Prediction during spoken language processing in monolingual and multilingual children

Investigating the role of literacy

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Listeners use linguistic cues to anticipate upcoming words, but not all do so to the same extent. While we know that monolingual children use prediction during spoken language processing from a young age and that adult L2 speakers may sometimes be slower, very few studies have focused on bilingual or multilingual children. Moreover, previous research suggests that literacy boosts anticipation in spoken language processing, but this has not been tested yet in bi/multilinguals. We investigated linguistic prediction and its relation to reading and vocabulary skills in 38 eight- to twelve-year-old bilingual and multilingual children who speak different heritage languages and Italian as the majority language, in comparison to 32 age-matched monolingual Italian children. Using a visual world eye tracking method, we tested children's ability to anticipate nouns based on morphosyntactic cues (gender- and number-marked articles) in Italian. The results show efficient prediction in both groups, although monolinguals were faster than bi/multilinguals. While we found a positive relation between predictive language processing and reading in monolingual children, there were no reliable effects in bilingual and multilingual children. Future work is required to better understand the relation between prediction and literacy in this population.

Keywords: prediction, language processing, literacy, multilingual children, morphosyntactic cues

1. Introduction

Language is processed very fast and efficiently: people integrate information immediately as sentences unfold, and they rely on linguistic cues to pre-activate

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upcoming words before they are encountered. This pre-activation, which facilitates language processing, occurs during reading (e.g., DeLong et al., 2005; Federmeier & Kutas, 1999; Staub & Clifton, 2006), as well as when listening to speech (e.g., Altmann & Kamide, 1999, 2007; Lew-Williams & Fernald, 2007). Listeners and readers anticipate upcoming words by relying on lexical semantic cues (Altman & Kamide, 1999; DeLong et al., 2005), pragmatics (Foppolo & Marelli, 2017), or grammatical cues such as gender and number agreement (Barber & Carreiras, 2005; Fuchs, 2022; Van Berkum et al., 2005).

Previous research focusing on monolinguals has shown that this is the case not only for adults, but also for very young children (Havron et al., 2019; Kouider et al., 2006; Lew-Williams & Fernald, 2007; Mani & Huettig, 2012; Mornati et al., 2022). For example, Mornati and colleagues (2022) found that Italian infants were already able to use the grammatical gender of articles to anticipate upcoming nouns at 12 months, and Kouider and colleagues (2006) found that 24-month-old English-speaking children were able to pre-activate nouns based on subject-verb number agreement.

While prediction may be an important and early-acquired mechanism that facilitates language processing, it is not required for comprehension, and not all humans make use of it to the same extent (Huettig & Mani, 2016; Pickering & Gambi, 2018). Some groups of people, such as young children and older adults, but also people with low literacy skills, tend to predict considerably less than the population of healthy, young, monolingual adults that typically participate in psycholinguistic experiments (Favier et al., 2021; Federmeier et al., 2010; Mani & Huettig, 2012; Mishra et al., 2012; Pickering & Gambi, 2018).

Another group that in some cases shows less prediction consists of second language (L2) speakers. Whereas earlier studies did not observe linguistic anticipation in adult L2 processing (Grüter et al., 2012; Lew-Williams & Fernald, 2010; Martin et al., 2013), it has now become clear that people can also predict in their L2 (see Kaan & Grüter, 2021). However, depending on the level of proficiency and cross-linguistic differences, L2 speakers may be less likely to anticipate, and their anticipatory response may be weaker or slower in comparison to L1 speakers (e.g., Dussias et al., 2013; Morales et al., 2016, see Kaan & Grüter, 2021). Such differences in processing may be related to the degree of automaticity, which is expected to increase as L2 learners become more proficient (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2005). In addition, the degree to which people predict in L2 processing seems to depend on the linguistic domain that is tested. While there is abundant evidence for predictive processing based on semantic cues in L2 speakers (e.g., Chun & Kaan, 2019; Dijkgraaf et al., 2017; Ito et al., 2018), studies focusing on anticipation based on morphosyntactic cues show mixed results (Foucart & Frenck-Mestre, 2011, 2012; Lew-Williams & Fernald, 2010; Mitsugi

& MacWhinney, 2016). This could be explained by the hypothesis proposed by Clahsen and Felser (2006, 2018), which states that L2 speakers have shallower and less fine-grained syntactic representations, leading them to focus more on lexical cues rather than grammatical information.

While predictive processing has been studied extensively in monolingual and bilingual adults, and to a lesser extent also in monolingual children, bilingual children may be seen as 'the missing piece of the puzzle' (Karaca et al., 2021). As Karaca and colleagues point out, studying prediction in bilingual children would provide us with an opportunity to improve our understanding of bilingual language processing as well as of the predictive mechanisms themselves, since the large variation that is present among bilingual children allows us to test effects of individual differences. So far, however, very little attention has been paid to predictive processing in bilingual children, and the few studies that are available report mixed results (Bosch et al., 2022; Bosch & Foppolo, 2022; Brouwer et al., 2017; Lemmerth & Hopp, 2019; Meir et al., 2020). Moreover, to the best of our knowledge, the relation between reading skills and prediction has not yet been studied in bilingual children. It is important to investigate how non-native reading development might be interrelated with children's L2 processing, as a large number of children currently learn to read in a majority language that differs from the one spoken in their family. Given that bilingual children and adults sometimes show different patterns in predictive language processing, testing the link between literacy and predictive processing in bilingual children would also inform us about the generalizability of the effect in more diverse populations.

Using a visual world eye tracking paradigm, the current study therefore aims to investigate to what extent bilingual and multilingual children use predictive language processing based on different types of cues, how they compare to their monolingual peers, and whether the degree to which children predict is modulated by their reading skills. We focus on Italian, by testing anticipation of nouns preceded by gender- and number-marked articles.

In what follows, we will elaborate on predictive language processing in bilingual and multilingual children (Section 1.1), and on the potential relationship between literacy and prediction in spoken language processing (Section 1.2). After that, we will present a brief description of grammatical gender and number agreement in Italian (Section 1.3), followed by our research questions and hypotheses (Section 1.4). Subsequently, we will present our methods (Section 2) and our results (Section 3), and we will conclude with a discussion of our findings (Section 4).

1.1 Prediction in bilingual children

To date, only a handful of studies have focused on predictive processing in bilingual children. The first to investigate this were Brouwer and colleagues (2017), who used a visual world eye tracking paradigm to test children's ability to anticipate upcoming nouns based on the semantic properties of preceding verbs. They focused on 4- and 5-year-old simultaneous and early successive bilingual children who spoke Dutch as a societal language in addition to a wide variety of heritage languages, in comparison to monolingual Dutch children. While monolingual and bilingual children in both age groups were able to anticipate nouns in Dutch, bilingual 4-year-olds were significantly faster than monolingual 4-year-olds, suggesting a bilingual advantage in the developmental pattern of predictive processing.

