

Predictive processing in bilingual children

Predictive processing of grammatical gender in bilingual children: The effect of cross-linguistic incongruency and language dominance*

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Abstract: The present study investigates linguistic prediction based on grammatical gender in Italian-German bilingual children between the ages of six and ten, using a visual world eye-tracking paradigm. Children listened to sentences while they looked at pictures of objects that either matched or mismatched in grammatical gender, and that varied with respect to cross-linguistic gender congruency. To explore the effect of language dominance on bilingual processing, we tested participants enrolled in bilingual schools in Italy and Germany, with an experiment in Italian ($N = 63$) and in German ($N = 25$). The results show rapid predictive processing, as children anticipated nouns on the basis of the grammatical gender of articles. Furthermore, in the Italian task (but not in the German task), we found that children exhibited a ‘gender congruency effect’, i.e., they experienced cross-linguistic influence when the grammatical gender of the two languages did not overlap, leading to delayed anticipation. In contrast to previous research, this effect was also observed in simultaneous bilingual children. Both the extent to which children relied on predictive processing and the likelihood of a gender congruency effect were related to children’s language dominance, operationalized as relative language proficiency in terms of vocabulary knowledge.

Keywords: visual world paradigm, predictive processing, grammatical gender, cross-linguistic influence, bilingual children

1. Introduction

Listeners process speech rapidly and incrementally, and they predict upcoming words on the basis of lexical or morphosyntactic cues. One such cue is grammatical gender, which monolingual children use efficiently in spoken word recognition (Cholewa et al. 2019; Lew-Williams & Fernald 2007). While gender processing has been studied extensively in adult L2 learners, research on bilingual children is scarce. Recent evidence shows that bilingual children can predict on the basis of gender, but that they may experience cross-linguistic influence between the two gender systems, suggesting a crucial difference between simultaneous and sequential bilingual acquisition (Lemmerth & Hopp 2019). However, it is still unclear to what extent language dominance may contribute to this.

Focusing on Italian-German bilingual children living either in Italy or in Germany, our study examines (1) whether they anticipate nouns on the basis of gender of articles in a visual world eye-tracking paradigm, (2) whether they experience a gender congruency effect, and (3) how this is influenced by relative language proficiency.

In what follows, Section 2 will first address previous research on the acquisition and processing of grammatical gender in monolingual and bilingual children, as well as the ‘gender congruency effect’ in bilingual processing, followed by a description of the grammatical gender systems of Italian and German. The methods of the current study are presented in Section 3 and the results in Section 4. We conclude with a discussion of our findings in Section 5.

2. Background

2.1 The acquisition of gender in monolingual and bilingual children

Gender is a grammatical feature of nouns which may have certain morphosyntactic implications for other elements in the sentence, such as determiners, pronouns, adjectives and verbs (Corbett 2013). In most languages that have grammatical gender, monolingual children learn very early that nouns have gender, as they rely on morpho-phonological and semantic regularities to correctly assign gender to nouns. German monolingual children start using gender-marked articles before the age of two, with 90% accuracy at age three and at-ceiling performance by the age of four, even though occasional errors may persist (Mills 1986; Szagun et al. 2007). In Italian, grammatical gender on articles is acquired even faster, with low error rates and almost adult-like performance by the age of three (Chini 1995; Cipriani et al. 1993; Pizzuto & Caselli 1992).

Previous studies show that monolingual children use gender cues incrementally during language processing and that they can anticipate a noun on the basis of gender information on the preceding article or adjective. This type of predictive processing has been found in monolingual German and Italian primary school children (Bosch et al. in press; Cholewa et al. 2019). Studies with Spanish and French monolingual children suggest that children are able to rely on such gender cues already from the ages of two or three, respectively (Lew-Williams & Fernald 2007; Van Heugten & Shi 2009).

In contrast, grammatical gender in the L2 tends to be a rather challenging feature, not only for adults (e.g., Bianchi 2013; Rogers 1987), but also for children (Unsworth et al. 2014; Unsworth 2008; Meisel 2018; Wegener 2011). While simultaneous bilingual children typically show qualitatively similar patterns as monolingual children in their acquisition of gender, these patterns may also be significantly delayed (Kupisch et al. 2002; Rodina &

Westergaard 2017; Unsworth 2013a) and may be influenced by differences or similarities across the two gender systems (Eichler et al. 2012; Kupisch et al. 2002). Early bilingual acquisition of gender has been shown to be strongly modulated by input and language dominance in both simultaneous and sequential bilingual children (e.g., Rodina & Westergaard 2017; Unsworth et al. 2014; Unsworth 2013a, 2008; Cornips & Hulk 2008).

Research on processing of gender in bilingual children is scarce, but the limited studies available suggest that bilingual children, like monolingual children, are sensitive to gender cues (Bosch et al. in press; Lemmerth & Hopp 2019). Yet, similarly to adult L2 speakers (e.g., Grüter et al. 2012; Dussias et al. 2013), sequential bilingual children are sometimes slower or less likely to predict than monolingual controls, which may be related to their language proficiency (Bosch et al. in press). They may also be less likely to anticipate nouns that have another gender in their L1 (Lemmerth & Hopp 2019). This is called a ‘gender congruency effect’, which we will elaborate on in the next section.

2.2 The gender congruency effect in bilingual processing

When a bilingual speaks two gender-marked languages, the gender values assigned to translation equivalents do not necessarily overlap, since grammatical gender is arbitrary. This may lead to a gender congruency effect, as evidenced by facilitation or inhibition in picture naming tasks (e.g., Klassen 2016; Lemhöfer et al. 2008) and translation tasks (e.g., Salamoura & Williams 2007; Paolieri et al. 2019). Although there is abundant behavioral evidence for the existence of a gender congruency effect in the adult L2 literature (see Sá-Leite et al. 2019), there are still very few studies that provide evidence for this type of cross-linguistic influence using online methods such as eye-tracking (Morales et al. 2016; Weber & Paris 2004).

