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Predictive processing in bilingual children: effects of language dominance, cross-linguistic influence and literacy

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Summary

This thesis investigates predictive language processing in bilingual children, who have thus far received little attention in the literature on linguistic prediction. **Chapter 1** presents the overarching theoretical background and an overview of previous research. As shown by prior studies, monolingual adults and children rapidly anticipate upcoming words by relying on linguistic cues, while adult L2 processing may sometimes be less efficient. To date, only few studies have tested predictive processing in bilingual children, and the results are mixed. Moreover, the potential effects of language dominance and literacy skills have not yet been investigated. To fill these gaps, we used the visual world eye tracking paradigm to investigate to what extent different groups of bilingual children show anticipation during language processing, which factors modulate their performance, and how they compare to monolingual peers.

Chapter 2 investigates the effects of language dominance and cross-linguistic influence by testing gender processing in a varied group of Italian-German bilingual children who live either in Italy or in Germany. Specifically, we tested whether children anticipate nouns on the basis of gender-marked articles, whether they are delayed if there is a mismatch in grammatical gender between Italian and German (i.e., if they show a 'gender congruency effect'), and whether the degree of predictive processing and the strength of a gender congruency effect are influenced by children's language dominance in terms of relative language proficiency. Our results showed clear linguistic prediction in both Italian and German, although anticipation effects were stronger for children who were tested in their dominant language. In the Italian task, but not in the German task, we found a gender congruency effect, which was also modulated by children's language dominance.

Subsequently, **Chapter 3** examines whether Italian-English bilingual children make use of number agreement to anticipate upcoming words in their L1 (Italian) and in their L2 (English), and whether this is related to their L2 proficiency. In the Italian experiment, we tested anticipation of nouns based on number-marked articles, while in the English experiment, we tested anticipation based

on subject-verb number agreement. We found evidence for efficient predictive processing both in the L1 and in the L2. Moreover, children with greater vocabulary knowledge in English showed more anticipatory eye movements, suggesting that L2 processing may become more native-like when L2 proficiency increases.

Chapter 4 investigates the effect of cross-linguistic differences, by comparing predictive processing based on gender- and number-marked articles in Mandarin-Italian and Arabic-Italian bilingual children, in comparison to monolingual controls. Mandarin and Arabic differ from Italian and from each other in two respects. Firstly, in contrast to Italian and Arabic, Mandarin does not have articles. Secondly, Mandarin has number but not gender, while Arabic has both gender and number, even though these are expressed differently than in Italian. Our results show that both bilingual groups anticipated nouns based on articles, suggesting that children are able to attend to a grammatical category that does not exist in their L1 or that does not provide the same type of cue. Yet, bilingual participants showed weaker predictive processing than their monolingual peers. Moreover, Mandarin-Italian bilinguals were delayed when processing gender compared to number, while Arabic-Italians showed the opposite pattern. This suggests that bilingual children's predictive processing may be influenced by the grammatical properties of their L1.

In **Chapter 5** we compare predictive processing in monolingual Italian children and multilingual children who speak a variety of heritage languages as their L1 and Italian as the majority language, and we explore whether anticipatory eye movements are modulated by children's reading skills. Again, we found clear linguistic prediction in both groups, although monolingual participants were faster than multilingual participants. In the monolingual group, we found that anticipatory eye movements were modulated by children's reading scores, providing new evidence for a link between literacy and prediction in spoken language processing. However, we did not find any reliable effects of reading in the multilingual children, possibly because the effect of being tested in a non-native or non-dominant language may override any subtle effects of literacy experience.

Finally, **Chapter 6** provides a general discussion of our findings. In this chapter we present an integrated overview of our findings, relating them to previous research and theory. It is concluded that, similarly to monolingual children, bilingual children are able to anticipate speech based on morphosyntactic cues. Yet, sometimes they are slightly delayed in comparison with monolingual peers, depending on both language dominance and cross-linguistic influence. Limitations as well as suggestions for future research are also discussed.

Summary (Italian version)

Questa tesi indaga il fenomeno della predizione nel corso dell'elaborazione linguistica in diversi gruppi di bambini bilingui, un argomento che fino ad ora ha ricevuto poca attenzione nella letteratura sulla predizione linguistica. Il **Capitolo 1** presenta un'introduzione teorica generale sul fenomeno della predizione e una panoramica delle precedenti ricerche. Come mostrato dagli studi precedenti, adulti e bambini monolingui sono in grado di utilizzare indizi linguistici per anticipare rapidamente le parole, mentre negli adulti L2 l'elaborazione di tali indizi risulta a volte meno efficiente. Ad oggi, solo pochi studi hanno indagato l'elaborazione incrementale del linguaggio nei bambini bilingui e i risultati sono contrastanti. Inoltre, in questa popolazione non sono ancora stati indagati i potenziali effetti della dominanza linguistica e del livello di alfabetizzazione sull'abilità predittiva durante l'elaborazione incrementale del linguaggio. Al fine di colmare questa lacuna, abbiamo misurato i movimenti oculari in un contesto visivoper studiare in che misura diversi gruppi di bambini bilingui mostrino capacità di predizione durante l'elaborazione linguistica, quali fatti modulino la loro performance e come si paragonano rispetto ai coetanei monolingui.

Il **Capitolo 2** indaga gli effetti della dominanza linguistica e l'influenza cross-linguistica testando l'elaborazione del genere grammaticale in un gruppo eterogeneo di bambini bilingui italo-tedeschi che vivono in Italia o in Germania. In particolare, abbiamo indagato se i bambini bilingui anticipano i nomi sulla base della marcatura di genere sull'articolo, se l'elaborazione è ritardata quando c'è un'incongruenza di genere grammaticale tra italiano e tedesco (e.g. se mostrano un "effetto di congruenza di genere"), e se il tipo di elaborazione e la l'effetto di congruenza di genere sono predetti dalla dominanza linguistica dei bambini, misurata in termini di competenza linguistica nelle due lingue. I nostri risultati mostrano una chiara capacità di predizione linguistica sia per l'italiano che per il tedesco, sebbene la capacità di anticipazione risulti più forte nella lingua dominante. Nel test in italiano, ma non in quello in tedesco, è emerso inoltre un effetto di congruenza di genere, anch'esso modulato dalla dominanza linguistica dei bambini.

Il **Capitolo 3** esamina se i bambini bilingui sequenziali italo-inglesi sanno usare l'accordo grammaticale di numero per anticipare le successive parole nella loro L1 (italiano) e nella loro L2 (inglese), e se questo fosse legato alla loro competenza nella L2. Nell'esperimento in italiano abbiamo testato l'anticipazione dei nomi sulla base dell'informazione di numero contenuta negli articoli, mente nell'esperimento in inglese abbiamo indagato l'anticipazione sulla base dell'accordo di numero soggetto-verbo. Abbiamo trovato evidenze di un'efficiente elaborazione predittiva in entrambe le lingue. Inoltre, i bambini con un'ampiezza di vocabolario maggiore in inglese mostravano più movimenti oculari anticipatori, suggerendo che l'elaborazione incrementale nella L2 diventi più simile a quella dei parlanti nativi man mano che la competenza nella L2 aumenta.

Il **Capitolo 4** indaga gli effetti delle differenze cross-linguistiche paragonando l'elaborazione incrementale delle informazioni di genere e numero sugli articoli in bambini bilingui parlanti mandarino-italiano e arabo-italiano rispetto a controlli monolingui. Il mandarino e l'arabo si differenziano tra loro, e dall'italiano, in due aspetti. Primo, rispetto all'italiano e all'arabo, il mandarino non ha articoli. Secondo, il mandarino ha la marcatura di numero ma non di genere, mentre l'arabo ha la marcatura di genere e numero, sebbene siano espresse in modo diverso rispetto all'italiano. I nostri risultati mostrano che entrambi i gruppi bilingui anticipano i nomi sulla base degli articoli, suggerendo che i bambini sono capaci di affidarsi ad una categoria grammaticale che non esiste nella loro L1 o che non fornisce lo stesso tipo di indizi. Tuttavia, i partecipanti bilingui mostrano una capacità di predizione più debole rispetto ai coetanei monolingui. Inoltre, i bilingui mandarino-italiano elaborano le informazioni di numero prima di quelle relative al genere, mentre i bilingui arabo-italiano mostrano il pattern opposto. Questo suggerisce che l'elaborazione incrementale del linguaggio potrebbe essere influenzato dalle proprietà grammaticali della loro L1.

Nel **Capitolo 5** abbiamo comparato il processamento predittivo nei bambini monolingui italiani rispetto a bambini multilingui, che parlano diverse lingue d'origine in famiglia e l'italiano come lingua di maggioranza, e abbiamo esplorato se i movimenti oculari anticipatori siano modulati dalle abilità di lettura dei bambini. Anche qui abbiamo trovato una chiara capacità di predizione

linguistica in entrambi i gruppi, sebbene i monolingui fossero più veloci dei bambini multilingui. Nei bambini monolingui abbiamo trovato che i movimenti oculari anticipatori sono modulati dai punteggi ottenuti nella lettura, fornendo nuove evidenze al legame tra l'alfabetizzazione e la predizione nell'elaborazione incrementale del linguaggio parlato. Tuttavia, non abbiamo trovato nessun effetto affidabile delle misure di lettura nei bambini multilingue, e questo può essere dovuto al fatto che i bambini multilingui sono stati testati nella loro lingua non nativa o non dominante, rendendo meno evidente un possibile effetto dell'esperienza di alfabetizzazione sui processi predittivi.

Infine, il **Capitolo 6** fornisce una discussione generale dei nostri risultati. In questo capitolo presentiamo una panoramica integrata dei nostri risultati collegandoli con le precedenti ricerche e con gli aspetti teorici delineati nel Capitolo 1. Quello che emerge dagli studi presentati è che, analogamente ai bambini monolingui, i bambini bilingui sono in grado di anticipare il parlato sulla base di indizi morfosintattici, sebbene sia stato evidenziato un leggero ritardo rispetto ai coetanei monolingui, dovuto a un effetto di dominanza linguistica o alle influenze cross-linguistiche. In questo capitolo sono anche discussi i limiti del presente lavoro e i suggerimenti per ricerche future.

Chapter 1

General Introduction: Predictive processing and child bilingualism

Language is processed very fast and efficiently: people integrate information immediately as sentences unfold, and they rely on linguistic cues to pre-activate upcoming words (e.g., Altmann & Kamide, 1999, 2007; Federmeier, 2007; Huettig, 2015; Pickering & Gambi, 2018; Van Petten & Luka, 2012). Recent work suggests that adults are able to do this both in their first language (L1) and in a second language (L2), although L2 learners may sometimes be slower and experience cross-linguistic influence from their L1 (Kaan & Grüter, 2021). We also know that monolingual children use such anticipatory mechanisms from a very young age (Brouwer et al., 2019; Havron et al., 2019; Mani & Huettig, 2012), but to date, very few studies have investigated online language processing in bilingual children. The present thesis aims to fill this gap, by investigating predictive language processing in different groups of bilingual children, who either grew up with two languages simultaneously, or who learned their L2 during early childhood. In particular, we investigated to what extent bilingual language processing in children is affected by language dominance, cross-linguistic influence and literacy skills.

In section 1 of this chapter, we will first introduce the phenomenon of predictive processing and how this has been studied using eye tracking in a visual world context. Then, we will discuss previous studies that investigated individual variation in predictive language processing, including potential effects of literacy and differences between L1 and L2 speakers. In section 2, we will turn to the topic of child bilingualism, focusing on language dominance, cross-linguistic influence and online sentence processing. A general overview of our research questions and how they relate to the different chapters in this thesis is provided in section 3.

1. Prediction in human language processing

1.1 What is prediction?

Humans use prediction to process information about the world around them. As pointed out by Huettig (2015), people mentally prepare their next moves in a wide variety of everyday activities, such as playing the piano (Land & Furneaux, 1997), driving (Land & Lee, 1994), making tea (Land et al., 1999) and making a sandwich (Hayhoe et al., 2003). Moreover, people have been found to pre-activate their motor systems when anticipating other people's movements (Killner et al., 2006; Ramnani & Miall, 2004). With respect to language, many psycholinguists have proposed an important role of anticipation in language processing (Altmann & Mirkovic, 2009; Huettig, 2015; Pickering & Garrod, 2013). It has been proposed that, in addition to the automatic activation of lexical items through association mechanisms (i.e., *prediction-by-association*), comprehenders may anticipate upcoming utterances by activating linguistic forms in their production systems. This is referred to as *prediction-by-production*, which allows for faster and more efficient processing (Pickering & Garrod, 2013; Pickering & Gambi, 2018). This type of prediction is argued to be an optional mechanism that may facilitate processing, but it is not considered to be a prerequisite for successful comprehension (Huettig, 2015; Huettig & Mani, 2016; Pickering & Gambi, 2018).

Prediction should be distinguished from integration, even though it is difficult to fully disentangle these two mechanisms. While linguistic prediction refers to the pre-activation of upcoming language input before it is encountered, integration regards the combination of newly encountered information with a representation of the preceding language input (Abashidze et al., 2019; Mantegna et al., 2019; Pickering & Gambi, 2018). Thus, prediction involves top-down processing and programming, while integration refers to bottom-up incremental processing. Ferreira and Chantavarin (2018) propose that prediction and integration are two closely related complementary mechanisms; rather than anticipating exact words, the purpose of prediction may be

to create a 'state of preparedness' in the comprehender that facilitates the processing and integration of new information.

A large body of research has provided evidence that people anticipate upcoming words while processing sentences in their native language, both while reading texts (e.g., De Long et al., 2005; Federmeier & Kutas, 1999; Staub & Clifton, 2006) and while listening to speech (e.g., Altmann & Kamide, 1999, 2007; Lew-Williams & Fernald, 2007). In other words, regardless of modality, people tend to pre-activate representations of words before they are encountered in a sentence, which accelerates subsequent processing. They do so by relying on lexical semantic cues (Altman & Kamide, 1999; DeLong et al., 2005; Kamide et al., 2003), pragmatic cues (Foppolo & Marelli, 2017), and morphosyntactic cues such as verb tense (Altman & Kamide, 2007), case marking (Kamide et al., 2003), grammatical aspect (Bosch et al., 2021; Foppolo et al., 2021; Zhou et al., 2014) or gender and number agreement (Barber & Carreiras, 2005; Van Berkum et al., 2005).

Predictive processing occurs not only in adults but also in young children, who have been found to rely on both lexical information (Borovsky et al., 2012; Brouwer et al., 2019; Mani & Huettig, 2012; Nation et al., 2003) and grammatical cues (Brouwer et al., 2017; Havron et al., 2009; Kouider et al., 2006; Özge et al., 2019). For example, Kouider et al. (2006) found that English-speaking 2-year-olds are able to pre-select a plural noun when hearing *where are the* rather than *where is the*. Children's prediction abilities have been associated both with their offline language comprehension (Borovsky et al, 2012) and their language production skills (Mani & Huettig, 2012).

1.2 Methods to test linguistic prediction

Empirical evidence for predictive processing mostly comes from three types of experimental methods: reading studies (including eye tracking during reading and self-paced reading), electrophysiological studies and eye tracking in the visual world paradigm (Huettig, 2015).

Reading studies have shown that participants read predictable words much faster than

unpredictable words, while they slow down when they encounter unexpected information (Clifton et al., 2016; Rayner & Well, 1996; Van Berkum et al., 2005). A study by Staub and Clifton (2006) shows that this also occurs at the syntactic level, as they found faster reading times for *or*-clauses when they were preceded by an *either*-clause. However, it should be noted that it is difficult to disentangle prediction from integration in this type of studies (Pickering & Gambi, 2018).

In electrophysiological studies, participants read or listen to sentences which are manipulated for predictability, while their brain activity is recorded (Kutas et al., 2011). Words with a high Cloze-probability (i.e., words that are semantically predictable within a certain sentence context) typically elicit a weaker N400, a negative ERP component which peaks at approximately 400 ms after stimulus onset (DeLong et al., 2005; Van Berkum et al., 2005; Van Petten & Luka, 2005). Moreover, grammatical violations typically elicit a P600, a positive ERP component that peaks at around 600 ms from stimulus onset (Barber & Carreiras, 2005; Friederici et al., 1996; Wicha et al., 2004). For example, Wicha et al. (2004) recorded ERPs while Spanish speakers read sentences that were manipulated for both semantic predictability and grammaticality; i.e., nouns were either expected or unexpected based on the sentence meaning, and they were preceded by an article that either matched or mismatched in grammatical gender. They found that semantically unexpected nouns elicited an N400, while gender-disagreeing nouns and articles that were unexpected based on the sentence context elicited a P600. Moreover, these effects interacted with each other, leading to larger N400 and P600 effects for double violations.

Further evidence for predictive processing is provided by language-mediated anticipatory eye movements in studies using the *visual world paradigm* (Altmann & Kamide, 1999, 2007; Kamide et al., 2003; Mani & Huettig, 2012). In this method, participants listen to sentences as they are looking at a visual scene, while their eye movements are being recorded to measure visual attention during language processing. The visual world paradigm has been consolidated as a sensitive method to study online language comprehension, which has shown that people incrementally integrate visual and auditory input by moving their gaze toward an object as soon as the relevant word is mentioned

(Eberhard et al., 1995; Sedivy et al., 1999; Tanenhaus et al., 1995). Altmann and Kamide (1999) extended this finding by showing that speech is not only processed incrementally, but also predictively: when participants heard the sentence *The boy will eat the cake* while looking at a picture displaying a boy, a cake and some toys, they started directing their gaze toward the cake as soon as they heard the verb *eat.* In other words, anticipatory eye movements revealed that participants pre-activated the noun based on the lexical semantics of the verb (see also Kamide et al., 2003). Moreover, Altmann and Kamide (2007) showed that anticipatory eye movements also occurred based on morphosyntactic cues. For example, participants were presented with a scenario containing a full glass of beer and an empty wine glass, while they listened to sentence *The man will drink…* or *The man has drunk…* Their results showed that participants started looking at the relevant picture (i.e., the full or the empty glass, respectively) upon hearing *will* or *has*, indicating that the verb tense elicited pre-activation of the target noun.

An advantage of the visual world paradigm is that it can also be used with young children and with people with limited reading abilities. Moreover, when there is enough time in between the predictive cue and the disambiguating cue, it allows us to disentangle predictive processing from facilitation effects during sentence integration. In the current thesis, we therefore used the visual world paradigm to test to what extent bilingual and monolingual children show prediction during online sentence processing.

1.3 Individual variation in prediction

While prediction may be an important 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). Even within individuals there is a lot of variation: in a visual world paradigm, participants are less likely to anticipate upcoming words when they have less time to explore the visual display (Ferreira et al., 2013; Huettig & Guerra, 2019), when the speech input is

presented at a faster rate (Huettig & Guerra, 2019), and when concurrent working memory load is increased (Ito et al., 2018; see Kaan & Grüter, 2021).

Moreover, some groups, such as young children and older adults, but also L2 speakers and people with poor literacy, tend to predict considerably less than the population of healthy, young, monolingual adults that typically participate in psycholinguistic experiments (Brouwer et al., 2019; Federmeier et al., 2010; Mani & Huettig, 2012; Mishra et al., 2012; Pickering & Gambi, 2018). In this section, we will discuss individual variation in linguistic prediction, focusing on the effects of literacy skills and on the difference between L1 and L2 processing.

1.3.1 Potential effects of literacy

Humans are genetically predisposed to acquire and use spoken language, but literacy is a relatively new cultural invention, which may nevertheless have profound effects on human cognition. Experience with reading and writing affects the way in which we process language in several ways, and these altered processing mechanisms may transfer into the modality of spoken language (Huettig & Mishra, 2014). Specifically, it has been hypothesized that literacy improves people's ability to anticipate upcoming words while reading text or listening to speech, making language processing particularly fast and efficient. In skilled readers, the pace of processing written text is much faster than the pace of processing spoken language, which is by definition limited to the rate of speaking. In contrast, reading is self-paced, which encourages readers to anticipate upcoming words in order to be as fast as possible (Huettig & Pickering, 2019).

There are several factors inherent to reading that may boost predictive processing. 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, Reichle & Laurent, 2006). Secondly, while listeners have to wait for each phoneme to unfold, skilled readers can process multiple letters simultaneously (Bertram & Hyona, 2003;

Dehaene, 2009), which allows for faster prediction based on the relations between individual words. Finally, 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. 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).

In addition to this primary effect of reading, the association between reading and prediction may be explained by secondary correlates of literacy, such as vocabulary knowledge (Huettig & Pickering, 2019). Several studies report associations between children's lexical knowledge and their reading performance (Bosch et al., submitted; Cain & Oakhill, 2011; Ouellette, 2006; Proctor et al., 2005; Verhoeven et al., 2011; Verhoeven, 2000). On the one hand, stronger vocabulary skills aid children as they learn to read. On the other hand, since rare words are more likely to be encountered in books than in everyday conversation (Cunningham & Stanovich, 1998), reading experience greatly increases vocabulary size. Literacy also seems to lead to more sophisticated associative lexical networks (Seidenberg, 2005) and improved depth of word understanding (Andrews, 2008). Visual world eye tracking studies with children (Mani & Huettig, 2012; Borovsky et al., 2012; Nation et al., 2003) and adults (Hintz et al., 2017; Rommers et al., 2015) suggest that increased vocabulary knowledge facilitates the anticipation of spoken language. In other words, reading acquisition may be closely related to vocabulary development, which may in turn facilitate predictive processing.

Moreover, literacy provides additional graphemic representations, and it sharpens pre-existing representations that are shared in reading and listening, including lexical, syntactic and phonemic representations (Huettig & Pickering, 2019). The fact that words in written text are separated by spaces contributes to the sharpening of lexical representations, since it creates a word bias that is not present in a continuous speech stream. Building more fine-grained linguistic representations and additional graphemic representations leads to the formation of new neural connections (Ehri, 2014), which allows for faster and more precise predictive processing (DeHaene

et al., 2010). This process may be supported by improved phonological awareness resulting from literacy (e.g., Morais et al., 1979; Kolinsky & Morais, 2018), which makes words and morphemes more salient (Huettig & Pickering, 2019).

Considering that linguistic prediction has been observed in preliterate children (Mani & Huettig, 2012; Borovsky et al., 2012), literacy is not a prerequisite for predictive processing. However, several studies have observed a relation between reading skills and predictive processing of spoken language, by focusing on children at the early stages of literacy acquisition (Mani & Huettig, 2014), 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). In Chapter 5 we will provide a more detailed overview of empirical studies on the relation between reading and prediction.

Thus, reading experience may boost predictive processing, and reading acquisition may facilitate linguistic prediction through improved linguistic representations as well as stronger vocabulary knowledge. It is still unclear, however, to what extent the relation between reading and prediction can also be observed in bilingual or multilingual speakers, who might have weaker vocabulary skills and show less prediction when tested in their non-native or non-dominant language. The next section will discuss previous studies on L2 predictive processing.

1.3.2 Prediction in L1 versus L2 processing

During the last decades, the difference between L1 and L2 processing in adults has been the focus of a great number of studies. These studies have shown that even at high proficiency levels and with target-like production and comprehension, differences in language processing may still be observed (Liu & Cao, 2016; Nicol, 2001). While early studies failed to find any evidence for linguistic prediction in L2 learners (Grüter et al., 2012; Lew-Williams & Fernald, 2010; Martin et al., 2003), there is now a general consensus that predictive processing occurs also in the L2 (Kaan & Grüter,

2021). However, depending on the linguistic domain, language 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; Hopp & Lemmerth, 2018; Kaan & Grüter, 2021; Morales et al., 2016).

An important factor that may account for L1-L2 differences in prediction is automaticity (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2005), which can be defined in terms of awareness, intentionality, controllability and efficiency (Bargh, 1994; Garrod & Pickering, 2007). Linguistic prediction has been hypothesized to involve both automatic and non-automatic processes (Ito & Pickering, 2021). For example, prediction-by-association is largely automatic, since it happens without conscious awareness, intent or controllability, and without taxing cognitive resources. In comparison, prediction-by-production seems to be less automatic, especially with respect to efficiency, since predictive language processing has been shown to be modulated by cognitive load (Ito et al., 2018). Assuming that prediction is partly non-automatic, L2 speakers may not always have enough cognitive resources to make linguistic predictions, since L2 processing tends to be more resource-demanding (i.e., less efficient) than L1 processing (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2005). Specifically, L2 speakers may need more time and effort to access lexical representations and compute syntactic meaning, and they may experience interference from competing L1 representations (Chambers & Cooke, 2009; Morales et al., 2016). It may be particularly resource-demanding for L2 speakers to process features that are absent in their L1, because they cannot transfer rules or linguistic representations. Consequently, L2 speakers seem to be less likely to use prediction when processing L2-specific features as compared to features that are shared between their L1 and L2 (Van Bergen & Flecken, 2017; Dussias et al., 2013; Foucart & Frenck-Mestre, 2011; Frenck-Mestre et al., 2019; Hopp & Lemmerth, 2018).

Through extensive practice, L2 processing may become more automatized, leading to a decrease in working memory load and faster processing (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2005; Ullman, 2001). Several studies suggest that high-proficiency L2 speakers tend to

make more use of predictive processing than low-proficiency L2 speakers, and that they may eventually reach native-like processing, even when it comes to L2-specific linguistic features (Dussias et al., 2013; Hopp, 2013; Hopp & Lemmerth, 2018). However, other studies found no correlation between proficiency and predictive processing (Hopp, 2015; Ito et al., 2018; Kim & Grüter, 2021; Perdomo & Kaan, 2021), suggesting that high proficiency does not automatically imply more predictive processing. As pointed out by Kaan and Grüter (2021), the use of prediction during language processing may be modulated by the degree of utility (see also Kuperberg & Jaeger, 2016). Assuming that prediction is an optional mechanism, its utility for language comprehension may depend on the speaker's linguistic experience, task demands, the reliability of the predictive cues and available cognitive resources. As such, L2 speakers may differ from L1 speakers and from each other, as they adapt their strategies to optimize processing efficiency in a certain context (Kaan & Grüter, 2021).

