The Use of Gender Information in Lexical Processing in Czech 23-Month-Olds: an Eyetracking Study

Filip Smolík

1. Grammatical morphemes and gender in language acquisition

The acquisition of grammatical morphology is one of the important components of language development. Grammatical morphemes are used to mark important meaning distinctions in language, such as number or tense. They also mark relations between different parts of sentences, such as in subject-verb agreement. Children initially tend to omit most grammatical morphemes in their productions, especially in languages such as English, in which the majority of grammatical morphemes are freestanding grammatical words. However, the mastery of grammatical morphology is important both for producing grammatical language, as well as for reliable comprehension, and it is thus important to understand how children start the process of morpheme acquisition. Given that comprehension precedes production for most elements of language, it is likely that the first signs of morpheme knowledge will demonstrate in language comprehension.

Another important aspect of language acquisition is the need to acquire various grammatical categories, such as parts of speech, syntactic roles, or categories such as tense, number or gender. In order to show productive formation of phrases and sentences in a language, children must possess the knowledge of structural regularities in the language, and these structural regularities typically make use of grammatical categories. One goal in studying language acquisition is to describe how children develop the knowledge of these categories. The study reported in the present paper examined the early comprehension of gender-marking morphemes, thus addressing the development of both grammatical morphology and of abstract grammatical categories. Specifically, the study examined young children acquiring Czech and tested whether they can make use of gender-marking morphemes in subsequent word identification.

In order to show sensitivity to gender, children must possess knowledge of the grammatical morphemes in question, and at the same time know the gender of nouns they hear. Existing research on Dutch and French has shown that children have this sensitivity early in their third year (E. Johnson, 2005; Van Heugten &

Shi, 2009), but the studies used articles as the gender-marking morphemes. The present study extends the findings to a different language and to a situation in which gender is encoded in bound morphemes.

1.1 Morphemes, gender and gender agreement

Some amount of sensitivity towards grammatical morphemes may be observed even in newborns, who were shown to discriminate between content words and function words in the language they hear as early as newborns (Shi, Werker, & Morgan, 1999). Further research showed that children during the first year learn to know the forms of some grammatical morphemes, and know something about their placement in sentences (e. g. Shady & Gerken, 1995; Shafer, Shucard, Shucard, & Gerken, 1998; Hohle & Weissenborn, 2000). The increasing knowledge about the placement of grammatical morphemes shows later during the second year, when children show sensitivity towards relations between different grammatical morphemes within a sentence (Santelmann & Jusczyk, 1998; Soderstrom, Wexler, & Jusczyk, 2002). Children also show some knowledge of the morphemes they omit; if morphemes in a sentence are replaced by nonsense syllables, the omission rate decreases considerably (Gerken, Landau, & Remez, 1990).

Sensitivity to the presence of grammatical morphemes, their position, and their co-occurrence with other morphemes does not imply that children understand the function of these morphemes. There is some evidence showing that this knowledge is acquired during the second and third year. In the seminal study by Katz, Baker, and Macnamara (1974), children aged 17 to 24 months showed that they understood the consequences of using an article before a novel noun. While novel nouns modeled with an article were interpreted as category labels, nouns modeled without articles were interpreted as proper nouns. Kouider, Halberda, Wood, and Carey (2006) showed that 24 month olds understand whether a sentence refers to one or more actors based on the number form of the auxiliary verb (but see V. Johnson, de Villiers, & Seymour, 2005, for evidence to the contrary). Children in their second and third year thus extract meaning from at least some grammatical morphemes, but experimental evidence is limited and sometimes contradictory.

A specific area for examining grammatical morphemes is the acquisition of grammatical agreement, where the selection of a grammatical morpheme depends on the category membership of a different word. One example is the use of gender-marked articles and nouns in languages such as German or French. To use a noun phrase correctly, one must know which article corresponds to which gender, and at the same time, what is the gender of the head noun. E. Johnson (2005) provided evidence that Dutch 26- to 30-month-olds are sensitive to this relationship in their comprehension. Children recognized nouns more easily when these were preceded by the correct article, compared to nouns preceded by an article of differ-

ent gender. Similar findings were reported from 25-month-old children acquiring French (Van Heugten & Shi, 2009). It thus appears that young 2-year-olds have some knowledge of noun gender and the gender of some grammatical morphemes. Moreover, children appear to utilize this knowledge during lexical processing (see also Lew-Williams & Fernald, 2007). However the existing research is limited in one respect. All the existing studies of children's sensitivity to gender agreement used articles as the gender marking morphemes, and articles are special in several respects. They are free morphemes, i.e. separate words, which may make them especially conspicuous and easy to detect. Also, articles only carry limited information; for French and Dutch, which were examined in the existing studies, it is only definiteness, gender and number. It may thus be relatively easy for children to identify the gender-marking function of articles.