To our knowledge, there is only one study so far which investigated the gender congruency effect in bilingual children. Lemmerth and Hopp (2019) tested 12 simultaneous

Russian-German bilinguals, 12 early successive bilinguals (with an age of onset of German before the age of four), and 15 monolingual German children, aged eight to nine at the time of testing. All children lived in Germany and were tested with a visual world eye-tracking experiment in German.

The results showed that simultaneous bilingual children, like monolingual German children, anticipated the upcoming noun on the basis of the gender of the determiner. In contrast, successive bilingual children only made predictive use of gender when the grammatical gender of the target noun was congruent with that of the Russian translation equivalent, but not when there was a gender mismatch between Russian and German.

According to Lemmerth and Hopp, the discrepancy between simultaneous and sequential bilinguals results from the fact that sequential bilinguals acquired their two gender systems asynchronously, allowing for transfer from their L1 (Russian) into the L2 (German) system during early development. However, as the authors point out themselves, the age of onset and type of acquisition are not the only differences between the two bilingual groups in this study. Crucially, all participants lived in Germany, which means that the simultaneous bilingual children (who had only one Russian parent) most likely received less input in Russian than sequential bilingual children (who had two Russian parents, and thus always spoke Russian at home). This was reflected by their offline proficiency scores; children scored similarly on all German tasks, but the sequential bilinguals outperformed the simultaneous bilinguals in the Russian tasks assessing vocabulary knowledge and gender assignment. As cross-linguistic influence is less likely to be observed when children are tested in their more proficient language (Yip & Matthews 2007) or in the language in which they receive more input (Unsworth et al. 2014; Herve et al. 2016; Bosch & Unsworth 2020), differences in language dominance may also have contributed to their findings.

The present study builds on Lemmerth and Hopp (2019) by extending their findings to a new language pair and by further exploring the possible effects of language dominance in the processing of gender in bilingual children. Language dominance can be operationalized in terms of differences in language use, or in terms of relative proficiency (Unsworth 2013b). Here we decided to focus on differences in language proficiency by considering children's vocabulary knowledge in both Italian and German. Since we tested bilingual children who were growing up in Italy (Milan), as well as children who were growing up in Germany (Cologne, Munich or Hamburg), proficiency in the two languages was expected to be highly variable. Before turning to our research questions and hypotheses, we provide a description of the gender systems of Italian and German.

2.3 Grammatical gender in Italian and German

The Italian gender system

Italian nouns are marked for gender following a binary gender system, in which nouns are either masculine or feminine. This classification is arbitrary, although in the case of animate nouns gender assignment generally reflects the biological gender of the referent of the noun (e.g., *bambino*_{MASC} 'boy' and *bambina*_{FEM} 'girl'). We can outline some phonological regularities in gender classification of nouns in Italian; the majority of masculine singular nouns end in *-o* (e.g., *libro*_{MASC} 'book'), while the majority of feminine singular nouns end in *-a* (e.g., *matita*_{FEM} 'pencil') (approximately 70% of all words). There are, however, also many exceptions (e.g., *moto*_{FEM} 'motorbike'; *poema*_{MASC} 'poem'). In addition, there is a subclass of nouns ending in *-e*, which may be either masculine or feminine (e.g., *noce*_{FEM}, 'nut'; *sole*_{MASC}, 'sun'), as well as nouns that can refer both to female or male human referents, independently

of their final vowel (e.g., *collega*, ‘colleague’) (Chini 1995; Padovani & Cacciari 2003; Panzini 2017). This is illustrated in (1).

- (1)
- | | | | |
|----|---|----|---|
| a. | <i>il libro</i>
the _{MASC} book _{MASC} | b. | <i>la matita</i>
the _{FEM} pencil _{FEM} |
| c. | <i>il sole</i>
the _{MASC} sun _{MASC} | d. | <i>la noce</i>
the _{FEM} nut _{FEM} |
| e. | <i>il collega</i>
the _{MASC} colleague _{FEM} | f. | <i>la collega</i>
the _{FEM} colleague _{MASC} |

As exemplified above, the definite singular determiner *la* is unambiguously marked for feminine gender, whereas the definite singular determiner *il* is marked for masculine gender. For a small group of masculine nouns, the determiner *lo* is used, based on phonological rules (e.g., nouns starting with *z*, as for *lo zaino* ‘the backpack’). Furthermore, when a noun starts with a vowel, *il* and *la* are both abbreviated to the contracted form *l’* (e.g. *l’amico_{MASC}* and *l’amica_{FEM}* ‘the friend’). Note that articles are not the only elements in the sentence that carry information about gender, as it is also overtly expressed on adjectives, personal pronouns and past participles (Chini 1995; Panzini 2017).

In the present study, we only focus on the prototypical definite determiners *il* and *la*, which express masculine and feminine gender, respectively.

The German gender system

German has a tripartite gender system, distinguishing between masculine, feminine and neuter gender (Durrell 2011). German gender also follows biological gender (e.g.

*Mutter*_{FEM} 'mother' and *Vater*_{MASC} 'father'). At first sight, there seems to be little correspondence between the phonological form of nouns and their gender, but there are in fact several phonological tendencies that can account for 60% of all nouns (e.g., bisyllabic nouns ending in *schwa*, 16% of all nouns, tend to be feminine) (Wegener 2011). However, the scope and validity of these rules differ, as there are many exceptions (e.g., *Löwe*_{MASC} 'lion'), making the German system less transparent than the Italian one (Durrel 2011; Wegener 2011).

