 1, the composition of the adjective lexicons (i.e.

meanings typically associated with adjectives) is largely comparable across the five languages in this study. Furthermore, the order of adjective acquisition and early frequencies of use are strongly related to the child's cognitive development. Hence, it is perfectly explicable that there are only marginal differences in how adjectives are used across semantic classes in the five languages. Semantic development in this sense stands in contrast to the development of adjectival morphology, which is markedly different across the languages in our sample (Korecky-Kröll 2011). However, in view of the small sample size (per language), we can only make tentative conclusions about the role of language-specific factors. In future studies, we need not only denser samples per individual, but also more corpora per language. That is, if one wants to generalize over languages as well as to pinpoint language-specific elements in the development of children, one would need, at least, fifteen children per language in order to have an acceptable power. Unfortunately, such corpora are not available to date.

As far as the second question is concerned, there is clear evidence that parental adjective use changes over time. We found a steady increase in the parental use of the adjective category as a whole, as well as of the (relatively) frequent semantic classes (e.g. colour, modal, physical-state, physical-property, spatial, evaluative adjectives). The adjective classes that are barely used by the children (e.g. age, behavioural, conformity, internal-state, numeral, quantitative terms) are barely used by the caregivers as well. It is reasonable to assume that the use of these categories, that are conceptually more demanding than the categories denoting perceptually salient properties, will increase in both CDS and CS as children grow older and become more cognitively mature. A follow-up study will need to trace the development of these semantic classes after age three.

These results are consistent with the theory of audience design (Clark & Murphy 1982) and parental scaffolding (Wood et al. 1976) in the sense that parents clearly adjust their adjective use to the capacities and interests of the child. They come to use adjectives more frequently as children grow older and start using adjectives themselves. Furthermore, parents of two-year-olds barely use adjectives with abstract semantics that are still too complex in the third year of life. These results confirm earlier findings on the nature of CDS (Maouene et al. 2011; Ravid et al. 2008; Stevens et al. 1998).

The current results appear to be at odds with earlier findings reported in Behrens (2006), suggesting that part-of-speech distributions in CDS remain stable (cf. Aksu-Koc, Terziyan & Taylan 2012). This inconsistency is probably due to using a different approach. Behrens (2006) calculated the proportions of different parts of speech in CDS using a dense corpus of a German-speaking child, whereas in this paper, we modelled the probability of adjective occurrence in an utterance, at the same time taking talkativeness of children and their caregivers into account.

It may be proposed that the probability of adjective use in CDS grows only because parents come to talk more as a function of children's age (cf. Stevens et al. 1998; Van de Weijer 1999). In this case, frequencies of all parts-of-speech should increase at the same pace. However, this is not what empirical findings show. Research by Van Veen (2011) using the same method as in the present study demonstrated that parental use of connectives (e.g. *and, but, because*) remains stable over time. This means that the fact that parents increase their adjective use is not just due to growing talkativeness. Parents seem to be particularly aware of adjective production and start using adjectives more often as the child develops a capacity to represent properties conceptually (Kowalski & Zimiles 2006; Pitchford & Mullen 2001). There is also evidence in the literature that adjective use by the parents may stimulate the child's ability to attend selectively to dimensions, thereby providing a further boost to adjective acquisition (see Smith 1989 for a review). Unlike adjectives, connectives are function words with little lexical meaning; they are primarily used to express relations between discourse segments. Hence, parents do not keep track of connective frequencies the way they do for adjectives. It can be hypothesized that the application of the growth curve analysis to other word classes would reveal similarities between parental use of adjectives and other content words (e.g. nouns, verbs) and between connectives and other function words (e.g. prepositions, articles). It is also possible that parental scaffolding would be more intensive for adjectives and verbs than for common nouns, since noun referents are more accessible to a language learner (Gentner 1982, 2006; Gentner & Boroditsky 2001).