In contrast to languages such as Dutch or French, many languages with rich systems of gender agreement have no articles. This is true for most Slavic languages, in which gender agreement is typically marked using bound morphemes. In Czech, for example, the phrase *mladá žena* "young woman" shows the nominative feminine singular ending *-á* on the adjective, while *mladý muž* "young man" shows its masculine counterpart. It is a question whether two-year-olds are sensitive to gender when it is encoded in bound morphemes, as in Czech, and not in articles, as in French or Dutch. The present study addressed this question.

1.2 Gender and inflection in Czech

Czech is a West Slavic language with rich nominal and verbal inflection. The language has no articles, but it has a rich system of agreement. There are three genders in Czech, masculine, feminine, and neuter. Nouns have arbitrary gender, and inflect for number and case. There is no explicit gender-marking morpheme on nouns, but the inflectional classes differ across genders. These classes determine which morphemes will mark which combination of number and case, and are different in different genders. There are 14 major classes of noun inflection, 6 for masculine, and 4 each for feminine and neuter. Noun are inflected by endings, and sometimes by changing parts of the stem.

Gender agreement in Czech surfaces in two types of elements. Adjectives must agree with the head noun of the noun phrase in number, case, and gender. Adjectival type inflection is also used with some pronouns and numerals. The second type of gender agreement is between the sentence subject and the past participle of the predicate verb, if used in the sentence. Participles have different forms for masculine, feminine, neuter and plural.

1.2 The present study

The present experiment was designed to extend the findings that were reported by E. Johnson (2005) and Van Heugten and Shi (2009) to a language with-

out articles. The design of the experiment is a simplified version of the existing studies. Children were presented with pairs of pictures accompanied with an audiorecording of a noun phrase. The phrase consisted of two gender-marked words and a noun that labeled one of the stimulus pictures. Gender marking on the words preceding the target noun was either correct, with gender morphemes matching the head noun gender, or incorrect, with mismatched morphemes and the noun. In the incorrect trials, the mismatched morphemes corresponded to the gender of the non-target noun, i. e. the noun labeling the other picture in the trial. Children were expected to shift their gaze toawards the picture labeled by the target noun. If they are sensitive to gender agreement within noun phrase, they should shift their gaze faster if the phrase shows correct agreement.

The working hypothesis thus was that children would show faster orientation towards the target picture in the matching-gender trials. In fact, the possible outcomes in Czech may be viewed from two perspectives. On one hand, it is possible that identifying the form and function of bound gender-marking morphemes is more difficult in Czech than in languages that mark gender by free morphemes. It may also be more difficult to learn gender of individual nouns if gender is mostly marked on bound morphemes. On the other hand, Czech is a language in which inflectional morphology plays an important role, and children use grammatical morphemes from the earliest stages of acquisition. Children may thus acquire grammatical morphemes earlier than in other languages, partly because the input language provides rich learning material, and partly because morphology is needed to interpret and correctly use many sentences. Given the important role of bound morphemes in Czech, and also the facility of young Czech children with grammatical morphology (Smolík, 2002), it seems more appropriate to expect that Czech children will be sensitive to grammatical morphemes from early on. For this reason, the children examined in the present study were younger than in the previous comparable studies, just below 2 years.

The present study has one additional novel aspect. The participating children were given two offline tasks measuring their language development. These were used to examine whether sensitivity to gender and the identification of the target words in the task are related to the experiment performance.

2. Method

Participants The children who participated in the experiment were 21 to 24 months old. A total of 52 children were able to finish the eye-tracking experiment session. However, children were also given additional tasks that were used in subsequent analyses. Only 35 children completed the whole protocol that included the experiment, a lexical comprehension task and a grammatical comprehension task. Additional 3 children were excluded because they showed side bias in the experiment.

Stimuli Children were presented with pairs of pictures, and with short noun phrases in which the noun referred to one of the pictures shown. The pictures were chosen so that the nouns describing them were of different gender, feminine and masculine. In total, four pairs of pictures were used (book-ball, banana-fish, pacifier-frog, cat-dog) in eight trials. Each pair was thus presented twice, each time with a different picture as the target.