Similar to Italian, German marks gender through agreement on determiners, adjectives and personal pronouns (but not on past participles). German determiners also mark case (nominative, accusative, dative, genitive), in addition to number. Depending on definiteness, number and case, the gender of determiners and adjectives may sometimes be ambiguous. For example, in nominative and accusative case, the definite feminine singular article is identical to the plural article, independently of gender (e.g., *die*_{FEM}. *Frau*_{FEM.SING} 'the woman' versus *die*_{PLURAL} *Kinder*_{NEUT.PLURAL} 'the children') (Durrel 2011).

Example (2) illustrates the three German gender values in the definite, singular form with nominative case (i.e., with the determiners *der*_{MASC}, *die*_{FEM} and *das*_{NEUT}). In this study, we will only be concerned with definite, singular nouns and determiners in nominative case in the feminine and masculine form.

(2)

- a. *der Bleistift*
the_{MASC} pencil_{MASC}
- b. *die Sonne*
the_{FEM} sun_{FEM}
- c. *das Buch*
the_{NEUT} book_{NEUT}

2.4 Research questions and hypotheses

We aim to investigate the online processing of grammatical gender in a diverse population of Italian-German bilingual children resident and schooled in either Italy or Germany. Our research questions are as follows:

1. Do Italian-German bilingual children make linguistic predictions on the basis of grammatical gender?
2. Is there a gender congruency effect? I.e., is there cross-linguistic influence when the grammatical gender of translation equivalents in Italian and German does not overlap?
3. What is the effect of language dominance, operationalized as relative proficiency in terms of vocabulary size?

Hypothesizing that bilingual children, like monolingual children and adults, use predictive processing, we expect that they will anticipate nouns on the basis of gender-marked articles in a visual world eye-tracking paradigm. This will be reflected by an increase of looks to the target picture during the determiner in a condition in which the gender of the target and competitor do not overlap. However, given that the efficiency of linguistic anticipation has been related to language proficiency in bilingual speakers (Bosch et al. in press; Dussias et al. 2013), we expect that predictive processing may be more efficient for children who are tested in their dominant language.

Furthermore, we hypothesize that gender incongruency between the two languages may lead to cross-linguistic influence in bilingual children, similar to the gender congruency effect which has often been observed in adult L2 speakers (Sá-Leite et al. 2019). We predict that anticipatory looks to the target will be delayed for nouns in which there is a mismatch in grammatical gender between the two languages.

Considering the findings of Lemmerth and Hopp (2019), we expect that simultaneous bilinguals may be less likely to show a gender congruency effect than early sequential

bilinguals. However, we hypothesize that the interaction between two grammatical systems is also related to language dominance (defined here as relative proficiency in the two languages). By testing children in two different countries, we expect to find varying levels of bilingual proficiency in our sample, with children resident in Germany more likely to be German-dominant and children growing up in Italy more likely to be Italian-dominant. We expect German-dominant bilinguals to be more likely to show cross-linguistic interference from German in an Italian task, as compared to Italian-dominant bilinguals. Following the same logic, German-dominant bilinguals are expected to be less likely to show cross-linguistic interference in a German task than in an Italian task.

3. Methods

3.1 Participants

We carried out two experiments: one in Italian and one in German. In the Italian experiment (Experiment 1), we tested 74 Italian-German bilingual children between the ages of six and ten. Forty-four were resident in Italy (Milan) and 30 in Germany (Cologne, Munich or Hamburg). Seven children were excluded because they spoke a third language at home, two because of eye-tracking calibration problems, one because of missing data and one because of extensive track loss (criteria are specified below). The final sample consisted of 63 children, of whom 40 were resident in Italy and 23 in Germany.

In Germany, 31 children also participated in an experiment in German (Experiment 2). Six children were excluded: four because of trilingualism and two because of calibration problems. The final sample for the German experiment included 25 children, 22 of whom were the same participants as in the Italian experiment.

Prior to testing, children's parents signed a consent form that was approved by the ethics committee of the university of Milano-Bicocca. They also completed a short questionnaire based on Ladas and colleagues (2015), addressing the child's language history and language use at home. All children were enrolled in formal bilingual education, exposed to both languages before the age of six and had at least two years of exposure at the time of testing. An overview of the characteristics of our participants is provided in Table 1.

Table 1. *Characteristics of participants tested in Italy and Germany in Experiment 1 and 2.*

	Italy ($N = 40$)	Germany ($N = 26$) ¹
Experiment	Experiment 1 (Italian)	Experiment 1 (Italian) $N = 23$ Experiment 2 (German) $N = 25$
Age	$M = 8;08, SD = 0;04$	$M = 8;02, SD = 0;10$
Type of acquisition	27.5% simultaneous 62.5% early L2 German ($M_{Onset} = 3;00, SD = 1;07$) 10% missing survey data	65.5% simultaneous 11.5% early L2 German ($M_{Onset} = 5;00, SD = 1;00$) 11.5% early L2 Italian ($M_{Onset} = 4;03, SD = 2;00$) 11.5% missing survey data
Type of school	50/50 bilingual education	92% German stream (daily Italian lessons) 8% Italian stream (daily German lessons)

3.2 Materials and procedure

Eye-tracking experiments

Testing took place in a quiet room within the schools, with a portable, screen-based eye-tracker (Tobii Pro X3-120) capturing gaze data at 120 Hz. The experiment was run using E-Prime 3 (Psychology Software Tools, Pittsburgh, PA). The child was seated approximately

¹ After checking calibration issues, 22 children from Germany were included in the analyses in both tasks, one was included only in the analysis of Experiment 1 and three only in the analysis of Experiment 2.