Furthermore, prediction in L2 processing differs across linguistic domains (Ito & Pickering, 2021). While a large number of studies report evidence for prediction based on semantic information (e.g., Chambers & Cooke, 2009; Chun & Kaan, 2019; Dijkgraaf et al., 2017; Ito et al., 2018), the results are mixed with respect to prediction based on syntactic cues (Foucart & Frenck-Mestre, 2011, 2012; Hopp, 2013; Lew-Williams & Fernald, 2010; Mitsugi & MacWhinney, 2016). In a direct comparison between syntactic and semantic prediction, Hopp (2015) found that L2 speakers of German pre-activated upcoming referents by making use of semantic information, while they failed to make predictive use of case marking. This is in line with the proposal of Clahsen and Felser (2006; 2018), who claim that L2 speakers may rely more heavily on lexical elements rather than on grammatical cues, due to shallower and less detailed syntactic representations (Clahsen & Felser, 2006; 2018).

In sum, adult L2 speakers sometimes make less use of prediction than L1 speakers, possibly due to less automatized processing and a focus on meaning over form. This may be modulated by various factors, including language proficiency, cross-linguistic differences and considerations of

utility. Given that there are important differences between children and adults, both at the neurobiological level (Birdsong, 2018; Perani & Abutalebi, 2005) and and with respect to L2 teaching approaches and learning environments (Lichtman, 2013), children who are learning an L2 might achieve more automatized and native-like processing than adults (Ullman, 2001). However, predictive processing in child L2 learners has to our knowledge not yet been investigated. To date, only three studies have investigated predictive processing in early bilingual children, leading to mixed results (Brouwer et al., 2017; Lemmerth & Hopp, 2019; Meir et al., 2020). Before discussing these studies in detail, we will provide some background about child bilingualism and previous studies on language processing in bilingual children.

2. Child bilingualism

2.1 Defining child bilingualism

Bilingual children, who grow up speaking more than one language during childhood, offer a particularly interesting window to human language processing. While their cognitive and linguistic developmental trajectories are similar to those of monolingual children (Nicoladis & Genesee, 1997), they differ in that they acquire more than one linguistic system. As a natural consequence of being exposed to two languages, bilingual children do not receive the same amount of input in each language as monolingual peers, leading to great individual differences in language use and proficiency (Armon-Lotem & Meir, 2019; Unsworth, 2013a). Moreover, the presence of two languages in one mind may lead to cross-linguistic influence, which we will elaborate on below.

We should distinguish between different types of child bilingualism (or *multilingualism,* to include children who speak more than two languages). Firstly, children who are exposed to two languages from birth or shortly thereafter are called *simultaneous bilinguals* (De Houwer, 2009; Unsworth, 2013a). These children typically grow up in families or communities in which two

languages are spoken. The language acquisition of simultaneous bilinguals is sometimes also referred to as *bilingual first language acquisition*. Secondly, when the L2 is introduced after children started learning their L1, with the native language system being already partly in place, they are called *sequential bilinguals* or *successive bilinguals* (Chondrogianni, 2018). These children may come from families with a migration background, and they learn the language of the country in which they live (also referred to as the *majority language* or *societal language*) in addition to the language of their family (also referred to as the *minority language* or *heritage language*). Their first exposure to the majority language typically coincides with the moment in which they enter daycare or kindergarten, or the moment in which their family moves from their country of origin. The group 'sequential bilingual children' includes *early successive bilinguals*, who are first exposed to their L2 as toddlers, and *child L2 learners*, whose first exposure to the L2 may be at a later point during childhood. Previous studies have defined the exact boundaries between these categories in many different ways, but in the present thesis, we will use the term 'simultaneous bilinguals' to refer to children who are exposed to both languages from birth (following De Houwer, 2009), 'early successive bilinguals' for children who are first exposed to their L2 before the age of 4 (following Genesee et al., 2004; Van Dijk et al., 2021), 'child L2 learners' for children who start learning the L2 between the ages of 4 and 7 approximately (following Chondrogianni, 2018; Meisel, 2009), and 'successive bilinguals' or 'sequential bilinguals' as umbrella terms that encompass both early successive bilinguals and child L2 learners. The term 'multilinguals' will be used when referring to a group of children that includes children who speak three or more languages.

In what follows, we will first introduce the concepts of language dominance and cross-linguistic influence, which are both fundamental when studying child bilingualism. After that, we will discuss previous studies on language processing in bilingual children, with a specific focus on linguistic prediction.

2.2 Language dominance

Child bilingualism is characterized by large variation in patterns of language use and relative language proficiency. Most bilingual children speak one language better than the other, due to more frequent use or differences in exposure. This phenomenon is referred to as *language dominance* (Treffers-Daller, 2019; Unsworth, 2013a). When bilingual children are assessed in their dominant language, they typically do not differ much from their monolingual peers in terms of linguistic abilities. However, with respect to the weaker, less dominant language, there may be great individual differences among bilingual children, depending on the quantity and quality of the input and the specific context in which they grow up (De Houwer, 2009).

The dominant language of bilingual children can change over time, for example when their daily language input changes as they start attending school (Oppenheim et al., 2020; Yip & Matthews, 2007). In general, bilingual children eventually tend to become dominant in the societal language of the country in which they live. This is especially the case for so-called 'heritage speakers' who speak a minority language at home (Oppenheim et al., 2020).

Language dominance may be operationalized in two different ways, i.e., in terms of exposure and language use, or in terms of relative language proficiency (Treffers-Daller & Silva-Corvalan, 2016; Unsworth, 2013a). Language exposure and use are typically assessed through parental questionnaires, but it may also be assessed directly by analyzing the frequency of utterances in recorded parent-child interactions. Language proficiency may be assessed by computing measures such as the mean length of utterances in each language, or by using standardized tests of language proficiency (typically, vocabulary knowledge). These different measures may then be used to calculate a balance score indicating language dominance, by subtracting scores obtained in one language from those obtained in the other one (Bedore et al., 2012; Bosch & Unsworth, 2021; Cantone et al., 2008; Pérez-Leroux et al., 2011; Unsworth, 2013a).

Previous research suggests that language dominance may also influence the way in which the

two languages of a bilingual child interact during language development and during language processing (Bosch & Unsworth, 2021; van Dijk et al., 2021; Hervé et al., 2016; Unsworth et al., 2014; Unsworth, 2016; Yip & Matthews, 2007). Specifically, the dominant language seems to be more likely to influence the weaker language than vice versa. The exact ways in which two languages may interact during bilingual language development will be discussed next.

2.3 Cross-linguistic influence

Considering that the languages of a bilingual child do not develop in isolation from each other, they may influence each other in different ways. For example, an Italian-English bilingual child might produce an utterance such as *I have 5 years old* in English, since the verb 'to have' would be used for this construction in Italian (i.e., *ho 5 anni*) (see Nicoladis, 2019). Such cross-linguistic influence may occur at the level of syntax, morphology, phonology and the lexicon, in simultaneous bilinguals (Nicoladis, 2018; Serratrice, 2013) as well as in sequential bilinguals (Chondrogianni, 2018; Unsworth, 2016). In child L2 learners, the L2 tends to be influenced by properties of the L1, and the degree of cross-linguistic influence has been found to be related to children's age of L2 onset (Chondrogianni, 2018; Unsworth, 2016). In contrast, in simultaneous and early successive bilinguals cross-linguistic influence is more likely to be bidirectional (Nicoladis, 2012; Zhou et al., 2021), although this may depend on children's language dominance (Herve et al., 2016; Unsworth et al., 2014). It should be emphasized, however, that cross-linguistic influence does not imply confusion: even simultaneous bilingual children are able to differentiate their languages from very early in development (De Houwer, 2009; Nicoladis & Genesee, 1996), and cross-linguistic influence is only observed in a small minority of instances (Nicoladis, 2018). Moreover, there is great individual variation, with some bilingual children showing much more cross-linguistic influence than others (Gathercole. 2007; Serratrice, 2013).

In a recent meta-analysis of 26 experimental studies on 750 simultaneous and early successive

bilingual children, van Dijk et al. (2021) found a significant small to moderate average effect size of morphosyntactic cross-linguistic influence, indicating that it is 'part and parcel of bilingual development'. Moreover, children who were tested in the majority language of their country of residence showed significantly stronger cross-linguistic influence (suggesting an important role of dominance), but there were no effects of children's age, the linguistic domain tested and surface overlap between the two languages (suggesting that cross-linguistic influence may be persistent and that it may occur in a wide range of linguistic contexts).

Cross-linguistic influence often manifests itself as an overuse of a structure that is present in both languages, leading to utterances that are grammatically correct yet different from those of monolingual peers. For example, Italian-English bilingual children have been found to overuse overt pronouns in Italian under the influence of English (Serratrice et al., 2004). However, cross-linguistic influence may in some cases also lead to qualitatively different linguistic structures, such as word orders that are taken from the other language (Nicoladis, 2012; Strik & Pérez-Leroux, 2011; Unsworth, 2016). It has been hypothesized that this type of cross-linguistic influence is a by-product of the co-activation of two languages during bilingual processing, which leads to a competition between two linguistic forms at the lemma level of speech production (i.e., when the lexical and grammatical forms are selected to convey a previously established conceptual message, before its phonetic realization) (Nicoladis, 2006; 2012).

In addition to the transfer of linguistic structures due to lexical co-activation, cross-linguistic influence may lead to delays as well as accelerations in developmental patterns (Paradis & Genesee, 1996), depending on the properties of the two languages involved with respect to the linguistic phenomenon under investigation. For example, Kupisch (2007) observed that Italian-German simultaneous bilingual children used articles in German earlier than monolingual German children, which is argued to be due to positive transfer from Italian, which has a less complex and earlier-acquired article system than German. This facilitation effect occurred for Italian-dominant and balanced bilingual children, but not for German-dominant children.

Bilingual children do not only show cross-linguistic influence during language production, but also in their language comprehension and judgements (Bosch & Unsworth, 2020; Meroni et al., 2017; Serratrice, 2007). For example, Serratrice (2007) investigated pronoun resolution in Italian-English bilingual children. When hearing the sentence *Il portiere saluta il postino, mentre lui apre la porta* 'The porter greets the postman, while he opens the door', bilingual children differed in their interpretation of who opened the door. While in Italian the most likely co-referent is the object (i.e., the postman), in English the subject would be preferred (i.e., the porter), and as a result, Italian-English bilingual children were more likely to accept overt subject pronouns as being co-referents of a subject antecedent.

While a great number of studies have provided evidence for cross-linguistic influence in bilingual children's production, research focusing on comprehension is relatively scarce. Moreover, even fewer studies have focused on cross-linguistic influence during online sentence processing, which will be addressed in the following section.

2.4 Language processing in bilingual children

Traditionally, most studies on monolingual and bilingual language acquisition have used offline experiments to test children's language comprehension. For example, researchers would present children with a sentence and ask them to select a matching picture. However, this does not inform us about the real-time processing of language input, as it gives children the time to use their metalinguistic abilities and explicit language knowledge before giving their response. In contrast, online methods, such as self-paced listening/reading, word monitoring, cross-modal priming, EEG or eye tracking in the visual world paradigm, tap directly into children's implicit and automatized linguistic skills (Marinis, 2010).

Most studies that have investigated language processing in bilingual children have compared the processing abilities of sequential bilinguals to those of monolingual peers. Many of these studies

found that bilingual children were as sensitive to grammatical morphemes as monolingual children, even when they showed difficulties in production (Chondrogianni & Marinis, 2012; Chondrogianni, Marinis et al., 2015; Chondrogianni, Vasić et al., 2015; Marinis, 2007). For example, using an online word monitoring task, Chondrogianni and Marinis (2012) found that Turkish child L2 learners of English were fully aware of the ungrammaticality of omitting tense morphemes, even though their production of tense morphology was variable. However, others found delayed processing or reduced sensitivity with respect to a certain grammatical property (Blom & Vasić, 2011; Marinis & Saddy, 2013). Blom and Vasić (2011), for example, found that Turkish child L2 learners of Dutch only noticed incorrect gender agreement in a self-paced listening task if gender was overtly marked on the noun.

Furthermore, a limited number of studies have used online methods to study cross-linguistic influence in bilingual children. Some studies have focused on lexical co-activation in simultaneous or early successive bilingual children (Koutamanis et al., 2021; Von Holzen & Mani, 2012). For example, Koutamanis et al. (2021) tested whether 4- to 9-year-old Dutch-Greek bilingual children could be primed in their recognition of Dutch nouns (e.g. *rok* 'skirt') by briefly presenting them with Greek words that were phonologically similar (e.g., *roda* 'wheel'), by Greek translation equivalents (e.g., *fousta* 'skirt') or by Greek words whose translation equivalent in Dutch was phonologically similar to the target word (e.g., *vrachos* 'rock' - *rots* in Dutch), in comparison to unrelated primes. Their results showed priming effects in all critical conditions, providing evidence for an integrated bilingual lexicon, as well as cross-linguistic influence during lexical processing at the level of phonology and semantics (corroborating previous work on bilingual toddlers by Von Holzen & Mani, 2012).

Recently, a few studies have also used online methods to test cross-linguistic influence during sentence processing at the level of (morpho)syntax, focusing on word order (van Dijk et al., 2022), pronouns (van Dijk, 2021) and grammatical gender (Lemmerth & Hopp, 2019). In particular, Lemmerth and Hopp (2019) investigated cross-linguistic influence during predictive processing of

nouns based on gender-marked articles and adjectives in Russian-German bilingual children. This study will be described in detail in the next section, which addresses predictive processing in bilingual children.

2.4.1 Prediction in bilingual children

Whereas 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). The study of prediction in bilingual children has the potential to provide new insights about bilingual language processing and the underlying mechanisms of linguistic prediction itself, since the great individual variation in language dominance allows us to test effects of individual differences. Moreover, when bilingual children develop both languages more or less in parallel, we may expect bidirectional cross-linguistic influence during language processing (Karaca et al, 2021). To date, only a few studies have investigated predictive processing in bilingual children, and these have reported mixed results.

Bonifacci et al. (2011) investigated non-linguistic anticipation in bilingual children. Aiming to test potential bilingual advantage effects in executive functions, they presented 4- and 5-year-old bilingual and monolingual children with a series of nonverbal cognitive tasks. One of these tasks was a color-sequence learning paradigm, in which children first learned a sequence of colors, after which they were tested on their ability to anticipate the next color. Their results showed faster and more accurate anticipation in bilingual children, even though there were no differences in other tasks measuring reaction times, inhibition and working memory. The authors argued that this advantage might be due to the fact that bilingual children have practice anticipating upcoming elements in a sentence in more than one language, which may have boosted their prediction skills.

The first to investigate linguistic prediction in bilingual children were Brouwer et al. (2017), who used a visual world eye tracking paradigm similar to the one used by Mani and Huettig (2012)

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. Prediction abilities in bilingual children were positively correlated with their performance on a forward digit span task (i.e., verbal working memory), but not with their scores on a more complex backward digit span task, an inhibition task or a Dutch vocabulary test, and no correlations were found for monolingual children.

Furthermore, Meir et al. (2020) tested predictive processing and production of case morphology in Russian-Hebrew simultaneous and early successive bilingual children (aged 4-8) growing up in Israel, as well as in monolingual Russian- and Hebrew-speaking children (aged 3-6 and 4-7, respectively). Russian and Hebrew both have case, but they differ in the way in which this is expressed morphologically: while Russian case marking is highly reliable and provides multiple cues on nouns and adjectives, case morphology in Hebrew is relatively impoverished and less reliable (specifically, the accusative marker is used only with definite nouns). As a result, monolingual Russian-speaking children were at-ceiling in production of accusative case, and in a visual world paradigm they showed rapid anticipation of argument structure based on case markers. In contrast, monolingual Hebrew-speaking children failed to show any sensitivity to case marking during sentence processing, despite at-ceiling performance in a production task. Russian-Hebrew bilingual children differed from their monolingual peers in several ways. Firstly, their accuracy in production was significantly lower in both languages. With respect to processing, bilingual participants used case morphology in Russian predictively, but they were significantly slower than monolingual children. Crucially, however, unlike monolingual Hebrew-speaking children, they also anticipated argument structure based on case marking in Hebrew. This suggests that processing strategies in the two languages interact, and that weak predictive cues in one language may be reinforced when stronger

cues are available in the other language.

A third study that provides evidence for linguistic prediction in bilingual children was conducted by Lemmerth and Hopp (2019), who tested 8- and 9-year-old simultaneous and early successive Russian-German bilingual children growing up in Germany, in comparison to age-matched monolingual German children. Using a visual world paradigm, they tested children's ability to anticipate upcoming nouns on the basis of gender marking on articles and adjectives in German. German and Russian have similar grammatical gender systems, but they differ in the way in which gender is expressed. The authors aimed to test the effect of cross-linguistic differences in two different ways. Firstly, they manipulated the 'gender congruency' of the nouns tested (i.e., they compared nouns that have the same gender in Russian and German to nouns for which there is a mismatch in gender). Secondly, they compared gender-marked articles (which are absent in Russian) to gender-marked adjectives (which are present in both languages). With respect to the effect of gender congruency, their results showed that simultaneous bilingual children and monolingual German children anticipated nouns based on gender cues, while early successive bilingual children failed to do so when there was a mismatch in grammatical gender with the Russian translation equivalent. Lemmerth and Hopp argue that the asynchronous acquisition in successive bilinguals allows for cross-linguistic influence, as the L2 gender is initially accessed through the L1 lexicon. However, they found no differences between articles and adjectives, suggesting that syntactic cross-linguistic differences did not affect children's processing. Different aspects of this study will be discussed in more detail in Chapter 2 and 4.

To summarize, the few previous 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., Brouwer et al., 2017; the Hebrew task in Meir et al., 2020), while in other cases their processing was delayed (i.e., the Russian task in Meir et al., 2020; the successive bilinguals in Lemmerth and Hopp, 2019), or there was no difference (i.e., the simultaneous bilinguals in Lemmerth and Hopp, 2019). Cross-linguistic differences and similarities

appear to play an important role, which may either facilitate or impede predictive processing. It should be noted, however, that all three studies focused on simultaneous or early successive bilingualism, while predictive processing in child L2 learners has not yet been investigated. Moreover, the effect of language dominance still remains unexplored. The present thesis aims to fill these gaps. In the next section we will present our research questions and provide an outline of the different chapters.

3. Thesis outline

The aim of this thesis is to investigate predictive language processing in different groups of bilingual children, focusing on different language pairs and various educational settings. We created five visual world eye tracking experiments in three languages (Italian, German and English), in which we tested whether children would anticipate nouns on the basis of gender or number agreement. In total we tested 234 children between the ages of 6 and 12, who were either simultaneous bilinguals, sequential bilinguals, or monolingual Italian children.

Our main research questions are as follows:

1. To what extent do simultaneous and sequential bilingual children make use of predictive language processing based on morphosyntactic cues, and how do they compare to monolingual peers?
2. What is the effect of language dominance and proficiency?
3. Do bilingual children experience cross-linguistic influence during predictive processing?
4. Is predictive processing in bilingual and monolingual children related to their literacy skills?

In **Chapter 2**, we will first explore the effects of language dominance and cross-linguistic influence, by investigating gender processing in Italian and German in Italian-German simultaneous and sequential bilingual children who are growing up either in Italy or in Germany. Specifically, we test whether children experience a 'gender congruency effect' when they process words for which

there is a mismatch in grammatical gender across their two languages. In **Chapter 3**, we will examine L1 and L2 processing, and whether these are influenced by language proficiency, by testing prediction based on number cues in Italian and English in a group of native Italian-speaking children who acquire English in a bilingual school. Subsequently, in **Chapter 4**, we will test the effect of linguistic differences, by comparing gender and number processing in Italian in Mandarin-Italian and Arabic-Italian sequential bilingual children versus monolingual Italian controls. Arabic has both grammatical gender and number, but these are expressed differently than in Italian, while Mandarin has number but not gender and no articles. This allows us to test to what extent the presence of grammatical cues in the L1 may facilitate predictive processing in the L2. After that, **Chapter 5** will address the question of whether predictive processing in multilingual and monolingual children is related to their reading skills as well as their vocabulary knowledge. The multilingual children in this study all speak Italian as the societal language in addition to a wide variety of heritage languages. Finally, in **Chapter 6** we will conclude with a general discussion of our findings and suggestions for future research.

Chapter 2

Predictive processing of grammatical gender in Italian-German bilingual children[1]

Abstract: The present study investigates linguistic prediction based on grammatical gender in Italian-German bilingual children between the ages of 6 and 10, 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

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1. Introduction

As we discussed in the previous chapter, 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 (Brouwer et al., 2017; 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 3 and at-ceiling performance by the age of 4, 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 3 (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 primary school children (Cholewa et al., 2019) and Dutch-speaking kindergartners (Brouwer et al., 2017). Moreover, studies with Spanish and French monolingual infants suggest that children are able to rapidly integrate such gender cues to facilitate subsequent processing from the ages of 2 or 3, 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) and they 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, 2008, 2013b; Cornips & Hulk, 2008).

Research on processing of gender in bilingual children is still scarce, but the one study that has been conducted so far suggests that bilingual children, like monolingual children, are sensitive to

gender cues (Lemmerth & Hopp, 2019). Yet, early successive bilingual children appear to be less likely to anticipate nouns that have another grammatical 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 4), and 15 monolingual German children, aged 8 to 9 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 further exploring the possible effects of language dominance in the processing of gender in bilingual children. 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.

We also extended the question of whether bilingual children show a gender congruency effect to a new language pair, namely German and Italian. Differently from the language pair tested by Lemmerth and Hopp, the languages selected in our study have similar morphosyntactic manifestations of gender agreement in the sentence. Specifically, in both languages, determiners preceding nouns carry gender agreement, and thus they might be experimentally manipulated and exploited by participants as morphological cues during incremental sentence processing. Albeit with some differences in the implementation, our study employs a similar paradigm as Lemmerth and Hopp's: we recorded participants' eye-movements during the online incremental interpretation of

sentences in a visual world paradigm, with a specific lens on the determiner region. To better understand the rationale of the study, we will first provide a description of the two gender systems in Italian and German, and of the way gender is marked on articles in the two languages.

2.3 Grammatical gender in Italian and German

2.3.1 The Italian gender system

Italian has 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*$_{\text{MASC}}$ 'boy' and *bambina*$_{\text{FEM}}$ 'girl'). We can outline some phonological regularities in the gender classification of nouns in Italian; the majority of masculine singular nouns end in *-o* (e.g., *libro*$_{\text{MASC}}$ 'book'), while the majority of feminine singular nouns end in *-a* (e.g., *matita*$_{\text{FEM}}$ 'pencil') (approximately 70% of all words). There are, however, also many exceptions (e.g., *moto*$_{\text{FEM}}$ 'motorbike'; *poema*$_{\text{MASC}}$ 'poem'). In addition, there is a subclass of nouns ending in *-e*, which may be either masculine or feminine (e.g., *noce*$_{\text{FEM}}$, 'nut'; *sole*$_{\text{MASC}}$, '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.	*il libro*	b.	*la matita*
	the$_{\text{MASC}}$ book$_{\text{MASC}}$		the$_{\text{FEM}}$ pencil$_{\text{FEM}}$
c.	*il sole*	d.	*la noce*
	the$_{\text{MASC}}$ sun$_{\text{MASC}}$		the$_{\text{FEM}}$ nut$_{\text{FEM}}$
e.	*il collega*	f.	*la collega*
	the$_{\text{MASC}}$ colleague$_{\text{FEM}}$		the$_{\text{FEM}}$ colleague$_{\text{MASC}}$

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*$_{\text{MASC}}$ and *l'amica*$_{\text{FEM}}$ 'the friend'). Note that articles are not the only elements in the sentence that are marked for 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.

2.3.2 The German gender system

German has a tripartite gender system, distinguishing between masculine, feminine and neuter gender (Durrel, 2011). German gender also follows biological gender (e.g. *Mutter*$_{\text{FEM}}$ 'mother' and *Vater*$_{\text{MASC}}$ *'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*$_{\text{MASC}}$ '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*$_{\text{FEM.}}$ *Frau*$_{\text{FEM.SG}}$ 'the woman' versus *die*$_{\text{PL}}$ *Kinder*$_{\text{NEUT.PL}}$ '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*$_{\text{MASC}}$, *die*$_{\text{FEM}}$ and *das*$_{\text{NEUT}}$). 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$_{\text{MASC}}$ pencil$_{\text{MASC}}$
b. *die Sonne*
   the$_{\text{FEM}}$ sun$_{\text{FEM}}$
c. *das Buch*
   the$_{\text{NEUT}}$ book$_{\text{NEUT}}$

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 either in Italy or in 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 values of the target and competitor do not overlap. However, given that the efficiency of linguistic anticipation has been related to proficiency in bilingual speakers (Dussias et al., 2013; Henry et al., 2020; Hopp & Lemmerth, 2018), we expect that predictive processing may be faster 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 show stronger 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 6 and 10. 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, Carroll and Vivas (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 6 and had at least two years of exposure to both languages 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)[2]
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% sequential (L2 German) (M_{Onset} = 3;00, SD = 1;07) 10% missing survey data	65.5% simultaneous 11.5% sequential (L2 German) (M_{Onset} = 5;00, SD = 1;00) 11.5% sequential (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

3.2.1 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 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).

[2] 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.

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*$_{\text{FEM}}$*, la forchetta*$_{\text{FEM}}$) and in German (*die Möhre*$_{\text{FEM}}$, *die Gabel*$_{\text{FEM}}$). 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*$_{\text{FEM}}$*, il fungo*$_{\text{MASC}}$) and German (*die Erdbeere*$_{\text{FEM}}$*, der Pilz*$_{\text{MASC}}$). 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*$_{\text{MASC}}$) but feminine in German (*die Maus*$_{\text{FEM}}$); 'butterfly' is feminine in Italian (*la farfalla*$_{\text{FEM}}$) and masculine in German (*der Schmetterling*$_{\text{MASC}}$). An overview of the items used in the Italian and the German experiment is provided in Appendix 1 and 2, respectively.