Recently, other studies have also investigated anticipation based on morphosyntactic cues in bilingual children. For example, Meir et al. (2020) found efficient anticipation of argument structure based on case morphology in Russian and Hebrew in 4- to 8-year-old Russian-Hebrew bilingual children. While bilinguals were significantly slower than monolingual Russian-speaking children, they were faster than monolingual Hebrew-speaking children, who did not show anticipatory eye movements at all, due to the unreliability of the Hebrew case marking system. This suggests that even though bilinguals might sometimes be delayed compared to monolinguals, weaker predictive cues in one language may be reinforced when stronger cues are available in the other language.

Furthermore, a few studies have provided evidence for anticipation of nouns based on grammatical gender or number (Bosch et al., 2022; Bosch & Foppolo, 2022; Lemmerth & Hopp, 2019). For example, Bosch and colleagues (2022) tested the anticipation of nouns based on gender- and number-marked articles in Italian in 8- to 11-year-old Mandarin-Italian sequential bilingual children and their monolingual peers. The results show that both groups anticipated nouns based on gender and number, although bilingual children were significantly slower with gender than with number, and significantly delayed compared to monolingual children overall. Moreover, gender processing was influenced by children's L2 proficiency: bilingual children with stronger receptive vocabulary knowledge in Italian were more likely to anticipate upcoming nouns based on gender than children with weaker vocabulary skills. The discrepancy between gender and number processing might have been influenced by cross-linguistic differences: articles in Italian are marked for both gender and number, but Mandarin has neither articles nor grammatical gender, while it does have a conceptual notion and grammatical expression of number.

Two other studies also found anticipation of nouns based on gender-marked articles and adjectives in simultaneous and sequential bilingual children, even

though children sometimes experienced cross-linguistic influence when there was a mismatch in grammatical gender across their two languages (Bosch & Foppolo, 2022 for Italian-German bilinguals; Lemmerth & Hopp, 2019 for Russian-German bilinguals). Lemmerth and Hopp (2019) found an effect of the type of bilingualism: early sequential bilinguals failed to show anticipation when there was a gender mismatch, while simultaneous bilinguals performed like monolinguals. Moreover, the results of Bosch and Foppolo (2022) point towards an important role of language dominance (i.e., relative vocabulary size), since Italian-dominant bilingual children showed stronger anticipation and less influence from German when tested in Italian.

To summarize, the few studies on predictive processing in bilingual children suggest that they are able to anticipate upcoming words based on linguistic cues. In some cases they turned out to be faster than their monolingual peers (i.e., 4-year-olds in Brouwer et al., 2017; the Hebrew task in Meir et al., 2020), while in other cases their processing was slower (i.e., Bosch et al., 2022; the Russian task in Meir et al., 2020; successive bilinguals in Lemmerth and Hopp, 2019), or there was no difference (i.e., 5-year-olds in Brouwer et al., 2017; simultaneous bilinguals in Lemmerth and Hopp, 2019). Predictive processing in bilingual children seems to be related to vocabulary knowledge, but we do not know yet whether it might also be influenced by their reading skills. The next section will discuss previous research on the relation between prediction and literacy.

1.2 Effects of literacy

Literacy may influence the way in which humans process spoken language in several ways. Specifically, reading appears to strengthen prediction in speech processing, and vice versa. This relationship is hypothesized to be driven by both direct and indirect effects.

First of all, there are several secondary correlates of reading experience that are positively associated with predictive language processing. Most importantly, reading improves lexical knowledge (Andrews, 2008; Cunningham & Stanovich, 1998), which may facilitate lexical anticipation in spoken language (Borovsky et al., 2012; Mani & Huettig, 2012; Rommers et al., 2015). It also leads to more fine-grained phonological and lexical representations as well as additional graphemic representations (Huettig & Pickering, 2019), leading to the formation of new neural connections (Ehri, 2014), which in turn allow for faster and more precise predictive processing (DeHaene et al., 2010). These factors (i.e., strengthened vocabulary knowledge and sharpened linguistic representations) are primarily expected to facilitate anticipation based on lexical semantic cues.

However, there are also several factors inherent to reading that may boost predictive mechanisms, which is expected to affect both lexical and morphosyntactic anticipation. Firstly, the physical act of reading requires planning and anticipation, because readers learn to plan their saccadic eye movements in such a way that they optimize the amount of time they fixate on each word (Reichle et al., 2003). Secondly, while listeners have to wait for each phoneme to unfold, skilled readers can process multiple letters simultaneously (Dehaene, 2009), which allows for faster prediction based on the relations between individual words. Thirdly, while human speech might be messy and characterized by individual variation, there is very little variance in the form of written words, which increases the reliability of predictive processing in reading. Because of this, reading allows for a much faster pace than everyday speech processing – which is by definition limited to the pace of speaking, and skilled readers are therefore more prone to identify upcoming words as soon as possible to optimize the time required to process written information. The act of reading therefore offers an environment optimally suited for training predictive mechanisms, which may subsequently transfer to spoken language comprehension (Huettig & Pickering, 2019).

Several studies observed a relation between reading skills and predictive processing of spoken language, by comparing literates to illiterates (Mishra et al., 2012), by comparing typical readers to dyslexics (Huettig & Brouwer, 2015; Persici et al., 2019), or by considering individual variation in literacy skills in healthy adults (Ng et al., 2018; Favier et al., 2021). Only one study has focused on children at the early stages of literacy acquisition: Mani and Huettig (2014) investigated the link between literacy and predictive processing by considering individual variation in reading skills in 8-year-old German children. They tested semantic anticipation of nouns on the basis of the lexical meaning of verbs. The results showed that children relied on verb semantics to anticipate upcoming nouns, and that their anticipatory eye movements strongly correlated with their word reading skills.

In sum, there is ample evidence for a relation between literacy-related skills and predictive processing in adults, but to date only one study has focused on children (focusing on lexical anticipation) and none have investigated this issue in bilingual or multilingual children. Therefore, the current study explores whether the extent to which bi-/multilingual and monolingual children anticipate nouns based on morphosyntactic cues is related to their reading skills. Focusing on Italian, we tested the anticipation of nouns based on gender and number agreement, which we will briefly elaborate on below.

1.3 Gender and number in Italian

In Italian, grammatical gender and number are marked through suffixes on nouns, and via morphosyntactic agreement, with different elements in the sentence. Italian distinguishes between singular and plural nouns, which are classified as being either feminine or masculine.

The gender and number of nouns can reliably be predicted by looking at preceding articles, since they are unambiguously marked for both gender and number. The masculine singular definite article is *il* (e.g., *il tavolo* 'the$_{\text{MASC.SG}}$ table'), the feminine singular definite article is *la* (e.g., *la sedia* 'the$_{\text{FEM.SG}}$ chair'), the masculine plural definite article is *i* (e.g., *i tavoli* 'the$_{\text{MASC.PL}}$ tables'), and the feminine plural definite article is *le* (e.g., *le sedie* 'the$_{\text{FEM.PL}}$ chairs') (Ferrari & Zampese, 2016; Panzini, 2017). There are many exceptions to this pattern, but in the current study we will only be concerned with the more prototypical forms.