65 cm from the screen. Calibration took place after a short familiarization phase consisting of three practice items. In between trials, a fixation cross ensured that children were looking at the middle of the screen before the experiment continued.

Participants were presented with a visual scenario depicting two objects, while they listened to sentences starting with ‘Where is the ...’ (*Dov’è la/il...* in Italian and *Wo ist die/der...* in German). The objects shown were colored pictures displayed on a white 500 x 500 background, displayed on the left and right side of a black (1920 x 1080) screen.

We manipulated predictability and gender congruency between German and Italian in three conditions (Figure 1). The *No Prediction* condition served as a control condition, in which the two depicted objects had the same grammatical gender (feminine or masculine) in both German and Italian, so the target could not be identified before hearing the noun and there was no possibility of cross-linguistic influence. In the example, both depicted objects (carrot, fork) are feminine in Italian (*la carota*_{FEM}, *la forchetta*_{FEM}) and in German (*die Möhre*_{FEM}, *die Gabel*_{FEM}). In the other two conditions there was a mismatch between the grammatical gender of the two depicted objects, so that anticipatory eye-movements could be observed during the determiner based on the gender cue. These are both labelled *Prediction*, but they differ with respect to congruency of the grammatical gender of the objects in the two languages. In the *Prediction/Congruent* condition, the German and Italian gender of the objects depicted overlapped. In the example, one object (strawberry) is feminine and one object (mushroom) is masculine in both Italian (*la fragola*_{FEM}, *il fungo*_{MASC}) and German (*die Erdbeere*_{FEM}, *der Pilz*_{MASC}). In the *Prediction/Incongruent* condition, gender was incongruent for the German and Italian translation equivalents, allowing for cross-linguistic interference between the two gender systems. In the example, one object is feminine and one is masculine but the gender of the translation equivalents is inverted in the two languages: ‘mouse’ is

masculine in Italian (*il topo*_{MASC}) but feminine in German (*die Maus*_{FEM}); ‘butterfly’ is feminine in Italian (*la farfalla*_{FEM}) and masculine in German (*der Schmetterling*_{MASC}).²

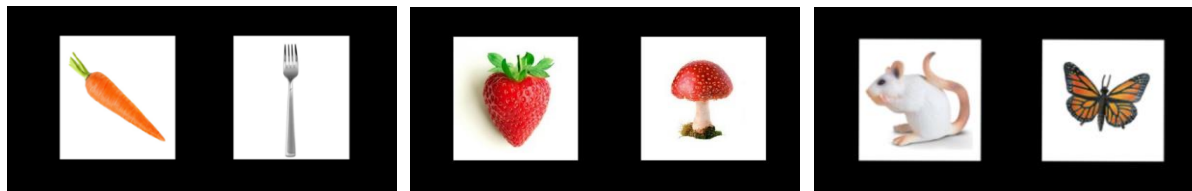


Figure 1. Example of visual displays in the three experimental conditions. From left to right: No prediction condition; Prediction/Congruent condition; Prediction/Incongruent condition.

The audios were recorded by female native speakers of Italian and German. The intonation of the sentences was intended to sound like a guessing game (using a rising pitch, as if the speaker was building suspense), in order to allow for a prolonged article and a natural silence in between the determiner and the noun. We spliced the audio fragments using Praat (Boersma 2001), so that the first part of the sentence was identical for each item. In both tasks, we ensured that the article started exactly 1750 ms after the onset of the trial, and that there were always 1000 ms between the onset of the article and the onset of the noun. On average, the article lasted 670 ms, followed by 330 ms of silence.

Sentences were presented through headphones, starting about one second after the onset of the of the visual stimuli (1000 ms in the German task, 1250 ms in the Italian task), so that there was enough time for exploration of the screen and lexical retrieval. After 500 ms from the end of each sentence, a question mark appeared in the center of the screen, and the child was asked to select the correct picture by pressing the left or right mouse button.

² A full list of the experimental stimuli can be found here: https://osf.io/4w8up/?view_only=42f7438510c1453d9cc985f19b98ac6a.

For participants in Germany, who were tested in both languages, the order of administration of the tests in Italian and German was counter-balanced and there were always at least three days in between the two sessions.

Vocabulary tests

In order to have a comparable measure of proficiency in both languages, we administered the Peabody Picture Vocabulary Test (PPVT), a standardized test measuring receptive vocabulary knowledge, in Italian (PPVT-R; Stella et al. 2000) and German (PPVT-2; Lenhard et al. 2015). We calculated language dominance scores by subtracting the German standard score from the Italian standard score (following Yip & Matthews 2006), so that a positive score indicated greater vocabulary knowledge in Italian while a negative score indicated greater vocabulary knowledge in German.

3.3 Analysis

A track loss analysis was performed on the relevant eye-tracking data. Trials for which eye-movements during the sentence were not properly registered in at least 50% of the samples were removed from the analyses (6.4% in the Italian task and 9.5% in the German task). We also removed trials that were answered inaccurately (1.7% in the Italian task and 1% in the German task).

The data were analyzed with generalized linear mixed effects models in *R*, using *eyetrackingR* (Dink & Ferguson, 2015) and the *glmer* function of the *lme4* package (Bates et al. 2015). We created a Time Region variable, by dividing sentences in three regions of interest: the introduction (i.e., ‘Where is’), the determiner, and the noun. For each of these time regions we added 200 ms to the onset times to account for saccade planning (Altmann

2011). In the statistical analyses we focused on the comparison between the introduction of the sentence ('Where is') and the determiner.