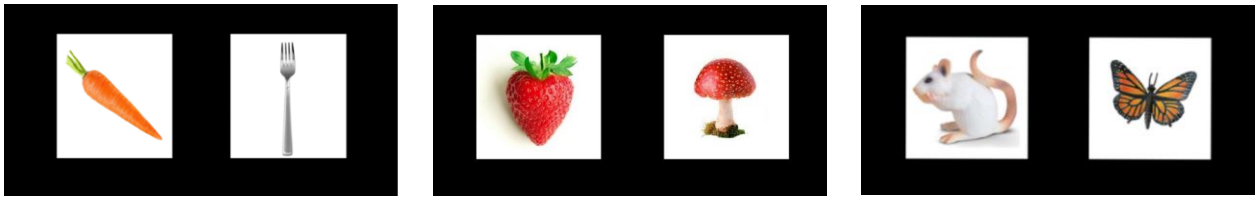

Figure 1. Example of visual displays in the three experimental conditions. From left to right: No prediction condition; Prediction/Congruent condition; Prediction/Incongruent condition.

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.

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.

3.2.2 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 *lme*4 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 (even though there were also some Italian-dominant children in the sample), while participants resident in Italy were Italian-dominant.

4.2 Eye tracking

4.2.1 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.

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.

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.

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	*p*
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
Language 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 odds 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 odds 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 shows the gaze pattern of the participants resident in Italy and Figure 4 shows the gaze pattern of participants resident in Germany. As can be seen from these figures, children in Italy showed stronger prediction than the 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.

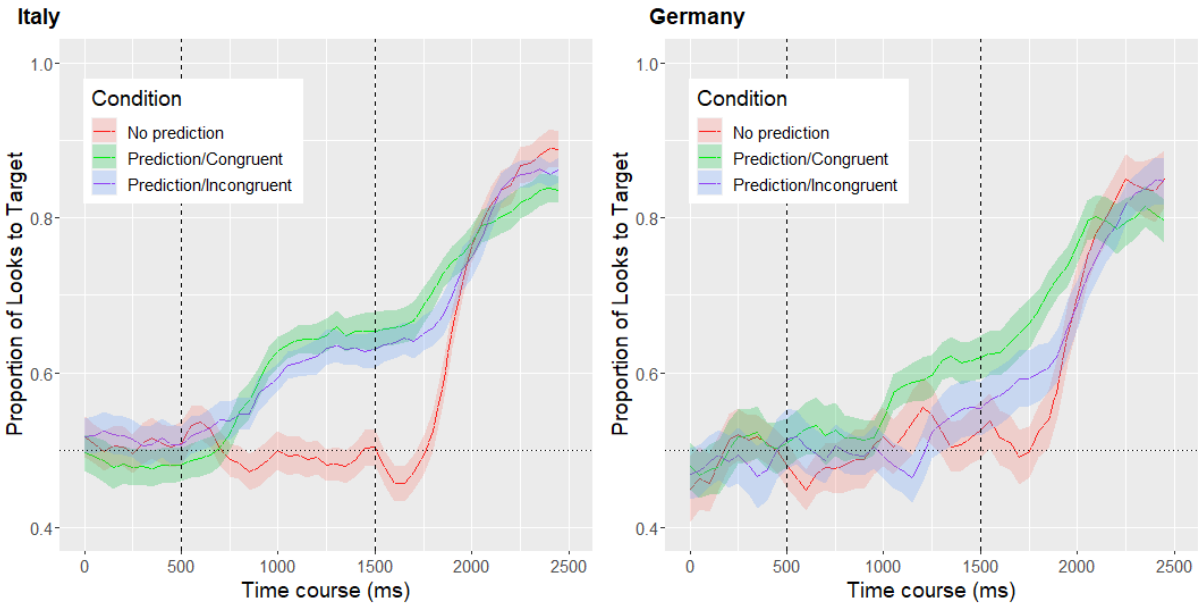

Figure 3. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the Italian task for participants resident in Italy (on the left) and in Germany (on the right). The first vertical line represents article onset; the second vertical line represents noun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

The time course of eye movements of the simultaneous bilinguals is plotted in Figure 5, and the summary of the model output of the analysis focusing on this subgroup is provided in Table 3. In this analysis, the final model included main and interaction effects of Time Region and Condition, and random intercepts for Item and Subject with random slopes for Item Order and Time Region.

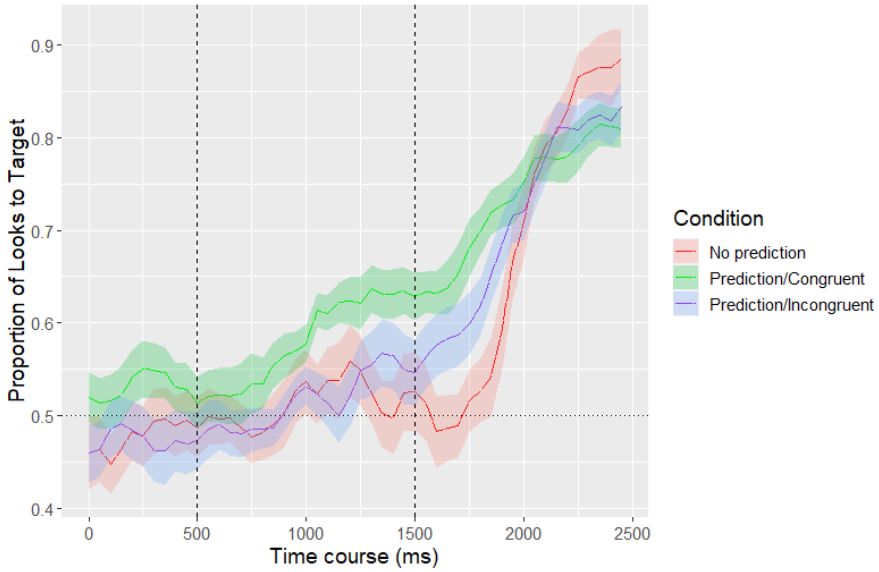

Figure 5. Time course of the proportions of looks toward the target (versus competitor) in the three conditions in the Italian task for simultaneous bilinguals only. The first vertical line represents article onset; the second vertical line represents noun onset.

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

Generalized linear mixed model Looks to target (yes or no) ~ Time region (intro vs determiner) * Condition (no prediction vs prediction/congruent vs prediction/incongruent) + (1 | Item) + (1 + Item order + Time region | Subject)			
Fixed factor	Est. odds ratio	95% CI	*p*
Time region	1.21	1.10 .. 1.33	<.001
Condition (predictability)	1.21	.965 .. 1.51	.100
Condition (congruency)	1.20	.936 .. 1.55	.148
Time region : Condition (predictability)	1.33	1.29 .. 1.38	<.001
Time region : Condition (congruency)	1.32	1.27 .. 1.38	<.001

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. This is also illustrated by Figure 5, showing clear anticipation of the noun during the determiner in the Prediction/Congruent condition but not in the Prediction/Incongruent condition. 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.

4.2.2 Experiment 2: German

Figure 6 plots the time course of looks to the target in the German experiment, which was only administered in Germany. As can be seen from this, 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).

Figure 6. 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

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 4.

As in the results of the Italian experiment, 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 informative gender-marked 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 4. *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)			
Fixed factor	Est. odds ratio	95% CI	*p*
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
Language 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 on the basis of 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 predictive language processing.

With respect to the first research question, our study confirmed that bilingual children anticipate upcoming nouns based on the grammatical gender of preceding determiners, as we found linguistic prediction in both Italian and German. Thus, similarly to monolingual children (Brouwer et al., 2017; Cholewa et al., 2019), bilingual children use grammatical gender as a cue to anticipate

upcoming speech (supporting Lemmerth & Hopp, 2019).

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 adult L2 learners is related to language proficiency (Dussias et al., 2013; Henry et al., 2020; Hopp & Lemmerth, 2018).

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 results 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, early successive 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 many sequential

bilinguals. 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, Caramazza & Sebastian-Galles, 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; Van Dijk et al., 2022). 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.

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.

Chapter 3

Predictive processing of number in Italian-English bilingual children

Abstract: This study investigates predictive processing on the basis of number agreement in 7- to 8-year-old Italian-English sequential bilingual children (*N* = 36). Using a visual world eye tracking method, we tested whether children anticipated upcoming nouns based on number agreement in their L1 (Italian) and in their L2 (English), and whether the degree of predictive processing was related to children's language proficiency. Children were presented with pictures showing either one object or a pair of objects, while they listened to sentences in Italian or English. In the Italian experiment, the target could be identified by relying on the number of the article (i.e., *la* the$_{FEM.SG}$ vs *le* the$_{FEM.PL}$), while in the English experiment, the number cue was provided by subject-verb agreement (i.e., *is* vs *are*). Our results show fast predictive processing in both the L1 and the L2. Moreover, children with stronger English vocabulary knowledge were more likely to anticipate nouns based on verb morphology, suggesting that L2 processing becomes more native-like as proficiency increases.

Keywords: visual world paradigm, predictive processing, number agreement, child L2 learners

1. Introduction

Whereas the previous chapter focused on grammatical gender processing, in this chapter we will shift our attention to the processing of number. Focusing on Italian children who learn English as their L2, we aimed to test prediction based on morphosyntactic cues in both the L1 and the L2. In Italian, we tested anticipation of nouns based on number agreement on articles (e.g., *Adesso trova la*$_{SG}$ *banana*$_{SG}$ 'Now find the banana' vs. *Adesso trova le*$_{PL}$ *banane*$_{PL}$ 'Now find the bananas'). In English, we tested anticipation of nouns based on number agreement on verbs (e.g., *Where is*$_{SG}$ *the banana*$_{SG}$*?* vs *Where are*$_{PL}$ *the bananas*$_{PL}$*?*).

Number processing has been studied extensively in L1 adults, and to a lesser extent also in adult L2 learners and monolingual children, but to our knowledge, this is the first study that looks at number processing in bilingual children. Recall that in some cases adult L2 learners tend to make less use of morphosyntactic cues to anticipate upcoming words (Kaan & Grüter, 2021), possibly because L2 processing is less automatized (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2009; Ullman, 2001), or because L2 processing might be more focused on semantic cues due to less detailed syntactic representations (Clahsen & Felser, 2006; 2018). However, this may be modulated by language proficiency, with processing becoming more native-like as L2 proficiency increases (Dussias et al., 2013; Henry et al., 2020; Hopp, 2013). The current chapter aims to investigate whether this also holds for children, by investigating L1 and L2 processing in the same group of early successive bilingual children.

In the next section, we will first discuss previous research on the acquisition and L1 and L2 processing of number, followed by a more detailed description of number agreement in Italian and English, and our hypotheses. After that, we will present our methods in Section 3, the results in Section 4 and a discussion of our findings in Section 5.

2. Background

2.1 The acquisition of number

Differently from gender, which is an arbitrary feature of nouns pertaining to lexical representations, number is a conceptual feature signaling the quantity of the referents, which may surface morphosyntactically on various elements in the sentence (Antón-Méndez et al., 2002; Barber & Carreiras, 2005). In other words, number is not only a linguistic but also a real-world feature, which is acquired very early in life. Various studies have observed pre-linguistic understanding of number in young infants (e.g., Antell & Keating, 1983; Feigenson & Carey, 2003, 2005; Li et al., 2009). For example, in Li et al. (2009), infants who did not yet comprehend the linguistic distinction between singular and plural were able to discriminate a "one" condition, in which a single object was presented, from a "more-than-one" condition, in which they saw several objects of the same type.

Morphological number marking is used from a very young age. In monolingual English children, the plural morpheme –s is one of the earliest acquired bound morphemes, and typically developing children use it correctly 90% of the time before the age of 3 (Brown, 1973; Kouider et al., 2006). Number agreement is also acquired early: 3-year-old English-speaking children (Kenney & Wolfe, 1972) and 2-year-old Italian-speaking children (Caprin & Guasti, 2009) only rarely make mistakes with respect to subject-verb agreement and number marking on articles.

With respect to comprehension, from the age of 2, children learning different languages have been shown to be sensitive to number agreement and to be able to integrate such information during online processing (e.g., Kouider et al., 2006 for English; Robertson et al. 2012, for French). For example, using a preferential looking paradigm, Robertson and colleagues (2012) investigated processing of number marking on the article in French-speaking 2-year-olds. They found that toddlers looked longer at the target in an informative condition (in which the target could be identified by relying on the number of the article; *le*$_{SG}$ vs *les*$_{PL}$) than in an uninformative condition (in which the

article did not reveal any identifying information about the target; *le*$_{SG}$ vs *le*$_{SG}$ or *les*$_{PL}$ vs *les*$_{PL}$). Although children did not pre-select the noun, they showed a facilitation effect of number agreement. Similarly, Kouider et al. (2006) investigated English-speaking toddlers' sensitivity to two different types of number cues, which were either expressed with noun morphology only (i.e., *Look at the blickets* vs *Look at the blicket*), or with noun morphology, verb morphology and quantifiers (i.e., *Look, there are some blickets* vs *Look, there is a blicket*). Their results showed that, in an informative condition, 24-month-old infants (but not 20 month-olds) were able to pre-select the noun based on number agreement, as they started shifting their gaze to the target when hearing the verb. However, unlike 36-month-olds, 24-month-olds were not yet sensitive to the plural *–s* when it appeared without other morphosyntactic cues earlier in the sentence, suggesting that they initially rely on subject-verb agreement when processing number.

The next section will discuss how L2 speakers compare to L1 speakers in the way in which they process number agreement.

2.2 Processing of number agreement in the L1 vs L2

Studies investigating the processing of number agreement in adult native speakers consistently found facilitation and anticipation effects, both within the noun phrase and across phrases (i.e., between subjects and verbs) (e.g., Cole & Segui, 1994; Faussart et al., 1999; Lukatela et al., 1987). Number agreement effects have also been evidenced in neuroimaging and electrophysiological studies, reporting a sensitivity to number agreement violations (Barber & Carreiras 2003, 2005; Carreiras et al., 2010). For example, Barber and Carreiras (2003, 2005) found that number agreement violations elicit a Left Anterior Negativity (LAN) and a P600, which respectively correspond to early morphosyntactic integration and syntactic reanalysis, as well as an N400, which is associated with semantic integration (Friederici, 2002). This suggests that number is integrated both at the syntactic level and at the semantic level.

Considering L2 learners, the acquisition of number agreement generally appears to be rather unproblematic, both for adults (Nicol & Greth, 2003; White et al., 2004) and for children (Blom & Baayen, 2012; Nicol et al., 2001), although number agreement errors may occur depending on language proficiency (Blom & Baayen, 2012; Hoshino et al., 2010) and L1 characteristics (Blom & Baayen, 2012; Jackson et al., 2018). With respect to processing, different studies have shown that adult L2 learners are able to use number-marked articles to rapidly distinguish between single and multiple referents, allowing for the anticipation of subsequent nouns (Hopp, 2012 for German; Lew-Williams & Fernald, 2010 for Spanish). Studies using neurophysiological methods also provide evidence for native-like processing of number in L2 speakers, at least at the higher levels of proficiency (Gabriele et al., 2013; Gillon-Dowens et al., 2010; Rossi et al., 2006), although sensitivity to number agreement violations may be influenced by the degree of similarity between the L1 and the L2 (Chen et al., 2007; Gillon-Dowens et al., 2011).

However, some studies focusing on beginner L2 learners have reported non-nativelike ERP patterns (Gabriele et al., 2013; Tokowicz & MacWhinney, 2005). Gabriele et al. (2013) investigated number processing in native English late learners of Spanish with varying levels of proficiency (low, intermediate and advanced). While advanced and intermediate learners exhibited a P600 response to a grammatical number mismatch, only a marginally significant P600 effect was found in low-proficiency learners. Another study testing native English low-proficiency learners of Spanish reported no P600 response to number violations at all (Tokowicz & MacWhinney, 2005).

In sum, late L2 learners can reach native-like processing of number, as shown in both behavioral and neurophysiological data. Yet, L2 production and processing may be modulated by the degree of similarity between the L1 and the L2, as well as by L2 proficiency. Until now, the L2 literature has mostly focused on late L2 learners: to our knowledge, this is the first study to investigate number processing in bilingual children. Before presenting our hypotheses, we will first describe the morphological marking of number and number agreement in both Italian and English.

2.3 Number in Italian and English

2.3.1 Italian number agreement

In Italian, number is expressed on nouns through suffixes, syncretic with gender marking. The plural form of regular masculine nouns typically ends in *–i* (e.g., *libro*$_{\text{MASC.SG}}$ 'book' vs *libri*$_{\text{MASC.PL}}$ 'books'), while the plural form of regular feminine nouns typically ends in *–e* (e.g., *matita*$_{\text{FEM.SG}}$ 'pencil' vs *matite*$_{\text{FEM.PL}}$ 'T-shirts'). The plural form of nouns ending in *-e* typically ends in *-i*, regardless of grammatical gender (e.g., *noci* $_{\text{FEM.PL}}$, 'nuts'; *soli* $_{\text{MASC.PL}}$, 'suns'). There are, however, exceptions: some nouns do not mark plurality through suffixation (e.g., *computer* $_{\text{MASC.SG}}$ 'computer' vs *computer* $_{\text{MASC.PL}}$ 'computers'; *città* $_{\text{FEM.SG}}$ 'city' vs *città*$_{\text{FEM.PL}}$ 'cities'), and other nouns change their grammatical gender according to number (e.g., *dito* $_{\text{MASC.SG}}$ 'finger', *dita* $_{\text{FEM.PL}}$ 'fingers') (Ferrari & Zampese, 2016; Panzini, 2017).

Nouns in Italian agree in number with different words in the sentence, such as articles, personal pronouns, verbs, adjectives and past participles (Panzini, 2017). In this study, we focus on number agreement with articles. Definite and indefinite articles are unambiguously marked for number; singular masculine nouns are typically preceded by *il* (definite) or *un* (indefinite), singular feminine nouns by *la* (definite) or *una* (indefinite), plural masculine nouns by *i*, and plural feminine nouns by *le*. For a small group of masculine nouns, the articles *lo* and *uno* are used in the singular form, while *gli* is used in the plural form. The use of these articles is based on phonological rules (e.g., nouns starting with *z; lo zaino* 'the backpack'; *uno zaino* 'a backpack'; *gli zaini* 'the backpacks') (Ayoun & Maranzana, 2020; Ferrari & Zampese, 2016; Panzini, 2017).

The example in (1) shows the typical agreement pattern with a masculine singular noun (here *vaso* 'vase'), which includes the masculine singular article *il* and the vocalic ending /o/ for the personal pronoun *mio* 'my', the adjective *rosso* 'red' and the past participle *stato rotto* 'is broken'. In the case of a feminine singular noun like *tazza* 'cup' in (2), the corresponding article *la* and the vocalic ending /a/ are typically used. The agreement with masculine plural nouns, such as *vasi* 'vases' in (3),

typically involves the article *i*, as well as the vocalic ending /i/ for the other elements of the sentence (*miei* 'my', *rossi* 'red', *stati rotti* 'are broken'). Finally, the typical agreement pattern for feminine plural nouns such as *tazze 'cups'* is shown in (4), in which the article *le* and the vocalic ending /e/ are used.

1. *Il mio vaso rosso è stato rotto*
   the $_{\text{MASC.SG}}$ my$_{\text{MASC.SG}}$ vase $_{\text{MASC.SG}}$ red $_{\text{MASC.SG}}$ is $_{\text{SG}}$ been $_{\text{MASC.SG}}$ broken $_{\text{MASC.SG}}$
   'My red vase has been broken'
2. *La mia tazza rossa è stata rotta*
   the$_{\text{FEM.SG}}$ my $_{\text{FEM.SG}}$ cup $_{\text{FEM.SG}}$ red $_{\text{FEM.SG}}$ is $_{\text{SG}}$ been $_{\text{FEM.SG}}$ broken $_{\text{FEM.SG}}$
   'My red cup has been broken'
3. *I miei vasi rossi sono stati rotti*
   the $_{\text{MASC.PL}}$ my $_{\text{MASC.PL}}$ vase $_{\text{MASC.PL}}$ red $_{\text{MASC.PL}}$ are $_{\text{PL}}$ been $_{\text{MASC.PL}}$ broken $_{\text{MASC.PL}}$
   'My red vases have been broken'
4. *Le mie tazze rosse sono state rotte*
   the $_{\text{FEM.PL}}$ my $_{\text{FEM.PL}}$ cup $_{\text{FEM.PL}}$ red $_{\text{FEM.PL}}$ are $_{\text{PL}}$ been $_{\text{FEM.PL}}$ broken $_{\text{FEM.PL}}$
   'My red cups have been broken'

2.3.2 English number agreement

In English, plurality is marked on nouns by adding the plural morpheme /s/, /z/, or /ɪz/ or /əz/, depending on phonological rules. Specifically, devoiced noun endings are followed by /s/ (e.g., /kæts/*cats*), voiced noun endings are followed by /z/ (e.g., /dɒgz/ *dogs*), and sibilants are followed by /ɪz/ or /əz/ (e.g., /ˈhaʊsəz/ or /ˈhaʊzɪz/ *houses*). While this system is very reliable, there are some irregular plural nouns that are stored in the lexicon (e.g., *children* or *mice*) (Greenbaum, 1996; Köpcke, 1998)

In English, few syntactic relationships are overtly marked through agreement: number is not marked on definite articles, adjectives, personal pronouns or past participles (Bock & Eberhard, 1998; Greenbaum, 1996). For definite articles, the form *the* is used for both singular and plural nouns, For indefinite articles, the article *a* or *an* is only used for singular nouns, while plural nouns may appear

without an article. Another important exception is subject-verb agreement, since verbs must agree in number with the subject noun. While it is not always explicit, for most verbs, the third-person present form varies according to the number of the subject noun (Bock & Eberhard, 1998). This is illustrated by the English translations in Example 1 to 4: the singular nouns *vase* and *cup* are followed by the third-person singular form *has* while the plural nouns *vases* and *cups* are followed by the third-person plural form *have.* In addition, for the verb *to be*, the first- and third-person forms vary according to the number of the subject noun in both present and past tense (e.g., *am/is/are* and *was/were*) (Bock & Eberhard, 1998; Greenbaum, 1996).

2.4 Research questions and hypotheses

This study investigates L1 and L2 sentence processing in Italian-English bilingual children, focusing on linguistic prediction based on number. While number seems to be early acquired in monolingual children and rather unproblematic for adult L2 learners, number processing in the L2 may differ significantly from L1 processing, depending on language proficiency as well as cross-linguistic differences. To date, no previous studies have investigated number processing in bilingual children. We aim to fill this gap, by testing L1 and L2 processing of number in native Italian-speaking children who are learning English in a bilingual school.

Our research questions are as follows:

1. Do children anticipate nouns on the basis of number marking on articles in Italian (the L1)?
2. Do children anticipate nouns on the basis of number marking on verbs in English (the L2)?
3. What is the effect of proficiency in terms of vocabulary knowledge on L1 and L2 processing?

We hypothesize that in child L2 learners, linguistic anticipation based on number may occur in both the L1 and the L2. This might be the case even at lower levels of proficiency, since no specific lexical knowledge is required to be able to make use of a number cue. Moreover, the number feature exists in both Italian and English, which may result in positive cross-linguistic transfer. Therefore,

we predict that children will show anticipatory eye movements in a visual world eye tracking paradigm in Italian as well as in English. In an Italian task, this will manifest itself in looks to a target picture based on the number marking on articles (i.e., *la* $_{\text{FEM.SG}}$ vs *le* $_{\text{FEM.PL}}$), while in English it will be reflected by target looks based on verbs (i.e., *is* $_{\text{SG}}$ vs *are* $_{\text{PL}}$). The reasons for focusing on article-noun agreement in Italian and subject-verb agreement in English will be elaborated on in Section 3.3.

Based on previous findings on L2 processing in adults (Dussias et al., 2013; Henry et al., 2020; Hopp & Lemmerth, 2018) and the production of number agreement in child L2 learners (Blom & Baayen, 2012), as well as our findings reported in Chapter 2, we hypothesize that the degree to which children make us of predictive processing in their L2 is related to their language proficiency, with more proficient children being more likely to anticipate upcoming words. Therefore, we predict that anticipatory looks to the target in the English experiment will be modulated by English vocabulary knowledge, which serves as a measure of proficiency. We also test whether L1 processing is related to vocabulary knowledge in the L1. One study found a positive relation between productive vocabulary knowledge and predictive processing based on semantic cues in monolingual toddlers (Mani & Huettig, 2012), but it is unclear whether such an effect will also be present in older children when testing anticipation based on a morphosyntactic cue.

3. Methods

3.1 Participants

A total of 36 Italian-English sequential bilingual children participated in this study (M_{Age} = 7;08, *SD* = 0;05). Of these children, 34 participated in both the Italian and the English experiment, while two children were only tested in Italian. The data of one child had to be excluded from the English task due to extensive track loss (>50%), leaving us with a sample of 36 children for the Italian task and 33 children for the English task. We only included typically developing children who were

raised in Italian-speaking families. All children were first exposed to English by the age of four and had at least three years of exposure to English at the time of testing.

Participants attended Grade 2 of an Italian-English bilingual school in Milan, where they followed a 50/50 bilingual program. Parents completed a language background questionnaire based on Ladas et al. (2015), with missing data for one child. According to the survey, 26 children had previously attended a bilingual kindergarten while nine children attended an English-only kindergarten; 10 children attended a bilingual daycare, four children an English daycare and 21 children an Italian daycare. Four children had lived abroad with their families for a period of three to five years: two in the United states, and two in non-English speaking countries. Nine children were reported to speak a third language at an elementary level of proficiency.

3.2 Procedure

Prior to investigation, parents signed an informed consent form that was approved by the ethics committee of the University of Milano-Bicocca.

Participants were tested in two sessions: one in Italian and one in English. Each session consisted of a visual world eye tracking experiment testing anticipation of nouns on the basis of number agreement, followed by a vocabulary test. This time we used productive vocabulary tests, since previous research suggests that productive vocabulary skills may also play an important role in prediction (Mani & Huettig, 2012). We used the word naming test of the BVL_4-12 (Marini et al., 2015) for Italian and the Word Finding Vocabulary Test of the Renfrew Language Scales (Renfrew, 1998) for English. Half of the children were first tested in Italian, while the other half were first tested in English, with at least three days in between the two sessions.