As far as the third research question is concerned, initially there is a strong relation between adjective use by the child and by the caregivers. For most of the semantic classes, the correlations remained high and stable during the whole period of investigation, which means that adjective use by the children mirrors that of parental speech. However, this relation appears to diminish once children come to use adjectives more independently, which may be seen as a marker of acquisition and replicates earlier applications of the growth curve analyses to CS-CDS relation (Van Veen 2011; Van Veen et al. 2009). The decreasing correlation between adjective frequencies in CS and CDS has been observed for both the adjective category as a whole and for a few semantic classes that are very prominent in CS at this period (colour, spatial and evaluative adjectives). In these semantic classes, CS closely resembles CDS at the outset of the study and hardly mirrors it at the end of the investigated period. Given that the frequency of physical-property adjectives in CS exceeds that of colour terms, spatial and evaluative adjectives, it is surprising that the correlations between CS and CDS do not decrease for physical-property terms. As already mentioned above, it is possible that developmental patterns in this case are obscured by the heterogeneity of the adjectives traditionally included in this semantic class (cf. Blackwell 2005; Saylor 2000). An alternative interpretation

would be that in the investigated period there are hardly any changes in the use of physical-property adjectives by children (see Figure 4).

This study provides evidence of the close relation between adjective use in CS and CDS. It is likely that parental adjective use influences adjective use by children. However, this cannot be concluded based on the correlations between CDS and CS. In other words, we cannot be confident that it is parents rather than children who take the lead in increasing adjective use. Although it is perfectly reasonable to expect that caregivers start using adjectives (of specific semantic classes) more often when they think their child is mature enough to understand them, which in its turn triggers increased use in CS, we cannot conclude this on the basis of the analyses conducted in this study. In order to pinpoint the causality of adjective use in CS *vs.* CDS, future studies should investigate the relation between CS and CDS in the preceding recordings.

The analyses presented in this paper provide useful insights about the role of input frequencies and adjective semantics in early adjective use by children. However, adjective use (operationalized as the probability of occurrence in CS and CDS) should not be equated with acquisition, since the latter presupposes attaining adult-like levels on a number of measures, such as productive use in novel adjective-noun combinations (cf. Tribushinina 2013b), diversification of the paradigm (e.g. Kilani-Schoch & Xanthos 2013) and target-like comprehension of adjectives. For example, even though adjectives of space and colour are frequently used by children from the very onset of adjective acquisition, numerous studies have shown that the understanding of these words is not yet adult-like at age four (e.g. Bornstein 1985; Cruse 1977; Harris et al. 1986; Istomina 1963; Maratsos 1973; Smith et al. 1986; Tribushinina 2013a).

Future research on the semantic development of adjectives will also benefit from studying adjective diversity (e.g. Tribushinina & Gillis 2012; Tribushinina et al. 2013) and development of individual adjectives in CS and CDS (see, for example, the analysis of the French *petit* 'small' in Kilani-Schoch & Xanthos 2013). It is also important to explore the impact of adjective semantics on other aspects of adjective use in early development. Research on English shows that children, like adults, associate adjectives denoting transient properties (e.g. physical-property terms) with the predicative position, whereas adjectives used for referent identification (e.g. colour and size terms) are more often used in the attributive position (Nelson 1976; Saylor 2000). There is also preliminary evidence that semantic diversification might be a pre-requisite to the grammatical development of adjectives. Across languages, children start using adjectives in full syntactic frames (e.g. predicatives, attributes) and regularly inflecting them when their productive vocabularies contain adjectives from, at least, six different semantic classes (Tribushinina & Levie 2011). It appears that semantically diverse adjectives invite

the child to (selectively) attend to properties and to generalize over them; this capacity in its turn creates the need to talk about properties of objects. Thus, a critical mass of adjectives from diverse semantic classes may be crucial to the formation and consolidation of the adjective category.

Finally, a methodological note is in order. In longitudinal studies of child language, it is very common to investigate development of linguistic phenomena by dividing the period under study into several (often arbitrarily defined) phases (e.g. trimesters). In this paper, we used a method which is much more suitable for longitudinal studies and leads to more accurate results — a growth curve analysis by means of a multilevel logistic regression. This method takes into account differences within children (different recordings of the same child), as well as differences between children. Since time is taken as a continuous independent variable, every single datapoint is taken into account. Furthermore, this approach allows for missing datapoints and for differences between corpora in the number and timing of recordings. Thus, the growth curve analysis allowed us to model the development of adjective use over time while keeping track of individual differences between children (parents). In this manner, the research reported here provides valuable insights into the development of early adjective vocabularies and into the relation between adjective frequencies in CS and CDS.