Looks to the target (yes or no) served as a binary outcome variable, and the models included random intercepts for Subject and Item. The predictors and random slopes that were included in the model were selected by bottom-up stepwise model comparison based on the Bayesian Information Criterion (BIC). The following factors were considered in the respective order; main effects and interaction terms of Time Region (Intro vs Determiner), Condition (Prediction/Congruent vs Prediction/Incongruent vs No Prediction) and Language Dominance (i.e., balance scores; Italian PPVT - German PPVT), fixed effects of Age (in months), and random slopes for Time region, Condition, Item Number and List. For Time Region, Intro was coded as $-1/2$, and Determiner as $+1/2$. For Condition, when comparing the two predictable conditions against the unpredictable condition, No Prediction was coded as $-2/3$, Prediction/Congruent coded as $+1/3$, and Prediction/Incongruent was coded as $+1/3$. When comparing the predictable congruent condition against the predictable incongruent condition, No Prediction was coded as 0, Prediction/Congruent was coded as $+1/2$, and Prediction/Incongruent coded as $-1/2$. All numeric predictors were rescaled and centered around the mean.

4. Results

4.1 Vocabulary tests

The mean standard score on the Italian vocabulary test was 99.5 ($SD = 19.7$), indicating that on average the bilinguals in our sample did not deviate from monolingual Italian norms. Children resident in Italy scored significantly better ($M = 109.5$, $SD = 11.8$) than children resident in Germany ($M = 84$, $SD = 19.6$); $t(36.9) = -6$, $p < .001$). The mean

standard score on the German PPVT was 91.4 ($SD = 21.8$), indicating that our participants had slightly weaker vocabulary knowledge compared to the norms for monolingual German children. On this test, children resident in Italy scored significantly lower ($M = 82.1$, $SD = 17.2$) than children resident in Germany ($M = 106.3$, $SD = 24.3$); $t(43.5) = 4.83$, $p < .001$).

The mean balance score was 8.02 ($SD = 39$), indicating slightly greater proficiency in Italian with great individual variation. For the children resident in Italy the mean balance score was 27.4 ($SD = 18.5$) while the mean balance score for children in Germany was -23 ($SD = 38.1$). This shows that on average participants in Germany were German-dominant in terms of proficiency, while participants resident in Italy were Italian-dominant.

4.2 Eye-tracking

Experiment 1: Italian

The time course of eye movements is visualized in Figure 2, showing that participants anticipated the noun on the basis of the determiner in the two Prediction conditions but not in the No Prediction condition. This anticipation effect is however greater for congruent trials, as indicated by the fact that the proportion of looks to the target during the article increases more rapidly in the Prediction/Congruent condition than in the Prediction/Incongruent condition. This suggests that cross-language gender incongruency modulates predictive processing.

This pattern was confirmed by the statistical analysis. The best model that converged included a three-way interaction between Time Region, Condition, and Language Dominance (balance scores) and their main effects, and random intercepts for Item and Subject with random slopes for Item Order and Time Region. The summary of the model output is provided in Table 2.

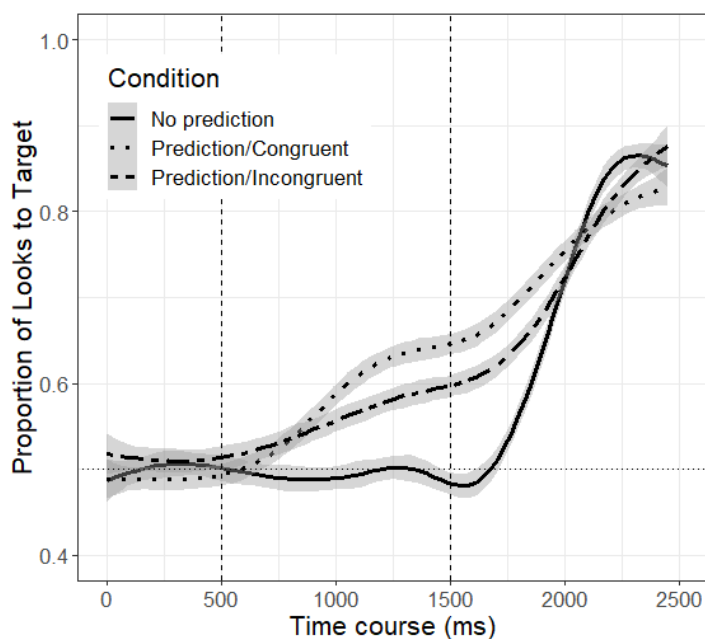


Figure 2. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the Italian task. The first vertical line represents article onset; the second vertical line represents noun onset. The dotted horizontal line represents chance performance.

Table 2. Estimated odds ratios, 95% confidence intervals and associated *p*-values of main and interaction effects for the analysis of the Italian experiment.

Generalized linear mixed model			
Looks to target (yes or no) ~ Time region (intro vs determiner) * Condition (no prediction vs prediction/congruent vs prediction/incongruent) * Dominance (balance scores) + (1 Item) + (1 + Item order + Time region Subject)			
Fixed factor	Est. odds ratio	95% CI	<i>p</i>
Time region	1.28	1.21 .. 1.37	<.001
Condition (predictability)	1.30	1.06 .. 1.58	.010
Condition (congruency)	1.06	.822 .. 1.36	.656
Dominance	1.05	1.02 .. 1.08	.002
Time region : Condition (predictability)	1.43	1.40 .. 1.46	<.001
Time region : Condition (congruency)	1.20	1.17 .. 1.23	<.001
Time region: Dominance	1.12	1.06 .. 1.19	<.001
Condition (predictability) : Dominance	1.07	1.06 .. 1.08	<.001
Condition (congruency): Dominance	.929	.917 .. .941	<.001
Time region : Condition (predictability) : Dominance	1.20	1.17 .. 1.23	<.001
Time region: Condition (congruency): Dominance	.903	.880 .. .926	<.001

The significant main effect of Time Region indicates that, overall, participants were more likely to look at the target during the determiner than during the introduction (i.e., ‘Where is’). The interaction between Time Region and Condition (predictability) shows that the difference in the likelihood of looking at the target between the introduction and the determiner was significantly greater in the two Prediction conditions than in the No Prediction condition, indicating anticipation of the noun on the basis of grammatical gender. Furthermore, the interaction between Time Region and Condition (congruency) shows that the difference between the likelihood of looking at the target between the introduction and the determiner was significantly greater in the Prediction/Congruent condition than in the Prediction/Incongruent condition, indicating stronger anticipation when the grammatical gender in Italian and German overlapped. As the three-way interactions with Language Dominance indicate, the strength of the prediction effect and the gender congruency effect were both significantly modulated by relative language proficiency.