We used the same experimental set-up as in the study described in Chapter 2: eye gaze data were collected with a Tobii-Pro X2-120 portable eye-tracker (120 Hz), and at the end of each trial off-line responses were obtained by asking children to select the right picture by clicking on the

mouse. Children were first presented with two practice items, after which calibration took place. During each trial, children saw two pictures, while listening to sentences telling them to look for one or more objects on the screen. Again, a fixation cross ensured that children were looking at the center of the screen in between trials.

3.3 Materials

The two eye tracking experiments were created by combining the materials that are described in Chapter 2 and Chapter 4. Each experiment consisted of 20 items divided over two conditions: a predictable condition in which one picture displayed a singular object while another picture displayed a pair of two objects (Early Number), and an unpredictable control condition in which both pictures displayed either one or two objects (Late). Thus, number-based anticipation would be possible in the Early Number condition but not in the Late condition. Figure 1 provides an example of the visual displays in the two experimental conditions. The Early Number condition is shown on the left ('where is the leaf' vs 'where are the cakes' in English and *adesso trova la foglia* 'now find the$_{SG}$ leaf' vs *adesso trova le torte* 'now find the$_{PL}$ cakes' in Italian). The Late condition is shown on the right ('where is the wheel' vs 'where is the chair' in English and *adesso trova la ruota* 'now find the$_{SG}$ wheel' vs *adesso trova la sedia* 'now find the$_{SG}$ chair' in Italian).

Figure 1. Example of visual displays. The predictable *early number* condition is shown on the left; the *late* control condition is shown on the right.

In the English experiment, children heard the question *where is the…* or *where are the…*, followed by a noun. The audio fragments were spliced so that the first part of the sentence was always exactly the same, and to ensure that here were always exactly 750 ms in between the onset of the number-marked verb and the onset of the noun.

In the Italian experiment, children heard the sentence *adesso trova la…* 'now find the$_{\text{FEM.SG}}$' or *adesso trova le…* 'now find the$_{\text{FEM.PL}}$', followed by a noun. Again, audio fragments were spliced to keep the stimuli as similar as possible: there were always exactly 750 ms in between the onset of the number-marked determiner and the onset of the noun. We only included feminine nouns, since the plural-singular contrast in masculine nouns would be obscured by a longer phonological overlap at the beginning of the word (i.e., *il*$_{\text{MASC.SG}}$ vs *i*$_{\text{MASC.PL}}$).

Note that the English experiment tests the processing of number information on the verb (since articles are not marked for number in English), while the Italian experiment tests the processing of number-marked articles (even though verbs may also show number agreement). This decision was based on two reasons. Firstly, testing prediction based on number-marked verbs in Italian would automatically imply having a double number cue (e.g., *dove è la* 'where is$_{\text{SG}}$ the$_{\text{FEM.SG}}$' vs *dove sono le* 'where are$_{\text{PL}}$ the$_{\text{FEM.PL}}$'), as opposed to having only one number cue in English. Secondly, in spoken Italian *dove è* 'where is' is pronounced as *dov'è,* meaning that it would be impossible to keep the pre-critical part of the sentence equal in the singular and plural form, as it would provide an unintended number cue on the word *dove* 'where'. Therefore, we decided to focus on number marking on prenominal articles in Italian and on subject-verb agreement in questions with subject-auxiliary inversion in English.

In the Early Number condition, for half of the items the target was plural while for the other half it was singular. The items were presented in a random order, and the position of the target on the screen was balanced across trials. For both the Italian and the English experiment, we created two lists, in which target and competitor were reversed. An overview of the stimuli is provided in Appendix 3 and 4.

3.4 Analysis

First, we conducted a track loss analysis on the eye tracking data, removing trials in which data loss exceeded 25% (27.2% in the Italian experiment and 22.6% in the English experiment). We also removed trials for which the offline response was inaccurate. This lead to a total sample of 520 trials in the Italian experiment and 444 trials in the English experiment.

We conducted two statistical analyses: one focusing on the Italian experiment and one focusing on the English experiment. Data were analyzed with generalized linear mixed effects models in *R*, with the *eyetrackingR* package (Dink & Ferguson, 2015) and the glmer function of the *lme*4 package (Bates et al., 2015). We focused on the critical prenominal time region, which lasted 750 ms from the onset of the disambiguating number-marked word (i.e., the article in the Italian experiment and the verb in the English experiment) until the onset of the noun. The boundaries were shifted 200 ms to take saccade planning into account (Altmann, 2011).

We modeled Looks to the target (yes or no) as a function of main and interaction effects of Time from trial onset and Condition (Late, coded as 0, vs Early Number, coded as 1). Random intercepts for Subject and Item were included, with random slopes for Time and Condition. We also considered the following factors: Item order, Vocabulary in Italian (scores on the BVL) in the Italian analysis, Vocabulary in English (scores on Renfrew's Word Finding Vocabulary test) in the English analysis, and interactions between Time, Condition and Vocabulary scores. Models were compared using the Bayesian Information Criterion (BIC). The numeric variables Time from trial onset and Vocabulary were rescaled and centered around the mean.

4. Results

4.1 Vocabulary tests

The mean score on the Italian vocabulary test was 60.8 out of 67 (*SD* = 3.2, *Range* = 54-65), indicating strong vocabulary knowledge with little variation in Italian. All children scored within the normal range, with 27.8% scoring more than 1 standard deviation above and 5.6% more than 1 standard deviation below the mean. On the English vocabulary test, the mean score was 20.9 (*SD* = 6.9, *Range* = 4-37) out of 50, showing that overall children's vocabulary knowledge was considerably weaker in English, with great variation among participants. When comparing to the norms established for monolingual English children, 94.1% of the children scored more than 2 standard deviations below the mean while 5.9% scored within the normal range. There was no significant correlation between English and Italian vocabulary scores (p = .382).

4.2 Eye tracking

4.2.1 Experiment 1: Italian

The mean offline accuracy in the Italian experiment was 99.5% (*SD* = .07%). The analysis reported below focuses on accurately answered trials only.

The pattern of eye movements is provided in Figure 2. As can be seen from this, participants started directing their gaze to the target picture before hearing the noun in the predictable Early Number condition, but not in the Late control condition.

Figure 2. Time course of the proportions of looks toward the target (versus competitor) in the predictable (*Early Number*) vs unpredictable (*Late*) condition in the experiment in Italian. The first vertical line represents article onset; the second vertical line represents noun onset.

This pattern was confirmed by the statistical analysis. A summary of the model output is provided in Table 1. Item order and Italian Vocabulary scores were removed from the model, as they did not improve the model fit.

Table 1. *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 * condition (late vs early number) + (1 | item) + (1 + time + condition | subject)			
Fixed factor	Est. odds ratio	95% CI	*p*
Time	.959	.88 .. 1.05	.342
Condition	1.16	.65 .. 2.1	.614
Time : Condition	1.37	1.3 .. 1.4	< .001

We found a significant interaction between Time and Condition, showing that children became significantly more likely to look at the target picture during the course of the article in the predictable Early Number condition but not in the Late condition. This means that children pre-selected the noun based on the number marking on the article.

4.2.2 Experiment 2: English

The mean accuracy in the English experiment was 89.5% (*SD* = 29.9%). As in the previous analysis, only accurately answered trials were included in the analysis.

Figure 3 displays the pattern of eye movements during accurate trials in the English experiment. Again, participants showed clear anticipation based on number; they started looking at the target before hearing the noun in the predictable Early Number condition, but not in the Late control condition. In this case, children pre-selected the noun based on the number marking on the verb (i.e., *is* vs *are*). Compared to the time course of eye movements in the Italian experiment (see Figure 2), in the English experiment children were slightly less likely to look at the target at the onset of the noun (69% in the Italian task vs 63% in the English task), but overall the patterns are very similar across the two experiments.

A summary of the model output is provided in Table 2. Item order did not improve the model fit and was removed from the analysis. The significant interaction between Time and Condition shows that children anticipated nouns by relying on the number-marking on the verb; in the predictable Early Number condition (but not in the Late condition), participants became increasingly more likely to look at the target picture while listening to the verb and subsequent article, before having heard the noun. Moreover, this effect was modulated by English vocabulary knowledge, as shown by the significant three-way interaction between Time, Condition and English vocabulary.

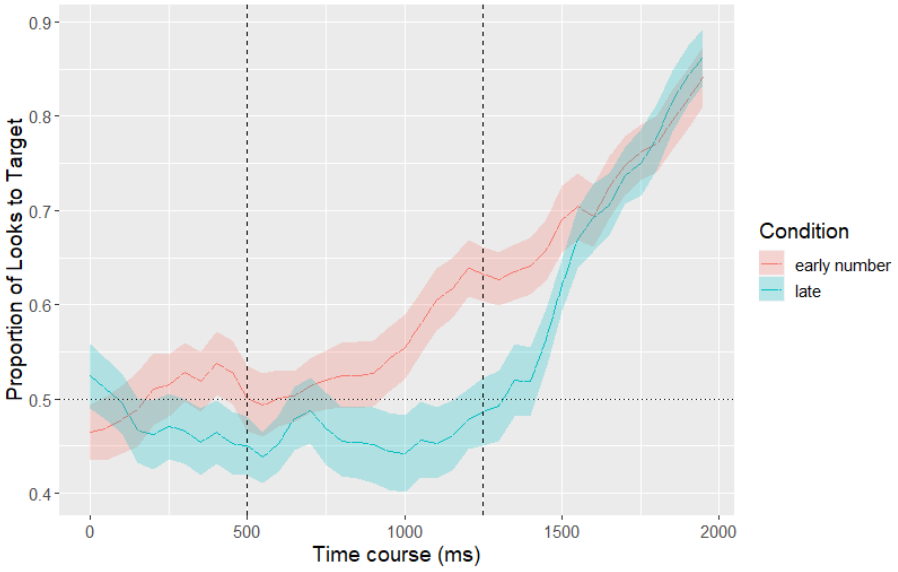

Figure 2. Time course of the proportions of looks toward the target (versus competitor) in the predictable (*Early Number*) vs unpredictable (*Late*) condition in the experiment in English. The first vertical line represents verb onset; the second vertical line represents noun onset.

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

Generalized linear mixed model

Looks to target (yes or no) ~ time * condition (late vs early number) * English Vocabulary + (1 | item) + (1 + time + condition | subject)

Fixed factor	Est. odds ratio	95% CI	*p*
Time	.990	.87 .. 1.1	.871
Condition	1.55	.91 ... 2.6	.106
English vocabulary	1.09	.83 .. 1.4	.518
Time : Condition	1.19	1.1 .. 1.2	< .001
Time : English vocabulary	1.14	1.0 .. 1.3	.042
Condition : English vocabulary	1.12	.77 .. 1.6	.555
Time : Condition : English vocabulary	.94	.90 .. .99	.014

In order to understand the effect of vocabulary knowledge, we divided the participants in a High-proficiency and a Low-proficiency group, using a median split. We then plotted the difference between these two groups in Figure 4, which shows mean proportions of looks to the target and competitor during the last 200 ms of the critical time region (i.e., the first 200 ms after the noun onset, during which saccadic eye movements cannot yet reflect processing of the noun itself). As illustrated by this plot, participants with high English proficiency looked at the target on average 66% of the time, compared to 53% of the time for participants with low English proficiency, while both groups looked to the target around 47% in the control condition.

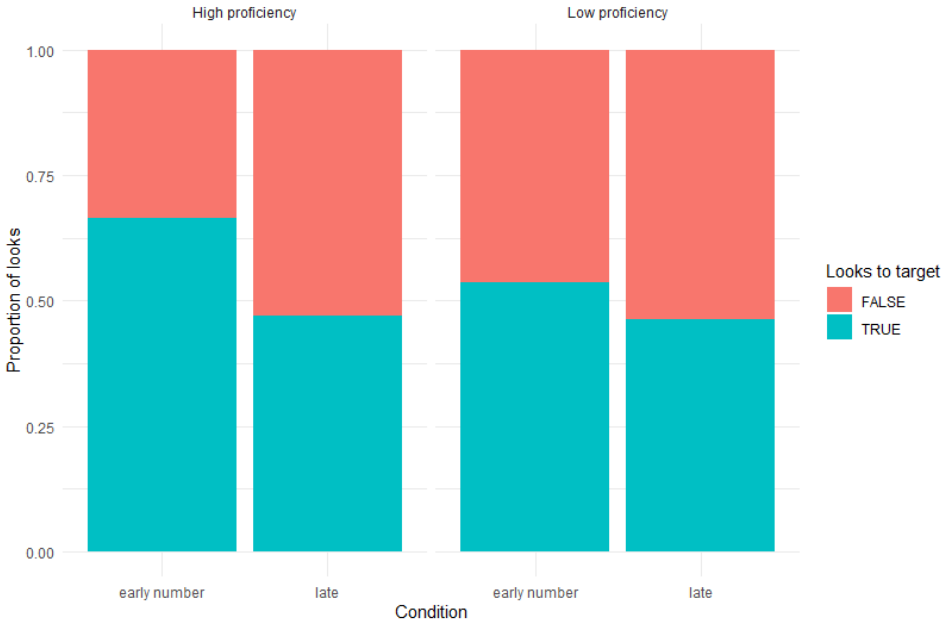

Figure 4. Proportions of looks to the target and competitor during the last 200 ms of the critical time region, with the High-proficiency group on the left and the Low-proficiency group on the right.

5. Discussion

In this chapter, we investigated L1 and L2 processing of number agreement in Italian children who speak English as their L2. We tested whether children would anticipate nouns on the basis of number-marking on articles in Italian, whether they would anticipate nouns on the basis of subject-verb agreement in English, and whether the degree to which children made use of prediction would be related to their vocabulary knowledge in the L1 and the L2.

With respect to our first two research questions, our results show very clear predictive processing in both Italian and English. In other words, children were able to rely on number agreement to identify the target as quickly as possible, not only in their L1 but also in their L2. This is especially interesting given that the vocabulary tests and offline accuracy rates suggest relatively low proficiency in English overall. Previous studies on adult L2 learners and monolingual children already showed that the acquisition and processing of number agreement is rather unproblematic (Gillon-Dowens et al., 2010; Hopp, 2012; Kouider et al., 2006; Lew-Williams & Fernald, 2009; Robertson et al., 2012; Rossi et al., 2006), and our findings extend this to sequential bilingual children. Moreover, these results corroborate previous research showing that bilingual children can make use of morphosyntactic cues to anticipate upcoming speech (Lemmerth & Hopp, 2019; Meir et al., 2020), which was also found in our study presented in Chapter 2.

Regarding our third research question, children with higher scores on the English vocabulary test were significantly more likely to show predictive processing in the English experiment than children with lower scores. This suggests that L2 processing becomes more native-like as proficiency increases, which is in line with previous research on the online processing of number agreement in adult L2 learners (Gabriele et al., 2013). It also adds to previous findings on the effect of language proficiency on predictive processing in adult L2 learners (Dussias et al., 2013; Henry et al., 2020; Hopp, 2013), and to our findings related to the effect of language dominance reported in Chapter 2.

Although linguistic prediction has been found to be modulated by productive vocabulary knowledge in monolingual toddlers (Mani & Huettig, 2012), in our study, predictive processing in the L1 was not influenced by L1 vocabulary knowledge. This may be due to the age of our participants and the fact that all of them had already acquired a high proficiency in Italian, as shown by the high scores on the Italian vocabulary test. Another reason may be the fact that our experiment tested prediction based on a morphosyntactic feature that does not require lexical knowledge, while Mani and Huettig tested anticipation based on semantic cues.

Our findings do not lend support to theories stating that L2 syntactic representations are less detailed than L1 representations, leading to an underuse of grammatical cues (as proposed by Clahsen & Felser, 2006, 2018). In fact, our participants clearly showed sensitivity to number marking in their L2; they made efficient use of subject-verb agreement in English to anticipate upcoming nouns, suggesting that they were able to quickly integrate morphosyntactic information on the verb in an automatized manner. It has been argued that adult L2 processing is less automatized than L1 processing, which may be related to the explicit nature of late L2 learning (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2005; Ullman, 2001). Through extensive practice, late L2 learners may move from controlled processing relying on declarative memory toward automatic processing relying on procedural memory, which means that working memory load decreases and speech processing becomes faster (Ullman, 2001). However, L2 processing in young children might be more automatic even in the early stages of L2 acquisition, since their L2 is typically taught in a more implicit manner (Lichtman, 2013). Future studies should investigate this further.

Specifically, a follow-up of the current study should include a group of Italian-speaking low- to intermediate-proficiency adult L2 learners of English who are tested with the same materials, in order to make a direct comparison with the data presented in this chapter. This would inform us about the potential differences between adult L2 processing and child L2 processing. Assuming that young children may acquire an L2 in a less explicit way than adults, we hypothesize that L2 processing in

children may be more automatic, which may lead to stronger predictive processing in L2 children compared to L2 adults who have the same level of proficiency.

Finally, it should be noted that our two experiments are not directly comparable, since they do not test exactly the same type of number agreement. This means that any differences between the degree to which children anticipate in the two experiments may also be influenced by subject-verb agreement being more salient than article-noun agreement, or vice versa. For a more direct comparison between L1 and L2 processing, future studies might want to focus on two languages that mark number in the exact same way. On the other hand, one might also want to focus on two languages with greater typological distance, in order to test whether sequential bilingual children are able to anticipate nouns in their L2 on the basis of number agreement when they have to rely on a grammatical category that is absent in their L1. We investigate this in the study presented in Chapter 4, which will contrast gender and number processing in different groups of bilingual children in comparison to monolingual controls.

Chapter 4

Prediction on the basis of gender and number in Mandarin-Italian and Arabic-Italian bilingual children[3]

Abstract: The present study investigated the online processing of grammatical gender and number in Italian in 25 Mandarin-Italian and 21 Arabic-Italian sequential bilingual children, in comparison to 32 monolingual Italian children. Using a visual world eye tracking method, we examined how children anticipated upcoming nouns on the basis of gender and number cues on the preceding article. Previous research suggests that gender may be more challenging for L2 learners than number due to its arbitrariness and its dependence on lexical knowledge (Gabriele et al., 2013; Gillon-Dowens et al., 2010; Lew-Williams & Fernald, 2009). We aimed to investigate whether such a gender-number discrepancy is modulated by cross-linguistic differences: whereas Arabic linguistically encodes both gender and number, Mandarin has a conceptual notion of number but it does not have gender. Moreover, gender and number are not marked on articles in Arabic, while Mandarin does not have articles at all. The results show that, overall, participants made predictive use of articles when processing subsequent nouns, suggesting that bilingual children are able to attend to a grammatical category that is absent in their L1 or that does not provide the same type of cues. Yet, monolingual children showed stronger prediction than bilingual children. While there was no difference in the processing of gender and number in monolingual children, we found that Mandarin-Italian bilinguals tended to be slower when processing gender than number, with Arabic-Italian bilinguals showing the opposite pattern. This suggests that L2 processing in bilingual children might be influenced by grammatical properties of their L1, and that they might show positive transfer when a grammatical feature is available in both of their languages.

Keywords: visual world paradigm, gender, number, cross-linguistic differences, child bilingualism, predictive processing

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1. Introduction

The previous chapters have shown that simultaneous as well as sequential bilingual children, similarly to monolingual speakers, are able to anticipate nouns on the basis of both gender and number agreement. Yet, as we have seen in Chapter 2, sometimes predictive processing may be influenced by cross-linguistic differences. In the current chapter, we contrast gender and number processing in two different populations of sequential bilingual children (i.e., Mandarin-Italian and Arabic-Italian bilinguals), in comparison to monolingual Italian children. In Italian, articles are consistently marked for both gender and number, and can thus be used to anticipate upcoming nouns. The L1s of the bilingual children have crucial linguistic differences with respect to the phenomena under investigation: Mandarin has neither articles nor grammatical gender, while it does express number. In contrast, Arabic has articles as well as grammatical gender and number, even though these are expressed differently than in Italian. This provides us with an interesting test case to investigate the effect of cross-linguistic differences on predictive language processing in bilingual children.

This chapter will first discuss previous research on the processing of grammatical gender and number, in monolingual children as well as L2 learners, followed by a linguistic description of Italian, Mandarin and Arabic with respect to gender and number marking. After that we will turn to our hypotheses, methods and results, before concluding with a discussion of our findings.

2. Background

2.1 The discrepancy between gender and number processing

Although advanced L2 learners are able to reach native-like proficiency in the production, comprehension and online processing of both grammatical gender and number (White et al., 2014; Gabriele et al., 2013; Gillon-Dowens et al., 2010, 2011), grammatical gender appears to be more

challenging to acquire than number. While the L2 acquisition of number is typically rather unproblematic (White et al., 2004), with advanced learners showing native-like processing (Hopp, 2012; Lew-Williams & Fernald, 2009; Gabriele et al., 2013; Gillon-Dowens et al., 2010; Rossi et al., 2006), grammatical gender often remains difficult, even for highly proficient speakers (Grüter et al., 2012; Lew-Williams & Fernald, 2010).

Previous research suggests that gender processing in bilingual adults is influenced by linguistic differences between the L1 and the L2 (Dussias et al., 2013; Foucart & Frenck-Mestre, 2011, 2012). Dussias et al. (2013) explored the effect of L1 characteristics on Spanish L2 processing of gender, by comparing native speakers of English (a language lacking grammatical gender) to native speakers of Italian (a language which has a grammatical gender system comparable to Spanish), while taking into account different levels of proficiency. The results showed that, like monolingual Spanish speakers, native English high-proficiency L2 learners exhibited predictive processing on the basis of gender-marked articles, while native English low-proficiency L2 learners failed to do so. Interestingly, native Italian low-proficiency L2 learners of Spanish showed anticipatory eye movements, but only with the feminine article *la,* which is identical to its Italian counterpart. This suggests that low-proficiency participants experienced positive transfer when there was overlap between their L1 and their L2. Moreover, at the neurophysiological level, L2 speakers may respond differently to violations in grammatical gender agreement than native speakers, depending on the morphosyntactic realization and the degree of syntactic overlap between the L1 and the L2 (Foucart & Frenck-Mestre, 2011, 2012).

Similar to gender processing, number processing in adult L2 speakers also appears to be influenced by L1 characteristics. Gillon-Dowens et al. (2011) tested the effect of linguistic differences by investigating the processing of number agreement violations in Spanish by native speakers of English and of Mandarin with advanced L2 Spanish proficiency. While number agreement violations elicited a native-like biphasic Left Anterior Negativity (LAN) - P600 pattern in English speakers, they only elicited a P600 but no LAN in Mandarin speakers. The authors argue that the different ERP

patterns between the two groups may be due to L1 effects: contrary to English and Spanish, Mandarin does not mark number through morphosyntactic agreement, which may have affected the early syntactic processing of number agreement violations.

Several studies have directly compared number processing to gender processing in L2 populations, but there are some mixed results. For example, Tokowicz and MacWhinney (2005) investigated the production and online processing of grammatical gender and number agreement in native English late L2 learners of Spanish. They found that even though participants were less accurate with grammatical gender than with number in a grammaticality judgement task, their ERP patterns showed sensitivity to agreement violations with gender but not with number. The authors argue that their participants were implicitly sensitive to morphosyntactic agreement with a feature that is unique to their L2 (i.e. gender), but not with a feature that exists in both the L1 and the L2 but which is expressed differently in the two languages (i.e. number).

In contrast, many other studies found an advantage for number over gender in L2 learners, both in behavioral tasks (White et al., 2004) and in online language processing (Gabriele et al., 2013; Gillon-Dowens et al., 2010; Lew-Williams & Fernald, 2009; Hopp, 2012). For example, capitalizing on the fact that articles in Spanish are marked for both grammatical gender and number, Lew-Williams and Fernald (2009) found that native English late L2 learners of Spanish made rapid use of number cues when identifying subsequent nouns, while they were not able to rely on grammatical gender cues unless the same pairs of articles and nouns were used throughout the experiment. Similarly, studying native English high-proficient L2 speakers of German, Hopp (2012) found more variable performance with gender processing than with number processing. While L2 speakers reliably anticipated nouns on the basis of the number marking on articles and adjectives, participants with sub-optimal performance in an offline gender assignment task were less likely to anticipate nouns on the basis of grammatical gender in a visual world eye tracking experiment.

A few studies have compared ERP responses to gender and number agreement violations in bilingual adults. Testing native English late learners of Spanish, Gabriele et al. (2013) found no

difference between gender and number processing for low-proficiency speakers, who showed only a marginal P600 effect for both gender and number agreement violations. A dissociation between number and gender appeared in the intermediate learners, who showed native-like ERP patterns for number but not for gender. In advanced learners, the advantage for number over gender was only quantitative, in that the P600 was significantly weaker when processing gender as compared to number agreement violations. A similar pattern was observed in the native English high-proficiency L2 learners of Spanish tested by Gillon-Dowens et al. (2010), who showed a delayed LAN and a weaker P600 when processing agreement violations with grammatical gender but not with number.

It has been claimed that this dissociation between number and gender is related to different representations at the conceptual level (Antón-Méndez et al., 2002; Igoa et al., 1999). Grammatical gender is an abstract feature usually described as an intrinsic property of the noun, and as such, grammatical gender is assumed to be stored at the level of the lexicon (Harris 1991). On the other hand, in many languages, number is a morphosyntactic feature that is attached to the lexical stem and that refers to the quantity of the referent. Contrary to grammatical gender, number can be retrieved from the referential context (Ritter 1993), making it a more meaningful feature for L2 learners. 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; Tsimpli & Mastrapavlou, 2007).

Interestingly, the dissociation between gender and number has also been evidenced in monolingual populations, both in adults (Antón-Méndez et al., 2002; Barber & Carreiras, 2003, 2005; Carreiras et al., 2010; Igoa et al., 1999; Lukatela et al., 1987) and children (Dispaldro et al., 2015). Monolinguals tend to produce more gender errors than number errors (Antón-Méndez et al., 2002) and are slower to process gender than number (Lukatela et al., 1987). Barber & Carreiras's (2003, 2005) findings suggest that although early processes seem to be similar, differences arise in later processing. More specifically, they found that the second phase of the P600 response to agreement

violations was larger for gender than for number. They argue that this difference in the ERP pattern reflects more complex reanalysis processes for gender than for number. The existence of a gender-number dissociation is also supported by neuroimaging data that showed that the processing of gender and number activate different areas of the brain (Carreiras et al., 2010).