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Résumé

Cet article présente une étude longitudinale de l'usage de l'adjectif — entre 1;8 et 2;8 ans — dans la production spontanée d'enfants et de leurs parents, parlant allemand, français, hébreu, néerlandais et turc. Chaque occurrence de l'adjectif a été codée en fonction de sa classe sémantique. Le développement de ces différentes classes sémantiques a été analysé dans le langage des enfants et dans le langage adressé aux enfants au moyen d'un modèle de régression logistique à niveaux multiples. Les résultats montrent que l'usage des adjectifs croît avec l'âge des enfants mais que cette évolution ne s'applique qu'aux classes sémantiques dénotant des concepts concrets, tel que des propriétés physiques comme la couleur et la taille. Les adjectifs dénotant des propriétés plus abstraites sont rarement utilisés par les enfants et les parents durant la première année de l'acquisition de l'adjectif. Les corrélations entre les fréquences de l'adjectif dans le langage des enfants et dans le langage adressé aux enfants sont très fortes au début, mais diminuent avec le temps, au fur et à mesure que les enfants développent un usage indépendant de l'adjectif. La composition des premiers lexiques d'adjectifs est très similaire dans les cinq langues de l'étude.

Appendix 1. The model

This is a longitudinal study on changes in the frequency of adjective use. Hence, the objective of the analysis can be described as "identifying … intraindividual change and interindividual patterns of intraindividual change in … development" (Baltes & Nesselrode 1979: 7). At least two goals can be derived from this quote: (1) identification of intraindividual change (i.e. a function that relates the observed adjective use to the age of the participant); (2) similarities in intraindividual changes (i.e. variation between individuals in the development function). Suppose, F is the frequency that is analyzed as a random variable and dependent on T(ime of measurement). Application of the first goal boils down to identifying the function $F = f(T)$. Application

of the second goal leads to the identification of individual developmental functions $F_j = f_j(T)$ for individual *j*.

Many types of functions have been proposed in the past (Goldstein 1979; Healy 1989). We prefer polynomial functions as polynomials are extremely flexible. Suppose F_{ij} refers to the frequency of adjective use on the *ith* measurement of the *jth* individuals at T_{ij}. Now a polynomial can be written as:

$$F_{ij} = \beta_0 * T_{ij}^{\ 0} + \beta_1 * T_{ij}^{\ 1} + \beta_2 * T_{ij}^{\ 2}$$

The observed frequency, however, can be interpreted in different ways, as the number of utterances differs between measurement occasions within children and between children as well; hence the interpretation of a specific number of adjectives depends on the length of a recording. Therefore, not the frequencies of adjectives are analyzed, but the logit of these frequencies: $\ln(\frac{F_{ij}}{N_{ij} - F_{ij}})$. Such a logit transformation has several advantages: logits can vary from — ∞ to ∞, but the corresponding probabilities (i.e. $p[\text{logit}(x)] = \frac{1}{1+e^{-x}}$) of adjective use always vary between 0 and 1.

To relate the occurrence of adjectives in a given semantic class to the age at which they occur, a polynomial function is used (see Goldstein 1979; Van den Bergh, Rijlaarsdam, Janssen, Braaksma, Van Weijen & Tillema 2009); the (logit of the) observed frequencies are modeled as a function of powers of age. If we assume a second order polynomial, this function can be written as:

$$\begin{aligned} &\text{logit}(F_{ij}) = b_0 + b_1 * age_{ij}^{\ 1} + b_2 * age_{ij}^{\ 2} \\ &(i = 1, 2, \ldots, I_j; j = 1, 2, \ldots, J). \end{aligned} \tag{1}$$

Polynomials are very flexible, they can take almost any shape depending on the number of parameters (b_0, b_1, b_2, …) and their numerical values. A general rule to decide whether a next power of age should be included in the model is: (1) the specific power of age should attribute significantly to the explanation of differences in the observed (logit of the) frequencies and (2) all lower powers should be significant.