In Italian, both gender and number are early acquired features in first language acquisition, with almost adult-like performance before the age of 3 (Caprin & Guasti, 2009; Cipriani et al., 1993). However, while number generally appears to be rather unproblematic for L2 learners, gender seems to be a more challenging feature both for adult L2 learners (Bianchi, 2013; White et al., 2004) and bilingual children (Martinez-Nieto & Restrepo, 2023; Meisel, 2018; Unsworth et al., 2014).

Several studies comparing online processing of gender and number in bilingual adults have found an advantage for number, with participants showing faster and more native-like processing of number compared to gender features (Gabriele et al., 2013; Gillon-Dowens et al., 2010). This dissociation has been hypothesized to be related to differences in conceptual representations: gender is an arbitrary feature pertaining to the lexicon while number is a more meaningful morphosyntactic feature that can be retrieved from the referential context. The discrepancy between gender and number may also be interpreted in the framework of the Interpretability Hypothesis, which would regard gender as an uninterpretable feature that may be inaccessible for L2 learners when it is not shared by the L1 (Tsimpli & Dimitrakopoulou, 2007). It should be noted, however, that a gender-number discrepancy has also been observed in monolingual populations, both in adults (Antón-Méndez et al., 2002; Igoa et al., 1999) and children (Dispaldro et al., 2015).

So far, only one study has compared gender and number processing in bilingual children (Bosch et al., 2022). As mentioned above, the Mandarin-Italian bilingual children in this study were considerably faster to anticipate nouns in Italian based on number-marked articles rather than gender-marked articles, which was not the case to the same extent for monolingual Italian participants.

In addition to testing the effect of reading skills on predictive processing, the current study will therefore also compare gender and number processing.

1.4 Research questions and hypotheses

The aim of this study is to investigate predictive processing and its relation to reading abilities in bilingual and multilingual children (henceforth, they will be referred to combinedly as 'multilingual children'), in comparison to their monolingual Italian peers. Capitalizing on the fact that Italian marks grammatical gender and number on articles, we tested (1) whether monolingual and multilingual children make use of articles to predict upcoming nouns when processing Italian sentences in a visual world eye tracking paradigm, (2) whether there are differences between gender and number processing, and (3) if and how literacy-related skills in Italian are related to anticipatory eye movements during online language processing.

Given previous findings, we hypothesize, first, that both multilingual and monolingual children predict upcoming information during spoken language processing. Specifically, we expect an increase of looks toward the target during the article in a condition in which there is a mismatch in grammatical gender or number between target and competitor, but not in a condition in which the grammatical gender and number of the two depicted objects overlap. Secondly, we hypothesize that multilingual children who speak a minority language at home may show weaker predictive processing based on morphosyntactic cues in the majority language than monolingual children, as lower exposure may be associated with less automatized language processing. This will be reflected by delayed anticipatory eye movements in comparison with monolingual peers. Grammatical gender processing may differ from number processing, since grammatical gender is an arbitrary feature stored in the lexicon which is only present in some languages, while number is a meaningful morphosyntactic feature that can be retrieved from the referential context which is grammatically expressed in most languages. Therefore, we predict that number will be processed faster than gender, and that this difference will be greater for multilinguals than for monolinguals. Finally, based on the hypothesis that literacy-related skills are positively related to prediction in spoken language (Huettig & Pickering, 2019), we expect children's predictive processing in Italian to be related to their reading skills as well as their Italian vocabulary knowledge.

2. Methods

2.1 Participants

We tested a total of 84 children between the ages of 8 and 12 at a public school in the suburban area of Milan. One child was excluded because she refused to read and one child because he could not be classified as being either monolingual or multilingual (i.e., he spoke another language during the first years of life but was then adopted by a monolingual Italian family). Additionally, ten children had to be excluded because of calibration problems and four children because of extensive track loss (see Section 2.3 Analysis for more details).

The final sample included 38 multilingual children (M_{Age} = 9;11, *SD* = 1;00, *Range* = 7;10–12;08) and 32 monolingual Italian children (M_{Age} = 9;08, *SD* = 1;01, *Range* = 8;00–11;10). There was no significant difference in age between the groups (t = .807, p = .422). The monolingual children were also included in the study by Bosch et al. (2022). All participants were typically developing children without any diagnosis of learning disabilities, language impairment or developmental dyslexia, and we only included children who had at least 5 years of exposure to Italian at the time of testing.

Parents signed an informed consent form that was approved by the ethics committee of the University of Milan-Bicocca, and they completed a questionnaire based on Ladas et al. (2015), which served to obtain information about the child's language background and parental education as a proxy for socioeconomic status. According to this survey, participants tended to be from medium-low socioeconomic backgrounds: 30.6% of the monolingual children and 38.6% of the multilingual children had mothers who did not finish secondary school, while respectively 25% and 20.5% of the mothers obtained a post-secondary education. The two groups did not differ significantly from each other with respect to maternal education (W = 629, p = .707).

The multilingual children were mostly from immigrant families and spoke a wide variety of languages at home, i.e. Arabic (N = 16), Spanish (N = 6), Albanian (N = 5), Filipino (N = 4), Mandarin Chinese (N = 4), Romanian (N = 2), English (N = 1) and Sardinian (N = 1). All Filipino-speaking children, two Arabic-speaking children and one Chinese-speaking child also spoke English at home as a third language. In total, 76% of the multilingual children spoke a language with grammatical gender as a native language, while for 24% their native language did not have grammatical gender. The majority of the multilingual participants (76.3%) were born in Italy, while 23.7% arrived in Italy by the age of 4. The mean age of first exposure to Italian was 1;02 (*SD* = 2;03, *Range* = 0;00–4;02).

2.2 Materials and procedure

2.2.1 *Literacy-related skills*

Reading abilities were tested using various reading tests that have been standardized for monolingual Italian children. Italian word and nonword reading skills were assessed with the DDE-2 (Sartori et al., 2007), and text reading skills were assessed using a reading fluency passage of the MT-3 (Cornoldi & Carretti, 2016). We measured both reading speed and accuracy. In addition, we tested productive vocabulary knowledge in Italian using the BVL_4-12 (Marini et al., 2015).

2.2.2 *Eye tracking*

We used the same visual world eye tracking experiment as in Bosch et al. (2022), to test anticipation of nouns based on gender- and number-marking in Italian. Children were presented with two pictures on a screen that displayed either a singular object or a pair of objects, while they listened to the sentence *Adesso trova la/il/le …* 'Now find the $_{\text{FEM.SG}}$ / the $_{\text{MASC.SG}}$ / the $_{\text{FEM.PL}}$ …' followed by a noun. We selected frequently occurring nouns referring to concrete, inanimate, common objects that were matched for syllable length across targets and competitors.[1] All nouns were bi- or trisyllabic and had transparent morphology (i.e., all masculine singular nouns ended in *-o*, all feminine singular nouns end in *-a* and all feminine plural nouns end in *-e*). The auditory stimuli were recorded by a female native speaker of Italian and manipulated using Audacity® (Audacity Team, 2022) to ensure that the first part of the sentence was always the same. The articles *la, le* and *il* lasted 315, 350 and 370 ms, respectively, and there was always exactly 750 ms between the onset of the article and the onset of the noun. The sentences were presented like a 'guessing game' in which the speaker pronounced the article with a longer vowel that created a natural pause in between the article and the noun. This allowed us to capture anticipatory looks before the onset of the noun, rather than incremental processing based on bottom-up integration.[2]

1. Please note that no up-to-date resource is available to check the frequency of Italian words in child language or child-directed speech, so it is not possible to provide a meaningful estimate of the frequency of the words used. However, some of the stimuli used in our experiment (65%) are also words listed in the Italian version of the MacArthur-Bates CDI for children aged 18–36 months (Caselli et al., 2007). For these words, the mean age of acquisition is 23 months.