The noun phrases consisted of three words: a demonstrative pronoun, an adjective, and the target noun. The pronoun and adjective were tri-syllabic and both were inflected according to the Czech hard adjectival paradigm. In this paradigm, the nominative case singular form differs between genders in the final phoneme which is [i:] (written -ý) in masculine and [a:] (written -á) in feminine.

The following examples show the noun phrases for one pair of pictures, i. e. one masculine and one feminine noun. For each noun, phrases from the matching and non-matching condition are shown.

(1) taková veliká ryba / *takový *veliký ryba
     such$_{fem}$ big$_{fem}$ fish$_{fem}$ / such$_{masc}$ big$_{masc}$ xfish$_{fem}$
     Such a big fish!

(2) takový veliký banán / *taková *veliká banán
     such$_{masc}$ big$_{masc}$ banana$_{masc}$ / such$_{fem}$ big$_{fem}$ banana$_{masc}$
     Such a big banana!

The stimulus phrases were recorded with a male voice using very slow tempo and exaggerated intonation. The recordings were prepared so that the duration of the demonstrative and the adjective was the same in all trials, 1000 ms for the demonstrative and 1500 ms for the adjective.

In each trial, the picture pair was presented for two periods of 6.5 seconds. During the first period, children only heard neutral phrases to attract their attention to the picture: "Look, what is it? Watch, what do you see?" During the second period, they heard the stimulus phrase.

Children were presented with eight trials, and heard one picture from each pair described by a phrase from the matching condition and one from the non-matching conditions. Two counterbalanced versions of the protocol were used so that half of the children heard a particular target noun in a matching condition, and half in the non-matching condition. Before presenting the experiment trials, two practice trials were presented. These had the same structure as the target trials, except that both pictures were labeled with a neuter noun. The gender marking morphemes used in the practice trials were thus different from those presented in experimental trials.

Offline tasks In addition to the experiment, children were presented with two offline tasks. Receptive vocabulary was measured using an experimental picture vocabulary task with similar format as the PPVT (Dunn & Dunn, 2007) with 20 trials. Grammatical skills were tested using an experimental task in which children

saw two pictures and heard a sentence or phrase describing one of them. Children were asked to point to the corresponding picture. The task consisted of 22 trials in 4 blocks that tested the comprehension of different grammatical devices: prepositions, plurals, case marking and word order, and subject-verb agreement.

Procedure During the lab visit, children were given the three tasks in a constant sequence, first the eyetracking experiment, and then the lexical and grammatical tests. The experiment was presented on a screen of a remote eyetracker system (Interactive Minds, Dresden, Germany). The setup included a 22' presentation screen with the eyetracking cameras placed in a black box below the presentation screen. Children were seated in front of the eyetracker in a high chair or in their parent's lap, depending on the preferences of the child and parent. If parent was seated or standing behind the child during the recording session, they were given non-transparent glasses so that they would be blind to the location of the target picture on the screen. The recording session began with calibration, in which the children were shown a red ball moving across the screen to nine different positions. After successful calibration, stimulus presentation for the experiment started immediately. If the calibration went smoothly and did not have to be repeated, it lasted less than 3 minutes.

Analysis The data were analyzed using binomial, or logistic, mixed model analysis. This made it possible to model the continuous change in the probability of fixating the target picture. In binomial models, the dependent variable is a dichotomous categorical variable. The present analysis examined whether the child fixated the target picture or not at a particular time. The key predictors in the model were time and experimental condition (noun phrase with matching vs. non-matching endings), including their interaction. When children hear the target word, the likelihood of fixating the target picture sharply increases, which is reflected by the effect of time in the model. If the target picture is identified faster in one experimental condition compared to the other, an interaction between the effects of time and condition should be observed. The analyses used second-degree polynomials of time because the increase in looks towards the target was not linear but the rate changed, resulting in a curved shape.

One potential problem in the analysis was that the sampling was fairly dense, with one measurement every 40 ms. There were thus many data points in the analysis, but it may be argued that these are not fully independent. It takes about 200 ms to program an eye movement, so two adjacent data points are very likely to show the same gaze direction. In order to establish the effects of time and experimental condition on gaze direction, one should study the effect of these predictors additionally over and above the effect of the previous gaze direction. In order to achieve this, the gaze direction on the preceding trial was used as an additional predictor in all analyses.