In order to gain better understanding of the effect of language dominance, the data collected in Germany and in Italy should be considered separately. Figure 3 compares the gaze pattern of the participants living in Italy against those of participants living in Germany. As can be seen from these figures, children in Italy showed stronger prediction than children in Germany: while the Italian group tended to look at the target between 60 and 68% of the times at the onset of the noun in the predictable conditions, the German group tended to do so only 52 to 65% of the times. Moreover, the figures make clear that the gender congruency effect was indeed much stronger in the German group than in the Italian group. Participants in Italy showed efficient prediction in both Prediction conditions, with a slight advantage in the Congruent with respect to the Incongruent condition. Participants in Germany, however, showed considerably stronger anticipation in the Congruent condition than in Incongruent condition, suggesting that they experienced more interference from German.

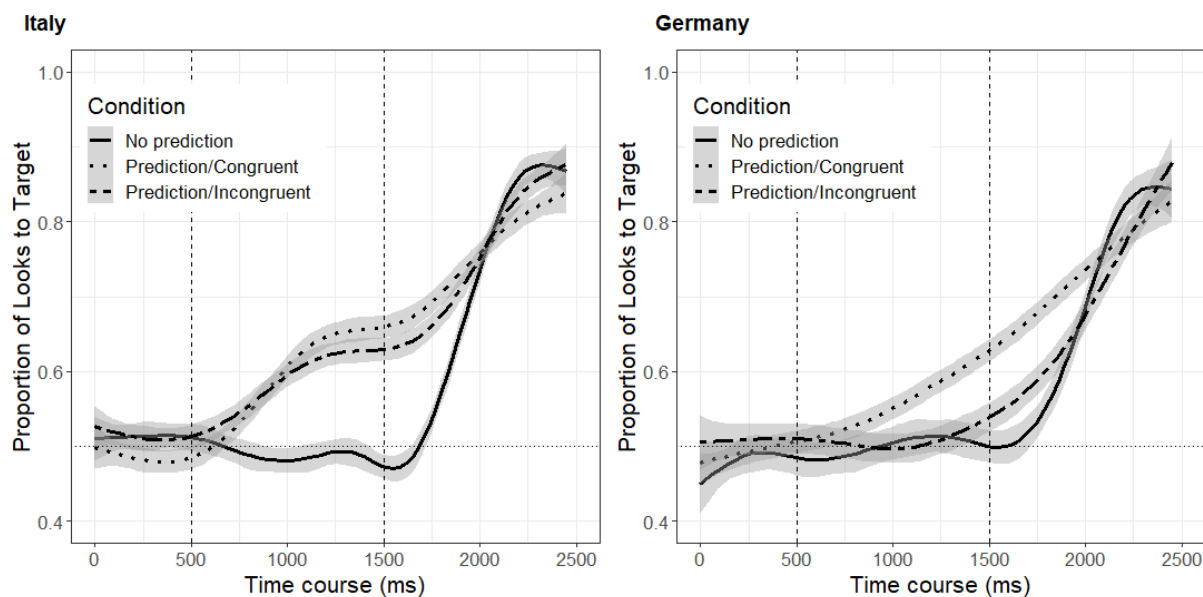


Figure 3. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the Italian task for participants resident in Italy (on the left) and in Germany (on the right). The first vertical line represents article onset; the second vertical line represents noun onset.

A post-hoc analysis focusing on simultaneous bilinguals only was conducted in order to draw a more direct comparison with Lemmerth and Hopp (2019), who found a gender congruency effect for sequential but not for simultaneous bilinguals. This analysis included 23 children: 11 growing up in Italy and 12 growing up in Germany. The mean age of these children was 8;1 ($SD = 0;09$), and their mean balance score was -9.3 ($SD = 26.5$), indicating that this subgroup of children was on average more proficient in German than Italian. As in the main analysis, we found a significant interaction between Time Region and Condition (congruency), indicating that simultaneous bilinguals were much more likely to shift their gaze toward the target during the determiner in the Prediction/Congruent condition than in the Prediction/Incongruent condition (Est odds ratio = 1.32, 95% CI = 1.27 .. 1.38, $p < .001$). In other words, the simultaneous Italian-German bilinguals in our study experienced a gender

congruency effect when predicting upcoming Italian nouns on the basis of gender. The time course of eye movements of the simultaneous bilinguals is shown in Figure 4.