2. Some previous studies have used an adjective between the article and the noun to increase the length of the time window between the onset of the article and the onset of the noun (e.g., point to the red car). However, this is not an ideal solution in Italian, since the large majority of articles can only appear post-nominally, and the few articles that can also appear before the noun (such as *bello* 'beautiful' or *grande* 'big') are appropriate in the pre-nominal position only in specific circumstances. Thus, opting for this solution would add uncontrolled noise to the

The experiment was run using E-Prime 3 (Psychology Software Tools) and children's eye movements were recorded using a portable eye-tracker (Tobii Pro X3-120) that captured eye gaze data at 120 HZ. Each session started with three practice items, after which calibration took place. Children were presented with a fixation cross in between trials, as to ensure that they were looking at the center of the screen before continuing the experiment. At the end of each trial, a question mark appeared and children were asked to select the correct picture using the mouse.

As illustrated by Figure 1, the experimental design consisted of two predictable conditions (Early Number and Early Gender) and one unpredictable condition (Late). In both predictable conditions, there was a mismatch between the target and the competitor, allowing for prediction on the basis of the article. In the Early Gender condition, participants saw one feminine and one masculine object, so that the gender of the article (*il* vs *la)* enabled prediction of the target. In the Early Number condition, participants saw a single object in one picture and a pair of objects in the other one, allowing for anticipation of the target based on the number marking on the article (*la* vs *le*). In the Late condition, the target and the competitor were matched in both gender and number, so that participants would have to wait until the onset of the noun before they could identify the target. There were three different pairs of unpredictable items: *la* vs *la*, *il* vs *il* (for gender) and *le* vs *le* (for number), as specified above. We did not include any masculine plural nouns because of the initial phonological overlap between the masculine singular article *i* and the masculine plural article *il*, and because the masculine plural *i* may also be used generically to refer to a combination of masculine and female referents.

The Early Gender condition consisted of 10 items (five feminine and five masculine targets), the Early Number condition consisted of 10 items (five singular and five plural targets), and the Late condition consisted of 15 items (five feminine singular, five masculine singular and five feminine plural targets). The position of the target was balanced across trials and the order of presentation was randomized. Children were randomly assigned to one of two lists, in which we reversed the targets and competitors, following a Latin-square design. A list of our experimental stimuli can be found here: https://osf.io/bqu2d/?view_only =82ff2a0078654b8f8fb947c4770a591a.

stimuli, possibly leading to unwanted bias for certain completions which might be due to external factors (e.g., the implicit reference to a standard size of a specific object when using gradable adjectives like "big" or "small" to refer to objects, or semantic/pragmatic factors related to the use of non-standard N-Adj combinations).

Early gender (predictable)
la banana vs *il tamburo*
the$_{\text{FEM SING}}$ banana vs the$_{\text{MASC SING}}$ drum

Early number (predictable)
la foglia vs *le torte*
the$_{\text{FEM SING}}$ leaf vs the$_{\text{FEM PLUR}}$ cakes

Late (unpredictable)
la ruota vs *la sedia*
the$_{\text{FEM SING}}$ wheel vs the$_{\text{FEM SING}}$ chair

Figure 1. Overview of experimental conditions

2.3 Analysis

2.3.1 *Literacy-related skills*

We ran a principal components analysis on the various literacy-related measures, including word-, nonword- and text reading speed and accuracy. Using the FactoMineR package (Lê et al., 2008), we aimed to identify the underlying construct that could explain most of the variance in the data. The first principal component (PC1) was then used as an independent variable in the statistical analysis as a proxy for reading skills.

2.3.2 *Eye tracking*

The data of 10 children (seven multilinguals and three monolinguals) were excluded from the analysis because of poor quality of the calibration of the eye tracker, and four children (two multilinguals and two monolinguals) were excluded due to extensive track loss (>50%). Additionally, all trials with inaccurate responses (0.1% for monolinguals and 1.4% for multilinguals) and trials with more than 50% track loss (14.3%) were removed from the analysis, leaving us with a final sample of 2100 trials, coming from 38 multilingual and 32 monolingual participants.

We divided the experimental sentences in three time windows: the introduction, the article and the noun. The boundaries of each time window were again shifted 200 ms to take saccade planning into account (Altmann, 2011). Mixed effects models were run using the glmer function of the lme4 package (Bates et al., 2015) in R (R Core Team, 2022). All numeric scores were rescaled and centered around the mean. Focusing on the article time window, we modeled the binary outcome Looks to the target (yes or no) as a function of Time from trial onset, Condition, and the interaction between them. Using Helmert contrasts, Late was coded as −2/3, Early Gender was coded as +1/3 and Early Number was coded as +1/3 to test whether children showed anticipation by comparing the two

Early conditions to the Late condition; in a second contrast, Late was coded as 0, Early Gender was coded as −1/2 and Early Number was coded as +1/2 to directly compare gender and number processing. In the analyses focusing on the effect of literacy-related skills, the two predictable conditions were merged into one to increase statistical power. In these analyses, Predictable was coded as +1/2 and Unpredictable as −1/2. We explored whether the prediction effect was modulated by Group (Monolinguals, coded as +1/2, or Multilinguals, coded as −1/2), reading skills (PC1) and vocabulary knowledge. Random intercepts for Item and Subject were included, with random slopes for Condition and Time. We also checked whether adding Age in months, Trial number and List improved the model fit, by bottom-up step-wise model comparison based on the Bayesian Information Criterion (BIC).

First, we compared predictive processing based on article-noun gender and number agreement in monolingual and multilingual participants. Second, we tested whether predictive processing was related to reading skills. After comparing the two groups in one model, we conducted separate analyses for monolingual and multilingual participants to explore whether anticipatory looks were modulated by reading scores. Finally, we tested whether there was a relation between Italian vocabulary knowledge and predictive processing in multilingual participants.

3. Results

3.1 Literacy-related skills

We conducted a principal components analysis on the literacy measures, in order to identify the underlying construct that explained the maximal amount of variance. The first principal component (henceforth: PC1) could explain 55.7% of the variance in the data. As can be seen in Figure 2, the most important variables were word reading speed (accounting for 22% of the variance in PC1) and text reading speed (21.9%). Thus, PC1 can be interpreted as a composite score of reading skills, which above all reflects children's word- and text reading speed.