One advantage of the logistic mixed models is that they can easily incorporate additional continuous covariates. This was utilized in examining the relation between the experiment results and the scores on the offline linguistic task. The

task score and its interactions with time and condition were included as additional predictors. All analyses were performed using the `lme4` library for R (Bates, Maechler, & Bolker, 2011).

2. Results

The initial analysis ignored experimental conditions and served to establish a reasonable time period of interest for subsequent analyses. The graph showing the proportion of looks towards the target picture throughout the trial is shown in Figure 1a. It shows that children started shifting their gaze towards the target picture ca. 400 ms after the target noun onset, and that the proportion of looks towards target peaked ca. 2 s after the noun onset. In order to examine the whole time course of comprehension, the period of interest was chosen to start at the noun onset. The endpoint was set to 2 s after noun onset, so that it included the whole period when the proportion of looks towards target peaked.

The first analysis of condition effects examined the effects of time and condition in the whole group of children who completed all tasks. The corresponding graph is reprinted in Figure 1b. The mixed model analysis (Model 1 in Table 1) revealed a significant linear and quadratic effect of time, which corresponds to the increase in fixations of the target picture after the stimulus noun is heard. As expected, there was a highly significant effect of gaze direction in the preceding frame. Most importantly, there were significant interactions between the experimental condition and the linear and quadratic time components, suggesting that the difference between the target fixation probabilities observed in Fig. 1b is statistically significant. The negative interaction between the linear effect and condition means a slower overall increase of looks towards the target in the non-matching condition, and the positive quadratic effect means somewhat less curved shape of the trajectory in this condition.

The subsequent analysis made use of the grammatical score as the additional covariate, addressing the question of whether linguistic knowledge shown in the offline test is related to the performance on the experiment. Figures 1c and 1d suggest that it is the case. The graphs show experiment results separately for children with lower and higher scores on the grammatical task, with the groups split on the median value. Children with lower grammatical scores show no difference between conditions (Figure 1c), while the high-score children's gaze shifted towards the target pictures faster in the matching-morpheme trials (Figure 1d). This was confirmed by a mixed model analysis that included grammatical score as an additional predictor (Model 2 in Table 1). This model includes significant three-way interactions between time components, experiment condition and grammatical score.

Besides the grammatical test, children were given a lexical test as well. Similar analysis as in Model 2 was performed, with lexical score used instead of the grammatical score. The results did not show any significant three-way interac-
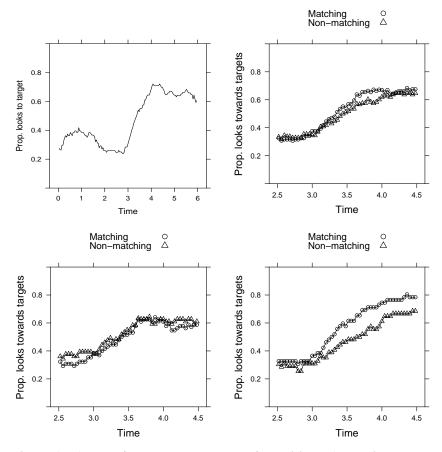
Figure 1: a) top left: results regardless of condition; b) top right: results for all children; c) bottom left: results in low-grammar children; d) bottom right: results in high-grammar children.

tions, but two-way interactions between time and lexical score suggested that children with higher lexical scores shifted their gaze towards the target picture faster. Because the model did not show significant interactions with the experimental condition, the results are not reported here.

3. Discussion

The experiment showed that as a group, Czech children below 24 months of age show sensitivity to the agreement between gender-marking suffixes and nouns. This sensitivity is more pronounced in children who show higher scores on a grammatical task. This replicates the findings from Dutch (E. Johnson, 2005)

Table 1: Estimated log-odds, standard errors and p-values from the binomial mixed models.

Predictor	Model 1			Model 2		
	LO	SE	p	LO	SE	p
Intercept	-3.40	0.24	< 0.001	-3.37	0.24	< 0.001
Condition (non-match)	0.40	0.19	0.04	0.31	0.20	0.12
Time	2.29	0.32	< 0.001	2.21	0.33	< 0.001
Time^2	-0.65	0.16	< 0.001	-0.58	0.16	< 0.001
Gram. score				0.09	0.05	0.05
Prev. fixation	4.19	0.07	< 0.001	4.20	0.07	< 0.001
Cond.:time	-0.98	0.46	0.03	-0.80	0.46	0.08
Cond.:time^2	0.40	0.22	0.07	0.30	0.23	0.19
Cond.:grammar				-0.19	0.06	< 0.001
Time:grammar				-0.13	0.10	0.16
Time^2:grammar				0.10	0.04	0.03
3-way (time)				0.30	0.13	0.02
3-way (time^2)				-0.15	0.06	0.02