The model written in Equation (1) assumes that the changes in (the logit of the) frequencies are the same for all children. However, due to child-specific factors (like intelligence, language or input) the changes in (the logit of the) frequencies may vary widely between children. Therefore, the parameters in Equation (1) are allowed to vary between children. By writing the regression coefficient(s) (b_0-b_2) for each child *j* as deviation from an average coefficient we get a multilevel model (Goldstein 1987; Quené & Van den Bergh 2008):

$$\begin{aligned} b_{0j} &= b_0 + u_{0j} \\ b_{1j} &= b_1 + u_{1j} \\ b_{2j} &= b_2 + u_{2j}. \end{aligned} \tag{2}$$

Substitution of (2) in (1) gives the model for the changes in adjective use for children:

$$\begin{aligned} \text{logit}(F_{ij}) = b_0 + b_1 * age_{ij}^{\ 1} + b_2 * age_{ij}^{\ 2} + \\ [u_{0j} + u_{1j} * age_{ij}^{\ 1} + u_{2j} * age_{ij}^{\ 2}] \end{aligned} \tag{3}$$

$$(i = 1, 2, \ldots, I_j; j = 1, 2, \ldots, J).$$

The residuals (u_{0j}, u_{1j}, u_{2j}) are assumed to be normally distributed with an expected value of 0.0, and a variance of S^2_{u0j}, S^2_{u1j}, and S^2_{u2j}, respectively. For these random parameters, the same restrictions apply as for the fixed coefficients: (1) higher order terms are only incorporated in the

model if the respective variance reaches significance and (2) all lower order terms are significant as well (see, Van den Bergh et al. 2009).

The model in Equation (3) holds for the estimation of changes in adjective use (per semantic class) for children. In the same conversation the adjective use of their caregivers is observed as well. Therefore, the model according Equation (3) can be extended to the multivariate case in which changes with time in adjective use are estimated for children and caregivers simultaneously.

Let logit(F_{hij}) denote the frequency of either a child (h = 1) or a caregiver (h = 2). Now a second order polynomial can be written as:

$$\begin{aligned}\text{logit}(F_{hij}) = {} & D_{(h=1)ij} * (b_{10} + b_{11} * age_{ij}{}^{1} + b_{12} * age_{ij}{}^{2} + [u_{10j} + u_{11j} * age_{ij} + u_{2j} * age_{ij}{}^{2}]) + \\ & D_{(h=2)ij} * (b_{20} + b_{21} * age_{ij}{}^{1} + b_{22} * age_{ij}{}^{2} + [u_{20j} + u_{21j} * age_{ij} + u_{22j} * age_{ij}{}^{2}]) \end{aligned} \quad (4)$$

($i = 1, 2, \ldots, I_j$; $j = 1, 2, \ldots, J$).

In fact, two separate polynomials (regression equations) are estimated. The fixed part of the model gives the average change in the (logit of the) frequency for either children ($b_{10} - b_{12}$) or parents ($b_{20} - b_{22}$). Differences between children are taken care of in the random part of the model that is reserved for children ($u_{10j} - u_{12j}$), whereas the differences between caregivers are estimated in the random part that is specified for caregivers ($u_{20j} - u_{22j}$).

Of course, adjective frequency (of a given semantic class) in CS and CDS is allowed to covary. Suppose, for both children and caregivers only the first-order polynomial term reaches significance. In this case, the random part of the model is presented in Table A1.

Table A1. The random part of the model in case only the first order polynomial coefficients reach significance for both children and caregivers

Child	S^2_{u10j}			
Child	$S_{u10,u11} * Age_{ij}$	$S^2_{u11j} * Age^2_{ij}$		
Caregiver	$S_{u10,u20}$	$S_{u11,u20} * Age_{ij}$	S^2_{u20j}	
Caregiver	$S_{u10,u21} * Age_{ij}$	$S_{u11,u21} * Age^2_{ij}$	$S_{u20,u21} * Age_{ij}$	$S^2_{u21j} * Age^2_{ij}$

From the estimates for both children and caregivers the variance at each age can be approximated:

$$\begin{aligned} S^2_{\text{children}} \mid \text{age} &= S^2_{u10j} + 2 * S_{u10,\,u11} * Age + S^2_{u11j} * Age^2 . \\ S^2_{\text{caregivers}} \mid \text{age} &= S^2_{u20j} + 2 * S_{u20,\,u21} * Age + S^2_{u21j} * Age^2 . \end{aligned} \quad (4)$$

So, in this case (first order random coefficients) the differences between both children and caregivers are both a function of Age and Age^2. This means that estimating differences in growth actually boils down to modeling of hetroscedasticity of variance with age.