In the analyses of the eye tracking data presented below, we decided to use PC1 as a proxy for reading skills. There was no significant difference between monolingual and multilingual participants with respect to their reading (PC1), $t(72) = -1.16$, $p = .250$. As for vocabulary knowledge in Italian, monolingual children scored significantly higher than multilingual peers $W(72) = 328.5$, $p < .001$, since most monolinguals scored at-ceiling while there was more variation among multilingual participants. The potential effect of vocabulary knowledge will there-

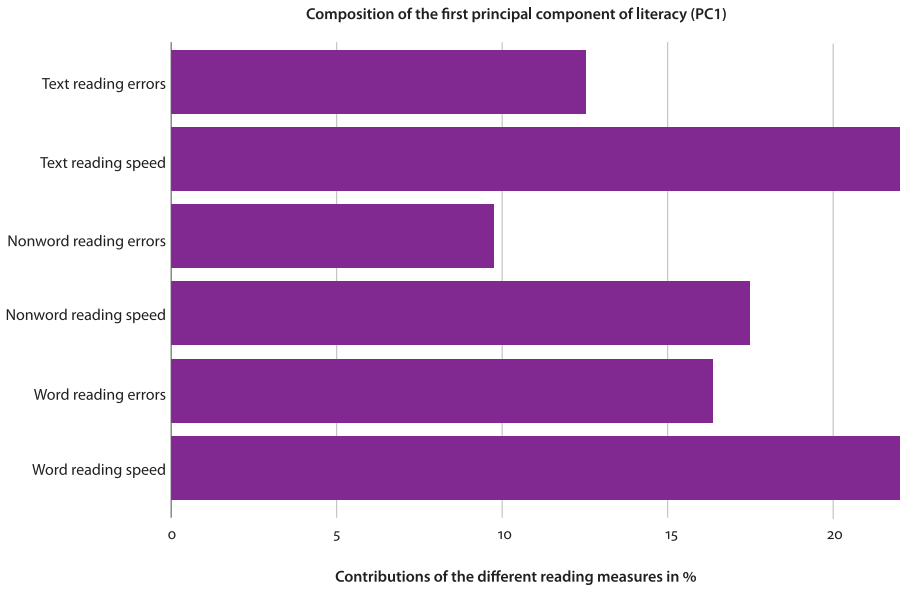

Figure 2. Composition of the first principal component of literacy (PC1)

fore only be examined in the multilingual group. Finally, there was a weak but significant positive correlation between PC1 and vocabulary scores, $r(72) = .340$, $p = .003$.

3.2 Eye tracking

3.2.1 *Monolinguals vs multilinguals*

We first compared anticipatory looks based on gender and number in monolingual versus multilingual children. The best model that converged included main effects of Condition, Time and Group as well as the interactions between them, and random intercepts for Subject and Item with random slopes for Condition and Time. Age, List and Trial Number did not improve the model and were removed from the analysis. The model output is presented in Table 1, and the eye gaze patterns of the monolingual and multilingual participants are shown in Figure 3.

The results show a significant main effect of Time, indicating that overall participants became more likely to look at the target during the determiner time window. The significant interaction between Time and Condition indicates that this effect differed between the two predictable conditions and the control condition. In other words, while listening to the article, participants showed anticipatory eye movements based on gender and number.

Furthermore, there was a significant three-way interaction between Condition (Early vs Late), Time and Group, showing that monolingual participants showed stronger anticipation than multilingual participants. This is illustrated by Figure 3: at the end of the article, the proportion of looks to the target tended to be between 64% and 73% for monolingual participants and between 56% and 64% for multilingual participants. We also found a significant interaction between Condition (Gender vs Number), Time and Group, showing that monolinguals and multilinguals differ in the way in which they process gender and number. Figure 3 shows that the two groups indeed displayed an opposite pattern; while monolinguals tended to be slightly faster with number than with gender, multilinguals were on average slightly faster with gender than with number. However, in both groups the observed differences are small, and to increase statistical power we merged the two predictable conditions into one for the analyses on the relation between reading and prediction presented below.

Table 1. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the comparison of gender and number processing in monolinguals and multilinguals

Generalized linear mixed model			
Looks to target (yes or no) ~ Condition (early gender vs early number vs late) * Time * Group (monolinguals vs multilinguals) + (1 | Item) + (1 + Condition + Time | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***p***
Condition (early vs late)	1.23	.952 .. 1.58	.114
Condition (gender vs number)	.977	.715 .. 1.34	.884
Time	1.14	1.08 .. 1.20	<.001
Group	1.14	.979 .. 1.32	.094
Condition (early vs late) : Time	1.21	1.19 .. 1.23	<.001
Condition (gender vs number) : Time	1.00	.978 .. 1.03	.719
Condition (early vs late) : Group	1.15	.840 .. 1.58	.378
Condition (gender vs number) : Group	1.19	.851 .. 1.68	.304
Time : Group	1.05	.949 .. 1.17	.330
Condition (early vs late) : Time : Group	.953	.915 .. .993	.020
Condition (gender vs number) : Time : Group	1.09	1.04 .. 1.15	.001

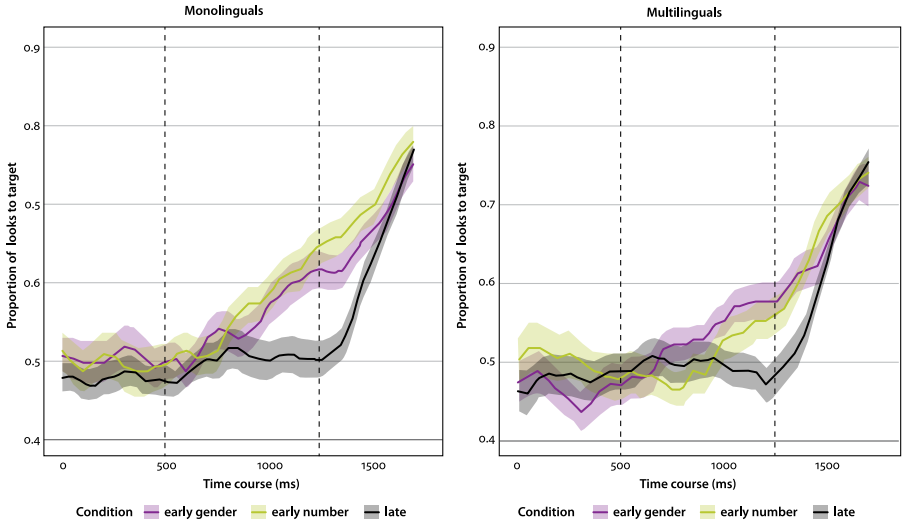

Figure 3. Time course of the proportions of looks toward the target (versus competitor) in the three conditions for monolingual participants (on the left) and multilingual participants (on the right). The first vertical line represents determiner onset and the second vertical line represents noun onset, shifted 200 ms to account for saccade planning

3.2.2 *The effect of reading*

Subsequently, we tested whether the degree to which children anticipate nouns based on preceding articles was related to their reading skills, using a model that included main effects of and interactions between Condition (Early vs Late), Time from trial onset, Reading scores (PC1) and Group (Monolinguals vs Multilinguals), as well as random intercepts for Subject and Item with random slopes for Condition and Time. The model output is provided in Table 2.