Although there is some conflicting evidence in the literature, most studies suggest that gender processing tends to be more challenging than number processing, not only for bilinguals but also for monolinguals. This difference has been explained at the representational level, where gender is an arbitrary feature of the lexicon while number is a morphosyntactic feature expressing a semantic property of the referent. It is not clear, however, to what extent a dissociation between gender and number processing in L2 speakers may also be influenced by the presence or absence of grammatical gender in the L1. All previous studies that compared gender and number processing in bilinguals focused on adults whose native language was English, a language that does not have grammatical gender. Therefore, the observed asymmetry between gender and number processing in L2 speakers may at least partly have been influenced by the fact that the gender feature, in contrast to number, was not present in the L1 of the participants. The current study aims to address this issue by contrasting gender and number processing in early L2 learners of Italian that speak typologically different languages as their L1, as will be described in section 2.3. In the next section, we will discuss previous research on gender and number processing in bilingual children.

2.2 Gender and number processing in bilingual children

Whilst there is extensive (yet inconclusive) literature on the differences between online processing of grammatical gender and number in adult L2 speakers, gender and number processing in early bilinguals remains largely unexplored. To our knowledge, there are no studies to date that have investigated number processing in bilingual children, while there is only one previous study that looked at gender processing in bilingual children.

As discussed in previous chapters, Lemmerth and Hopp (2019) investigated linguistic prediction based on gender-marked determiners and adjectives in German, by comparing 8- and 9-year-old German-Russian bilingual children to a group of age-matched monolingual controls. The bilingual children were divided in two groups: simultaneous bilinguals, who were exposed to both languages from birth, and early sequential bilinguals, who were exposed to German before the age of 4. The results showed that, similarly to monolingual children, simultaneous bilinguals anticipated upcoming nouns on the basis of the grammatical gender of the article or prenominal adjective. In contrast, sequential bilinguals only did so when the grammatical gender of the target noun was the same as that of its Russian translation equivalent. This means that native Russian early L2 learners of German experienced a gender congruency effect, i.e. their processing was delayed when there was a mismatch in grammatical gender between their two languages, due to cross-linguistic interference during the pre-activation of nouns based on articles and adjectives.

Russian and German both have a tripartite grammatical gender system (distinguishing between feminine, masculine and neuter gender), but they differ in the way in which gender is expressed. While both languages mark grammatical gender on prenominal adjectives, German also marks gender on articles, which are absent in Russian. This allowed the authors to explore the effect of linguistic differences, by testing whether participants would be more likely to show prediction based on adjectives than on articles.

A previous study on native Russian adult L2 learners of German (Hopp & Lemmerth. 2018) found that high-intermediate speakers showed predictive processing in German based on gender-marked adjectives but not on gender-marked articles, suggesting that cross-linguistic overlap in the morphosyntactic realization of grammatical gender facilitates processing in L2 learners. However, Lemmerth and Hopp (2019) observed identical patterns for both types of stimuli, which means that the delayed processing of grammatical gender in sequential bilingual children cannot be attributed to the absence of articles in Russian.

To summarize, the limited empirical evidence that is available suggests that bilingual children, like monolingual children and adults, are able to anticipate nouns on the basis of gender cues (at least if their two languages have a gender system, regardless of how gender is expressed exactly). However, it is still unclear to what extent child L2 learners make use of prediction when processing gender, and whether they may be influenced by the linguistic properties of their L1. Moreover, this is the first study to compare gender to number processing in bilingual children. Before presenting our research questions, the next section will provide a linguistic description of grammatical gender and number in Italian, in comparison to Mandarin Chinese and Arabic.

2.3 Grammatical gender and number systems

2.3.1 Italian

Recalll from Chapter 2 and 3 that Italian has both grammatical gender and number, which are marked through suffixes on nouns, and through an elaborate system of agreement with different elements in the sentence. We will provide a brief recap here. Italian distinguishes between singular and plural nouns, which are classified as being either feminine or masculine, following certain morpho-phonological regularities. That is, although there are exceptions, most masculine singular nouns end in -o (e.g., *libro*$_{\text{MASC.SG}}$ 'book'), most feminine singular nouns end in –a (e.g. *matita*$_{\text{FEM.SG}}$ 'pencil'), most masculine plural nouns end in -i (e.g. *libri*$_{\text{MASC.PL}}$ 'books'), and most feminine plural nouns end in *–e* (e.g. *matite*$_{\text{FEM.PL}}$ 'pencils'). There is also a sub-class of nouns ending in *–e* in the singular form and *–i* in the plural form which may be either feminine or masculine (e.g. *noce*$_{\text{FEM.SG}}$, 'nut' vs *noci*$_{\text{FEM.PL}}$, 'nuts'; *sole*$_{\text{MASC.SG}}$ 'sun' vs *soli*$_{\text{MASC.PL}}$ 'suns').

The gender and number of nouns can reliably be predicted by looking at the preceding article, since definite and indefinite nouns are unambiguously marked for both gender and number: the singular article is *il* (definite) or *un* (indefinite), the singular feminine article is *la* (definite) or *una* (indefinite), the plural masculine article is *i*, and the plural feminine article is *le*. Nouns that start with

a vowel are an exception, since they require the use of the elided article *l'*, which can either be followed by a feminine or a masculine noun (e.g. *l'amico*$_{\text{MASC}}$ and *l'amica*$_{\text{FEM}}$ 'the friend'). For a small group of masculine nouns, the articles *lo, uno* or *gli* are used, based on phonological rules (e.g. nouns starting with *z; lo zaino* 'the backpack'; *uno zaino* 'a backpack'; *gli zaini* 'the backpacks') (Ayoun & Maranzana 2020; Ferrari & Zampese 2016; Panzini 2017).

In Italian, nouns do not only agree in gender and number with articles, but also with personal pronouns, adjectives and past participles (Panzini, 2017). For more details, see the descriptions of the Italian gender and number system in Chapter 2 and 3.

2.3.2 Mandarin Chinese

Mandarin presents several contrasts with Italian. First, it lacks articles, as bare nouns may either have a generic or existential meaning, or a definite interpretation. Second, Mandarin does not have grammatical gender, but it uses nominal classifiers. These lexical items, which indicate to which class a noun belongs, appear obligatorily with numerals or quantifiers (Frankowsky & Ke, 2016). It has been argued that in some aspects classifier systems may not be qualitatively different from grammatical gender systems, as both systems entail nominal classification (Fedden & Corbett, 2017; Haspelmath, 2018). Unlike grammatical gender on nouns in Italian, however, classifiers in Mandarin do not involve morphosyntactic agreement, and it is not arbitrary. Nominal classification in Mandarin is based on semantic properties of the noun, such as its material and physical shape (Huang & Ahrens, 2003).

Number is unspecified in bare nouns in Mandarin, that is, they are neither singular nor plural (Corbett, 2000; Rullmann & You, 2006). There are, however, several ways of expressing the concept of number or quantity, for example by using numerals such as *yī* 'one' or *liǎng* 'two', or quantifiers such as *duì* (denoting a pair) or *tào* (denoting a set). Two other frequently discussed plural-encoding forms are *xīe* and *-mén* (Iljic, 1994). While *xīe* 'some' marks collectiveness, it is not obligatory, and

it can also be used with mass nouns. The suffix *-mén* is obligatorily used with pronouns to denote number, but it is restricted to human and definite referents. Moreover, it has been argued that plurality may be expressed by the reduplication of classifiers, while singularity may be expressed by using a simple classifier in the absence of a numeral (Zhang, 2014).

2.3.3 Arabic

Similar to Italian, Arabic distinguishes between masculine and feminine grammatical gender. Masculine gender is the default and not overtly marked on nouns, whereas feminine gender is typically marked with the suffix */-ah/* (e.g., مُدَرِّس /*mudarris*/ 'male teacher' vs مُدَرِّسَة /*mudarisa*/ 'female teacher', or كُرْسِي /*kursiː* / 'chair' vs طَاوِلَة /*tˤawila*/ 'table'). While this system is quite reliable for both animate and inanimate nouns, two exceptions should be noted. First, there are some collective nouns for which the use of the feminine suffix indicates singularity (e.g., بَقَرَة /*baqara*/ 'one cow' vs /*baqar*/ 'more than two cows'). Second, there are a few nouns, mostly body parts and natural phenomena, which are not overtly marked for feminine gender (e.g., شَمْس /*ʃams*/ 'sun'; Moawad, 2006; Ryding, 2005).

With respect to number, Arabic distinguishes between three classes: singular (one), dual (two) and plural (more than two). Singular nouns are unmarked for number, while dual masculine and feminine nouns are marked with the suffix */-aːn/* (e.g., مُدَرِّسان /*mudarrisaːn*/ 'two male teachers' vs مُدَرِّسَتان /*mudarrisataːn*/ 'two female teachers') . In Arabic, there are two types of plural nouns: regular plurals which are formed by attaching a suffix to the base of the noun (*/uːn/* for masculine human nouns and */-aːt/* for feminine nouns, e.g. مُدَرِّسُون/*mudarrisuːn*/ 'male teachers' vs مُدَرِّسات /*mudarrisaːt*/ 'female teachers'), and broken plurals, which are lexicalized items in which the root of the noun changes internally (e.g., كَلْب /*kalb*/ 'a dog' vs كِلاب */kilab/* 'dogs') (Lyovin, 1997; Moawad, 2006; Ryding, 2005).

In Arabic, there is grammatical gender and number agreement with adjectives and verbs, but not with articles, which are attached as prefixes to nouns. Adjective agreement is expressed with suffixes, while verb agreement is either expressed with suffixes or a prefixes, which differ depending on the tense of the verb (Moawad, 2006; Ryding, 2005).

2.5 Hypotheses and predictions

The present study addresses how Mandarin-Italian and Arabic-Italian sequential bilingual children use grammatical gender and number marking on articles to anticipate upcoming nouns, in comparison to monolingual Italian children. Whereas monolingual children have been shown to effectively rely on gender and number cues in spoken word recognition, to date very few studies have focused on bilingual children. The combination of Mandarin, Arabic and Italian provides an interesting test case: in Italian prenominal articles are marked for gender and number, while Mandarin lacks articles and grammatical gender (but not number). Arabic, in contrast, has articles as well as grammatical gender and number, but these are expressed differently than in Italian.

Firstly, we hypothesize that sequential bilingual children might show less prediction during language processing than monolingual children, especially if they have to rely on a grammatical category which is absent in their L1, or which does not provide the same type of cues. Since Mandarin and Arabic do not mark gender and number on articles, we predict that bilingual participants will be less likely to anticipate upcoming nouns on the basis of morphosyntactic features on the article. In other words, in a condition in which there is a mismatch in grammatical gender or number between the target picture and its competitor, we expect that participants will start directing their gaze toward the target picture after the onset of the article and before the onset of the noun, but bilingual participants may be delayed in comparison with monolingual participants.

Secondly, we hypothesize that grammatical gender is a more challenging feature to process than number, but we expect that this may be modulated by cross-linguistic differences between the

L1 and the L2. Specifically, since Mandarin lacks grammatical gender while it does have a conceptual notion and grammatical expression of number, we predict that Mandarin-Italian bilingual children will be slower when anticipating nouns based on a gender as compared to a number cue. In addition, the fact that gender processing requires a greater reliance on arbitrary lexical knowledge may contribute to a potential gender-number discrepancy in L2 learners. We therefore predict that Arabic-Italian bilinguals may also show a difference between gender and number processing, but we expect this asymmetry to be smaller than for Mandarin-Italian bilinguals, albeit possibly greater than for monolingual participants.

3. Methods

3.1 Participants

We tested a total of 90 children ranging from 8 to 11 years old. Data from two monolinguals, four Mandarin-Italian bilinguals and six Arabic-Italian bilinguals were excluded because of eye tracking calibration problems or track loss during the experimental phase (> 50%). Our final sample consisted of 32 Italian monolingual children (M_{Age} = 9;07, *SD* = 1;01, Range = 8;00 – 10;08), and 46 early L2 learners of Italian, who were native speakers of Mandarin Chinese (*N* = 25, M_{Age} = 9;09, *SD* = 1;02, Range = 8;06 – 11;09) or Arabic (*N* = 21, M_{Age} = 9;08, *SD* = 0;11, Range = 8;01 – 10;10)[4].

Bilingual children were from an immigration background and were raised in Mandarin-or Arabic-speaking families living in Milan. In these communities, children are typically first exposed to Italian when they enter (pre-)school between the age of three and six. All children in our sample had at least three years of exposure to Italian through formal education in Italy. Monolingual and Arabic-speaking children were tested at school, a public primary school in a suburban area of Milan,

[4] Initially we were planning to test 60 Mandarin-speaking children in different age groups in the Chinese school, but due to the Covid-19 pandemic, the school closed, and we had to cancel the second round of testing.

while the Mandarin-speaking children were tested at a Chinese heritage language school which they attended on Saturdays.

Of the Arabic-speaking children, 57.1% were second generation immigrants born in Italy, while 28.6% were born in Egypt and 14.3% in Morocco. For those children who were born abroad, the mean age of arrival in Italy was 3 years and 4 months (*SD* = 2;03, Range = 0;01 – 7;05). Of the Mandarin-speaking children whose parents returned the questionnaire, 83.3% were born in Italy and 16.7% were born in China (survey data were missing for 11 children[5]). For the children born in China, the mean age of arrival in Italy was 5 years and 6 months (*SD* = 1;04, Range = 4;01 – 6;09).

Two different tests were used to measure Italian language proficiency in bilingual participants[6]. The Mandarin-speaking children were tested with the Peabody Picture Vocabulary Test (PPVT-R; Stella, Pizzoli & Tressoldi 2000), a measure of receptive vocabulary knowledge in Italian. The mean standard score on this task was 85 (*SD* = 15) [7], indicating that on average their vocabulary size in Italian was substantially smaller in comparison to monolingual norms (*M* = 100, *SD* = 15). Of the Mandarin-Italian bilingual children, 28.6% scored more than 2 standard deviations below the norm established for monolingual children. Arabic-speaking children, instead, were tested with the word naming task of the BVL_4-12 (Marini et al., 2015), which is a measure of productive vocabulary knowledge. The average score was 50 out of 67 (*SD* = 9.3), which is also considerably lower than the monolingual norms: 61.9% of the Arabic-Italian bilingual children scored more than 2 standard deviations below the mean on the productive vocabulary test.

[5] Due to the Covid-19 pandemic we were not able to return to the school to obtain the missing surveys.
[6] We used two different vocabulary tests, because at first we did not plan to compare these two groups to each other. Initially, we were planning to test a larger group of Mandarin-Italian bilinguals in both of their languages, using the PPVT in Italian and Mandarin, but due to the Covid-19 pandemic we were not able to complete the data collection of the vocabulary tests in Mandarin. The Arabic-speaking children, on the other hand, were initially tested as a part of the study presented in Chapter 5, for which they were tested with a productive vocabulary test which is faster to administer and therefore more convenient to be used within a larger test battery.
[7] Note that we had missing data on the vocabulary test for four children.

3.2 Materials and procedure

Participants took part in a visual world eye tracking experiment to measure their ability to predict upcoming nouns on the basis of gender and number marking on articles. We used a similar experimental procedure as described in Chapter 2 and 3, which was approved by the ethics committee of the University of Milan-Bicocca.

The auditory stimuli consisted of Italian sentences asking participants to search for one or more objects on the screen, starting with *Adesso trova la/il/le* 'Now find the $_{\text{FEM.SG}}$ / the $_{\text{MASC.SG}}$ / the $_{\text{FEM.PL}}$'. The sentences were recorded by a female native speaker of Italian, and the audios were manipulated with the Audacity® software (Audacity Team, 2022). We spliced the audio fragments in order to ensure that the introduction of the sentence (*Adesso trova la/il/le* 'Now find the') was always the same length. The determiners *la*, *le* and *il* had a duration of 315 ms, 350 ms and 370 ms, respectively. The noun always started exactly 750 ms after the determiner onset, so that in each condition anticipatory eye movements could be observed before the onset of the noun. Background noise was removed.

Sixty high-frequency nouns were selected, and their corresponding pictures were created. All nouns referred to inanimate concrete objects and were two or three syllables long. Pictures depicted either one single object or two identical objects on a white background. Targets and competitors were matched in syllable length.

Three conditions manipulated predictability and type of cue: Early Gender, Early Number, and Late (see Figure 1). In both Early 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, pictures showed one feminine object and one masculine object. Due to this gender mismatch, the gender marking on the article (*il* vs *la)* could elicit anticipatory eye-movements toward the target. In the Early Number condition, pictures displayed one single object on one side and two identical objects on the other side. Thus, there was a number mismatch (with matched feminine gender), so that

anticipatory eye-movements to the target could be generated from 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 in three different types of pairs: *la* vs *la*, *il* vs *il* and *le* vs *le*. This condition is labelled Late because the target could not be identified before the onset of the noun.

There were 10 items in each Early condition and 15 items in the Late condition. Each noun was used only once in the experiment. Gender and number of the target were balanced within the corresponding condition so that five items targeted a feminine noun in the Early Gender condition, and five items targeted a plural noun in the Early Number condition. In the Late condition, five targets were masculine singular, five were feminine singular and five were feminine plural. The target appeared on the right side in 17 trials and on the left side in 18 trials, and the presentation order of the items was randomized. To avoid any preference bias toward one of the pictures, we created a second list of 35 items in which targets and competitors were reversed. Participants were randomly assigned to one of the two lists. A full list of our experimental stimuli is provided in Appendix 5.

Figure 1. Overview of experimental conditions.

3.3 Analysis

The analysis was based on trials for which the offline response was accurate, excluding trials in which there was more than 35% track loss. As a result, 161 trials were removed for the monolinguals (32 in the Early Gender condition, 60 in the Early Number condition and 69 in the Late

condition), 160 for the Mandarin-Italian bilinguals (57 in the Early Gender condition, 42 in the Early Number condition and 61 in the Late condition) and 105 for the Arabic-Italian bilinguals (37 in the Early Gender condition, 32 in the Early Number condition and 34 in the Late condition), leaving respectively 959, 711 and 630 trials for the statistical analysis.

We created three time windows corresponding to the introduction (starting 500 ms before the onset of the article), the article (750 ms starting from the article onset until the noun onset) and the noun (ending 500 ms after the onset of the noun). The boundaries of each time window were shifted by 200 ms, which is the estimated time required for the planning and execution of saccadic eye movements (Altmann, 2011). We used the *eyetrackingR* (Dink & Ferguson, 2015) and *ggplot2* (Wickham, 2016) packages to visualize the eye gaze patterns in *R* (R Core Team, 2019).

In the statistical analyses we compared looks toward the target versus competitor during the article time window. Data were analyzed with a generalized linear mixed-effects model in which Looks to the target (yes or no) served as a binary dependent variable, using the glmer function of the *lme*4 package (Bates et al., 2015) in *R*. We compared the three groups of participants (monolinguals, Mandarin-Italian bilinguals and Arabic-Italian bilinguals), to examine (1) whether they differ in the extent to which they use articles to anticipate upcoming nouns and (2) whether they differ with respect to prediction based on gender versus number. We considered various predictors, such as Condition (Early Gender vs Early Number vs Late), Group (Monolingual vs Mandarin vs Arabic), Age in months, List and Item Order, as well as random intercepts for Item and Subject, and random slopes for Time and Condition. We used ternary contrasts to examine the effects of Group and Condition. For Group, when comparing monolinguals to bilinguals, Monolingual was coded as +2/3, and Mandarin and Arabic were each coded as -1/3. When comparing the two bilingual groups against each other, Mandarin was coded as +1/2 and Arabic was coded as -1/2. For Condition, Late was coded as -2/3 and Early Gender and Early Number were both coded as +1/3 to compare the two early conditions against the late condition, while Early Gender was coded as -1/2 and Early Number was coded as +1/2 to compare gender versus number processing. All the numerical variables were rescaled

and centered around the mean. The best model was selected through a bottom-up stepwise model comparison using the Bayesian Information Criterion (BIC).

4. Results

The mean offline accuracy on the task was 98.9% for Mandarin-Italian bilinguals (*SD* = 10%), 99.0% for Arabic-Italian bilinguals (*SD* = 10%), and 99.9% for monolingual participants (*SD* = 3.7%). The analysis of the eye tracking data includes data from accurate trials only.

The time course of target fixations of monolingual Italian children, Mandarin-Italian bilinguals and Arabic-Italian bilinguals during the sentence in the three different conditions is displayed in Figure 2.

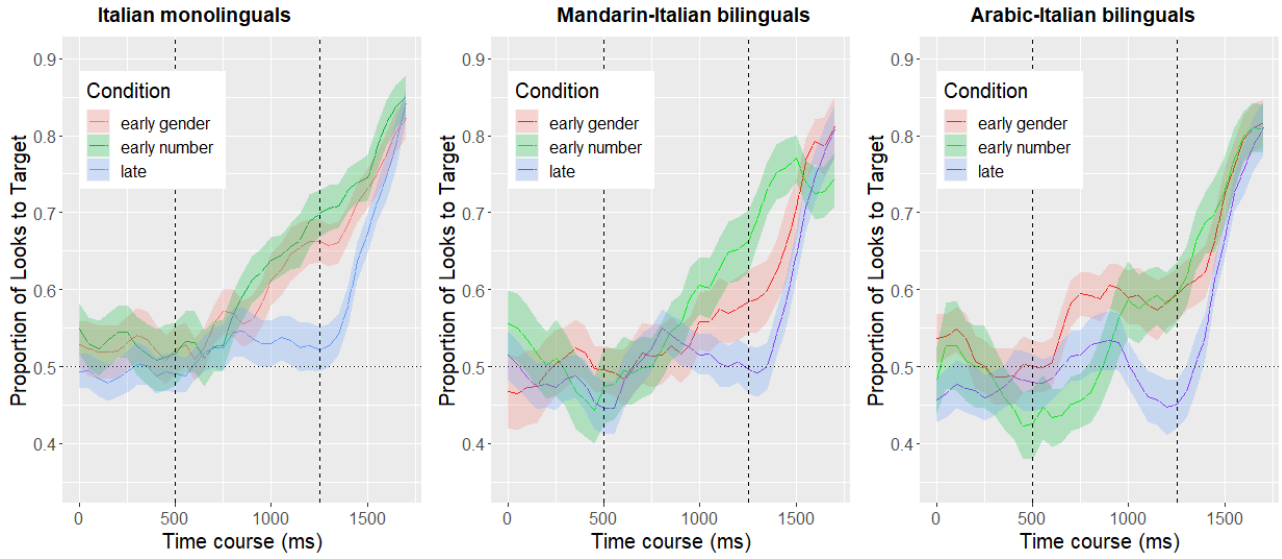

Figure 2. Time course of the proportions of looks toward the target (versus competitor) in the three conditions for monolinguals (on the left), Mandarin-Italian bilinguals (in the middle), and Arabic-Italian bilinguals (on the right). The first vertical line represents determiner onset and the second vertical line represents noun onset, shifted 200 ms to account for saccade planning.

As can be seen from Figure 2, for monolingual children the proportion of looks to the target picture started increasing during the article, before the onset of the noun, in the Early Gender and the Early Number condition, but not in the Late condition. This suggests that monolinguals anticipated nouns on the basis of articles, with nearly identical patterns for gender and number. In contrast, Mandarin-Italian bilinguals also showed anticipation of the target noun, but they seemed to be considerably slower to direct their gaze to the target picture in the Early Gender condition than in the Early Number condition. Arabic-Italian bilinguals displayed an opposite pattern; they started looking at the target picture earlier in the Early Gender condition than in the Early Number condition. Note that the proportion of target looks at the end of the article is very similar in the two predictable conditions, suggesting that the apparent difference between gender and number might be due to different starting points at the beginning of the article.

The output of the statistical analysis is provided in Table 3. The most predictive model that converged included a three-way interaction between Time, Condition and Group as well as their main effects, a main effect of Item Order, and random intercepts for Item and Subject with random slopes for Time and Condition.

The main effect of Time indicates that, overall, participants became more likely to look at the target picture while listening to the article. Item order also had a significant effect; participants became less likely to look at the target during the course of the experiment, possibly due to a fatigue effect. The significant interaction between Time and Condition (Early vs Late) constitutes a prediction effect; the difference between the odds of looking at the target in the (predictable) Early conditions and the (unpredictable) Late condition became significantly greater while listening to the article, indicating that participants anticipated the target noun on the basis of determiner features. This general prediction effect was greater for monolinguals than for bilinguals, as shown by the three-way interaction between Time, Condition (Early vs Late) and Group (Bilingual vs Monolingual). When focusing on the comparison between the two bilingual groups - i.e. the interaction between

Time, Condition (Early vs Late) and Group (Mandarin vs Arabic), Arabic-Italian bilinguals showed a stronger prediction effect than Mandarin-Italian bilinguals.

Table 3. *Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects for the comparison between monolingual and bilingual participants.*

Generalized linear mixed model Looks to target (yes or no) ~ Time * Condition (early gender vs early number vs late) * Group (monolingual vs mandarin vs arabic) + Item Order + (1 | Item) + (1 + Time + Condition | Subject)			
Fixed factor	Est. odds ratio	95% CI	*p*
Time	1.17	1.1 .. .1.2	<.001
Condition (early vs late)	1.24	.97 .. 1.6	.088
Condition (gender vs number)	.982	.72 .. 1.3	.910
Group (mono vs bi)	1.17	.99 .. 1.4	.065
Group (Arabic vs Mandarin)	.982	.79 .. 1.2	.865
Item order	.980	.97 .. .99	<.001
Time : Condition (early vs late)	1.21	1.2 .. 1.2	<.001
Time : Condition (gender vs number)	1.11	1.1 .. 1.1	<.001
Time : Group (mono vs bi)	1.01	.91 .. 1.1	.882
Time : Group (Arabic vs Mandarin)	1.04	.91 .. 1.2	.536
Condition (early vs late) : Group (mono vs bi)	1.10	.80 .. 1.6	.509
Condition (gender vs number): Group (mono vs bi)	1.13	.82 .. 1.5	.477
Condition (early vs late) : Group (Arabic vs Mandarin)	.907	.62 .. 1.3	.614
Condition (gender vs number): Group (Arabic vs Mandarin)	1.46	.94 .. 2.3	.095
Time : Condition (early vs late) : Group (mono vs bi)	.958	.92 .. .99	.033
Time : Condition (gender vs number): Group (mono vs bi)	.938	.89 .. .99	.017
Time : Condition (early vs late) : Group (Mandarin vs Arabic)	.932	.89 .. .98	.006
Time : Condition (gender vs number): Group (Mandarin vs Arabic)	.920	.86 .. .98	.014

With respect to the difference between gender and number, we found a significant interaction between Time and Condition (Gender vs Number), suggesting that number was processed significantly faster than gender. The significant three-way interaction between Time, Condition

(Gender vs Number) and Group (Bilingual vs Monolingual) indicates that the difference between gender and number processing is greater for bilinguals than for monolinguals. Moreover, when comparing Mandarin-Italian bilinguals to Arabic-Italian bilinguals, we see that the gender-number discrepancy differs significantly in the two groups, as shown by the interaction between Time, Condition (Gender vs Number) and Group (Mandarin vs Arabic).