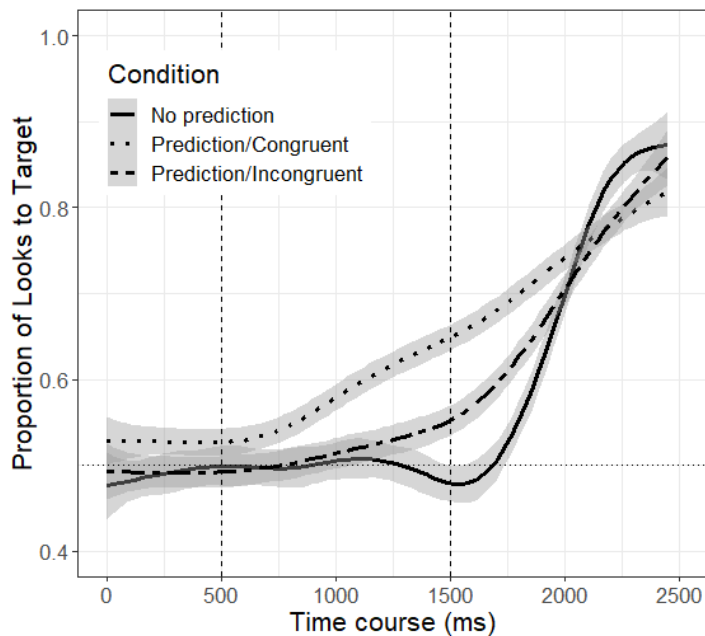


Figure 4. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the Italian task for simultaneous bilinguals. The first vertical line represents article onset; the second vertical line represents noun onset.

Experiment 2: German

Figure 5 provides the time course of looks toward the target in the German experiment, which was only administered in Germany. As can be seen from this plot, participants showed efficient prediction in the German task, but no effect of gender congruency (i.e., the proportion of target looks during the article increases in the two Prediction conditions but not in the No Prediction condition, while there is no difference between the Prediction/Congruent and the Prediction/Incongruent condition).

The final model of the German experiment includes a three-way interaction and main effects of Time Region, Condition and Language Dominance, and random intercepts for Item

and Subject with random slopes for Item Order and Time Region. The summary of the model output is provided in Table 3.

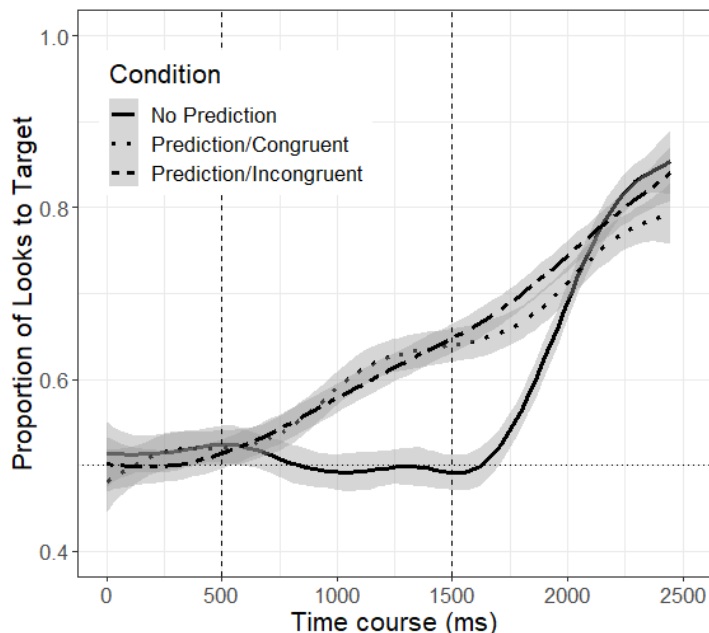


Figure 5. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the German task for participants resident in Germany. The first vertical line represents article onset; the second vertical line represents noun onset.

As in the results of the Italian task, there was a significant main effect of Time Region, indicating that on average participants were more likely to look at the target during the determiner than during the introduction time region (i.e., ‘Where is’). A significant interaction between Time Region and Condition (predictability) shows that participants anticipated the noun when hearing the determiner. However, this time we found no gender congruency effect, as the interaction between Time Region and Condition (congruency) was not significant. The prediction effect was again modulated by Language Dominance, suggesting that children who were more proficient in German were faster in predicting upcoming nouns than children who were more proficient in Italian.

Table 3. *Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects for the analysis of the German experiment.*

Generalized linear mixed model			
Looks to target (yes or no) ~ Time region (intro vs determiner) * Condition (no prediction vs prediction/congruent vs prediction/incongruent) * Dominance (balance scores) + (1 Item) + (1 + Item order + Time region Subject)			
<u>Fixed factor</u>	<u>Est. odds ratio</u>	<u>95% CI</u>	<u>p</u>
Time region	1.28	1.12 .. 1.47	<.001
Condition (predictability)	1.23	.979 .. 1.32	.075
Condition (congruency)	1.02	.796 .. 1.32	.848
Dominance	.977	.930 .. 1.03	.369
Time region : Condition (predictability)	1.71	1.65 .. 1.77	<.001
Time region : Condition (congruency)	.990	.951 .. 1.03	.621
Time region: Dominance	.862	.753 .. 987	.032
Condition (predictability) : Dominance	1.04	1.02 .. 1.06	<.001
Condition (congruency): Dominance	1.04	1.02 .. 1.07	<.001
Time region : Condition (predictability) : Dominance	1.06	1.03 .. 1.10	<.001
Time region: Condition (congruency): Dominance	.966	.929 .. 1.01	.090

5. Discussion

This study investigated linguistic prediction based on grammatical gender in Italian-German bilingual children. By testing participants in Italy as well as in Germany, we were able to explore the effect of language dominance on bilingual processing.

With respect to the first research question, our study confirmed that bilingual children anticipate the upcoming noun based on the grammatical gender of the determiner, as we found linguistic prediction in both Italian and German. Thus, similarly to monolingual children (Cholewa et al. 2019; Lew-Williams & Fernald 2007; Van Heugten & Shi 2009), bilingual children can process speech rapidly and incrementally, by making use of predictive mechanisms (supporting Lemmerth & Hopp 2019 and Bosch et al. in press).