As in the previous analysis, there was a significant interaction between Condition and Time, indicating that in the predictable condition participants became more likely to look at the target while listening to the article. Again, this prediction effect was significantly greater for monolinguals than for multilinguals, as shown by the significant interaction between Condition, Time and Group. Furthermore, the results show a highly significant four-way interaction between Condition, Time, Group and PC1, indicating that the two groups differ from each other with respect to the effect of reading on prediction. To be able to interpret this interaction, we split the analysis of the effect of reading by group.

Table 2. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the comparison of the effect of reading in monolinguals and multilinguals

Generalized linear mixed model			
Looks to target (yes or no) ~ Condition (early vs late) * Time * PC1 * Group (monolinguals vs multilinguals) + (1 | Item) + (1 + Condition + Time | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***p***
Condition (early vs late)	1.22	.947 .. 1.57	0.199
Time	1.1	1.04 .. 1.56	<.001
Group	1.13	.959 .. 1.33	0.147
PC1	0.972	.885 .. 1.07	0.56
Condition (early vs late) : Time	1.88	1.16 .. 1.21	<.001
Condition (early vs late) : Group	1.13	.825 .. 1.56	0.441
Condition (early vs late) : PC1	1.1	.916 .. 1.32	0.307
Time : Group	1.05	.949 .. 1.17	0.331
Time : PC1	1.03	.971 .. 1.10	0.307
Group : PC1	0.923	.764 .. 1.12	0.409
Condition (early vs late) : Time : Group	0.957	.919 .. .997	0.036
Condition (early vs late) : Time : PC1	0.995	.972 .. 1.02	0.671
Condition (early vs late) : Group : PC1	1.08	.746 .. 1.56	0.683
Time : Group : PC1	1.04	.917 .. 1.17	0.575
Condition (early vs late) : time : Group : PC1	1.14	1.09 .. 1.19	<.001

Firstly, we investigated whether anticipatory eye movements in monolingual children were modulated by reading scores. The model included main effects of and interactions between Condition (Early vs Late), Time from trial onset and reading scores (PC1), and random intercepts for Subject and Item with random slopes for Condition and Time. The model output is summarized in Table 3.

In order to visualize the effect of reading scores, we divided our participants into 'good readers' and 'poor readers' based on the centered PC1 scores (i.e., those with positive scores were labeled 'good readers' and those with negative scores were labeled 'poor readers'). Figure 4 illustrates the difference in anticipatory eye movements between monolingual good readers ($N=19$) and monolingual poor readers ($N=13$). As can be seen from this figure, monolingual good readers showed slightly stronger prediction than monolingual poor readers. At the end of the article time window and in the predictable condition, monolingual

Table 3. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the analysis on the effect of reading in monolinguals

Generalized linear mixed model			
Looks to target (yes or no) ~ Condition (predictable vs unpredictable) * Time * PC1 + (1 | Item) + (1 + Condition + Time | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***P***
Condition (predictable vs unpredictable)	1.31	.926 .. 1.85	0.127
Time	1.13	1.05 .. 1.21	0.001
PC1	0.934	.788 .. 1.11	0.434
Condition (predictable vs unpredictable) : Time	1.16	1.13 .. 1.20	<.001
Condition (predictable vs unpredictable) : PC1	1.14	.842 .. 1.55	0.394
Time : PC1	1.05	.955 .. 1.57	0.309
Condition (predictable vs unpredictable) : Time : PC1	1.07	1.02 .. 1.11	0.002

good readers tended to look at the target on average 69% of the time, in comparison with 65% of the time for monolingual poor readers. In other words, even though we found similar patterns regardless of reading skills, monolingual good readers were slightly more likely to anticipate the upcoming noun than monolingual poor readers.

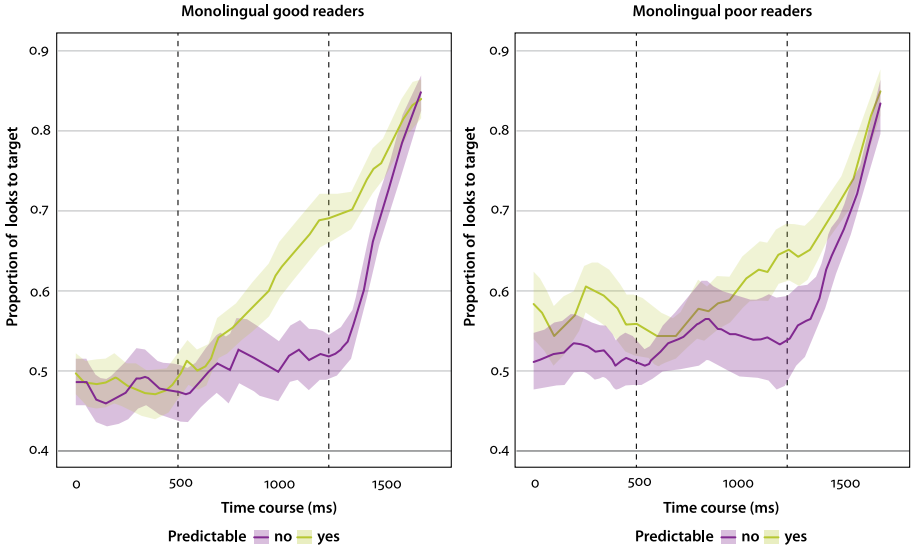

Figure 4. Time course of the proportions of looks toward the target (versus competitor) for monolingual good readers (on the left) and monolingual poor readers (on the right)

Secondly, we tested the relation between predictive processing and reading in our multilingual participants, using the same model as for the monolingual participants. The results of the analysis focusing on multilingual children are provided in Table 4.

The significant interaction between Condition and Time indicates that, similarly to monolingual participants, multilingual participants became more likely to look at the target while listening to the article in the predictable condition. We also found a significant three-way interaction between Condition, Time and PC1, which suggests that the effect of Condition during the course of the article differs depending on children's reading scores.

Table 4. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the analysis on the effect of reading in multilinguals

Generalized linear mixed model			
Looks to target (yes or no) ~ Condition (early vs late) * Time * PC1 + (1 | Item) + (1 + Condition + Time | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***p***
Condition (predictable vs unpredictable)	1.15	.81 .. 1.60	.42
Time	1.07	.99 .. 1.16	.07
PC1	1.01	.92 .. 1.12	.76
Condition (predictable vs unpredictable) : Time	1.23	1.19 .. 1.26	<.001
Condition (predictable vs unpredictable) : PC1	1.07	.87 .. 1.32	.04
Time : PC1	1.01	.95 .. 1.08	.66
Condition (predictable vs unpredictable) : Time : PC1	0.93	.91 .. .95	<.001

However, an inspection of the gaze patterns, which are provided in Figure 5, shows that this effect is in the opposite direction, and most likely driven by noise in the control condition, possibly related to the small number of participants across the two groups. At the end of the article time window in the predictable Late condition, both good multilingual readers ($N=21$) and poor multilingual readers ($N=17$) on average look at the target picture around 60% of the time, but in the unpredictable condition good readers on average look at the target 46% of the time while poor readers do so 54% of the time. To avoid obtaining misleading results caused by unexplained differences in the control condition, we repeated the analysis focusing on the predictable condition only. The model output is provided in Table 5. In this analysis, we found a significant main effect of Time, which reflects anticipatory eye movements, but no significant effect of reading scores.