5. Discussion

This study addressed linguistic prediction on the basis of determiner features in Mandarin-Italian and Arabic-Italian sequential bilingual children, in comparison to monolingual Italian children. We aimed to contrast the processing of grammatical gender with number, since gender may be particularly challenging for L2 speakers, specifically when this feature is absent in the L1. By testing both native speakers of Mandarin (which has number but not gender) and of Arabic (which has both number and gender), we aimed to investigate the possible influence of cross-linguistic differences on predictive language processing.

The first aim of this study was to investigate to what extent Mandarin-Italian and Arabic-Italian sequential bilingual children use articles to anticipate upcoming nouns in Italian, in comparison with monolingual children. Hypothesizing that predictive processing might be less efficient in bilingual children who are tested in a non-native or non-dominant language, especially if they need to rely on grammatical cues that differ from those available in their L1, we predicted that Mandarin-Italian and Arabic-Italian bilingual participants would be less likely to anticipate target nouns on the basis of articles than monolingual Italian participants. Our results confirm this hypothesis. We also found a slightly stronger prediction effect in Arabic-Italian bilinguals than in Mandarin-Italian bilinguals, which is interesting given the fact that articles exist in Arabic but not in Mandarin. In other words, even though articles are not marked for gender or number in Arabic, the

mere existence of articles in the L1 might cause Arabic-Italian bilinguals to be more sensitive to this grammatical category than Mandarin-Italian bilinguals.

Yet, it should be emphasized that all three groups anticipated nouns based on morphosyntactic agreement on the article, complementing previous research showing that children process speech predictively (Brouwer et al., 2017; Cholewa et al., 2019; Mani & Huettig, 2012 for monolinguals, and Brouwer et al., 2017; Lemmerth & Hopp, 2019; Meir et al., 2020 for bilinguals). It also corroborates the results reported in Chapter 2 and 3, which suggested that bilingual children are able to make efficient use of gender and number cues in both their L1 and their L2. Moreover, the findings of this study show that both Mandarin-Italian and Arabic-Italian bilingual children are able to attend to articles, suggesting that they can rely on a grammatical category that does not exist in the L1 (in the case of Mandarin-speaking children) or that does not provide the same type of cues (in the case of Arabic-speaking children). Similar findings were reported by Lemmerth and Hopp (2019), who found that Russian-German bilingual children were able to anticipate nouns in German by relying on gender-marked articles, even though Russian does not have articles.

Our second aim was to compare the processing of grammatical gender and number in Mandarin-Italian and Arabic-Italian bilingual children with that of their monolingual Italian peers. Based on previous studies with late L2 learners (Gabriele et al. 2013; White et al. 2004; Gillon-Dowens et al. 2010; Lew-Williams & Fernald 2009; Hopp 2012), we hypothesized that gender processing would be more challenging than number processing also for sequential bilingual children. It has been claimed that such an advantage for number over gender may be due to different representations at the conceptual level. Assuming that L2 learners have more difficulties with lexical retrieval, they may experience more difficulties with gender, since gender processing requires reliance on arbitrary lexical knowledge, whereas number is conceptually more tangible and strongly linked to the referential context. Moreover, we hypothesized that L1 characteristics might play a role, since previous studies reporting an asymmetry between gender and number processing all focused on L2 learners whose L1 does not have grammatical gender (i.e., English). Therefore, we expected a

gender-number discrepancy to be greatest for Mandarin-Italian bilingual children, since Mandarin lacks grammatical gender despite having a conceptual notion and grammatical expression of number, while Arabic has both gender and number.

The results show that Mandarin-Italian bilingual children were indeed significantly faster with number than with gender. In contrast, we found the opposite pattern in Arabic-Italian bilinguals, as they showed more anticipatory looks based on gender than on number. It should be noted that the proportions of target looks at the end of the article in the gender and number condition were very similar for Arabic-Italian bilinguals, which means that the advantage for gender may in fact have been caused by different baselines at the onset of the article, with no real difference between the two predictable conditions. Crucially, however, Arabic-Italian bilinguals did not show the same pattern as Mandarin-Italian bilinguals, suggesting that the presence or absence of a certain feature in the L1 may influence predictive processing in the L2. This is in line with the findings of Meir et al. (2020), which showed that Russian-Hebrew bilingual children benefitted from the existence of reliable case morphology in Russian while processing less reliable case markers in Hebrew. In other words, bilingual children might transfer their processing strategies when a certain predictive cue is available in both of their languages.

We point out that Arabic-Italian bilingual children may also have experienced cross-linguistic interference due to competing gender representations. Italian nouns and their translation equivalents in Arabic do not always have the same grammatical gender, which may have led to a speed up or a slow down for certain items. This 'gender congruency effect' is beyond the scope of the current chapter, but it is elaborated on in more detail in Chapter 2.

One limitation of the present study is that we could not test the effect of language proficiency, since the groups were too small to conduct a statistically reliable analysis of individual differences, and because Arabic-Italian and Mandarin-Italian bilingual children were not assessed with the same vocabulary test. Therefore, we are not able to fully tease apart the two possible explanations for a potential discrepancy between gender and number processing for bilingual participants. Unlike

Arabic-Italian bilinguals and Italian monolinguals, Mandarin-Italian bilinguals showed an advantage for number processing over gender processing, but we cannot be certain whether this is due to L1 effects, to child-level factors such as proficiency, or to both. The effects of language dominance and L2 proficiency on linguistic prediction are explored in Chapter 2 and Chapter 3, but more research is needed to systematically examine the effect of such individual differences on gender versus number processing. Although follow-up studies should be conducted with a larger sample in order to confirm the observed patterns, we believe that this study offers some valuable insights and a good starting point for future research on the effect of linguistic differences on predictive language processing in bilingual children.

Chapter 5

Investigating the role of reading in monolingual and multilingual children's linguistic prediction[8]

Abstract: Previous research suggests that predictive processing is facilitated by literacy, but this effect has not yet been studied in a bilingual population. We investigated the relationship between prediction in spoken language and reading skills in 38 multilingual children who speak a variety of heritage languages and Italian as the majority language, in comparison to 32 monolingual Italian children. Using a visual world eye tracking method, we tested children's ability to anticipate nouns on the basis of gender- and number-marked articles during the incremental processing of Italian sentences. A principal components analysis of various reading measures extracted a first principal component that reflected children's word and text reading speed. While we found a positive relation between experimentally elicited anticipation and reading skills (i.e., PC1) in monolingual children, we found no reliable effects for multilingual children. We argue that this might be due to the fact that these children already show suboptimal predictive processing by virtue of being tested in a non-native or non-dominant language. Future work is required to better understand the relation between prediction and reading in bilingual speakers, ideally taking L1 processing and potential effects of biliteracy into account.

Key words: predictive processing, literacy, bilingual children, visual world paradigm

[8] We thank Falk Huettig for his advice on data analysis and for his contribution to a different but related project, which inspired the current study.

1. Introduction

As we have seen in the previous chapters, bilingual children are able to make use of anticipatory mechanisms to pre-select upcoming nouns, by relying on morphosyntactic cues. However, the extent to which they do so seems to be related to cross-linguistic differences between their two languages, as well as to their relative language proficiency. As a result, when bilingual children are tested in a non-dominant or non-native language, they may be less likely to show predictive processing than their monolingual peers. These findings are in line with previous research on predictive processing in late L2 learners (Dussias et al., 2013; Lew-Williams & Fernald, 2010; Martin et al., 2013).

Another group that has been found to show weaker predictive processing consists of people with limited reading experience, such as illiterate people (Mishra et al., 2012) or people with dyslexia (Huettig & Brouwer, 2015; Persici et al., 2019). As discussed in Chapter 1, it has been hypothesized that reading experience improves people's ability to anticipate upcoming words by training the core mechanisms involved in prediction (Huettig & Pickering, 2019). 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 encouraged to identify upcoming words as soon as possible to optimize the time required to process written information. There are several factors inherent to reading that may boost predictive mechanisms, including the fact that saccadic eye movements during reading require planning and anticipation (Reichle et al., 2003, 2006; Reichle & Laurent, 2006). Moreover, reading improves lexical knowledge (Andrews, 2008; Cunningham & Stanovich, 1998), and it leads to more fine-grained phonological and lexical representations as well as additional graphemic representations (Huettig & Pickering, 2019). This may all contribute to faster predictive sentence processing, which may subsequently transfer into the spoken language modality (Huettig & Mishra, 2014; Huettig & Pickering, 2019).

Thus, predictive processing tends to be weaker in L2 learners, as well as in people with poor literacy skills, but these factors have not yet been investigated together, and very little attention has been paid to multilingual children. Therefore, in this chapter we aim to investigate whether multilingual and monolingual Italian children differ in the way in which they anticipate nouns on the basis of preceding articles, and whether this is related to their reading skills in Italian. To our knowledge, this is the first study to investigate predictive processing and its relation to literacy in multilingual children.

In the next section, we will discuss previous studies that investigated the link between reading and prediction in spoken language. After that we will present our research questions and hypotheses, the methods of the current study, the results, and a discussion of our findings.

2. Background

2.1 Previous research on the relation between reading and prediction

During the last decade, several studies have provided empirical evidence for a relation between literacy and prediction in spoken language processing. The first to investigate this were Mishra et al. (2012), who compared the predictive processing skills of low- and high-literates in India, using a visual world eye tracking experiment that tested whether participants were able to anticipate nouns on the basis of semantic, associative and syntactic cues on preceding adjectives and particles. While the high-literacy group showed rapid anticipation (i.e., they started looking at the target picture before the onset of the noun), the low-literacy group failed to do so. This led the authors to conclude that literacy may be crucial for fine-tuning the predictive mechanisms involved in pre-activating representations of upcoming words. However, it may be difficult to disentangle the effects of literacy from the effects of formal schooling. Therefore, 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 who were at the early stages of reading acquisition. They tested semantic anticipation of nouns on the basis of the lexical meaning of verbs. For example, when presented with a picture of a bird and a picture of a cake, participants heard the sentence *Der Junge isst den grossen Kuchen* 'The boy eats the big cake'. 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. No correlation was found, instead, with their nonword reading skills, their phonological awareness or their offline word recognition skills in a naming task.

Moreover, studies comparing typical readers to reading-impaired populations have shown that people with dyslexia are less likely to anticipate upcoming speech. For example, comparing Dutch adults with and without dyslexia, Huettig and Brouwer (2015) tested incremental processing as well as linguistic prediction in a visual world eye tracking paradigm. A first experiment showed that dyslexics were similar to typical readers in their ability to incrementally integrate spoken language input, since both groups effectively directed their attention to the relevant picture in a manner that was closely time-locked to the sentence. A second experiment showed that both groups were able to anticipate nouns on the basis of the grammatical gender of articles, but participants with dyslexia were considerably delayed. Moreover, their word reading scores positively correlated with their anticipation skills. Similarly, Persici et al. (2019) compared prediction skills in Italian children with and without developmental dyslexia (*M* age = 10;1). Starting from previous research showing that people with dyslexia have difficulties anticipating rhythmic structures (Pagliarini et al., 2020), they focused on morphosyntactic anticipation as well as on rhythmic abilities tested in a task that required participants to anticipate an upcoming beat by relying on a warning sound. Children with dyslexia underperformed in the rhythmic task, and they were slower in a picture selection task testing the recognition of nouns preceded by gender-marked clitics, but not in a task with gender-marked determiners. The authors concluded that deficiencies in reading and rhythm are both related to a core deficit in predictive mechanisms, or more generally in the efficient use of temporal structural

regularities (see Guasti et al., 2017). Note that this approach differs in the sense that it assumes that predictive processing supports reading, rather than the other way around.

Recently, two studies also provided evidence for a relation between reading skills and predictive speech processing in healthy adults. Ng and colleagues (2018) tested American adults with varying levels of literacy skills, as measured by several standardized reading tasks. Participants listened to spoken sentences that were either expected or unexpected, while their EEG was recorded (see Ng et al. 2017 for a similar study on written text processing). Items were either strongly constraining (e.g. 'The prisoners were planning their escape/party) or weakly constraining (e.g. 'He slipped and fell on the floor/rock'), based on their cloze probability. The results showed larger N400 amplitudes for less expected words, regardless of the level of literacy. However, there was an early effect of literacy skills over anterior channels, as high-literacy participants showed reduced negativity for strongly predictable words, while low-literacy participants did not. These findings suggest that even though literacy skills are not related to incremental processing and semantic integration, people with weaker literacy skills may be less likely to anticipate upcoming speech (Ng et al., 2018). This was confirmed by Favier et al. (2021), who tested healthy adult speakers of Dutch, using a visual world eye tracking paradigm. Their results showed that high-literacy adults were more likely than low-literacy adults to anticipate target nouns based on a syntactic cue indicating the passive voice. Participants' literacy level (which was based on a statistically determined composite score consisting of receptive vocabulary, author recognition, reading habits, word reading and pseudoword reading) was the strongest predictor of anticipatory eye movements, independently of general cognitive skills.

In sum, there is ample evidence for a relation between literacy-related skills and predictive processing in adults, but to date very few studies have focused on children. Moreover, the question of whether this effect can also be observed in multilingual children has not yet been explored.

2.2 Research questions and hypotheses

The aim of the current study is to investigate predictive processing and its relation to reading abilities in multilingual children, in comparison to their monolingual Italian peers. Capitalizing on the fact that Italian marks grammatical gender and number on articles, as described in Chapter 4, we tested whether monolingual and bilingual children make use of articles to predict upcoming nouns when processing Italian sentences in a visual world eye tracking paradigm. In this chapter we will focus on children's prediction in relation to their literacy-related skills in Italian, exploring if and how these predict their anticipatory eye movements during online language processing.

Given previous findings, we hypothesize, first, that multilingual children predict upcoming information during spoken language processing. Specifically, we expect an increase of looks toward the target during the article in a predictable condition (in which there is a mismatch in grammatical gender or number between target and competitor), but not in an unpredictable 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 in the majority language than monolingual children. This will be reflected by delayed anticipatory eye movements in comparison with monolingual peers. Recall from chapter 4 that grammatical gender processing may differ from number processing, since grammatical gender is an arbitrary feature stored in the lexicon while number is a morphosyntactic feature that can be retrieved from the referential context. Therefore, we expect that some multilingual participants might show an advantage when processing number compared to gender, but this will not be the main focus of the present chapter. Instead, we will explore to what extent prediction abilities are related to literacy-related skills. Based on previous research with monolingual children and adults with varying levels of literacy, we expect children's reading skills to be positively related to their predictive speech processing in Italian. In this chapter, we will investigate the link between reading and prediction in spoken language processing in both monolingual and multilingual children.

3. Methods

3.1 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 4.4 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). All participants were typically developing children without any diagnosis of learning disabilities, language impairment or developmental dyslexia.

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, children 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 multilingual children were 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) and English (*N* = 1). All Filipino-speaking children, two Arabic-speaking children and one Chinese-speaking child also spoke English at home as a third language. The majority of the multilingual participants, 76.3%, were second generation immigrants who were born in Italy, while 23.7% arrived in Italy before age 4. Table 1 provides some additional demographic data of the multilingual participants in our sample.

The monolingual children and the Arabic-speaking bilingual children in this study were also included in the study presented in Chapter 4.

Table 1. *Characteristics of multilingual participants*

	Multilinguals
Age at the time of testing	*M* = 9;11 (*SD* = 1;00) Range = 7;10-12;08
Age of first exposure to Italian	*M* = 1;02 (*SD* = 2;03) Range = 0;00-4;02
Length of exposure to Italian	*M* = 8;06 (*SD* = 2;10) Range = 5;02-12;07

3.2 Materials and procedure

3.2.1 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).

3.2.2 Eye tracking

We used the same eye tracking experiment and procedure as in Chapter 4 (for a list of experimental items, see Appendix 5). As illustrated in Figure 1, taken from Chapter 4 and repeated here for your convenience, 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* and *le* vs *le.*

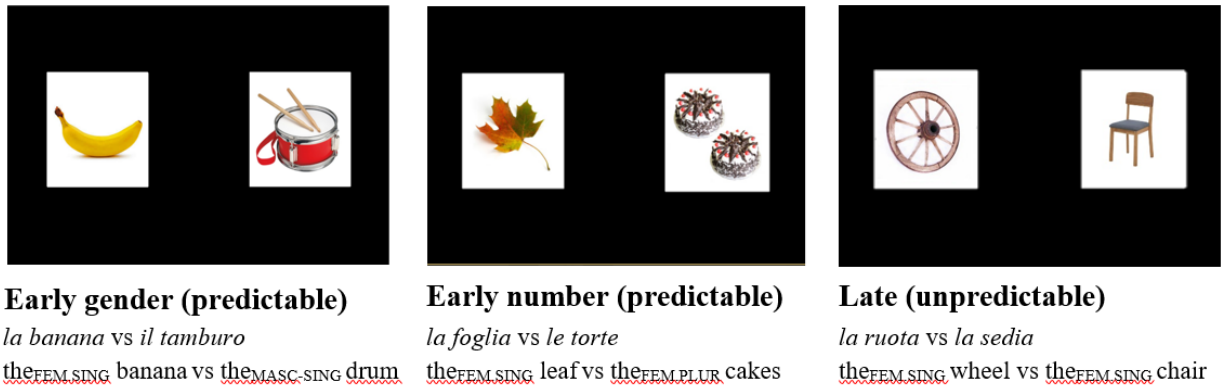

Figure 1. Overview of experimental conditions. Repeated from Chapter 4.

3.3 Analysis

3.3.1 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.

3.3.2 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.

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, 2019). 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. When comparing the two early conditions to the late condition, Late was coded as -2/3, Early Gender was coded as +1/3 and Early Number was coded as +1/3; when comparing gender versus number, Late was coded as 0, Early Gender was coded as -1/2 and Early Number was coded as +1/2. 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 +.5, or Multilinguals, coded as -.5), reading skills (PC1) and vocabulary knowledge. Random intercepts for Item and Subject were included, with random slopes for Condition, Time and PC1. We also checked whether adding Age in months, Trial number and List improved the models, but this was not the case.

First, we compared predictive processing based on gender and number in monolingual and multilingual participants. After that, 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.

4. Results

4.1 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.

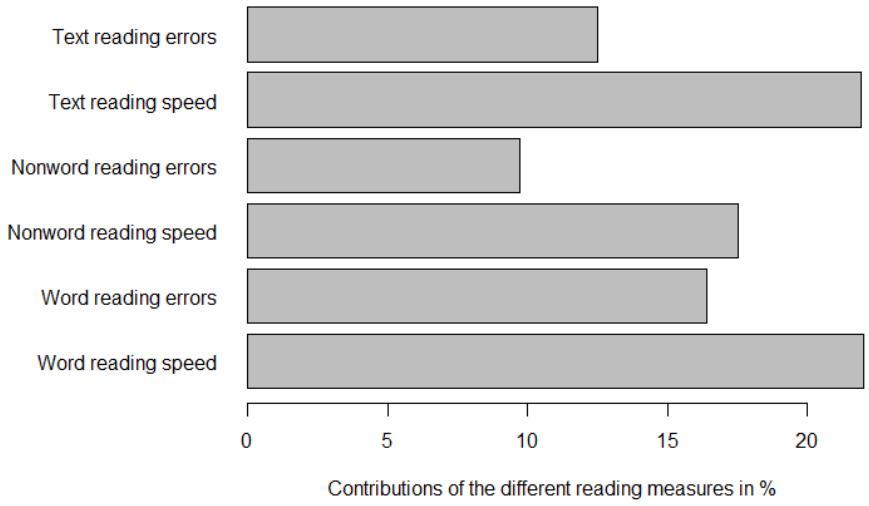

Figure 2. Composition of the first principal component of literacy (PC1)

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), $t(72) = -1.17$, $p = .246$. 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 therefore only be examined in the multilingual group. Finally, there was a weak but significant positive correlation between PC1 and vocabulary scores, $r(72) = .339$, $p = .003$.

4.2 Eye tracking

4.2.1 Monolinguals vs multilinguals

First, we compared anticipatory looks based on gender and number in monolingual versus multilingual children. The best model that converged included Condition, Time and Group as well as the interaction between them, and random intercepts for Subject and Item with random slopes for Condition and Time. Age, List and Item order did not improve the model and were removed from the analysis. The model output is presented in Table 2, 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 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, monolingual

participants tend to look at the target between 64% and 73% of the time, while multilingual participants only tend to do so between 56% and 64% of the time.

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, the observed differences are small, and since the gender-number discrepancy is not the focus of the current chapter, we merged the two predictable conditions into one for the analyses presented below.

Table 2. *Estimated odds ratios, 95% confidence intervals and associated p-values of main and interaction effects of the comparison between 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)	.990	.766 .. 1.28	.939
Condition (gender vs number)	.972	.711 .. 1.33	.857
Time	1.24	1.14 .. 1.36	<.001
Group	1.07	.891 .. 1.29	.460
Condition (early vs late) : Time	1.37	1.33 .. 1.42	<.001
Condition (gender vs number) : Time	1.01	.964 .. 1.05	.719
Condition (early vs late) : Group	1.22	.885 .. 1.67	.226
Condition (gender vs number) : Group	1.08	.765 .. 1.52	.663
Time : Group	1.09	.916 .. 1.30	.331
Condition (early vs late) : Time : Group	.923	.862 .. .988	.020
Condition (gender vs number) : Time : Group	1.16	1.06 .. 1.27	.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.

4.2.2 The effect of reading

First, 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), as well as random intercepts for Subject and Item with random slopes for Condition, Time and PC1. The model output is summarized in Table 3.

As in the previous analysis, there was a significant main effect of Time and 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. Furthermore, this prediction effect was significantly modulated by reading scores (PC1).

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 + PC1| Subject)			
Fixed factor	Est. odds ratio	95% CI	*P*
Condition (predictable vs unpredictable)	1.10	.780 .. 1.56	.581
Time	1.22	1.08 .. 1.37	.001
PC1	.911	.742 .. 1.12	.374
Condition (predictable vs unpredictable) : Time	1.28	1.22 .. 1.35	<.001
Condition (predictable vs unpredictable) : PC1	1.09	.784 .. 1.48	.643
Time : PC1	1.09	.924 .. 1.29	.306
Condition (predictable vs unpredictable) : Time : PC1	1.11	1.04 .. 1.19	.003

In order to visualize the effect of reading scores, we divided our participants in 'good readers' and 'poor readers', using a median split. Figure 4 illustrates the difference in anticipatory eye movements between good and poor readers among monolingual children. 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 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.

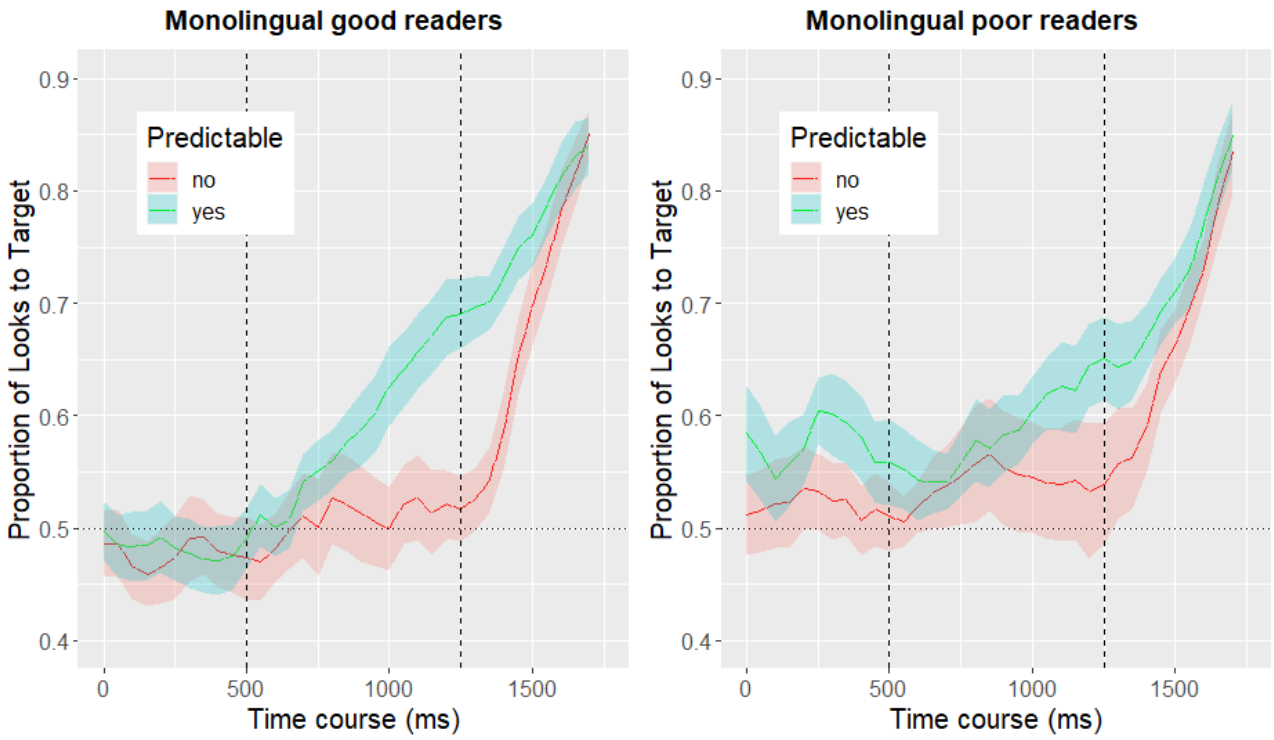

Figure 4. Time course of the proportions of looks toward the target (versus competitor) for monolingual good readers (on the left) and monolingual poor readers (on the right).