and French (Van Heugten & Shi, 2009), with some important extensions. First, it confirms that 2-year-olds in highly inflected languages are sensitive to bound morphemes that encode gender. This indicates that the results from Dutch and French are not due specifically to the knowledge of articles or determiners, but more generally to the knowledge of gender-marking morphemes. Second, the children in the present study were younger than in the previous studies, generally below 24 months. Sensitivity to gender is thus present earlier than documented in the previous studies. This is so even though Czech does not have articles or other obligatory gender-marking elements. On the other hand, the language is heavily inflected and many elements that appear in noun phrases, such as adjectives, pronouns and numerals, may be marked with a gender-inflected morpheme. The third extension is the observed relationship between an offline grammatical task and the experiment results. Children with higher scores on the grammatical task showed clearer effects of the experimental manipulation with gender morphemes. This supports the validity of the experiment results, and points out that there are individual differences in early language comprehension that may play a role in experimental investigations of emerging grammatical comprehension.

Together, the present observations demonstrate that children develop their sensitivity to gender-marking morphemes during the second year, when they show only very limited use of these morphemes in their own productions. It suggests that from the very early stages of development, children build representations of abstract categories that are not explicitly marked in the input language, such as the category of noun gender.

While the current study demonstrated children's sensitivity to gender, the nature of this sensitivity remains and open question. The results suggest that children must know the gender-marking function of some grammatical morphemes, as well as the gender value of some nouns. However, this kind of knowledge can be represented in different ways. One possibility is that children have fully abstract representation of gender, and that upon hearing the gender-marking morpheme, they form expectations about the nouns that can follow. On the other hand, it is possible that children represent for each noun separately which morphemes are expected to occur before this noun. This would be consistent with the constructivist approach to language acquisition (e. g. Tomasello, 2000). It is also possible that children operate on some intermediate level of abstraction. Czech nouns fall in 14 major declensional classes, 6 for masculine, and 4 each for feminine and neuter. Perhaps children check whether the grammatical morphemes preceding the noun correspond to its declensional class, rather than gender, and later form the gender category based on their knowledge of declensional classes (cf. Bordag & Pechmann, 2009). It thus remains a topic for further research to determine the nature of knowledge that underlies the early sensitivity for gender. In any case, the existing results and the present study suggest that the process of acquiring gender is well on its way around the second birthday.

Unlike the previous studies, the study presented here included an offline task measuring children's level of grammatical development. Children with better scores at this grammatical task showed stronger effects of experimental condition, which supports the validity of the findings, suggesting that children with better language skills show stronger sensitivity to gender. However, it should be pointed out that the grammatical task was quite difficult for children and most of them scored at the chance level. A large part of the variability among children is due to the differences in the number of items on which children attempted response. Children with high scores are mostly those who completed more trials, and not necessarily those who responded correctly to most trials. It is thus possible that the measure is more strongly related to attentional control than to linguistic level.

Even though the children in the present study were younger than in the previous similar studies, it does not mean that Czech children show sensitivity to gender substantially earlier than children who acquire French or Dutch. First of all, the final sample of 32 children analyzed here consisted of children who were able to complete the experiment, as well as two additional tasks. There were additional 18 children who participated in the experiment but did not complete the offline tasks, and about 20 other children who did not finish the experiment. It is thus likely that the children analyzed here were rather advanced in attentional control and perhaps other aspects of cognitive development. Another reason for showing sensitivity in very young children may be the analytic method, which is likely to detect smaller changes in looking patterns than the analysis of aggregated looking times used in previous studies. Finally, the design and procedure of the present experiment were somewhat simpler than in the previous studies, and the

gender morphemes appeared twice in every stimulus phrase. The task itself might thus be easier for children than the comparable studies in French and Dutch.

To conclude, the current study adds to the growing body of research on the early knowledge of gender. It is clear that at least some children begin to represent gender and gender agreement before their second birthday. Together with studies by E. Johnson (2005) and Van Heugten and Shi (2009), the study demonstrated that young children make use of grammatical morphemes, and have some knowledge of noun gender in some common nouns. The present study extended this knowledge by showing that children detect gender even when encoded by bound morphemes, and that this ability is related to their individual performance on other linguistic tasks.

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