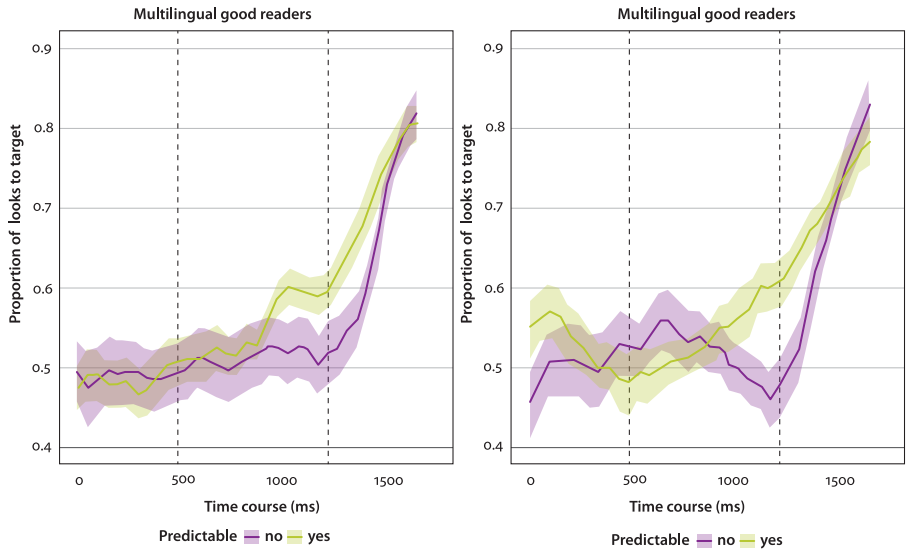

Figure 5. Time course of the proportions of looks toward the target (versus competitor) for multilingual good readers (on the left) and multilingual poor readers (on the right)

Table 5. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the analysis on the effect of reading in multilinguals, focusing on the predictable condition only

Generalized linear mixed model			
Looks to target (yes or no) ~ Time * PC1 + (1| Item) + (1 + Time + PC1 | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***P***
Time	1.18	1.06 .. 1.31	.002
PC1	1.05	.93 .. 1.18	.39
Time : PC1	.963	.88 .. 1.05	.41

3.2.3 *The effect of vocabulary knowledge*

Finally, we investigated whether anticipatory eye movements in multilingual children were related to their productive vocabulary knowledge in Italian. The model included main effects of and interactions between Condition (Early vs Late), Time and Italian vocabulary scores, and random intercepts for Subject and Item with random slopes for Condition and Time. The model output is presented in Table 6.

While we observed the same prediction effect described above (i.e., a significant interaction between Condition and Time), this effect did not seem to be modulated by vocabulary knowledge, since the interaction between Condition, Time, and Vocabulary was not significant.

Table 6. Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the analysis on the effect of vocabulary knowledge in multilinguals

Generalized linear mixed model			
Looks to target (yes or no) ~ Condition (early vs late) * Time * Vocabulary + (1 | Item) + (1 + Condition + Time | Subject)			
Fixed factor	**Est. odds ratio**	**95% CI**	***p***
Condition (predictable vs unpredictable)	1.12	.791 .. 1.58	.53
Time	1.09	1.01.. 1.18	.03
Vocabulary	1.09	.991 .. 1.20	.07
Condition (predictable vs unpredictable) : Time	1.23	1.20 .. 1.27	<.001
Condition (predictable vs unpredictable) : Vocabulary	0.959	.78 .. 1.18	.68
Time : Vocabulary	1.04	.97 .. 1.11	.19
Condition (predictable vs unpredictable) : Time : Vocabulary	0.98	.95 .. 1.01	.11

4. Discussion

The present study aimed to investigate prediction in spoken language processing and its relation to literacy in monolingual Italian children as well as in multilingual children who speak a variety of heritage languages and Italian as the majority language. We tested whether monolingual and multilingual children differ in the extent to which they anticipate upcoming nouns when listening to sentences in Italian, and whether their language-mediated anticipatory eye movements are related to their reading skills and vocabulary knowledge. We will first discuss the results of the comparison between multilingual and monolingual participants, after which we will turn to the effect of reading skills and vocabulary knowledge.

4.1 Predictive processing in multilingual and monolingual children

We hypothesized that both monolingual and multilingual children make use of prediction while listening to sentences, but that prediction might be stronger in

monolingual children, since they are per definition tested in their native language. Therefore, we expected to find prediction in both groups, with earlier and faster language-mediated anticipatory eye movements in monolingual participants. These predictions were borne out by the data. We found clear anticipation effects in multilingual children, which shows that they are able to make efficient use of predictive mechanisms when processing morphosyntactic cues (corroborating Bosch et al., 2022; Bosch & Foppolo, 2022; Lemmerth & Hopp, 2019; Meir et al., 2020). Yet, monolinguals were significantly faster than multilinguals.

The difference between monolingual and multilingual children may be due to reduced automaticity during language processing, since L2 processing is more resource-demanding than L1 processing. That is, more time and effort may be required to access lexical representations, to compute syntactic meaning and to inhibit competing linguistic forms from the L1 (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2009). Moreover, since prediction is an optional mechanism during language processing, considerations of utility may play a role (Huettig & Mani, 2016; Kaan & Grüter, 2021). For example, it might be more beneficial for multilingual children to allocate available cognitive resources to the monitoring of potential interference from competing linguistic representations rather than to linguistic anticipation.

Considering the type of cue used for anticipation, we expected processing to be slower for gender than for number. This prediction was based on the assumption that gender and number involve different conceptual representations; while number is a concrete, real-world feature, gender is an arbitrary and more abstract feature related to the lexicon that may be more difficult to process. The distinction between gender and number was therefore expected to be relevant for all children, but especially for multilinguals, who might be tested in a non-native or non-dominant language. Our results showed that monolingual Italian children indeed experienced a slight advantage of number over gender, even though the patterns were very similar. On the other hand, multilingual children turned out to be slightly faster with gender than with number, whilst previous studies have quite consistently shown a number advantage in bilingual speakers (Bosch et al., 2022; Dussias et al., 2013; Foucart & Frenck-Mestre, 2011; Hopp & Lemmerth, 2018).

We speculate that this different finding might be influenced by the fact that 76% of the multilingual children in this study spoke a language with grammatical gender as the heritage language (i.e., Arabic, Spanish, Albanian or Romanian). In contrast, studies that report an advantage of number over gender all focused on L2 learners whose L1 was English or Mandarin, which both have number but not grammatical gender. It is therefore not clear to what extent a discrepancy between gender and number processing may be modulated by the presence or absence of grammatical gender in the L1. Since it may be particularly resource-

demanding for L2 speakers to process L2-specific features, as they cannot transfer rules or linguistic representations, multilingual speakers may be more likely to use prediction when relying on features that are shared between their languages (Dussias et al., 2013; Foucart & Frenck-Mestre, 2011; Hopp & Lemmerth, 2018; Meir et al., 2020). In a related study based on a subset of the children who participated in the current study, we explored this issue further, by comparing gender and number processing in Mandarin-Italian and Arabic-Italian bilingual children. Whilst Mandarin-speaking children showed a clear advantage for number, Arabic-speaking children showed similar patterns for gender and number with a slight initial advantage for gender. We argue that this might be due to the fact that Mandarin lacks grammatical gender but not number, while both gender and number are present in Arabic (Bosch et al., 2022).