After that, 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 + PC1| Subject)			
Fixed factor	Est. odds ratio	95% CI	*p*
Condition (predictable vs unpredictable)	.909	.648 .. 1.27	.578
Time	1.12	.990 .. 1.28	.072
PC1	1.02	.907 .. 1.14	.754
Condition (predictable vs unpredictable) : Time	1.41	1.34 .. 1.48	<.001
Condition (predictable vs unpredictable) : PC1	1.19	.968 .. 1.46	.099
Time : PC1	1.04	.932 .. 1.115	.515
Condition (predictable vs unpredictable) : Time : PC1	.890	.956 .. .926	<.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 random differences in the control condition. At the end of the article time window in the predictable Late condition, both good and poor multilingual readers on average look at the target picture 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 children's anticipatory eye movements, but no significant effect of reading skills.

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	1.32	1.1 .. 1.6	.002
PC1	1.11	.94 .. 1.3	.231
Time : PC1	.981	.84 .. 1.1	.796

4.2.3 The effect of vocabulary knowledge

Finally, we investigated whether anticipatory eye movements in bilingual 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., the interaction between Condition and Time), we found no significant effect of vocabulary knowledge.

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)	.882	.62 .. 1.2	.474
Time	1.15	1.0 .. 1.3	.035
Vocabulary	1.04	.91 .. 1.2	.563
Condition (predictable vs unpredictable) : Time	1.42	1.3 .. 1.5	<.001
Condition (predictable vs unpredictable) : Vocabulary	.980	.80 .. 1.2	.851
Time : Vocabulary	1.07	.97 .. 1.2	.189
Condition (predictable vs unpredictable) : Time : Vocabulary	.968	.93 .. 1.0	.119

5. 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, and whether their language-mediated anticipatory eye movements are related to their reading skills in Italian.

We hypothesized that both monolingual and multilingual children make use of prediction while listening to sentences in Italian, but that prediction might be stronger in monolingual children, since they are per definition tested in their L1. Therefore, we expected to find prediction in both groups, with earlier and faster language-mediated anticipatory eye movements in monolingual participants, as we found in Chapter 4. These predictions were borne out by the data. We found clear anticipation effects in multilingual children, suggesting that they are able to make efficient use of predictive mechanisms when processing morphosyntactic cues in Italian. This was also found in the studies presented in Chapter 2 to 4 of this thesis, as well as by previous studies focusing on predictive processing in bilingual children (Lemmerth and Hopp, 2019; Meir et al., 2020). Yet, monolinguals were significantly faster than multilinguals. This complements previous findings in the adult L2 literature showing delayed processing in L2 learners in comparison with native speakers (Lew-Williams & Fernald, 2010; Martin et al., 2013; Dussias et al., 2013). As for children, Meir et al. (2020) reported partly similar results in Russian-Hebrew bilinguals, who showed significantly weaker predictive processing based on case markers in Russian than monolingual Russian-speaking children, despite an advantage in Hebrew compared to monolingual Hebrew-speaking children.

Given previous research showing that gender processing tends to be more challenging for L2 learners than number processing (Gabriele et al., 2013; Gillon-Dowens et al., 2010; Lew-Williams & Fernald, 2009; Hopp, 2012), we expected that multilingual children might be slower when processing gender compared to number, as was found for Mandarin-Italian bilingual children in Chapter 4. However, in the current study we found the opposite pattern: monolingual children were slightly faster with number, while multilingual children were slightly faster with gender (similar to the Arabic-speaking subgroup presented in Chapter 4). We speculate that this 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), whereas studies that report an advantage of number over gender all focused on adult L2 learners whose L1 was English, a language that does not have grammatical gender. The possible effect of L1 characteristics on L2 processing is addressed in more detail in Chapter 4 as well as Chapter 6.

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 (i.e., the first principal component), with real word and text reading speed contributing 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 word 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), experience with reading trains predictive mechanisms 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 (Huettig & Mishra, 2014; Huettig & Pickering, 2019).

In contrast, our multilingual participants did not show the same pattern, as we did not find any reliable effect of reading skills in this group. One interpretation of this finding is that these children already showed sub-optimal predictive processing because they were tested in their L2, and as such a subtle effect of reading skills may not surface in multilingual participants. In other words, we might have found a positive correlation between prediction and reading skills if the eye tracking experiment had been conducted in children's L1. Future studies might want to explore this further, while also taking potential effects of biliteracy into account.

Since highly proficient L2 speakers tend to show more native-like processing than speakers with low proficiency (Dussias et al., 2013; Henry et al., 2020; Hopp & Lemmerth, 2018), we also considered whether anticipatory eye movements of multilingual children were related to their productive vocabulary knowledge in Italian. Previous research suggests that predictive processing is facilitated by having strong vocabulary knowledge (Mani & Huettig, 2012; Borovsky et al., 2012; Nation et al., 2003; Hintz et al., 2017; Rommers et al., 2015), which may be especially relevant in a non-native or non-dominant language. Whilst we found significant effects of receptive vocabulary knowledge in Chapter 2 and productive L2 vocabulary knowledge in Chapter 3, in the current study we found no such effects. This might be related to our inclusion criteria: given that we tested reading abilities in this study, we only included multilingual children who had at least 5 years of exposure to Italian. As a result, multilingual children in this group had a higher proficiency in Italian, with less variation in children's scores on the vocabulary test.

It should be noted that we observed some unexpected effects in the (unpredictable) control condition as well as in the pre-critical time window, which might be experimental artefacts 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.

Finally, we point out that, like most current research in the field, our design is correlational. The present study therefore is not informative about the causal direction of the observed effect. If there is a relation between reading and prediction, we believe it is likely to be bidirectional: reading improves predictive processing and children who are better at anticipating upcoming language are at an advantage when learning to read. Future studies ideally could overcome this limitation by using experimental designs (such as a training intervention) or longitudinal studies in which children's predictive processing before the onset of formal reading instruction is taken into account (cf. Huettig et al., 2018).

Chapter 6

General Discussion

The present thesis aimed to investigate predictive language processing in different groups of bilingual children, who have thus far has received little attention in the literature on linguistic prediction. We examined (1) to what extent simultaneous and sequential bilingual children anticipate nouns based on morphosyntactic cues, (2) whether predictive processing is related to language dominance and L2 proficiency, (3) to what extent bilingual children experience cross-linguistic influence during predictive processing, and (4) whether children's literacy skills are related to prediction in spoken language processing. We addressed these questions in 5 experiments with different groups of bilingual participants. The overall findings of these studies related to the four questions under investigation will be discussed separately below.

1. Prediction in bilingual children

In all studies presented in this thesis, we found converging evidence for predictive processing in bilingual children, suggesting that children are able to anticipate nouns based on morphosyntactic cues not only in their L1 but also in their L2. Specifically, Chapter 2 showed that both simultaneous and sequential Italian-German bilingual children with varying levels of language dominance were able to anticipate nouns based on gender-marked articles in both of their languages, Chapter 3 showed that sequential Italian-English bilinguals used number cues to predict both in their L1 (article-noun agreement) and in their L2 (subject-verb agreement), and Chapter 4 and 5 showed that sequential bilingual children learning Italian as the majority language anticipated nouns in Italian based on gender- and number- marked articles. These findings support previous studies showing that bilingual children make use of predictive processing (Brouwer et al., 2017; Lemmerth & Hopp, 2019; Meir et al., 2020). While these prior studies focused exclusively on simultaneous and early successive

bilinguals, the studies presented in Chapter 2 and 4 also included participants who started learning their L2 after the age of 4 (but before the age of 7), and who might thus be considered 'child L2 learners'.

When directly comparing sequential bilingual children to their monolingual peers, as we did in Chapter 4 and 5, we found that bilingual participants showed slightly weaker prediction than monolingual participants, although the overall patterns were comparable. This is in line with Meir et al. (2020), who found that while Russian-Hebrew bilinguals were sensitive to case markers to anticipate argument structure in Russian, they did so to a lesser degree than monolingual controls.

These results suggest that even though bilingual children make use of linguistic anticipation in both of their languages, they may be less likely to do so when tested in a non-native or non-dominant language. This 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, 2018; Segalowitz & Hulstijn, 2009). Moreover, since prediction is an optional mechanism during language processing, considerations of utility may play a role (Huettig & Mani, 2016; Kaan & Gruter, 2021). For example, it might be more beneficial for bilingual children to allocate available cognitive resources to the monitoring of potential interference from competing linguistic representations rather than to linguistic anticipation.

While two previous studies found stronger predictive processing in bilingual children than in monolingual children, both for language (Brouwer et al., 2017) and for non-linguistic stimuli (Bonifacci et al., 2011), we found no such general bilingual advantage in any of our studies. This may be explained in two different ways. Firstly, differences in the children's age may have played a role, since both of these studies focused on kindergartners while we tested children in primary school. Moreover, Brouwer et al. observed a difference between bilinguals and monolinguals among 4-year-olds but not among 5-year-olds. This means that if there is a bilingual advantage in predictive processing due to increased attention to relevant cues and increased practice with linguistic prediction

in two languages, this may become apparent only in early developmental stages, since older children are expected to have more mature cognitive skills and further developed anticipatory processing mechanisms regardless of their monolingual or bilingual status.

A second factor that may explain the diverging findings relates to the type of cue that children were presented with, given that Brouwer and colleagues tested prediction based on semantic information, while we used morphosyntactic cues (as did Lemmerth & Hopp, 2019 and Meir, 2020). Clahsen and Felser (2006, 2018) argued that adult L2 speakers rely more heavily on lexical semantics than on grammatical information during sentence processing, and there does indeed seem to be such a discrepancy between semantic and morphosyntactic anticipation in the adult L2 predictive processing literature (Hopp, 2015). If grammatical processing is also more challenging for bilingual children, a bilingual advantage may be more likely to surface when testing prediction based on lexical cues, while any delays with respect to monolinguals may appear more readily when testing prediction based on morphosyntax. Future studies should explore this further. Moreover, direct comparisons between sequential bilingual children and adult L2 speakers would contribute to our understanding of the potential differences between adult L2 processing and child L2 processing, which may vary due to neurobiological factors (Birdsong, 2018; Perani & Abutalebi, 2005) as well as distinct learning environments and teaching approaches (Lichtman, 2013).

In sum, bilingual children are able to anticipate nouns based on morphosyntactic cues, but our results suggest that in some cases they are slightly delayed in comparison with monolingual peers. This seems to be influenced by children's language dominance and L2 proficiency, as will be discussed next.

2. Language dominance and proficiency

A second goal of this thesis was to investigate to what extent predictive processing in bilingual children is influenced by their language dominance and L2 proficiency. In Chapter 2, we

operationalized language dominance as relative language proficiency, by subtracting scores on a vocabulary test in one language from scores on a similar test in the other language, while in Chapter 3 and 5 we tested the effect of proficiency in terms of vocabulary size in minority language speakers who were tested in the majority language.

In the study presented in Chapter 2, we tested Italian-German bilingual children with different language backgrounds who lived either in Italy or in Germany, as to obtain a wide range of language dominance. Our results showed that in the Italian experiment, Italian-dominant children (who lived mostly in Italy) were significantly faster to anticipate nouns based on gender-marked articles than German-dominant children (who lived mostly in Germany). Moreover, the children in Germany were also tested in a German experiment, in which children who were relatively more proficient in German turned out to be significantly faster than children who were relatively more proficient in Italian. These results provide evidence that language dominance plays an important role in the way in which bilingual children process their two languages.

Furthermore, Chapter 3 reported that the degree to which Italian-dominant early successive Italian-English bilingual children anticipated nouns based on subject-verb agreement in English was positively related to children's L2 proficiency in English, with more proficient children showing stronger prediction. This suggests that L2 processing may become faster and more automatized as L2 proficiency increases (Ito & Pickering, 2021; Segalowitz & Hulstijn, 2009; Ullman, 2001). However, we found no such relation between predictive processing and vocabulary knowledge in Chapter 5. A possible reason for this is that these children were older and on average more proficient in the language of testing, which means that there may not have been enough variation to observe an effect.

To our knowledge, the studies presented in this thesis are the first to explore the effects of language dominance and proficiency on predictive processing in bilingual children. Previous research on L2 proficiency effects in adults has led to mixed results: while some studies found stronger predictive processing in high-proficient L2 speakers (Dussias et al., 2013; Henry et al., 2020; Hopp, 2013; Hopp & Lemmerth, 2018), others found no differences related to proficiency (Hopp, 2015; Ito

et al., 2018; Kim & Grüter, 2020; Perdomo & Kaan, 2021). Thus, with respect to adults, L2 proficiency seems to be important but not decisive, while more research is still needed to confirm to what extent language dominance and L2 proficiency modulate predictive processing in bilingual children.

While we operationalized language dominance as relative language proficiency in terms of vocabulary knowledge, it should be noted that this may in fact also reflect the everyday presence of the two languages in a child's life, including language input or language use (see Silva-Corvalan & Treffers-Daller, 2016; Unsworth, 2013). Future studies should disentangle how these different components of language dominance may affect bilingual sentence processing.

In addition to investigating the effect of language dominance on linguistic prediction, we also examined whether dominance modulated cross-linguistic influence during predictive processing. This will be addressed in the following section.

3. Effects of cross-linguistic influence

A third aim of this thesis was to investigate in which ways the languages of bilingual children may influence each other during predictive language processing. Firstly, we investigated whether children who speak two languages that have grammatical gender may be influenced by competing representations from the other language while anticipating nouns based on gender cues. More precisely, we tested if linguistic anticipation was delayed for nouns that did not have the same grammatical gender in the two languages (the so-called 'gender congruency effect). Secondly, we investigated whether the presence or the absence of a certain grammatical feature in the L1 affects predictive processing in the L2, and to what extent a feature should be expressed similarly for transfer to be possible.

With respect to the gender congruency effect, Chapter 2 reported that Italian-German bilingual children showed stronger anticipation of nouns based on gender-marked articles in Italian

when the target and competitor had the same gender in German. This effect was modulated by children's language dominance, since participants who were relatively less proficient in Italian and more proficient in German were more likely to experience cross-linguistic influence from German. However, no gender congruency effect was found in a German experiment, suggesting that children were influenced by their knowledge of German while processing sentences in Italian, but not the other way around. This may have been due to the fact that the group of children that participated in the German experiment was smaller and largely German-dominant.

Previously, Lemmerth & Hopp (2019) reported a gender congruency effect during predictive processing in Russian-German bilingual children. Comparing simultaneous to early successive bilinguals, they found that successive bilinguals failed to anticipate nouns based on gender cues in German when there was a gender mismatch between the two languages, while simultaneous bilinguals where not affected by gender congruency. This contrasts with our findings, since in the Italian experiment we found a strong gender congruency effect also in simultaneous bilingual children. We argue that this can be explained in terms of language dominance. The simultaneous bilinguals in Lemmerth and Hopp (2019) were all growing up in Germany and thus tested in their dominant language, similarly to our participants in the German experiment. In contrast, the children who participated in our Italian experiment were on average more balanced in terms of proficiency, as were the successive bilingual children in Lemmerth and Hopp (2019), who received a great amount of input in Russian at home. This suggests that bilingual children, regardless of the age of onset, may be more likely to display a gender congruency effect when they are tested in their less dominant language. Our findings corroborate previous research showing that even simultaneous bilingual children may be influenced by competing linguistic representations during language processing (Koutamanis et al., 2021; Van Dijk et al., 2022), as well as studies that showed that cross-linguistic influence is most likely to affect children's less dominant language (Bosch & Unsworth, 2020; Herve et al., 2016; Unsworth et al., 2014; van Dijk et al., 2022).

To understand the possible mechanisms that might underlie cross-linguistic influence during predictive processing, it may be useful to consider the prediction-by-production model of Pickering and Garrod (2013) in combination with the bilingual speech production model proposed by Nicoladis (2013). According to Pickering and Garrod (2013), listeners anticipate upcoming words by pre-activating linguistic forms in their production systems. This is the same level at which Nicoladis (2013) hypothesizes cross-linguistic influence to originate; she argues that cross-linguistic influence results from a competition between two linguistic forms at the lemma level of speech production. While this model originally meant to deal with cross-linguistic influence during production, it might also be applied to prediction-by-production. For example, if an Italian speaker hears *Mi passi la mela?* 'Can you pass me the$_{FEM}$ apple$_{FEM}$?' while looking at a table with an apple and some milk, they might anticipate the word *mela* 'apple' upon hearing *la,* since it is the only object with feminine gender on the table (*latte* 'milk' is masculine in Italian, and would have been preceded by the article *il* 'the$_{MASC}$'). However, if this speaker also knows German, a language in which the word 'apple' is masculine while 'milk' is feminine, seeing an apple may also trigger the pre-activation of the German word *Apfel* 'appel', and consequently its masculine gender, while seeing a bottle of milk may also pre-activate the word *Milch* together with feminine gender. This interplay between visual attention and bilingual speech processing, which is most likely influenced by a speaker's language dominance, may lead to cross-linguistic interference. As a result, linguistic predictions may be somewhat delayed, since L2 speakers need to direct cognitive resources toward the suppression of competing L1 representations (Chambers & Cooke, 2009).

Moreover, processing grammatical features that are absent in the L1 of a bilingual speaker may be especially resource-demanding, since it does not allow for the transfer of L1 linguistic representations. This is what we investigated in Chapter 4, in which we tested predictive processing based on gender- and number-marked articles in Mandarin-Italian and Arabic-Italian sequential bilingual children as well as monolingual Italian controls. Mandarin has neither articles nor grammatical gender, but it does mark number. In contrast, Arabic has articles and both grammatical

gender and number, even though these are expressed differently than in Italian. Firstly, we tested whether bilingual children would reliably attend to a grammatical category that does not exist in their L1 or that does not provide similar anticipatory cues (i.e., articles). Since our results showed efficient anticipation based on articles in both bilingual groups, we can conclude that bilingual children are able to predict even if it requires them to attend to a grammatical cue that is specific to their L2. This is also in line with Lemmerth and Hopp (2019), who found that Russian-German simultaneous and sequential bilinguals were equally sensitive to articles (which are absent in Russian) as to adjectives (which exist in both languages).

Secondly, we compared gender and number processing. Gender processing has been argued to be more challenging for L2 learners than number processing, due to its arbitrariness and its dependence on lexical knowledge (Gabriele et al., 2013; Gillon-Dowens et al., 2010; Lew-Williams & Fernald, 2009; Hopp, 2012). However, it should be noted that all prior studies that observed a gender-number asymmetry in L2 learners focused on native speakers of English (which has number but not gender). It is therefore not clear if the faster processing of number is due to the fact that this feature is shared across the two languages, or if it is due, as it is claimed in the literature, to different conceptual representations. Possibly, a discrepancy between gender and number may be modulated by the presence or absence of grammatical gender in the L1. Our goal was to investigate this hypothesis by comparing gender- and number processing in bilinguals speaking different language pairs. Indeed, many studies have found that adult L2 speakers are less likely to show prediction when processing features that are L2-specific (Bergen & Flecken, 2017; Dussias et al., 2013; Foucart & Frenck-Mestre, 2011; Frenck-Mestre et al., 2019; Hopp & Lemmerth, 2018), and we aimed to test whether this is the case also for sequential bilingual children.

As hypothesized, our results showed diverging patterns with respect to gender and number; Mandarin-Italian bilingual children were faster when processing number than gender, but Arabic-Italian bilinguals and the larger group of multilingual children tested in Chapter 5 patterned in the opposite direction. Since the vast majority of the multilingual children in our sample spoke an L1 that

has grammatical gender, we argue that gender processing might be more challenging than number processing only for those L2 learners whose L1 does not have gender. While these findings should be confirmed by studies with larger sample sizes, as to allow for individual differences in language proficiency to be taken into account, our results suggest that prediction during L2 processing in sequential bilingual children may be influenced by the grammatical properties of children's L1.

Similar results were found in the study by Meir et al. (2020) on predictive processing of case markers in Russian-Hebrew bilingual children. While case marking in Russian is highly productive and predictable, case marking in Hebrew provides relatively unreliable cues. As a result, monolingual Russian-speaking children made rapid use of case markers to predict upcoming speech, while monolingual Hebrew-speaking children did not show any sensitivity to case during online processing. In contrast, Russian-Hebrew bilingual children did not only show prediction based on case markers in Russian, but also in Hebrew. Taken together, these findings suggest that bilingual children can benefit from positive transfer when a grammatical cue is present in both of their languages.

In short, the studies presented in this thesis provide evidence that the languages of a bilingual child may interact during predictive language processing, which may lead to cross-linguistic interference due to competing representations, as well as transfer of processing strategies when grammatical features overlap across their two languages.

4. The relation between reading and prediction

Finally, this thesis aimed to investigated the relation between literacy and predictive processing in spoken language. While several studies have provided evidence that adults and children with better reading skills show stronger predictive processing (Favier et al., 2021; Huettig & Brouwer, 2015; Mani & Huettig, 2014; Mishra et al., 2012; Ng et al., 2018; Persici et al., 2019), this effect had previously not been investigated in bilingual speakers. Since bilingual adults and children show differences in predictive language processing compared to monolinguals (Kaan & Grüter, 2021; Meir

et al., 2020), testing the link between reading and prediction in bilinguals would inform us about the generalizability of this effect in more diverse populations. Moreover, given the fact that an increasing number of children with a migration background currently learn to read in a language that is not spoken in their family, it is crucial to gain more insight in their reading development and how this might be interrelated with their L2 processing skills. In Chapter 5 we therefore tested the effect of reading skills on linguistic prediction in Italian in a group of multilingual children who spoke a wide variety of heritage languages and Italian as the societal language, in comparison to monolingual Italian peers.

As hypothesized, in monolingual children we found a link between reading skills and predictive processing. We replicated the findings of Mani and Huettig (2014), who found a positive correlation between reading and prediction in monolingual German children, and we extended their findings to prediction based on morphosyntactic rather than semantic cues. This finding is interpreted in terms of the account proposed by Huettig and Pickering (2019), which states that reading experience may improve predictive processing both through indirect benefits (such as improved vocabulary knowledge and phonological awareness), and through primary effects on predictive mechanisms. Specifically, reading is assumed to boost anticipation skills, which may subsequently be transferred into the spoken language modality (Huettig, 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, or experimental designs such as training interventions (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 effect could not be confirmed in the multilingual participants, as we did not find any reliable relation between prediction and reading 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 bilinguals are tested in a non-native or non-dominant language, since there are too many other factors coming into play, such as reduced automaticity, individual differences in language dominance and competing linguistic representations from the other language.

Future studies should therefore aim to test predictive processing of bilingual children inboth 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, 2018; Hopp, 2015). Another promising avenue to pursue, especially in bilingual children, would be to investigate the relation between reading, linguistic prediction and non-linguistic prediction. For example, one might test children's anticipation of visual sequences, as was done by Bonifacci et al. (2011). Another possibility would be to test whether children's ability to anticipate upcoming beats in a rhythmic structure is related to their linguistic prediction and their reading skills (Persici et al., 2019). Guasti et al. (2017) argued that the ability to efficiently use temporal structural regularities, also called 'rhythmic timing' or 'predictive mechanisms', is the common source of language, motor and reading difficulties in developmental dyslexia. This hypothesis is supported by studies showing that children with developmental dyslexia fail to comply with rhythmic constraints of handwriting (Pagliarini et al., 2015) and have weaker rhythmic anticipation abilities (Pagliarini et al., 2020; Persici et al., 2019). Future research should extend this line of research also in typically developing monolingual and bilingual populations.