The covariance between the (logit of the) frequency of the adjective use of children and caregivers at each$_i$ is estimated as:

$$S_{\text{Children, parents}} \mid \text{age} = S_{u10,u20} + S_{u11,u20} * Age_{ij} + S_{u10,u21} * Age_{ij} + S_{u11,u21} * Age^2_{ij}. \quad (5)$$

By dividing the estimated co-variance at each age by the (square root of the product of) both (approximated) variances at this age, we get the correlation between the child's and her caregivers' adjective use (for each semantic class). It is important to note that the covariance coefficient (see Equation 5) as well as both variances depends on age (see Equation 4). Therefore, the re-

sulting correlation between children's and caregivers' adjective use is age-dependent as well; the correlation is allowed to vary with the age of children.

Appendix 2.

Table A2a. Parameter estimates per adjective class

	N_Adjectives		Age		Behavioural property		Colour		Conformity	
	Estimate	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**
	Fixed parameters (in logits)									
Intercept_Child	−2.490	(.199)	−6.114	(.550)	−7.056	(.365)	−4.574	(.228)	−4.996	(.347)
Age_Child^1*	0.314	(.092)	0.519	(.131)	−0.026	(.013)	0.707	(.152)	0.194	(.049)
Age_Child^2	−0.112	(.017)	−0.308	(.111)			−0.485	(.063)		
Intercept_Parent	−1.640	(.158)	−5.366	(.481)	−5.632	(.227)	−5.026	(.160)	−4.079	(.360)
Age_Parent^1*	0.126	(.025)			0.048	(.172)	0.415	(.089)	0.086	(.023)
	Random parameters (in logits)									
$S^2_{intercept\_child}$	0.389	(.176)	2.832	(1.315)	1.083	(.593)	0.473	(.228)	1.171	(.538)
$S_{age\_child,\ intercept}$	−0.125	(.070)			−0.692	(.527)	−0.080	(.108)		
$S^2_{age\_child}$*	0.080	(.037)			1.494	(.765)	0.166	(.093)		
$S_{parent,\ child}$	0.199	(.100)	2.530	(1.154)	0.298	(.278)	0.297	(.148)	0.0573	(.434)
$S_{parent,\ Child\_age}$	−0.090	(.044)			−0.266	(.308)	−0.028	(.073)		
$S^2_{intercept\_parent}$	0.249	(.112)	2.285	(1.040)	0.474	(.229)	0.235	(.114)	1.291	(.579)
$S_{age\_parent,\ intercept\_child}$	−0.014	(.016)			−0.192	(.207)	0.005	(.063)		
$S_{age\_parent,\ age\_child}$	0.009	(.008)			0.578	(.291)	0.035	(.022)		
$S_{age\_parent,\ intercept+parent}$	−0.011	(.009)			−0.088	(.126)	0.024	(.025)		
$S^2_{age\_parent}$*	0.005	(.003)			0.266	(.132)	0.062	(.035)		

* Age rescaled as (age − 805)/100

Table A2b. Appendix 2 continued.

	Internal state		Modal		Ordinal numeral		Other		Physical state	
	Estimate	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**	**Estimate**	**(se)**
	Fixed parameters (in logits)									
Intercept_Child	−7.271	(.470)	−6.444	(.438)	−6.562	(.416)	−6.236	(.276)	−6.598	(.248)
Age_Child^1*	0.361	(.158)	0.587	(.099)	1.263	(.290)			0.388	(.105)
Age_Child^2					−0.741	(.203)				
Intercept_Parent	−5.987	(.203)	−3.823	(.469)	−6.375	(.238)	−5.439	(.380)	−5.668	(.228)
Age_Parent^1*	0.169	(.012)	0.073	(.021)			0.220	(.046)	0.119	(.051)
	Random parameters (in logits)									
$S^2_{intercept\_child}$	1.854	(.961)	1.775	0.836	1.399	(.701)	0.659	(.340)	0.468	(.259)
$S_{age\_child,\ intercept}$										
$S^2_{age\_child}$*										
$S_{parent,\ child}$	0.476	(.334)	1.949	0.892	0.559	(.247)	0.785	(.315)	0.493	(.234)
$S_{parent,\ Child\_age}$										
$S^2_{intercept\_parent}$	0.358	(.184)	2.194	0.988	0.491	(.252)	1.412	(.646)	0.481	(.232)
$S_{age\_parent,\ intercept\_child}$										
$S_{age\_parent,\ age\_child}$	−0.218	(.108)								
$S_{age\_parent,\ intercept+parent}$										
$S^2_{age\_parent}$*	0.103	(.063)								

* Age rescaled as (age – 805)/100

Table A2c. Appendix 2 continued.