Future studies should explore this issue further, by comparing different groups of multilinguals to test to what extent L2 processing is influenced by the availability of a certain feature in the L1. Such a comparison was not possible in the current study due to the heterogeneity of the multilingual group. Note that, in the current study, multilingual children whose native language has grammatical gender might also have experienced cross-linguistic interference due to competing gender representations, leading to a speed up or slow down for certain items (see Bosch & Foppolo, 2022; Lemmerth & Hopp, 2019). A study focusing on gender processing in two specific language pairs should control for this, by matching the grammatical gender of items across languages. Finally, future studies might consider varying the experimental sentences more, in order to make the experimental items overall less predictable and improve ecological validity.

In sum, multilingual children are able to anticipate nouns based on morphosyntactic cues in a rapid and efficient manner. Yet, in some cases they are slightly delayed in comparison with monolingual peers. This can be interpreted in terms of decreased automaticity, which might be influenced by cross-linguistic differences and similarities. The next section will discuss the possible effects of literacy-related skills on predictive processing.

4.2 The relation between prediction and literacy

With respect to literacy, we hypothesized that the extent to which children engage in predictive processing is related to their reading abilities. We aimed to explore whether such an association would also be present in multilingual children who are tested in the majority language. Reading skills were operationalized as a composite score consisting of different decoding measures, to which real word and text reading speed contributed most.

In monolingual children, our hypothesis was confirmed: we found a positive correlation between reading scores and the anticipation of nouns based on morphosyntactic properties of preceding articles. This finding contributes to a growing body of research suggesting a positive association between literacy skills and prediction in spoken language processing (Favier et al., 2021; Huettig & Brouwer, 2015; Mani & Huettig, 2014; Mishra et al., 2012; Ng et al., 2018; Persici et al., 2019). Our study is most comparable to Mani and Huettig (2014), who considered individual variation in reading abilities in a group of typically developing German-speaking children. Using a semantic anticipation task, their results showed that anticipatory eye movements were positively related to reading skills. Focusing on Italian, our study extends this finding to anticipation based on morphosyntactic agreement.

This finding is compatible with the account of Huettig and Pickering (2019), who argue that, in addition to the indirect benefits of literacy (such as having improved vocabulary knowledge and phonological awareness), experience with reading trains the core mechanisms of prediction and sharpens linguistic representations which are common to reading and listening. These primary effects of reading may result in the transfer of prediction skills from reading to spoken language processing, leading to stronger anticipation, not only at a lexical level but also at a morpho-syntactic level (Huettig & Pickering, 2019). Considering that morphosyntactic anticipation has been observed in preliterate children (Lew-Williams & Fernald, 2007; Mornati et al., 2022), literacy is not a prerequisite for predictive processing. Nevertheless, better readers tend to make more use of anticipation in spoken language processing, due to the boost in predictive mechanisms and the sharpening of linguistic representations that is offered by the experience of reading. As a result, this increased use of linguistic anticipation may accelerate and facilitate the processing of new information during spoken language comprehension (Huettig & Pickering, 2019).

It should be noted that the design of our study, as well as that of most previous studies in the field, is correlational and thus not informative about the direction of the effect. Future studies may therefore want to use longitudinal designs that take into account children's anticipation skills before they learn to read (cf. Huettig et al., 2018). We hypothesize that the link between reading and prediction might be bidirectional: reading may not only improve predictive processing, but having strong prediction skills may also be an advantage during reading acquisition.

However, this pattern could not be confirmed in the multilingual participants, as we did not find any reliable effect of reading skills in this group. This might be due to the fact that these children already tended to have weaker predictive processing due to the fact that they were less proficient in Italian. In other words, the association between literacy and prediction in spoken language processing might

not surface when multilinguals are tested in a non-native or non-dominant language, since there are too many other factors coming into play, including competing linguistic representations and child-level factors such as individual differences in language dominance (e.g., Bosch & Unsworth, 2021; Hao & Chondrogianni, 2023; Soto-Corominas, 2021).

In the analyses on the effect of reading skills we observed some unexpected effects in the (unpredictable) control condition as well as in the pre-critical time window, which might be experimental artifacts due to an uneven division of poor and good readers across the two lists, or random noise due to relatively small sample sizes. Other studies investigating effects of individual differences on experimentally elicited predictive processing should aim to avoid such confounds by carefully balancing all independent variables that will be taken into account in the analyses across experimental conditions beforehand, and by increasing the sample size.

Furthermore, future studies should aim to test predictive processing of bilingual children in both languages, as to obtain a cleaner measure of their anticipation skills. Alternatively, they might want to test anticipation based on lexical semantics rather than morphosyntax, since lexically-based prediction appears to be easier for L2 speakers than grammatically-based prediction (Clahsen & Felser, 2006; Hopp, 2015). Another promising avenue to pursue, especially in multilingual children, would be to investigate the relation between reading, linguistic prediction and non-linguistic prediction that does not require language-specific knowledge. For example, one might test whether children's anticipation of visual sequences (Bonifacci et al., 2011) or of upcoming beats in a rhythmic structure (Guasti et al., 2017; Pagliarini et al., 2020; Persici et al., 2019) are related to children's reading skills and linguistic anticipation.

Finally, since previous research suggests that predictive processing is facilitated by having strong productive and receptive vocabulary knowledge, in monolingual children (Mani & Huettig, 2012; Borovsky et al., 2012) as well as bilingual children (Bosch et al., 2022; Bosch & Foppolo, 2022), we also tested whether anticipatory eye movements of multilingual children were related to their productive vocabulary knowledge in Italian. However, we found no effects of vocabulary skills in the current study. This might be related to the fact that there was very little variation on the vocabulary test: monolingual children scored at-ceiling and multilingual children also had relatively high proficiency in comparison with previous studies, since they were all growing up in Italy and exposed to Italian from a young age.

4.3 Conclusion

This study has shown that multilingual children are able to anticipate upcoming words by relying on morphosyntactic cues in Italian, which makes their language processing very fast and efficient. Yet, multilingual participants were slightly delayed in comparison with monolingual peers, possibly because their processing may be less automatized in a non-dominant or non-native language. Moreover, monolingual and multilingual participants showed different patterns depending on the type of cue they were presented with. While we found a positive relation between reading abilities and prediction in spoken language processing for monolingual children, we failed to replicate this effect in bilingual children. A possible reason for this is that the great individual differences in language proficiency and language use among multilingual children may override any subtle effects of literacy experience. Future studies should investigate this further, by considering different types of linguistic as well as non-linguistic prediction abilities, whilst taking into account the great individual variation that characterizes child bilingualism.

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Data availability statement

The data that support the findings of this study are openly available on OSF (https://osf.io/bqu2d/?view_only=82ff2a0078654b8f8fb947c4770a591a).

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