5. Conclusion

All in all, this thesis has shown that different groups of bilingual children are able to anticipate upcoming words by relying on morphosyntactic cues, which makes their language processing very fast and efficient. Yet, sometimes they are slightly delayed in comparison with monolingual peers, possibly because their processing may be less automatized in a non-native or non-dominant language. The degree to which bilingual children make use of prediction during sentence processing largely depends on their language dominance and L2 proficiency, suggesting that L2 processing may become more native-like as children become more proficient. Since the languages of a bilingual child do not develop in isolation from each other, they may interact in several ways. In particular, children may experience cross-linguistic influence due to competing linguistic representations during predictive sentence processing, and they may benefit from positive transfer when comparable grammatical cues are available in both of their languages. Finally, 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 use among bilingual 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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Appendix 1 Experimental items on gender-based prediction in Italian (Experiment 1, Chapter 2)

Item-List	Condition	Italian target	German target	Italian competitor	German competitor	Target (English)	Competitor (English)
1-A	P/I	il giornale	die Zeitung	la mela	der Apfel	Newspaper	Apple
1-B	P/I	la mela	der Apfel	il giornale	die Zeitung	Apple	Newspaper
2-A	P/I	il materasso	die Matratze	la scopa	der Besen	Mattress	Broom
2-B	P/I	la scopa	der Besen	il materasso	die Matratze	Broom	Mattress
3-A	P/I	il cassetto	die Schublade	la matita	der Bleistift	Drawer	Pencil
3-B	P/I	la matita	der Bleistift	il cassetto	die Schublade	Pencil	Drawer
4-A	P/I	il latte	die Milch	la valigia	der Koffer	Milk	Suitcase
4-B	P/I	la valigia	der Koffer	il latte	die Milch	Suitcase	Milk
5-A	P/I	il sapone	die Seife	la cintura	der Gürtel	Soap	Belt
5-B	P/I	la cintura	der Gürtel	il sapone	die Seife	Belt	Soap
6-A	P/I	il ragno	die Spinne	la scimmia	der Affe	Spider	Monkey
6-B	P/I	la scimmia	der Affe	il ragno	die Spinne	Monkey	Spider
7-A	P/I	la farfalla	der Schmetterling	il gatto	die Katze	Butterfly	Cat
7-B	P/I	il gatto	die Katze	la farfalla	der Schmetterling	Cat	Butterfly
8-A	P/I	la gonna	der Rock	il kiwi	die Kiwi	Skirt	Kiwi
8-B	P/I	il kiwi	die Kiwi	la gonna	der Rock	Kiwi	Skirt
9-A	P/I	la scarpa	der Schuh	il cioccolato	die Schokolade	Shoe	Chocolate
9-B	P/I	il cioccolato	die Schokolade	la scarpa	der Schuh	Chocolate	Shoe
10-A	P/I	la palla	der Ball	il tamburo	die Trommel	Ball	Drum
10-B	P/I	il tamburo	die Trommel	la palla	der Ball	Drum	Ball
11-A	P/I	la coppa	der Pokal	il fiore	die Blume	Cup (prize)	Flower
11-B	P/I	il fiore	die Blume	la coppa	der Pokal	Flower	Cup (prize)
12-A	P/I	la tigre	der Tiger	il topo	die Maus	Tiger	Mouse
12-B	P/I	il topo	die Maus	la tigre	der Tiger	Mouse	Tiger
13-A	P/I	la pentola	der Topf	il vaso	die Vase	Pot	Vase
13-B	P/I	il vaso	die Vase	la pentola	der Topf	Vase	Pot
14-A	P/I	il ponte	die Brucke	la sedia	der Stuhl	Bridge	Chair
14-B	P/I	la sedia	der Stuhl	il ponte	die Brucke	Chair	Bridge
15-A	P/C	il martello	der Hammer	la tazza	die Tasse	Hammer	Cup
15-B	P/C	la tazza	die Tasse	il martello	der Hammer	Cup	Hammer
16-A	P/C	il cucchiaio	der Löffel	la lampada	die Lampe	Spoon	Lamp
16-B	P/C	la lampada	die Lampe	il cucchiaio	der Löffel	Lamp	Spoon
17-A	P/C	il formaggio	der Käse	la chitarra	die Gitarre	Cheese	Guitar
17-B	P/C	la chitarra	die Gitarre	il formaggio	der Käse	Guitar	Cheese
18-A	P/C	il guanto	der Handschuh	la candela	die Kerze	Glove	Candle
18-B	P/C	la candela	die Kerze	il guanto	der Handschuh	Candle	Glove
19-A	P/C	il criceto	der Hamster	la capra	die Ziege	Hamster	Goat
19-B	P/C	la capra	die Ziege	il criceto	der Hamster	Goat	Hamster
20-A	P/C	il leone	der Löwe	la mucca	die Kuh	Lion	Cow
20-B	P/C	la mucca	die Kuh	il leone	der Löwe	Cow	Lion
21-A	P/C	la giraffa	die Giraffe	il cane	der Hund	Giraffe	Dog
21-B	P/C	il cane	der Hund	la giraffa	die Giraffe	Dog	Giraffe
22-A	P/C	la banana	die Banane	il miele	der Honig	Banana	Honey
22-B	P/C	il miele	der Honig	la banana	die Banane	Honey	Banana
23-A	P/C	la salsiccia	die Wurst	il fungo	der Pilz	Sausage	Mushroom
23-B	P/C	il fungo	der Pilz	la salsiccia	die Wurst	Mushroom	Sausage
24-A	P/C	la pera	die Birne	il treno	der Zug	Pear	Train
24-B	P/C	il treno	der Zug	la pera	die Birne	Train	Pear
25-A	P/C	la sega	die Sage	il tavolo	der Tisch	Saw	Table
25-B	P/C	il tavolo	der Tisch	la sega	die Sage	Table	Saw
26-A	P/C	la borsa	die Tasche	il palloncino	der Ballon	Bag	Balloon

26-B	P/C	il palloncino	der Ballon	la borsa	die Tasche	Balloon	Bag
27-A	P/C	il secchio	der Eimer	la corona	die Krone	Bucket	Crown
27-B	P/C	la corona	die Krone	il secchio	der Eimer	Crown	Bucket
28-A	P/C	la patata	die Kartoffel	il cappello	der Hut	Potato	Hat
28-B	P/C	il cappello	der Hut	la patata	die Kartoffel	Hat	Potato
29-A	No-P	il computer	der Computer	il vino	der Wein	Laptop	Wine
29-B	No-P	il vino	der Wein	il computer	der Computer	Wine	Laptop
30-A	No-P	il tè	der Tee	il maglione	der Pullover	Tea	Sweater
30-B	No-P	il maglione	der Pullover	il tè	der Tee	Sweater	Tea
31-A	No-P	il biscotto	der Keks	il tappetto	der Teppich	Cookie	Carpet
31-B	No-P	il tappetto	der Teppich	il biscotto	der Keks	Carpet	Cookie
32-A	No-P	il gallo	der Hahn	il pinguino	der Pinguin	Rooster	Penguin
32-B	No-P	il pinguino	der Pinguin	il gallo	der Hahn	Penguin	Rooster
33-A	No-P	il papagallo	der Papagei	il cervo	der Hirsch	Parrot	Deer
33-B	No-P	il cervo	der Hirsch	il papagallo	der Papagei	Deer	Parrot
34-A	No-P	il pettine	der Kamm	il casco	der Helm	Comb	Helmet
34-B	No-P	il casco	der Helm	il pettine	der Kamm	Helmet	Comb
35-A	No-P	la scatola	die Box	la collana	die Halskette	Box	Necklace
35-B	No-P	la collana	die Halskette	la scatola	die Box	Necklace	Box
36-A	No-P	la carota	die Möhre	la forchetta	die Gabel	Carrot	Fork
36-B	No-P	la forchetta	die Gabel	la carota	die Möhre	Fork	Carrot
37-A	No-P	la pipa	die Pfeife	la spazzola	die Bürste	Pipe	Brush
37-B	No-P	la spazzola	die Bürste	la pipa	die Pfeife	Brush	Pipe
38-A	No-P	la conchiglia	die Muschel	la scala	die Leiter	Shell	Ladder
38-B	No-P	la scala	die Leiter	la conchiglia	die Muschel	Ladder	Shell
39-A	No-P	la bambola	die Puppe	la pizza	die Pizza	Doll	Pizza
39-B	No-P	la pizza	die Pizza	la bambola	die Puppe	Pizza	Doll
40-A	No-P	la pala	die Schaufel	la pera	die Birne	Shovel	Pear
40-B	No-P	la pera	die Birne	la pala	die Schaufel	Pear	Shovel
41-A	No-P	la pianta	die Pflanze	la ciliegia	die Kirsche	Plant	Cherry
41-B	No-P	la ciliegia	die Kirsche	la pianta	die Pflanze	Cherry	Plant
42-A	No-P	la ghianda	die Eichel	la coca	die Cola	Acorn	Coke
42-B	No-P	la coca	die Cola	la ghianda	die Eichel	Coke	Acorn

Appendix 2 Experimental items on gender-based prediction in German (Experiment 2, Chapter 2)

Item-List	Condition	Italian target	German target	Italian competitor	German competitor	Target (English)	Competitor (English)
1-A	P/I	la valigia	der Koffer	il giornale	die Zeitung	Suitcase	Newspaper
1-B	P/I	il giornale	die Zeitung	la valigia	der Koffer	Newspaper	Suitcase
2-A	P/I	la sedia	der Stuhl	il materasso	die Matratze	Chair	Mattress
2-B	P/I	il materasso	die Matratze	la sedia	der Stuhl	Mattress	Chair
3-A	P/I	la scopa	der Besen	il cassetto	die Schublade	Broom	Drawer
3-B	P/I	il cassetto	die Schublade	la scopa	der Besen	Drawer	Broom
4-A	P/I	la matita	der Bleistift	il latte	die Milch	Pencil	Milk
4-B	P/I	il latte	die Milch	la matita	der Bleistift	Milk	Pencil
5-A	P/I	la mela	der Apfel	il sapone	die Seife	Apple	Soap
5-B	P/I	il sapone	die Seife	la mela	der Apfel	Soap	Apple
6-A	P/I	la scimmia	der Affe	il gatto	die Katze	Monkey	Cat
6-B	P/I	il gatto	die Katze	la scimmia	der Affe	Cat	Monkey
7-A	P/I	il topo	die Maus	la farfalla	der Schmetterling	Mouse	Butterfly
7-B	P/I	la farfalla	der Schmetterling	il topo	die Maus	Butterfly	Mouse
8-A	P/I	il fiore	die Blume	la gonna	der Rock	Flower	Skirt
8-B	P/I	la gonna	der Rock	il fiore	die Blume	Skirt	Flower
9-A	P/I	il vaso	die Vase	la scarpa	der Schuh	Vase	Shoe
9-B	P/I	la scarpa	der Schuh	il vaso	die Vase	Shoe	Vase
10-A	P/I	il cioccolato	die Schokolade	la palla	der Ball	Chocolate	Ball
10-B	P/I	la palla	der Ball	il cioccolato	die Schokolade	Ball	Chocolate
11-A	P/I	il kiwi	die Kiwi	la coppa	der Pokal	Kiwi	Cup (prize)
11-B	P/I	la coppa	der Pokal	il kiwi	die Kiwi	Cup (prize)	Kiwi
12-A	P/I	il ragno	die Spinne	la tigre	der Tiger	Spider	Tiger
12-B	P/I	la tigre	der Tiger	il ragno	die Spinne	Tiger	Spider
13-A	P/I	il tamburo	die Trommel	la pentola	der Topf	Drum	Pot
13-B	P/I	la pentola	der Topf	il tamburo	die Trommel	Pot	Drum
14-A	P/I	la cintura	der Gürtel	il ponte	die Brücke	Belt	Bridge
14-B	P/I	il ponte	die Brücke	la cintura	der Gürtel	Bridge	Belt
15-A	P/C	la corona	die Krone	il martello	der Hammer	Crown	Hammer
15-B	P/C	il martello	der Hammer	la corona	die Krone	Hammer	Crown
16-A	P/C	la chitarra	die Gitarre	il cucchiaio	der Löffel	Guitar	Spoon
16-B	P/C	il cucchiaio	der Löffel	la chitarra	die Gitarre	Spoon	Guitar
17-A	P/C	la candela	die Kerze	il pettine	der Kamm	Candle	Comb
17-B	P/C	il pettine	der Kamm	la candela	die Kerze	Comb	Candle
18-A	P/C	la tazza	die Tasse	il formaggio	der Käse	Cup	Cheese
18-B	P/C	il formaggio	der Käse	la tazza	die Tasse	Cheese	Cup
19-A	P/C	la mucca	die Kuh	il criceto	der Hamster	Cow	Hamster
19-B	P/C	il criceto	der Hamster	la mucca	die Kuh	Hamster	Cow
20-A	P/C	la giraffa	die Giraffe	il leone	der Löwe	Giraffe	Lion
20-B	P/C	il leone	der Löwe	la giraffa	die Giraffe	Lion	Giraffe
21-A	P/C	il cane	der Hund	la capra	die Ziege	Dog	Goat
21-B	P/C	la capra	die Ziege	il cane	der Hund	Goat	Dog
22-A	P/C	il palloncino	der Ballon	la banana	die Banane	Balloon	Banana
22-B	P/C	la banana	die Banane	il palloncino	der Ballon	Banana	Balloon
23-A	P/C	il miele	der Hönig	la borsa	die Tasche	Honey	Bag
23-B	P/C	la borsa	die Tasche	il miele	der Hönig	Bag	Honey
24-A	P/C	il fungo	der Pilz	la fragola	die Erdbeere	Mushroom	Strawberry
24-B	P/C	la fragola	die Erdbeere	il fungo	der Pilz	Strawberry	Mushroom
25-A	P/C	il tavolo	der Tisch	la sega	die Säge	Table	Saw
25-B	P/C	la sega	die Säge	il tavolo	der Tisch	Saw	Table
26-A	P/C	il cappello	der Hut	la lampada	die Lampe	Hat	Lamp

26-B	P/C	la lampada	die Lampe	il cappello	der Hut	Lamp	Hat
27-A	P/C	la salsiccia	die Wurst	il secchio	der Eimer	Sausage	Bucket
27-B	P/C	il secchio	der Eimer	la salsiccia	die Wurst	Bucket	Sausage
28-A	P/C	il treno	der Zug	la patata	die Kartoffel	Train	Potato
28-B	P/C	la patata	die Kartoffel	il treno	der Zug	Potato	Train
29-A	No-P	il casco	der Helm	il te	der Tee	Helmet	Tea
29-B	No-P	il te	der Tee	il casco	der Helm	Tea	Helmet
30-A	No-P	il maglione	der Pullover	il biscotto	der Keks	Sweater	Cookie
30-B	No-P	il biscotto	Der Keks	il maglione	der Pullover	Cookie	Sweater
31-A	No-P	il tappetto	der Teppich	il computer	der Computer	Carpet	Laptop
31-B	No-P	il computer	der Computer	il tappetto	der Teppich	Laptop	Carpet
32-A	No-P	il cervo	der Hirsch	il gallo	der Hahn	Deer	Rooster
32-B	No-P	il gallo	der Hahn	il cervo	der Hirsch	Rooster	Deer
33-A	No-P	il pinguino	der Pinguin	il papagallo	der Papagei	Penguin	Parrot
33-B	No-P	il papagallo	der Papagei	il pinguino	der Pinguin	Parrot	Penguin
34-A	No-P	il vino	der Wein	il guanto	der Handschuh	Wine	Glove
34-B	No-P	il guanto	der Handschuh	il vino	der Wein	Glove	Wine
35-A	No-P	la pera	die Birne	la scatola	die Box	Pear	Box
35-B	No-P	la scatola	die Box	la pera	die Birne	Box	Pear
36-A	No-P	la collana	die Halskette	la carota	die Möhre	Necklace	Carrot
36-B	No-P	la carota	die Möhre	la collana	die Halskette	Carrot	Necklace
37-A	No-P	la forchetta	die Gabel	la pipa	die Pfeife	Fork	Pipe
37-B	No-P	la pipa	die Pfeife	la forchetta	die Gabel	Pipe	Fork
38-A	No-P	la pizza	die Pizza	la conchiglia	die Muschel	Pizza	Shell
38-B	No-P	la conchiglia	die Muschel	la pizza	die Pizza	Shell	Pizza
39-A	No-P	la spazzola	die Bürste	la bambola	die Puppe	Brush	Doll
39-B	No-P	la bambola	die Puppe	la spazzola	die Bürste	Doll	Brush
40-A	No-P	la coca	die Cola	la pala	die Schaufel	Coke	Shovel
40-B	No-P	la pala	die Schaufel	la coca	die Cola	Shovel	Coke
41-A	No-P	la scala	die Leiter	la pianta	die Pflanze	Ladder	Plant
41-B	No-P	la pianta	die Pflanze	la scala	die Leiter	Plant	Ladder
42-A	No-P	la ciliega	die Kirsche	la ghianda	die Eichel	Cherry	Acorn
42-B	No-P	la ghianda	die Eichel	la ciliega	die Kirsche	Acorn	Cherry

Appendix 3 Experimental items on number-based prediction in Italian (Experiment 1, Chapter 3)

Item-List	Condition	Type	Target	Competitor	Target (English)	Competitor (English)
1-A	Early Number	la-le	La pipa	Le mele	Pipe	Apples
1-B	Early Number	la-le	Le mele	La pipa	Apples	Pipe
2-A	Early Number	la-le	La scala	Le torte	Ladder	Pies
2-B	Early Number	la-le	Le torte	La scala	Pies	Ladder
3-A	Early Number	la-le	La scatola	Le valigie	Box	Suitcases
3-B	Early Number	la-le	Le valigie	La scatola	Suitcases	Box
4-A	Early Number	la-le	La lampada	Le pentole	Lamp	Pots
4-B	Early Number	la-le	Le pentole	La lampada	Pots	Lamp
5-A	Early Number	la-le	La tazza	Le spade	Cup	Swords
5-B	Early Number	la-le	Le spade	La tazza	Swords	Cup
6-A	Early Number	la-le	Le corone	La patata	Crowns	Potato
6-B	Early Number	la-le	La patata	Le corone	Potato	Crowns
7-A	Early Number	la-le	Le penne	La sciarpa	Pens	Scarf
7-B	Early Number	la-le	La sciarpa	Le penne	Scarf	Pens
8-A	Early Number	la-le	Le sedie	La foglia	Chairs	Leaf
8-B	Early Number	la-le	La foglia	Le sedie	Leaf	Chairs
9-A	Early Number	la-le	Le stelle	La coppa	Stars	Cup (prize)
9-B	Early Number	la-le	La coppa	Le stelle	Cup (prize)	Stars
10-A	Early Number	la-le	Le coperte	La finestra	Blankets	Window
10-B	Early Number	la-le	La finestra	Le coperte	Window	Blankets
11-A	Late	la-la	La gonna	La carta	Skirt	Card
11-B	Late	la-la	La carta	La gonna	Card	Skirt
12-A	Late	la-la	La freccia	La pizza	Arrow	Pizza
12-B	Late	la-la	La pizza	La freccia	Pizza	Arrow
13-A	Late	la-la	La paletta	La ciliegia	Scoop	Cherry
13-B	Late	la-la	La ciliegia	La paletta	Cherry	Scoop
14-A	Late	la-la	La conchiglia	La medaglia	Shell	Medal
14-B	Late	la-la	La medaglia	La conchiglia	Medal	Shell
15-A	Late	la-la	La padella	La carriola	Pan	Wheelbarrow
15-B	Late	la-la	La carriola	La padella	Wheelbarrow	Pan
16-A	Late	le-le	Le scope	Le borse	Brooms	Bags
16-B	Late	le-le	Le borse	Le scope	Bags	Brooms
17-A	Late	le-le	Le scarpe	Le biglie	Shoes	Marbles
17-B	Late	le-le	Le biglie	Le scarpe	Marbles	Shoes
18-A	Late	le-le	Le bottiglie	Le magliette	Bottles	T-shirts
18-B	Late	le-le	Le magliette	Le bottiglie	T-shirts	Bottles
19-A	Late	le-le	Le collane	Le carote	Necklaces	Carrots
19-B	Late	le-le	Le carote	Le collane	Carrots	Necklaces
20-A	Late	le-le	Le fragole	Le cravatte	Strawberries	Ties
20-B	Late	le-le	Le cravatte	Le fragole	Ties	Strawberries

Appendix 4 Experimental items on number-based prediction in English (Experiment 2, Chapter 3)

Item-List	Condition	Type	Target	Competitor
1-A	Early Number	is-are	Plate	Candles
1-B	Early Number	is-are	Candles	Plate
2-A	Early Number	is-are	Helmet	Books
2-B	Early Number	is-are	Books	Helmet
3-A	Early Number	is-are	Notebook	Spoons
3-B	Early Number	is-are	Spoons	Notebook
4-A	Early Number	is-are	Train	Bananas
4-B	Early Number	is-are	Bananas	Train
5-A	Early Number	is-are	Fork	Pencils
5-B	Early Number	is-are	Pencils	Fork
6-A	Early Number	is-are	Mushrooms	Nest
6-B	Early Number	is-are	Nest	Mushrooms
7-A	Early Number	is-are	Pears	Hat
7-B	Early Number	is-are	Hat	Pears
8-A	Early Number	is-are	Knifes	Wheel
8-B	Early Number	is-are	Wheel	Knifes
9-A	Early Number	is-are	Hammers	Belt
9-B	Early Number	is-are	Belt	Hammers
10-A	Early Number	is-are	Guitars	Present
10-B	Early Number	is-are	Present	Guitars
11-A	Late	is-is	Newspaper	Sandwich
11-B	Late	is-is	Sandwich	Newspaper
12-A	Late	is-is	Drawer	Couch
12-B	Late	is-is	Couch	Drawer
13-A	Late	is-is	Laptop	Carpet
13-B	Late	is-is	Carpet	Laptop
14-A	Late	is-is	Table	Boat
14-B	Late	is-is	Boat	Table
15-A	Late	is-is	Bed	Drum
15-B	Late	is-is	Drum	Bed
16-A	Late	are-are	Buckets	Saws
16-B	Late	are-are	Saws	Buckets
17-A	Late	are-are	Sausages	Gloves
17-B	Late	are-are	Gloves	Sausages
18-A	Late	are-are	Combs	Sweaters
18-B	Late	are-are	Sweaters	Combs
19-A	Late	are-are	Flowers	Balls
19-B	Late	are-are	Balls	Flowers
20-A	Late	are-are	Balloons	Cherries
20-B	Late	are-are	Cherries	Balloons

Appendix 5 Experimental items on gender- and number-based prediction in Italian (Chapter 4-5)

Item-List	Condition	Type	Target	Competitor	Target (English)	Competitor (English)
1-A	Early Gender	il-la	La barca	Il letto	Boat	Bed
1-B	Early Gender	il-la	Il letto	La barca	Bed	Boat
2-A	Early Gender	il-la	La palla	Il treno	Ball	Train
2-B	Early Gender	il-la	Il treno	La palla	Train	Ball
3-A	Early Gender	il-la	La forchetta	Il cappello	Fork	Hat
3-B	Early Gender	il-la	Il cappello	La forchetta	Hat	Fork
4-A	Early Gender	il-la	La banana	Il tamburo	Banana	Drum
4-B	Early Gender	il-la	Il tamburo	La banana	Drum	Banana
5-A	Early Gender	il-la	La matita	Il panino	Pencil	Sandwich
5-B	Early Gender	il-la	Il panino	La matita	Sandwich	Pencil
6-A	Early Gender	il-la	Il nido	La pera	Nest	Pear
6-B	Early Gender	il-la	La pera	Il nido	Pear	Nest
7-A	Early Gender	il-la	Il fungo	La ruota	Mushroom	Wheel
7-B	Early Gender	il-la	La ruota	Il fungo	Wheel	Mushroom
8-A	Early Gender	il-la	Il coltello	La candela	Knife	Candle
8-B	Early Gender	il-la	La candela	Il coltello	Candle	Knife
9-A	Early Gender	il-la	Il gelato	La cintura	Ice cream	Belt
9-B	Early Gender	il-la	La cintura	Il gelato	Belt	Ice cream
10-A	Early Gender	il-la	Il tappeto	La chitarra	Carpet	Guitar
10-B	Early Gender	il-la	La chitarra	Il tappeto	Guitar	Carpet
11-A	Early Number	la-le	La pipa	Le mele	Pipe	Apples
11-B	Early Number	la-le	Le mele	La pipa	Apples	Pipe
12-A	Early Number	la-le	La scala	Le torte	Ladder	Pies
12-B	Early Number	la-le	Le torte	La scala	Pies	Ladder
13-A	Early Number	la-le	La scatola	Le valigie	Box	Suitcases
13-B	Early Number	la-le	Le valigie	La scatola	Suitcases	Box
14-A	Early Number	la-le	La lampada	Le pentole	Lamp	Pots
14-B	Early Number	la-le	Le pentole	La lampada	Pots	Lamp
15-A	Early Number	la-le	La tazza	Le spade	Cup	Swords
15-B	Early Number	la-le	Le spade	La tazza	Swords	Cup
16-A	Early Number	la-le	Le corone	La patata	Crowns	Potato
16-B	Early Number	la-le	La patata	Le corone	Potato	Crowns
17-A	Early Number	la-le	Le penne	La sciarpa	Pens	Scarf
17-B	Early Number	la-le	La sciarpa	Le penne	Scarf	Pens
18-A	Early Number	la-le	Le sedie	La foglia	Chairs	Leaf
18-B	Early Number	la-le	La foglia	Le sedie	Leaf	Chairs
19-A	Early Number	la-le	Le stelle	La coppa	Stars	Cup (prize)
19-B	Early Number	la-le	La coppa	Le stelle	Cup (prize)	Stars
20-A	Early Number	la-le	Le coperte	La finestra	Blankets	Window
20-B	Early Number	la-le	La finestra	Le coperte	Window	Blankets
21-A	Late	il-il	Il casco	Il libro	Helmet	Book

21-B	Late	il-il	Il libro	Il casco	Book	Helmet
22-A	Late	il-il	Il piatto	Il secchio	Plate	Bucket
22-B	Late	il-il	Il secchio	Il piatto	Bucket	Plate
23-A	Late	il-il	Il formaggio	Il quaderno	Cheese	Notebook
23-B	Late	il-il	Il quaderno	Il formaggio	Notebook	Cheese
24-A	Late	il-il	Il divano	Il regalo	Couch	Present
24-B	Late	il-il	Il regalo	Il divano	Present	Couch
25-A	Late	il-il	Il cucchiaio	Il martello	Spoon	Hammer
25-B	Late	il-il	Il martello	Il cucchiaio	Hammer	Spoon
26-A	Late	la-la	La gonna	La carta	Skirt	Card
26-B	Late	la-la	La carta	La gonna	Card	Skirt
27-A	Late	la-la	La freccia	La pizza	Arrow	Pizza
27-B	Late	la-la	La pizza	La freccia	Pizza	Arrow
28-A	Late	la-la	La paletta	La cigliegia	Scoop	Cherry
28-B	Late	la-la	La cigliegia	La palette	Cherry	Scoop
29-A	Late	la-la	La conchiglia	La medaglia	Shell	Medal
29-B	Late	la-la	La medaglia	La conchiglia	Medal	Shell
30-A	Late	la-la	La padella	La carriola	Pan	Wheelbarrow
30-B	Late	la-la	La carriola	La padella	Wheelbarrow	Pan
31-A	Late	le-le	Le scope	Le borse	Brooms	Bags
31-B	Late	le-le	Le borse	Le scope	Bags	Brooms
32-A	Late	le-le	Le scarpe	Le biglie	Shoes	Marbles
32-B	Late	le-le	Le biglie	Le scarpe	Marbles	Shoes
33-A	Late	le-le	Le bottiglie	Le magliette	Bottles	T-shirts
33-B	Late	le-le	Le magliette	Le bottiglie	T-shirts	Bottles
34-A	Late	le-le	Le collane	Le carote	Necklaces	Carrots
34-B	Late	le-le	Le carote	Le collane	Carrots	Necklaces
35-A	Late	le-le	Le fragole	Le cravatte	Strawberries	Ties
35-B	Late	le-le	Le cravatte	Le fragole	Ties	Strawberries