As for our second research question, which addressed the gender congruency effect, in the Italian experiment we found that prediction was much stronger when the grammatical gender of the target noun in German and Italian overlapped. This means that participants were influenced by their knowledge of German when processing sentences in Italian. However, we found no gender congruency effect in the German experiment, which may be explained by the fact that the group was German-dominant and possibly too small to detect very subtle effects.

Our third research question addressed the effect of language dominance (i.e., relative proficiency) on predictive processing and cross-linguistic influence. In both experiments we found stronger prediction when participants were tested in their dominant language. This is in line with previous studies showing that predictive processing of grammatical gender in the L2 is related to language proficiency (Bosch et al. in press; Dussias et al. 2013).

Moreover, the gender congruency effect in the Italian experiment was considerably stronger for German-dominant than for Italian-dominant participants. In other words, participants who were relatively more proficient in Italian were faster when processing Italian sentences, and they were less likely to experience cross-linguistic interference from German due to a gender mismatch, as compared to participants who were more proficient in German.

Our findings partly corroborate the findings by Lemmerth and Hopp (2019), who were the first to report anticipation based on gender in bilingual children, focusing on Russian-German bilinguals growing up in Germany. In their study, sequential bilinguals (who learned German as an early L2) failed to use the gender cue in German to anticipate the target noun when there was a gender mismatch between German and Russian, while simultaneous bilinguals did not show such a gender congruency effect. The results of our Italian experiment showed a different pattern, as we observed a gender congruency effect also in simultaneous bilingual children. If anything, the post-hoc analysis focusing on simultaneous bilinguals suggested that the gender congruency effect was stronger in the subset of simultaneous

bilinguals than in the complete sample, which included early L2 learners of Italian and early L2 learners of German. This may be due to two reasons. First, among the simultaneous bilinguals there were relatively more German-dominant children growing up in Germany while in the complete sample the majority were Italian residents whose dominant language tended to be Italian. Second, the native Italian early L2 learners of German may have been less likely to show interference in an Italian task than simultaneous bilinguals.

The difference between our results and those of Lemmerth and Hopp may, to some extent, have been influenced by the fact that our tasks included words that were cognates between Italian and German. A cognate facilitation effect may have led to faster processing and potentially stronger predictions in comparison with previous research (see Costa et al. 2000; Dijkstra et al. 1999). It is still unclear to what extent cognate status may also interact with a gender congruency effect: while some studies found that cognates may lead to stronger gender congruency effects, due to increased cross-language activation (Lemhöfer et al. 2008; Salamoura & Williams 2007), others found no such interaction (Janyan & Hristova 2007; Von Grebmer zu Wolfsthurn et al. 2021).

Importantly, the presence of cognates cannot fully explain the different findings, since we did not find a gender congruency effect in a German task, which also included cognates. We argue that a more likely interpretation of the diverging findings relates to language dominance. Recall that sequential bilinguals in Lemmerth and Hopp's study had two Russian parents, leading to increased exposure at home and greater proficiency in Russian as compared to the simultaneous bilinguals, who only had limited Russian input from one of their parents. This means that the simultaneous bilingual children in Lemmerth and Hopp and our participants in the German task were tested in their dominant language, while the sequential bilingual children in Lemmerth and Hopp and our participants in the Italian task were more balanced in terms of language dominance. In other words, the likelihood of a

gender congruency effect may be mostly related to differences in language dominance, rather than to the nature of asynchronous versus simultaneous acquisition.

Previous research has also shown that cross-linguistic influence in bilingual children is more likely to become apparent when children are tested in the language in which they have lower proficiency (Yip & Matthews 2007), or in the language to which they are exposed less (Bosch & Unsworth 2020; Herve et al. 2016; Unsworth et al. 2014). This means that the more dominant language affects the less dominant language more strongly than vice versa.

Regarding the acquisition of grammatical gender, several studies suggest that bilingual children are particularly sensitive to effects of language dominance (Rodina & Westergaard 2017; Unsworth et al. 2014; Unsworth 2013a; Unsworth 2008; Cornips & Hulk 2008). The present study extends these findings beyond production and offline comprehension to online processing. It should be noted that, while we have operationalized language dominance as relative proficiency in terms of vocabulary knowledge, this effect may in fact also reflect the everyday presence of the two languages in a child's life, including language input or language use (see Unsworth 2013b). Future studies should attempt to disentangle how these different components of language dominance impact on bilingual language processing.

What remains is the question of what exactly causes this type of cross-linguistic influence during speech processing, which is not limited to the classic type of transfer from a speaker's L1 into their L2. With respect to the gender congruency effect, we hypothesize that simultaneous and early sequential bilingual children, who typically learn both languages without explicit grammatical instruction, may initially build their lexical categorization of nouns in the two languages relying on the analogy between their two grammatical gender systems and that they do so on the basis of the overlap between grammatical and biological gender of animate nouns, which is subsequently generalized to inanimate nouns. Assuming that bilinguals have shared representations of grammatical gender in their two languages

(Salamoura & Williams 2007; Klassen 2016), and that children are no exception to this, hearing the feminine Italian article *la* may thus activate the feminine German article *die*. This may in turn influence linguistic anticipations about upcoming nouns, which might reflect in a speed up or slow down depending on whether the grammatical gender values of translation equivalents overlap. If we can assume that the two languages of a bilingual speaker are always activated to some extent in a bilingual mind (Grosjean 1989), this type of interaction is hypothesized to be a natural consequence of bilingual processing, and therefore expected to occur in different types of bilingual speakers, regardless of age and type of acquisition. It is very well possible, however, that the dominant language, which is more strongly established or perhaps more readily activated due to more frequent use, exerts a stronger influence in this process.

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