	Property		Quantitative		Spatial		Temporal		Evaluative	
	Estimate	(se)	Estimate	(se)	Estimate	(se)	Estimate	(se)	Estimate	(se)
	Fixed parameters (in logits)									
Intercept_Child	−3.894	(.248)	−5.902	(.195)	−4.228	(.281)	−6.429	(.470)	−4.625	(.132)
Age_Child^1*			0.650	(.112)	0.506	(.103)	1.120	(.370)	0.446	(.152)
Age_Child^2			−0.173	(.087)	−0.242	(.042)	−0.530	(.162)		
Intercept_ Parent	−3.812	(.181)	−4.678	(.307)	−4.121	(.187)	0.318	(.133)	−2.994	(.140)
Age_Parent^1*	0.060	(.021)	0.247	(.057)	0.085	(.024)	−5.559	(.297)	0.069	(.014)
	Random parameters (in logits)									
$S^2_{intercept\_child}$	0.603	(.275)	0.242	(.151)	0.757	(.349)	1.922	(.978)	0.150	(.078)
$S_{age\_child,\ intercept}$			0.033	(.052)	−0.168	(.105)	−1.008	(.608)	−0.093	(.072)
$S^2_{age\_child}$*			0.044	(.003)	0.080	(.044)	0.807	(.466)	0.211	(.103)
$S_{parent,\ child}$	0.370	(.184)	0.197	(.190)	0.438	(.216)	0.667	(.487)	−0.042	(.069)
$S_{parent,\ Child\_age}$			−0.049	(.089)			−0.019	(.304)	0.102	(.049)
$S^2_{intercept\_parent}$	0.323	(.147)	0.928	(.422)	0.342	(.157)	0.842	(.394)	0.193	(.088)
$S_{age\_parent,\ intercept\_child}$			−0.070	(.040)			−0.288	(.217)		
$S_{age\_parent,\ age\_child}$			0.022	(.014)			0.083	(.013)		
$S_{age\_parent,\ intercept+parent}$			−0.074	(.060)			−0.201	(.141)		
$S^2_{age\_parent}$*			0.022	(.014)			0.842	(.394)		

* Age rescaled as (age − 805)/100

Authors' addresses

Elena Tribushinina
Utrecht Institute of Linguistics
Utrecht University
Trans 10
3512 JK, Utrecht
The Netherlands

e.tribushinina@uu.nl

Huub van den Bergh
Utrecht Institute of Linguistics
Utrecht University
Trans 10
3512 JK, Utrecht
The Netherlands

h.vandenbergh@uu.nl

Dorit Ravid
School of Education
Tel Aviv University
Tel Aviv 69978
Israel

doritr@post.tau.ac.il

Ayhan Aksu-Koç
Department of Psychology
Bogazici University
Bebek, 34342
Istanbul
Turkey

koc@boun.edu.tr

Marianne Kilani-Schoch
University of Lausanne
School of French as a Foreign Language &
Department of language and information sciences Faculté des lettres Anthropole
1015 Lausanne
Switzerland

marianne.kilanischoch@unil.ch

Katharina Korecky-Kröll
University of Vienna
Department of Linguistics
Comparative Psycholinguistics Research Group Porzellangasse 4/2/4th floor
1090 Vienna
Austria

katharina.korecky-kroell@univie.ac.at

Iris Leibovitch-Cohen
Department of Communications Disorders
Sheba Hospital
Tel Aviv University
Tel Aviv 69978
Israel

irisleibo@gmail.com

Sabine Laaha
University of Vienna
Department of Linguistics
Comparative Psycholinguistics Research Group Porzellangasse 4/2/4th floor
1090 Vienna
Austria

sabine.laaha@univie.ac.at

Bracha Nir
Department of Communications Disorders
Haifa University
Mt Carmel Haifa 3498825
Israel

bnir123@gmail.com

Wolfgang Dressler
University of Vienna
Department of Linguistics
Comparative Psycholinguistics Research Group Porzellangasse 4/2/4th floor
1090 Vienna
Austria

wolfgang.dressler@univie.ac.at

Steven Gillis
Department of Linguistics
University of Antwerp
Prinsstraat 13
2000 Antwerpen
The Netherlands

steven.gillis@uantwerpen.be